This document is provided in support of John C. Hickson’s corrected PhD thesis. Where possible, previous text and the correction have been included in table 1. Not all corrected text is presented below due to the length of some corrections, where corrected text is not present please refer to the page number for the text in the document titled “Hickson thesis with track changes”. Text added in response to joint corrections totalled ~10000 words and represents a substantial addition to the thesis. I would like to express my thanks to both Dr. Steve Dugdale and Dr. Lindsay Banin for their constructive feedback and suggestions which have helped strengthen this thesis.

Table 1. Thesis corrections presented as part of PhD thesis submission.

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| Correction ID | Correction requested | Prior Text | Correction | Page no. |
| 1.1 | Please incorporate a thesis aims/objectives section at the end of the introduction; the objectives should correspond to the three data chapters of the thesis. | N/A | Aims and objectives have been moved from chapter 2 to chapter 1. | 17 |
| 2.1 | The section on lianas and associated subheadings could be revised – there is scope to include a further breakdown of both the environmental processes/properties driving lianas (both more broadly in terms of the clade and with respect to the specific lianas involved in this study). There could also be a more full explanation of liana physiology and functioning. It was also mentioned during the viva that C4 and C3 plants and lianas may respond differently. | 2.1. What is a liana?  Lianas (woody climbers) are a group of climbing plants that rely on trees to provide structural support to reach the forest canopy, which allows lianas to deploy leaves into the canopy with little investment in woody tissue (Gerwing, 2004; Schnitzer and Bongers, 2011; Soffiatti et al., 2022). Unlike (hemi) epiphytic plants, lianas retain a root stock throughout their life cycle (Schnitzer and Bongers, 2002). Lianas have evolved independently multiple times over the course of history, resulting in over 130 plant families now including at least one liana species (Putz, 1984; Gentry, 1991; Schnitzer and Bongers, 2002).  As lianas do not require the ability support themselves as they mature, they present a different structural functionality compared to their host trees (Gerwing, 2004; Isnard and Silk, 2009; Soffiatti et al., 2022). For example, by relying on trees for structural support, lianas can devote more resources to leaf production. Lianas can therefore contribute up to 30% of the total leaf area while only accounting for 5% of woody stems biomass (van der Heijden et al., 2013). To be able to transport water to their relatively large canopies, lianas have had to develop an efficient vascular architecture for transporting water to the canopy (Rowe et al., 2004; Soffiatti et al., 2022). These adaptations also increase the hydraulic conductivity of lianas during the dry season (van der Sande et al., 2019) allowing lianas to take advantage of increased light availability and allowing lianas to continue growing during periods where co-occurring trees are dormant (van der Sande et al., 2013; Schnitzer and van der Heijden, 2019; Smith-Martin et al., 2019).  Classically liana root systems have been suggested as some of the deepest root systems within tropical forests (Putz, 1984; Chen et al., 2015). The hypothesis for root system differentiation is that unlike tree root systems, lianas are free of the constraints of self-supporting growth and therefore do not need structural root systems (Ewers et al., 2015). Allowing for investment into roots that can reach deeper water sources than those of co-occurring tree species (Andrade et al., 2005; Chen et al., 2015). However recent research into liana biomass allocation has found, in contrast, that lianas did not root to depths greater than those of co-occurring trees (De Deurwaerder et al., 2018; Smith-Martin et al., 2020). Smith-Martin et al., (2020) note that rooting patterns and subsequent biomass allocation, differs between juvenile and adult lianas, with juvenile lianas typically allocating more biomass to leaves and stem than to roots. De Deurwaerder et al., (2018) found that lianas can maintain an active root system in shallow soil layers which allows for faster uptake of dry season precipitation and thus decreases direct resource competition with co-occurring trees.  Lianas deploy their leaves directly through the canopy, in many cases displacing or over topping the leaves of host trees directly competing for and intercepting light in upper and middle canopy layers (Schnitzer and Bongers, 2002; Rodríguez-Ronderos et al., 2016; García León et al., 2018). Within liana leaves concentrations of chlorophyll can vary by site conditions, Sanchez-Azofeifa et al. (2009) found that lianas growing in dryer conditions had lower chlorophyll concentrations. Comparative to host trees, lianas have a higher concentration of foliar phosphorous and nitrogen particularly in periods of drought (Kazda and Salzer, 2000; Cai et al., 2008). Thus, lianas can rapidly create new leaves and photosynthetic tissues, increasing leaf biomass faster than co-occurring trees (Kazda and Salzer, 2000). Liana leaves typically have greater water content than co-occurring tree species, combined with greater cavity space within the mesophyll of the leaves (Sánchez-Azofeifa and Castro-Esau, 2006) which allows for increased photosynthetic capacity due to greater gas diffusion through the photosynthetic pigments (Zhang et al., 2016). | I have revised all subheadings within the liana section of the literature review and have added a fuller treatment of liana physiology and function. I have included further information on the drivers of lianas as a group, but the drivers of liana proliferation are still poorly understood, hence the relevance of this thesis.  **2.2 Lianas as a lifeform**  Lianas (woody climbers) are a polyphyletic group of climbing plants that rely on trees to provide structural support to reach the forest canopy, which allows lianas to deploy leaves into the canopy with little investment in woody tissue (Gerwing, 2004; Schnitzer and Bongers, 2011; Soffiatti et al., 2022b). Unlike (hemi) epiphytic plants, lianas retain a root stock throughout their life cycle (Schnitzer and Bongers, 2002). Lianas have evolved independently multiple times over the course of history, resulting in over 130 plant families now including at least one liana species (Putz, 1984a; Gentry, 1991; Schnitzer and Bongers, 2002).  **2.2.1 Liana physiology**  The independent evolution of the climbing growth form has led to a diversity in functional and mechanistic traits within the liana grouping, many of which characteristically differ from co-occurring tree species. As lianas do not require the ability support themselves as they mature, they present a different structural functionality compared to their host trees (Gerwing, 2004; Isnard and Silk, 2009; Soffiatti et al., 2022b). For example, by relying on trees for structural support, lianas can devote more resources to leaf production. Lianas can therefore contribute up to 30% of the total leaf area while only accounting for 5% of woody stems biomass (van der Heijden et al., 2013). To be able to transport water to their relatively large canopies, lianas have had to develop an efficient vascular architecture for transporting water to the canopy (Rowe et al., 2004; Soffiatti et al., 2022b). Lianas usually have larger xylem vessels than tree species (Gartner et al., 1990; Rowe et al., 2004) although there is often compartmentalisation of within the xylem bundles to increase pressure of vertical water transport (Rowe et al., 2004; Ewers et al., 2015; Soffiatti et al., 2022b). This results in lianas typically having a higher sap flux density than host trees, especially when water availability is high (Chen et al., 2015; van der Sande et al., 2019). These adaptations also increase the hydraulic conductivity of lianas during the dry season (van der Sande et al., 2019) allowing lianas to take advantage of increased light availability and allowing lianas to continue growing during periods where co-occurring trees are dormant (van der Sande et al., 2013; Schnitzer and van der Heijden, 2019; Smith-Martin et al., 2019).  Lianas further differ from trees in stem pliability (Rowe and Speck, 1996; Rowe et al., 2004). Increased pliability of liana stems decreases the risk of mechanical injury from falling from host trees or from uncontrolled movement due to windstorms (Rowe and Speck, 1996, 2005; Ewers et al., 2015; Soffiatti et al., 2022a). Stem pliability is achieved through lower concentrations cellulose in the flexible wood of lianas, while simultaneously the concentration of hemicellulose is greater than that of co-occurring trees (Hoffmann et al., 2003; Rowe et al., 2004). These adaptations, collectively referred to as lianoid wood, are triggered when liana stems transition from self-supporting to wholly dependant on host trees for support (Rowe and Speck, 1996; Soffiatti et al., 2022a). This transition from stiff to flexible wood appears to be hard-wired into lianas, with evidence suggesting that there are diameter and length controls prompting the development of lianoid wood (Soffiatti et al., 2022a).  Lianas can be brought down from the forest canopy when host trees fall. This does not mean the end for a liana however. Fallen liana stems are capable of resprouting when in contact with the ground (Alvira et al., 2004; Gerwing, 2006) leading to high density clonal regrowth in treefall gaps (Ledo and Schnitzer, 2014; Rocha et al., 2020). Recent studies suggest that resprouting of lianas is positively linked to the severity of canopy fall, in manipulative experiments lianas which suffered the greatest damage doubled the number of clonal sprouts than those with minimal or no damage (Rocha et al., 2020).  Classically liana root systems have been suggested as some of the deepest root systems within tropical forests (Putz, 1984a; Chen et al., 2015). The hypothesis for root system differentiation is that unlike tree root systems, lianas are free of the constraints of self-supporting growth and therefore do not need structural root systems (Ewers et al., 2015). This would potentially allow investment into fine root structure that can reach deeper water sources than those of co-occurring tree species (Andrade et al., 2005; Chen et al., 2015). However recent research into liana biomass allocation has found, in contrast, that lianas did not root to depths greater than those of co-occurring trees (De Deurwaerder et al., 2018; Smith-Martin et al., 2020a). Smith-Martin et al., (2020) note that rooting patterns and subsequent biomass allocation, differs between juvenile and adult lianas, with juvenile lianas typically allocating more biomass to leaves and stem than to roots. De Deurwaerder et al., (2018) found that lianas can maintain an active root system in shallow soil layers which allows for faster uptake of dry season precipitation and thus decreases direct resource competition with co-occurring trees.  Lianas deploy their leaves directly through the canopy, in many cases displacing or over topping the leaves of host trees directly competing for and intercepting light in upper and middle canopy layers (Schnitzer and Bongers, 2002; Rodríguez-Ronderos et al., 2016; García León et al., 2018). Within liana leaves concentrations of chlorophyll can vary by site conditions, Sanchez-Azofeifa et al. (2009) found that lianas growing in dryer conditions had lower chlorophyll concentrations. Comparative to host trees, lianas have a higher concentration of foliar phosphorous and nitrogen particularly in periods of drought (Kazda and Salzer, 2000; Cai et al., 2008). Thus, lianas can rapidly create new leaves and photosynthetic tissues, increasing leaf biomass faster than co-occurring trees (Kazda and Salzer, 2000). Liana leaves typically have greater water content than co-occurring tree species, combined with greater cavity space within the mesophyll of the leaves (Sánchez-Azofeifa and Castro-Esau, 2006) which allows for increased photosynthetic capacity due to greater gas diffusion through the photosynthetic pigments (Zhang et al., 2016). | 20-31 |
| 2.2 | A more clearly structured section on FACE experiments, other CO2 fertilisation experiments, the concentrations used in comparison to real-world values/increases and their findings relevant to plant physiological change, liana physiological change and plant community shifts. It would be helpful to connect this with the remote sensing element by bringing in pigment/spectral change as a result of change in plant function. | N/A | I have structured my literature review to start with an additional section on CO2 and CO2 experiments. This section deals with the various technologies involved in CO2 enrichment experiments as well as some of the prior results and research gaps. | 18-20 |
| 2.3 | The section on remote sensing is too brief – there is an abundance of material in the literature about both laser scanning (ALS and TLS) that needs to be included. This should start broad with the basic functioning and purpose and then move to the finer details. Similarly, it would be good to pre-empt the material in chapter 5 with insights into RGB image processing and extraction of vegetation metrics using RGB indices, etc. | N/A | The remote sensing sections of my literature have been reformatted to work from basic purpose through to technical implementation, specifically in regard to trees and forest applications. I have substantially added to the TLS and Imaging sections as well as the basic theory sections. | 20-42 |
| 3.1 | This chapter is rather brief and more information could be provided about the environmental and geographic context of EucFACE. This was covered in some detail in the viva, so it would be good to see this material integrated into the chapter. | N/A | I have included a further paragraph on the geographic context of EucFACE and its location in the Sydney basin.  The study site is the Eucalypt Free Air CO2 Enrichment (EucFACE) experiment, which was established in December 2012 and consists of 6 experimental gas injection plots within a mature *Eucalyptus* dominated woodland located within a 167ha remnant of the Cumberland Plain woodland (Figure 3.1) (Ellsworth et al., 2017b). Cumberland plain woodland, which once stretched across much of the Sydney basin, is a critically endangered savannah like woodland (Threatened Species Scientific Committee, 2009), which is now limited to the western suburbs of Sydney, estimated to have covered ~ 125449ha (Tozer, 2003), currently around 6% remains (Tozer et al., 2010). Typically, woodlands in the Cumberland plain are dominated by *Eucalyptus tereticornis* or *Eucalyptus moluccana* trees with scattered shrubs and C3 and C4 grasses. The EucFACE experiment is surrounded by savannah-like grasslands with sparse *Eucalyptus­* trees indicating the fragmentation of the remnant forests. The EucFACE site is bisected by a fire clearway around a series of high-voltage pylons, separating rings 1 and 2 from the other rings by ~20m of open grassland. When the site is subjected to high volumes of rainfall, an ephemeral stream is known to form between rings 5 and 6 which flows westwards towards the Hawkesbury River. | 43 |
| 3.2 | Following on from the viva discussions, it would be helpful to have more information also on the ecological context of EucFACE – eg. other vegetation present, local fragmentation and disturbance, water table depth and hydro-ecological features that generate spatial heterogeneity across the site etc. | N/A | I have added further information of the environmental context of EucFACE. In addressing this correction, some of the context is included with the above correction (3.1).  The climate at EucFACE is categorised as temperate-subtropical. It is therefore a predominantly dry site receiving up to 800mm of precipitation per year with mean annual temperature of 17.5 ˚C (Ellsworth et al., 2017b), moisture availability follows a semi-seasonal pattern with soil water content regularly falling as low as 0.03m­3­m-3 during summer (Duursma et al., 2016; Ellsworth et al., 2017a). The site is known to be nutrient poor, primarily phosphorus (P) limited (Crous et al., 2015) with a loamy sand (>75% sand) soil at the surface which transitions to a sandy clay loam (>30% silt and clay) soil ca. 50-300cm depth (Duursma et al., 2016). Ground-water depth is between 12.6-12.9m below surface (Crous et al., 2015; Duursma et al., 2016; Gimeno et al., 2016). | 43 |
| 3.3 | A short table detailing all data available (remote sensing but also soil moisture and other hydrometeorological variables) would help pre-empt the relevant sections of the data chapters. | N/A | I have included an additional table (Table 3.1) of freely available data. Other data at EucFACE is controlled by the author who commissioned data collection and was not always freely available. | 47 |
| 3.4 | Some of the sentences are short and missing an object/subject. Please ensure that these are written as full sentences. | The liana present at the EucFACE is *Parsonsia straminea* (R.Br.) F.Muell. (Apocynaceae). Native to the eastern seaboard of Australia. P. straminea is a root climbing liana with some stem twinning, capable of reaching the canopy of host trees (Figure 3.3). The leaves of P. straminea are dimorphic, adult leaves are elliptic to oblong-ovate, 4–24 cm long, 1.5–8 cm wide, with glaucous undersides and a yellow-green top surface. As a juvenile plant, leaves of 1-5cm long, thin with purple lower surface with similar yellow-green top (National Herbarium of NSW, 2012). Ranges from Northern Queensland to Southern New South Wales with rare occurrences in Tasmania (Atlas of Living Australia). Found predominantly in rainforest and along forest margins where fires are rare ( Zich et al., 2020). There is observational evidence of tolerance to flooding as *P. straminea* have been found in woodlands that flood both from salt- and freshwater inundation (Grieger et al., 2019) | Species descriptions have been rewritten into full sentences rather than as a taxonomic style.  The liana present at the EucFACE is *Parsonsia straminea* (R.Br.) F.Muell. (Apocynaceae). Native to the eastern seaboard of Australia, *P. straminea* is a root climbing liana with some stem twinning, capable of reaching the canopy of host trees (Figure 3.3). The leaves of *P. straminea* are dimorphic, with adult leaves elliptic to oblong-ovate, 4–24 cm long, 1.5–8 cm wide, with glaucous undersides and a yellow-green top surface. Juvenile leaves are 1-5cm long, thin with purple lower surface with similar yellow-green top (National Herbarium of NSW, 2012). *P. straminea*’s native range extends from Northern Queensland to Southern New South Wales with rare occurrences in Tasmania (Atlas of Living Australia). *P. straminea* is predominantly found in rainforests and along forest margins where fires are rare ( Zich et al., 2020). There is observational evidence that *P. straminea* may be tolerant to flooding as this species has been found in woodlands occasionally inundated by salt- and freshwater (Grieger et al., 2019). | 48-49 |
| 4.1 | Revise the title to broaden the focus and allow for more nuance in the result given the limitations of the study. | **Elevated atmospheric carbon dioxide does not affect liana infestation in a mature eucalypt woodland.** | **Elevated atmospheric carbon dioxide does not affect liana infestation in a mature eucalypt woodland using a novel structural measurement from low resolution terrestrial laser scanning.** | 51 |
| 4.2 | The section at the end of the intro making the case for using TLS is extremely short and reads like an afterthought. There’s scope to highlight how/why TLS is a great tool for measuring lianas and explain how this adds to the body of knowledge etc. This could result in a short chapter ‘aims/objective’ statement at the end of the introduction. | “However, repeated field measurement of lianas at EucFACE were not available. We therefore used information from repeated Terrestrial Laser Scanning surveys at five time points from 2012 to 2022, as a rapid survey technique to address two major aims. These are to assess whether changes in i) the proportion of trees supporting lianas and ii) the progression of trunk infestation of lianas over time was driven by elevated CO2 conditions across the EucFACE experiment.” | I have revised the section of the introduction to include a fuller case for the use of TLS, thus leading into the aims of the chapter.  Monitoring lianas manually is time and labour intensive (van der Heijden et al., 2010). Ground based liana monitoring, while capable of accurately recording liana stem measurements, is limited by visibility when censusing lianas within dense forest canopies (Waite et al., 2019). Consequently there has been a drive towards the use of remotely sensed data for liana monitoring (Castro-Esau et al., 2004; Asner and Martin, 2008; Waite et al., 2019; van der Heijden et al., 2022). While satellite or aircraft-borne sensor systems can provide remotely sensed data on forest canopies and the lianas that reside there (Waite et al., 2019; Chandler et al., 2021a), ground based systems can provide data that is more suited to the study of lianas that reside within or below the canopy (Krishna Moorthy et al., 2018). Terrestrial laser scanning (TLS) generates a three dimensional digital recreation of forest structure (Disney, 2019) allowing for characterisation of vegetation profiles (Ashcroft et al., 2013), estimation of volume and mass of vegetation (Disney et al., 2018; Momo Takoudjou et al., 2018; Terryn et al., 2022a), and quantifying forest structure and architecture (Burt et al., 2013; Donager et al., 2018; Lau et al., 2018). TLS has thus been used to detect liana impacts on forest structure in tropical forests (Krishna Moorthy et al., 2018; Jiménez-Méndez et al., 2024). While it is well known that lianas are capable of rapidly colonising forests (Barry et al., 2015; Schnitzer et al., 2021) it is still poorly understood whether this speed of this response is driven by rising atmospheric CO2. Similarly little work has gone into the structural development of liana infestation in field studies, primarily due to difficulties in accessing lianas as they ascend host trees, while 3D scanning can allow for navigation within and below the canopy in ways not possible in the field. Therefore, multi-temporal TLS datasets could facilitate tracking of how liana infestations develop in high CO2 environments in lieu of high intensity field campaigns, using the 3D digital structure to census and quantify whether lianas respond to elevated CO2 concentrations.  We therefore used information from repeated Terrestrial Laser Scanning surveys at five time points from 2012 to 2022, as a rapid survey technique to address two major aims. These are to assess whether changes in i) the proportion of trees supporting lianas and ii) the progression of trunk infestation of lianas over time was driven by elevated CO2 conditions across the EucFACE experiment. | 55-56 |
| 4.3 | The methodology would benefit from being substantively expanded to include information about how ground points were removed, how lianas were manually segmented, etc. There is also a need to expand more about the implications of the TLS setup (ie. 180º scan locations, etc) for the study. | After co-registration, I digitally removed all ground vegetation <2m tall, from the point cloud to ensure a clear view of the tree stems and matched tree stems to previous stem location maps produced during earlier studies at EucFACE (Data from Ellsworth et al., 2017). Thereafter, I manually extracted individual trees, including any co-occurring lianas, from the imagery using CloudCompare (CloudCompare, 2021). Trees where canopies intersect or were joined by lianas were segmented at a fixed point throughout the temporal series. Multi-stemmed trees or trees for which canopies were indistinguishable were segmented as one entity. Trees were extracted individually based upon tree maps, originally created to track tree diameter (DBH) (c.f. Ellsworth et al. 2017). Tree stems below 10cm DBH are excluded as these are less likely to be canopy trees. For each living tree ≥10 cm DBH, I used the TLS data to determine whether lianas were present on the tree stem. For each tree, I identified the highest clearly observable liana stem or leaf tissue along the main stem and calculated the distance along the tree stem from the ground to the highest point of liana infestation in meters, as a measure of liana attained height (LAH; Fig. 4.1). I focussed on lianas climbing on tree stems as the efficacy of TLS data for liana detection was affected by canopy occlusion, thus decreasing the likelihood of rendering fine liana structures within tree canopies. Where lianas were unobservable in their entirety due to occlusion by trees or other foliage the entire tree was excluded from analysis. | The Methodology section has been substantially rewritten to include a more in depth treatment of data handling and method of data extraction.  Two initial scanning positions were chosen to avoid any ground based experimental infrastructure, e.g. leaf traps, and ground vegetation which at the initiation of the experiment was sparse and of low stature (Crous et al., 2015). Scans were originally commissioned to provide a rapid modelling of the tree biomass at EucFACE rather than a detailed structural survey. Scans from these limited positions therefore generate a sufficiently dense point cloud to allow geometric modelling of the trees using classic cylinder fitting (Calders et al., 2014), but are prone to occlusion of the lower tree trunk. This creates a “dark side” of trunks where lianas or tree trunk geometry, such as buttressing, are obfuscated. This could lower the detection efficacy of low lying or juvenile lianas within these scans which could lower the overall infestation detection accuracy.  The scans were spatially registered within the Riegl software and by manually manipulating the scans (sensu Calders et al., 2014; Lichti et al., 2019) to align them with the large permanent fibre-composite superstructure in each of the EucFACE rings. After co-registration, all ground vegetation, <2m tall, was manually segmented and removed from the point cloud in CloudCompare using the segmentation tools (CloudCompare, 2021) to ensure a clear view of the tree stems.  To remove ground vegetation, the initial point cloud was sliced at 2m height, all points within the resulting cloud that did not present as either tree trunk or adjacent lianas was then manually segmented out of the cloud. The lianas present a distinctive vegetative structure, all foliage within ~50cm of a tree trunk was visually inspected for lianescent structure before segmenting out or inclusion (Fig. 4.1). Similarly, the superstructure was removed from the point cloud by manual segmentation. This created a multipart point cloud made up of basal tree stems and tree canopies, this was then merged in CloudCompare leaving a point cloud of only trees with co-occurring lianas where they were present.  Thereafter, individual trees, including any co-occurring lianas, were extracted from the imagery using the segmentation tools in CloudCompare and matched tree stems to previous stem location maps produced during earlier studies at EucFACE (Data from Ellsworth et al., 2017). Manual segmentation involved identifying vegetative structures and removal of non-conforming structures by hand. Manual segmentation of each tree typically took an average of 3 hours per tree depending on canopy shyness, more complex canopies (where branches cross other trees or around superstructures) could take up to two days to fully extract from the original point cloud. | 57-58 |
| 4.4 | There is scope in the discussion to consider both the environmental drivers of the results (eg. P limitation but also age of infestation) and also community factors (eg. competition, forest structure, etc – see external examiner comments). | “The woodland at EucFACE is phosphorus limited (Ellsworth et al., 2017, Duursma et al., 2016), which has been shown to limit the growth of trees (Crous et al., 2015). As lianas appear to require greater concentrations of phosphorus than co-occurring trees (Collins et al., 2016), phosphorous limitation rather than CO2 may be limiting their growth.” | Liana establishment, i.e. how long lianas have been present, may influence response to elevated atmospheric CO2. There were only a few lianas, at the start of the experiment, with the majority not reaching the canopy of the trees that supported them (apart from in rings 5 and 6). Furthermore, although lianas in many of the rings reached the crowns of the trees that supported them in 2022, individual lianas stems were often still <2cm. These two factors may indicate that lianas may only recently have colonised the site. As liana abundance and biomass increase, liana-liana competition also increases which, as with trees, can result in self-thinning (Medina-Vega et al., In Prep; Westoby, 1981). More established liana populations may respond differently to CO2 fertilisation as larger more mature lianas typically invest more into fruits and flowers, rather than rapid growth (Wright et al., 2015b) and therefore changing how lianas use available carbon. Furthermore, larger lianas are more likely to extend between tree canopies (Putz, 1984b; Schnitzer et al., 2023) which increases the number of trees hosting lianas without directly increasing liana stem density or liana attained heights, as lateral growth of lianas would not increase liana attained height. The effects of elevated atmospheric CO2 on liana stem density are still currently unclear, although as juvenile lianas increase in growth under elevated CO2 conditions that liana stem density may also increase (Granados and Körner, 2002). |  |
| 4.5 | The discussion also needs to more clearly highlight the low sample size (ie. only 2x eCO2 rings had liana infestations), the spatio-temporal dependence of infestations and what the implications of these factors are for the results of the study. The temporal results could be showcased more thoroughly, and in relation to fluctuating environmental conditions. | N/A | I have attempted to provide a more thorough treatment of the temporal and spatial limits on the lianas at EucFACE. I have also included a discussion of the number of replicate rings with lianas.  Absolute change in liana attained height was lowest between 2018 and 2020 (Fig. 4.4), corresponding with a protracted period of drought on-site. While lianas are capable of growing during dry periods (Schnitzer and van der Heijden, 2019) and maintaining hydraulic security (Liu et al., 2022), through tighter stomatal control than trees (Chen et al., 2015), protracted droughts may cause sufficient water deficit that any potential fertilisation derived from eCO2 are effectively negated. Furthermore post-drought (2020-2022) absolute change in LAH became negative, driven by lianas in rings 5 and 6 may have slipped into tree branch unions. Lianas can slip on host trees due to their weight surpassing their adhesive strength (Isnard et al., 2009; Dias et al., 2021), host tree limb drop (Putz, 1984a; Alvira et al., 2004), or from external influence from severe weather events (Soffiatti et al., 2022b). During the 2020-2022 period EucFACE was subjected to frequent saturation of ground water, with rings 5 and 6 regularly flooding. Following the protracted drought, the heavy rains and persistent inundation may have reduced the ability of some lianas to maintain their positions within the crowns of the trees.  The increasing liana proliferation and liana attained height found in the first 6 years of EucFACE could also be a product of disturbance prior to the establishment of the CO2 injection rings. Schnitzer et al. (2021) found that lianas in the tropics proliferate in the wake of disturbance with lianas still being dominant within disturbed forests a decade after canopy gap creation. Canopy gaps remain few at EucFACE with a relatively homogeneous structure and tree height, despite this however there are distinct gaps within the forest structure where trees are supressed and perish. Lianas have been shown to thrive where gaps develop within forest structures (Schnitzer and Carson, 2010; Parthasarathy et al., 2014; Schnitzer et al., 2021). While every effort was made during construction to limit disturbance to the forest structure (Duursma et al., 2016; Norby et al., 2016), the addition of large semi-permanent structures may have caused enough mechanical disturbance to either soil or canopy, that lianas have proliferated.  The lianas at EucFACE are not distributed evenly between the experimental rings. Ring 1 (eCO2) remained liana free in the TLS point cloud for the duration of the study, while liana infestation in ring 2 was only 10-36% throughout the study period. These rings are separated from the other four experimental rings by a clearway surrounding high voltage utility cabling. Spatially, lianas can be influenced by host tree, nutrient, and moisture availability (Cai et al., 2007; Blick and Burns, 2011; Mori et al., 2016) and also by seed mobility and clonal propagation through forest soils at a woodland scale (Ledo and Schnitzer, 2014; Michel et al., 2014). As the utility clearway has removed all woody vegetation, and therefore liana hosts, from a ~20m stretch within the woodland, this may have effectively limited the advance of lianas through the woodland. Nutrient availability at EucFACE is low but indicative of many native woodland systems in Australia (Tozer, 2003; Crous et al., 2015). However, nutrient limitation is distributed evenly across the site (Crous et al., 2015) and is therefore unlikely to be limiting the spatial distribution of the lianas. | 67-68 |
| 5.1 | The end of the introduction needs some more clear aims/objectives that help steer the structure of the methodology and results. | “The EucFACE site has been recording daily imagery for all of the experiment rings since 2014, allowing me to explore 8 years of near-continuous data to examine i) whether tree and liana canopies respond to elevated atmospheric CO2 conditions and ii) whether the response is related to the availability of soil moisture.” | To address this correction I have included an extra passage of the objectives for this chapter in addition to the original aims.  The EucFACE site has been recording daily imagery for all of the experiment rings since 2014, allowing me to explore 8 years of near-continuous data to examine i) how tree and liana canopies respond to elevated atmospheric CO2 conditions and ii) whether the response is related to the availability of soil moisture. To achieve these aims the GCC has been used to determine the canopy response to elevated atmospheric CO2 for both lianas and trees. Using GCC allows for comparisons between i) the response to CO2 treatment per lifeform, ii) response to soil moisture per lifeform, iii) differences between lifeforms per CO2 treatment, and iiii) whether differences between treatments and between lifeforms are influenced by soil moisture. | 75 |
| 5.2 | The concept of a ‘greenness index’ and what it is needs to be given a thorough treatment in the introduction.  It’s also important to discuss other metrics that might be used to extract vegetation health information from RGB imagery (eg. HSI, NGRDI, etc) to demonstrate that you considered these other metrics before using GCC.  It would also be good in the corresponding ‘limitations’ section of the discussion to highlight the ‘black box’ nature of the RGB camera’s metering system and the extent to which this might have influenced results. | N/A | I have included a new passage on GCC and greenness metrics as part of my introduction.  The corresponding limitations of camera derived data has been included in the chapter discussion (see correction 5.7).  Vegetation indices, such as the green chromatic coordinate (GCC) (Sonnentag et al., 2012), excess greenness (eGI) (Ide and Oguma, 2010), hue, saturation and brightness (HSB) (Karcher and Richardson, 2003), hue, saturation and intensity (HHI) (Carron and Lambert, 1994), have all been applied to RGB imagery for use in studies of forest canopy health and phenology. Vegetation indices transform the pixel values from the red, green or blue channels of an imagery to either highlight the influence of a single channel, e.g. eGI, or provide an empirical metric which can be used to determine differences between sensors or images (Morgan and Gergel, 2013).  Indices are subject to limitations from both the hardware selection, i.e. sensor bias (Ide and Oguma, 2010; Kior et al., 2024), the influence of shading or over-illumination (Sonnentag et al., 2012; Mishra et al., 2017), and external factors, such as those of cloud cover or precipitation on either foliage or lenses (Seidl et al., 2011; Sonnentag et al., 2012). Illumination of the EucFACE site is highly variable, with long periods of high solar irradiation loosely corresponding to the southern hemisphere summers (Wang et al., 2016), and can change rapidly during data capture. It is therefore necessary to use a vegetation index that is relatively insensitive to changes in illumination. GCC is relatively unaffected by illumination, especially when illumination changes rapidly. GCC therefore is a suitable empirical index to monitor canopy response of trees and lianas to elevated CO2 from RGB imagery. | 74-75 |
| 5.3 | Methods: similar to chapter 4, please extend this section of the chapter to clarify all aspects of the study – i.e. Information on camera movement, inclusion of supplementary material on AOI generation and reference AOI, more info on camera movement and impacts on panorama generation etc.  It would also be helpful to give more detail in the methods about the other data you had available (e.g. soil moisture, solar radiation, etc.). | N/A | To address these suggestions I have added Table 5.1 Camera Pan-Tilt settings per ring. I have also included in the chapter the supplemental figure that showed an example of AOIs, now figure 5.3. Other data availability has been included as a text passage.  Selected images were then overlapped into a panorama image using PTgui 12.10 (New House Internet Services B.V.). This resulted in ~ 375 processed panorama images per ring, ~2250 total panoramas. The panorama process was batch processed without colour correction to maintain individual image colouration. Panorama images were processed to 2331x1580 resolution, 300dpi with 4.3x image crop following a roughly 7.4mm projection to maintain a hemispherical view of the lower canopy and stems of trees within the ring (Fig.5.2). Original pixels are resized for the panorama, within PTGui a nearest neighbour interpolation is used to smooth the image without colour correction. While the panorama process was mostly automated, images where there are obvious signs of wind influence or lighting profiles that differed from the initial reference required manual alignment to create the panoramic image. Image series where camera alignment was altered or had drifted resulted in poor panorama stitching with large gaps or severe warping to the image. Camera drift on the automated mount lead to several image series not being included as there was insufficient overlap between images to register the panorama. Manual stitching required matching of control points between images. Overlap between images was mainly concentrated towards the centre of the panoramic image (Fig.5.2) as well as on the superstructures to the far sides of the panorama. The number of control points used varied between per panoramic image, with most aligned using 20-40 control points though some required ~50 control points.  **5.3.4 Environmental Data**  Average daily soil volumetric water content at 30 cm depth was calculated using data collected at 15 min intervals from 48 soil moisture probes (CS650-L; Campbell Scientific, Logan, UT, USA) located within the six experimental rings (eight probes per ring). Daily precipitation was recorded on site but due to sensor drift, these data were not of sufficiently high quality to include within analysis. | 78-79,82 |
| 5.4 | Methods: A few more sentences explaining the data handling would be helpful – i.e. Explain how/why data from all FACE rings were pooled rather than assessing rings individually.  This would then make the statistical analyses a bit easier to follow.  Explain more clearly the time lag between RS data and soil moisture, how that was decided (including the reference mentioned) and the sensitivity check you conducted.  Add methodological detail around the temporal trend analysis described. | I used a bootstrapping approach to test for differences in the response of lianas and trees to elevated CO2. I resampled the GCC of 1000 pixels per image 2000 times. For each resample, the difference between treatments for each life form and subsequently the difference between lifeforms was calculated. I calculated the 95% confidence interval of these values by calculating the 97.5 and 2.5th percentiles and considered differences between treatments and lifeforms significant if confidence intervals did not intersect zero.  To determine how GCC of lianas and trees varied and whether there was an effect of elevated CO2, GCC values were tested with an ANCOVA fitted with mean soil moisture, lagged from image acquisition by 1 week to account for water transport uptake, treatment, either ambient or elevated, lifeform, either liana or tree, and season as factors. I fitted interaction effects between moisture and season, lifeform and season, mean soil moisture and Lifeform. Models were tested for performance using the MuMIn package in R. Time from start of experiment was initially included to assess how GCC had changed over time, but this was removed due to there being no influence on the model. | I have rewritten the passage on data analysis to include more detail on the bootstrapping process and to include further information of the time lag of soil moisture/GCC.  **5.3.5 Data Analysis**  AOI images were amalgamated by date for both lianas and trees per treatment. For this amalgamated raster image, GCC was calculated per pixel.  To test for differences between lifeforms through time a bootstrapping approach was used. First, a composite observed mean per lifeform and treatment was created based on the GCC value for amalgamated AOIs per lifeform and treatment per image acquisition. Pooling GCC data removed influence of spatial variation with the forest (supplemental figure 5.1). To create confidence intervals around this composite mean, the GCC from a subsample of 25% of the amalgamated raster image (1000 pixels per image) was iteratively resampled with replacement 2000 times until bootstrapped mean GCC matched that of the observed mean. This was used to create a mean GCC per treatment and per lifeform alongside the 95% confidence interval (the 97.5 and 2.5th percentiles).  For each resample iteration, the difference between treatments for each life form and subsequently the difference between lifeforms was calculated. Bootstrapped differences were used to calculate a 95% confidence interval (the 97.5 and 2.5th percentiles). Bootstrapped difference confidence intervals allowed visual assessment of differences of liana or tree GCC over as differences between treatments and lifeforms were considered significant if confidence intervals did not intersect zero.  To determine how the observed GCC of lianas and trees varied and whether there was an effect of elevated CO2, pooled mean GCC values from the original AOIs were tested with an ANCOVA fitted with mean soil moisture, image acquisition was lagged from soil moisture by 1 week to account for water transport uptake, treatment, either ambient or elevated, lifeform, either liana or tree, and season as factors. I fitted interaction effects between moisture and season, lifeform and season, mean soil moisture and lifeform. Prior studies have shown that leaf flush of *E. tereticornis* is closely related to change in soil moisture (Duursma et al., 2016), and that transpiration peaks within 5-10 days of peak soil moisture availability (Cramer et al., 1999; Wang et al., 2022), thus GCC is unlikely to be influenced by moisture content changes on that day, therefore lag between soil moisture and image acquisition was explored using correlation plots. Lags up to 28 days post soil moisture acquisition were tested against lifeform GCC, R­­­2 values peaked at the 7 day lag, although were generally low for both lifeforms (R2 range 0.01-0.12). | 82-83 |
| 5.5 | Following the viva discussions, important somewhere to make the point that you checked RGB metrics against solar radiation and you are sure that this does not explain patterns in figure 5.3. | N/A | I have mentioned this within the body of the methods text.  The influence of irradiance on GCC was examined using the mean irradiance of the date of image acquisition and explored using correlation plots. Effects of irradiance were not found after GCC transformation for either the lianas or the trees in both CO2 regimes (Correlation plots r2 < 0.04). | 81 |
| 5.6 | Results: would benefit from restructuring to more clearly highlight the key findings of the paper – these are all present, but some shifting around of material would help bring these to the fore. See point above about putting aims/objectives at end of intro to ‘steer’ flow of material in methods/results sections. | N/A | I have restructured my results with subheadings to better flow as, 1) Liana responses to elevated CO2, 2) Tree responses to elevated CO2, 3) Differences in GCC patterns between lifeforms. | 83-88 |
| 5.7 | Discussion: similar to chapter 4, this needs a considerably extended discussion section where you consider in more detail the physiological and community/environmental mechanisms driving the observed patterns, building on our discussions in the viva (eg. reduced water loss via stomatal closure).  This could include, for example, differences in leaf phenology/flushing between trees and lianas, in responses to soil moisture, described during the viva.  The discussion also needs a ‘limitations’ section where you consider about the effectiveness of GCC and critique the use of consumer grade security cams, etc. | N/A | I have added into the discussion section a passage on the physiological effects of CO2 (water savings driven) and its implications which dovetails into the discussion on environmental influence. The limitations of this study have been moved from chapter 7 to the discussion here and are preceded by a more general discussion of the use of GCC in this study. I have also inserted a paragraph detailing the issues of using “consumer” grade instruments more generally. | 89-93 |
| 6.1 | Similar to comments on previous sections, the introduction needs extending to include a) information on physiological reasons behind spectral reflectance variability whether these are stress responses or indicative of plants benefitting from eCO2 and  b) information on hyperspectral methods (including more background about MCARI and NDVI and how these relate to plant health (covering information on leaf moisture and chlorophyll levels), thus pre-empting the subsequent methods and results/discussion. | N/A | A discussion of the potential drivers of the “stress” response to elevated CO2 has been included within the introduction, however stating whether a response is entirely of benefit to the plants is difficult. Typically the quantification of a response would be whether growth (of the target flora) is increased, however there has been no reported growth increase in elevated CO2 reported at EucFACE. Similarly as yet mortality of trees at EucFACE has yet to be reported in the literature, an increase in mortality in either the control or elevated CO2 treatments could help elucidate whether these responses show a benefit or are indicative of decline of plant health or function.    A treatment of hyperspectral indicies and methods has also been added to the chapter introduction. | 96-99 |
| 6.2 | The end of the introduction would also benefit from clear aims and objectives that steer the subsequent methods/results sections. | As this chapter only considered the spectral response in the visible spectrum using higher spectral resolution data may provide more detailed information to allow me to determine whether and how the species of liana and tree in this ecosystem 1) differ spectrally and 2) differ in their responses to elevated CO2. | I have rewritten to include the further objectives of this chapter.  As Chapter 5 only considered the spectral response in the visible spectrum, using finer spectral resolution data that encompasses spectra into the infra-red may provide more detailed information to determine whether and how the species of liana and tree in this ecosystem 1) differ spectrally and 2) how lianas and trees differ in their spectral response to elevated CO2 conditions. This chapter will also use two commonly used vegetation indices to examine whether physiological change has occurred in either trees or lianas as a response to elevated atmospheric CO2. Furthermore we will examine leaf moisture and how changes in leaf moisture may relate to changes in spectra for both lifeforms in response to elevated CO2 conditions. | 99 |
| 6.3 | Similar to other data chapters, the methodology should be extended to clarify certain aspects. For example, the bootstrapping approach wasn’t clear, and you need to explain how your final spectra were essentially composites of all of the leaf clips observations | As the primarily interest of this chapter is if lianas and trees differ in their spectral response to elevated CO2, I calculated differences between the spectral response of both life forms in the observed and first derivative spectra for each of the treatments. I used a bootstrapping approach to test for differences in the response of lianas and trees to elevated CO2. I resampled the observed spectra 5000 times. For each resample, the difference between treatments for each life form and subsequently the difference between lifeforms was calculated. I calculated the 95% confidence interval of these values by calculating the 97.5 and 2.5th percentiles and considered differences between treatments and lifeforms significant if confidence intervals did not intersect zero. | I have rewritten my data analysis passage, to improve reproducibility I have clarified how the bootstrapping approach was set up.  To test whether the spectral response of lianas and trees differed between ambient and elevated CO2 treatments, mean reflectance curves were calculated from the observed reflectance for both lifeforms per treatment. Difference in the mean spectral returns were calculated per lifeform and subsequently per treatment in the observed and first derivative spectra.  A bootstrapping methodology was followed to generate confidence intervals around these composite means, and assess whether there was a significant difference in the mean spectral response of the different life forms to elevated CO2. For each lifeform and CO2 treatment, the full spectral returns, i.e. the entire spectral curve, were iteratively resampled 5000 times at which point the bootstrapped and composite means were near indistinguishable. For each iteration, spectral differences between lifeforms and treatment were calculated to generate confidence intervals at the 97.5 and 2.5percentiles. Differences between treatments and lifeforms were considered significant when confidence intervals did not intersect zero.  NDVI and MCARI spectral indices were created from the composite mean spectral returns. A two way ANOVA with post-hoc Tukey’s HSD tests were used to test whether the spectral indices, related to chlorophyll, and leaf moisture content differed between life forms and treatments. Interactions between lifeform and CO2 treatment were included in the analyses. All data analysis were performed in the R programming environment (R Core Team 2023). | 101-102 |
| 6.4 | Methods: it would also be helpful to include information on the environmental parameters at the time of data collection (eg. rainfall history), allowing subsequent discussion to focus on whether this might explain some of the results. | N/A | I have added a small section on the environmental conditions during field sampling as part of the methods section.  **6.3.1 Environmental conditions**  Leaf sampling took place at EucFACE in May 2022. In the month prior to sampling there had been ~100mm of rainfall (Station 067105, BOM 2022) at EucFACE, soil moisture was high with much of the site waterlogged and abundant standing water within the rings. Daily temperatures during field sampling ranged from 16 to 27°C (Station 067105, BOM 2022). | 99 |
| 6.5 | Methods: Clarify whether the ANOVA used was a 2-way ANOVA (presumably this was the case) |  | Yes. I have clarified this in text. | 102 |
| 6.6 | Figure 6.1: Could the two panels be merged into one plot, with different shades for ambient and eCO2 treatments? This would make the trends/differences easier to interpret. | N/A | I have replotted the data and replaced figure 6.1 with the new plot. | 104 |
| 6.7 | Results: Check significance of differences in Figure 6.8, as it does not appear that there is any significant differences between trees. | The NDVI of liana and tree leaves differed, with liana leaves having higher NDVI values then trees regardless of treatment (Fig. 6.8). CO2 treatment has a positive effect on liana NDVI, whereas the NDVI for trees was lower. | There was in fact no treatment effect when re-checked, as such discussion around NDVI has been removed except as a contrast to other papers.  The NDVI of liana and tree leaves differed, with liana leaves having higher NDVI values then trees regardless of treatment (Fig. 6.8). Elevated CO2 has a positive effect on liana NDVI, whereas the NDVI for trees was lower although neither showed a significant change in NDVI. | 111-112 |
| 6.8 | Discussion: Subheadings would help organise the flow of information in this section.  Also, the discussion should be extended to include information on co-limitation and resource partitioning and the results on leaf moisture. | N/A | The subjects of co-limitation resource portioning have been addressed in an added section titled “Influences on spectral response”. This section covers some of the material discussed about limitation of nutrients and flooding covered in the viva and also an interpretation of some of the other physiological co-limitations, i.e. other pigments.  Leaf moisture results are discussed in their own section titled “Leaf Moisture Contents” in the discussion.  I have added subheadings throughout the discussion to help guide the reader. | 113-119 |
| 6.9 | A deeper interpretation of the whether a change in CO2 is the only reason behind the altered spectral signature of lianas would also be good. | N/A | Other potential drivers of spectral response is discussed in the section “influences on spectral response” alongside the co-limitations of this study as the co-limitations may also influence the spectral results.  The change to spectral response shown in this chapter may not only be related to chlorophyll. Spectral reflectance in the visible light portion of the spectrum, where the majority of the spectral differences reported here occurred, is influenced by several key biophysical properties (Curran, 1989; Curran et al., 2001; Pacheco-Labrador et al., 2014). Pigments such as xanthophyll and anthocyanin play a role in the attenuation and reflectance of light from plant foliage (Stone et al., 2001; Sims and Gamon, 2002; Wujeska-Klause et al., 2019a). Production of anthocyanin is linked to photo-inhibition in trees, protecting sun saturated trees from damage, but is also released in leaves that are suffering from other stressors (Chalker-Scott, 1999; Stone et al., 2001; Hughes et al., 2007). In *Eucalyptus* sp. trees, anthocyanin, which has an attenuating effect on visible light, is increased in elevated CO2 (Wujeska-Klause et al., 2019a) thus affecting the reflectance as anthocyanin and chlorophyll both absorb and reflect light in very similar wavelengths. Increases in anthocyanin, or rather the spectral signatures associated with the increase, could therefore be responsible for why the spectral response of trees, both in this study and in others (e.g. Galvíncio et al., 2011b; Oki et al., 2013; Wujeska-Klause et al., 2019a) is similar to that of stressed vegetation (Carter, 1993; Stone et al., 2001; Smith et al., 2005).  Soil water inundation may have also played a role in the reflectance of both the lianas and trees in this study across both control and elevated CO2 conditions. Site conditions were described as flooded during field sampling, which while both lifeforms are capable of tolerating moderate inundation (Marcar, 1993; Tozer et al., 2010; Grieger et al., 2019), soil water salinity can stress trees, supressing growth and canopy health (Marcar, 1993; Nasim et al., 2009; Grieger et al., 2019). Soil inundation, can negatively influence transpiration, especially in anoxic conditions i.e. where soil water oxygen content is depleted (Akeroyd et al., 1998), and could therefore have a knock on effect upon the water balance of foliage and thus the reflectance. As both treatments were similarly inundated, further work would be needed in contrasting soil moisture conditions for both treatments, to elucidate whether the reflectance curves of both lifeforms showed an influence of soil inundation. | 117-118 |
| 6.10 | Similarly, it would be good to give a more thorough discussion of how/why eCO2 generates an observed stress responses in trees compared to lianas | N/A | The “stress” response of trees has been discussed in the “influences on spectral response” as it is likely a combination of lowered photosynthetic pigment and increased anthocyanins. See correction above. | 117-118 |
| 6.11 | Discussion: similar to other chapters, this needs a section exploring limitations (eg. viva discussions around lack of leaf chemistry data) and potential future work that might extend this study. | N/A | The chapter limitations have been moved from chapter 7 to the discussion here.  **Limitations**  Spectral reflectance was only sampled once during a period when moisture availability was particularly high and soils were waterlogged. During this period liana greenness was particularly high in both treatments (Chapter 5). Further sampling, especially in periods where liana and tree greenness are more similar, e.g. during periods of seasonal or prolonged drought, could further elucidate differences in liana and tree reflectance and how responses to elevated CO2 conditions may change in relation to moisture and seasonal change.  The patterns in spectral reflectance and any changes in chemical properties within the leaves were not corroborated using leaf chemical analyses (*sensu* Boyd et al., 2006). As some NIR and SWIR regions of the spectral response have been specifically tied to chemical composition of the leaves, such as leaf nitrogen concentrations, which differ between trees and lianas (Asner et al., 2009, 2015; Asner and Martin, 2012). In this study, liana and trees differ in their reflectance in nitrogen and protein related features in both treatment. It could be then that leaf nitrogen content changes equally for both lifeforms in elevated CO2 conditions, however without suitable lab analysis it is unclear whether this is an increase or decrease in nitrogen. | 118-119 |
| 7.1 | The paragraph on non-linear responses was useful, and could usefully be expanded to include co-limitation factors, and a more full treatment of the contrasting leaf-level and community level results (in relation to the extended discussion of this in the various data chapters). | The difference in spectral response of lianas, between my study and Oki et al. (2013) could be explained by our CO2 enrichment concentrations. The study of Oki et al. (2013) utilised a much higher concentration of CO2, 800ppm (400ppm above ambient), than is tested at EucFACE, ~550ppm (150ppm above ambient). This difference of +250ppm CO2 may be the difference of a relatively fertilising effect and a stressing effect of CO2, the relationship this may be indicating could be like a quadratic relationship, i.e. where increases in CO2 stimulate lianas up to a threshold and becomes a stressor beyond that. In a study by Granados and Körner (2002), which tested 5 different CO2 concentrations between 280ppm – 700ppm, a non-linear increase in liana biomass was found up to 560ppm (around that of EucFACE). Further enrichment up to 700ppm CO2 showed a levelling off of liana biomass increase (Granados and Körner, 2002), had the study continued enrichment to 800ppm it is possible that there would have been detection of stress in these lianas. | I have added a brief paragraph about potential co-limitations. The issue of conflicting leaf/community responses is intrinsically linked to the functional processes of lianas, and therefore have been worked into the response to correction 7.2 (below)  The differences in spectral response of lianas, between my study and Oki et al. (2013) could be explained by our CO2 enrichment concentrations. The study of Oki et al. (2013) used a much higher concentration of CO2, 800ppm (400ppm above ambient, than is tested at EucFACE, ~550ppm (150ppm above ambient). This difference of +250ppm CO2 may be the difference between CO2 having a fertilizing effect and it inducing a stress response, whereby increases in CO2 stimulate plant growth up to a threshold and it potentially limiting a growth response beyond that threshold. There is some evidence that this may be happening as in a study by Granados and Körner (2002), which tested 5 different CO2 concentrations between 280ppm – 700ppm, liana biomass increased non-linearly up to 560 ppm after which the liana biomass increase levelled off (Granados and Körner, 2002).  However, co-limiting factors, such as the phosphorus limitation of EucFACE, could also drive these non-linear relationships in the liana response to elevated atmospheric CO2. In elevated CO2 conditions, trees increase the recycling of phosphorus, which mitigates phosphorus limitation (Ellsworth et al., 2015). If lianas growing in elevated CO2 conditions recycle phosphorous is a similar way, it could trigger a growth response in lianas, which may result in a higher abundance of lianas and trees supporting lianas over time in sites where soil phosphorous may otherwise be a limiting factor (Pasquini et al., 2015). | 129-130 |
| 7.2 | In the viva we discussed differences between observed reflectance (and the various factors that contribute to that), specifically higher chlorophyll content and the interpretability of that in relation to increased photosynthetic rates and growth/competitive advantages. It would be good to sum up how the PhD connects with these various factors and what the remaining knowledge gaps are. | N/A | I have added a passage on the leaf responses of lianas and how these link to potential growth advantages versus trees. I have addressed some of the knowledge gaps still arising from this thesis, although these are given a fuller treatment in the future directions section (p.135-138).  The leaf level response, i.e. increased chlorophyll and higher rates of photosynthetic rates (Laugier-Kitchener et al., 2022), to elevated CO2 conditions does not appear to be mirrored by a CO2-driven vegetative growth response (Chapter 4) of lianas. There is no evidence of a CO2-driven response of liana attained height or the proportion of trees supporting lianas at EucFACE. Clearly then the relationship between photosynthesis, growth and colonisation of new host trees is complex. Growth of lianas can be influenced by many external factors including nutrient limitation (Pasquini et al., 2015) and soil water availability (Medina-Vega et al., 2022) as discussed earlier, but can also relate to life history traits (van der Sande et al., 2019). Liana growth mechanisms link with relative shade tolerance, Cai et al. (2007) found that shade intolerant lianas prioritised stem elongation while shade tolerant lianas prioritised fine root growth. As P. straminea is relatively shade tolerant (Benson and McDougall, 1993; Fairley and Moore, 2000), these lianas could therefore be prioritising root growth rather than stem, which would not have been detectable by the methods used in this thesis, regardless of any CO2-driven increased growth. A CO2-driven increase in root mass, would likely be a competitive advantage for lianas over trees, increased fine roots specifically could increase a lianas ability to acquire nutrients and moisture more efficiently compared to trees (Avila et al., 2020; Smith-Martin et al., 2020b), although very little is currently known about liana roots. A similarly functional trait, response of lianas that was unable to be tested but may be influenced by increased photosynthesis, is CO2-driven wood density change. Wood density can increase in response to elevated atmospheric CO2 for other woody lifeforms (Yazaki et al., 2005; Kostiainen et al., 2009), although this appears to be heavily species specific (Kim et al., 2020). Increased wood density can infer water savings mechanisms and be indicative of increased drought tolerance (Markesteijn et al., 2011) promoting liana competition with trees in water limited forests as atmospheric CO2 continues to rise. There is however, considerable work needed to elucidate how liana functional traits, such as wood density or root biomass, are affected by elevated CO2 conditions as while above ground traits are well studied (Gallagher and Leishman, 2012; Letcher and Chazdon, 2012; Gallagher, 2014), the below ground interactions of lianas are still poorly understood. | 130-131 |
| 7.3 | Good to see the limitations sections in this chapter. As discussed above, each data chapter should have its own more specific limitations section in the corresponding discussions, with Ch7’s limitations sections looking more broadly/holistically at limitations of the entire project (eg. drought events, single liana/tree species, etc). | N/A | I have added more broad limitations to the limitations section, specifically discussing the lack of diversity in study species and the protracted drought. I have also added a section acknowledging the inherent reproducibility of FACE experiments.  More broadly this study is limited by the lack of diversity in the woody species present at EucFACE. This site only hosts one liana species *Parsonsia straminea* and one dominant tree species *Eucalyptus tereticornis*. As lianas are a highly diverse poly-phyletic group, rather than a clade of related plants, there is a high degree of variability between species (Sánchez-Azofeifa et al., 2009; Gallagher and Leishman, 2012). As discussed below as a future research direction, there is likely a role of species specific traits, e.g. climbing mechanism, leaf structure, nutrient usage, that may influence the response of plants to elevated CO2 conditions (Oki et al., 2013; Wullschleger et al., 2015; Ainsworth and Long, 2021). Oki et al. (2013) showed that, of the three co-occurring lianas that were studied, two showed similar responses to elevated atmospheric CO2 whereas the third species, from a different genera, showed a different spectral response. Therefore it is difficult to attribute the results from this experiments to the lianescent life form as a whole.  The EucFACE site and FACE sites more generally are subject to local environmental conditions. In the case of EucFACE specifically this includes a protracted drought which culminated in what was described by the Australian media as the “Black Summer” where drought conditions led to large scale bushfires (Davey and Sarre, 2020). This drought had negative effects on the survival of the vegetation present (Peters et al., 2021). Results from both chapters 4 and 5 show that in drought conditions liana attained height increases were lower and GCC of both lianas and trees was negatively influenced regardless of CO2 treatment. Therefore, the drought may also have impacted the growth, survival and physiology of the lianas, if these are similarly affected by long-term droughts, regardless of atmospheric CO2, it would be likely that there is no advantage offered by elevated atmospheric CO2 under drought conditions. However direct measurement of liana growth, mortality and physiology in response to the drought, were not available due to technical limitations discussed above as well as the impact of the COVID-19 pandemic.  FACE experiments are resource and financially intensive, consequently FACE experiments are still relatively rare in forested environments (Norby et al., 1999, 2016). As such there are inherent limitations which all FACE sites are subjected to, that of low reproducibility and replicates (Calfapietra et al., 2010). The current generation FACE experiments are designed maximise statistical power, through higher replicates than the previous generation and being designed to be integrated into global carbon modelling approaches (Calfapietra et al., 2010; Norby et al., 2016). EucFACE contains 3 replicates of the elevated CO2 treatment and 3 of the ambient (control) conditions, located randomly throughout the larger forested site (Crous et al., 2015; Duursma et al., 2016). The Birmingham Institute of Forest Research (BIFoR) FACE experiment follows a similar replicate design with the addition of three plots with no superstructure as additional control conditions to derive greater statistical power (Hart et al., 2020). | 133-134 |