Submission to the Independent Planning Commission

Santos' Narrabri Gas Project

Submitted by Bronwyn Evelyn

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To Commissioners Steve O'Conner, John Hamm, Snow Barlow

I am Bronwyn Evelyn from Canowindra NSW and oppose Santos' Narrabri Gas Project, and the NSW Governments assessment of the project.

1. Santos is not welcome on Gamilaroi Land.

2. "Serious and irreversible damage to Aquifers and groundwater can't be ruled out" Fin.Review23/6/20. Santos in its own EIS cannot guarantee damage will not occur. Water is absolutely vital, for a single project to jeopardize the integrity of these aquifers and groundwaters is wrong and unacceptable. For this to be carried out on state owned land is unacceptable.

3. The Pilliga is the largest undisturbed remnant area of dry sclerophyll forest in NSW with significant conservation values and should be protected. Clearing native vegetation, removing habitat, reducing corridors to forested areas, fragmenting habitat, spreading weeds and feral pests is unacceptable today.

I don't understand how the present State Government can be "satisfied" that Santos can "minimise", "mitigate", "avoid impact", be "unlikely to significantly impact", "offset" "potential impact" and "contain" "negligible" "potential impacts" when recent inquiries have conclusively found that 'Australia's environment and iconic places are in an overall state of decline and are under increasing threat…the current environmental trajectory is unsustainable." Graeme Samuel, Independent Review into the EPBC Act, ABC News 20/6/20.

And a NSW Parliamentary Inquiry into the NSW Koala Population states that without urgent intervention the Koala will become extinct in NSW before 2050 (about the same time this project will wind up). Loss of habitat possess the most serious threat. The inquiry wants an URGENT investigation into using habitat on private land and STATE FORESTS to replenish populations devastated by bushfires.

"There must be a significant increase in Koala habitat, PROTECTED from logging, MINING, LAND-CLEARING and URBAN DEVELOPMENT", Ms Faehermann said, "the government needs to overhaul the FAILED biodiversity offsetting scheme, which allows core Koala habitat to be cleared." ABC News 30/5/20.

Koalas do not need Santos' "research" into their situation, they need habitat, more protections for their habitat and an end to fossil fuels so their habitat will survive.

Why is it that our unique natural environment has to be sacrificed EVERYTIME for "economic" gain?? Our landscape has constantly been hammered since white invasion/settlement. In merely 250years (5 of my lifetimes and I'm thinking your 3 combined, its pretty horrifying) our natural systems are on the brink of collapse. If the Murry-Darling Basin collapse the Catastrophic Bushfires of 2019-2020 aren't evidence enough that our management systems are hopelessly inadequate, we have dire warnings that if we don't rapidly change our ways it will get worse.

Once these systems are gone they cannot be retrieved.

I am listing the names of the animals that will be impacted by this project. They currently live and move through the proposed project area. I list these animals because they have a name and they matter. They are reliant on intact habitat, and habitat remains intact because of them. They are currently Vulnerable, Endangered and Critically Endangered, they will be further marginalised if this project goes ahead. Please take the time if you can to read and honour each species:

Birds; E. Black Necked Stork

V. Barking Owl

Black Falcon

Diamond Finch

Dusky Woodswallow

Glossy Black Cockatoo

Grey-crowned Babbler

Hooded Robin

Little Eagle

Little Lorikeet

Masked Owl

Speckled Warbler

Spotted Harrier

Square Tailed Kite

Turquoise Parrot

Varied Sitella

Painted Honeyeater

Migratory; Cattle Egret

Glossy Egret

Glossy Ibis

Fork Tailed Swift

Great Egret

Rainbow Bee-eater

Satin Fly-catcher

White Throated Needle-tail

Critically Endangered; Regent Honeyeater

Swift Parrot

Vulnerable;

Brolga

Black-breasted Buzzard

Black-chinned Honeyeater

Blue-billed Duck

Freckled Duck

Gilberts Whistler

Scarlet Robin

Magpie Goose

Sharptailed Sandpiper

Lathams Snipe

Endangered;

Australian Bustard

Bush Stone Curlew

Grey Falcon

Australian Bittern

Australian Painted Snipe

Vulnerable; Superb Parrot

Mammals; Endangered: Black-striped Wallaby

Mammals; Vulnerable: Eastern Bent-wing Bat

Eastern Cave Bat

Little Pied Bat

Yellow-bellied Sheath-tail Bat

Eastern Pygmy Possum

Squirrel Glider

Koala

Pilliga Mouse

South-eastern Long-eared Bat

Endangered; Spotted-tail Quoll

Vulnerable; Large-eared Pied Bat

Rufous Bettong

Stripe-faced Dunnart

Reptiles; Vulnerable: Pale Headed Snake

Fish; Silver Perch

Murry Cod

Eel-tailed Catfish ~likely

Invertebrates; River Snail

Santos cannot guarantee a better outcome for these species.

4. Catastrophic Bushfires are a very real threat. Santos will have no control over flaring's happening on Total Fire Ban days. This is a catastrophic outcome for the forests and contemptuous of our state laws.

5. We live on the driest continent on earth, water is so precious. Don't give Santos the opportunity to irreparably damage our aquifers, groundwater and waterways; leaving us a legacy of 850,000 tonnes of salt to dispose of…

6. This IS a gateway project, if this goes ahead it potentially opens up the central west of NSW to gas exploration and export (domestic/overseas)For Santos to fail to address this in its submission is disingenuous, arrogant and shows contempt for the region, the environment and the planet.

7. I agree with Georgina Woods from Lock the Gate when she says, "Rural communities should not be forced to sacrifice land, water, and their economic security in the name of quick and dirty resource exploitation." I live in Canowindra and have included a paper by Andrew Rawson,

published in “Biodiversity Dreaming”. “Climate Change, biodiversity and agriculture in the Central Tablelands. NSW”, by Andrew Rawson, I believe, gives a clear view of the impacts of climate change on agriculture in our region.

8. Climate change only intensifies the terrible consequences of Santos’ Narrabri Gas Project. This one project alone will increase our fossil fuel emissions by 1%!! It is a lie when the present State and Federal Governments say we need gas to ‘transition’ away from fossil fuels

In a paper published in the journal “Bioscience”,2019, 11,000 scientists, from across the world, declare the “climate crisis has arrived and is accelerating faster than most scientists expect.” Actions the scientific alliance say would lessen the worst effects of climate change include quickly transitioning to renewable energy, promptly reducing emissions of powerful short-lived climate pollutants like methane, increasing protection of biodiverse systems, an end to land clearing, planting more trees..

The UN Environment Programs ‘Production Gap Report 2019’ “The time to begin planning for a wind down of gas production is, as with other fossil fuels, already upon us. To meet ‘safer’ 1.5 degree warming limits, “gas production needs to peak this year”.

Two recent studies published in July 2020 in Earth Systems Science Data, and Environmental Research Letters say “US oil and gas drilling are driving up global emissions of the potent greenhouse gas methane”; “given that these reports show that methane emissions are currently increasing globally it does not encourage me that we will be able to reverse the trend and achieve the necessary reductions within the next decade..”,T.Weber, University Rochester New York.

“There are a lot policymakers and companies can do to cut methane emissions, but in most places around the world we aren’t doing them”,R.Jackson.Stanford University. Chair of the Global Carbon Project.

PLEASE DON’T LET US JUST BEGIN TO OPEN OUR GASFIELDS IN NSW!!!!!

“..the bad news is that four years on (from 2015 Paris Agreement) the best we can hope for is holding global increases to around 1.75*C. We can only do that if the world moves decisively toward zero net emissions by the middle of the century, if effective global action on climate change fails, I fear the challenge would be beyond contemporary Australia. I fear things will fall apart..” writes Ross Garnaut, The Conversation, 6/11/19. He goes on, “There has been an extraordinary fall in the cost of equipment for solar and wind energy, and of technologies to store renewable energy to even out supply…with abundant low-cost electricity Australia could grow into a major producer of minerals needed in a post carbon world…and there’s an immense opportunity for capturing and sequestering at relatively low cost, atmospheric carbon in soils, pastures, woodlands, forests and plantations.’’

Santos’ Gas Projects are redundant and I urge you to declare them as such. I don’t understand our current governments wedlock to the fossil fuel industry, but the relationship is destroying Australia as we know it

We have so many great opportunities in a renewable carbon neutral country. Santos acts as if it can use up Planet A, but we have no Planet B..

Our present governments and Santos' lazy rationale of cheap electricity at the cost of our environment, water, agriculture, the planets future, is insane. True insanity is doing the same thing over and over again, knowing the result and doing it anyway.

I know this was wordy, so I thank you for your time, and I mean all this sincerely, please don't grant Santos approval to operate in the Pilliga.

Thanks n sincerely from Bronwyn Evelyn. 27/6/20.

BIODIVERSITY DREAMING:

Sustaining nature and agriculture after 200 years of European inland settlement in the Central Western Region of NSW

Proceedings of a conference held in Bathurst, NSW

10–11 November 2015

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Preparation of the hardcopy for printing was undertaken by Sauce Design, Orange.

The name Wiradjuri is spelled in two ways in these Proceedings:

1. 'Wiradyuri' is the preferred spelling by the Bathurst Elders.
2. 'Wiradjuri' is the spelling used by most Wiradjuri people living outside of Bathurst.

Climate change, biodiversity and agriculture in the Central Tablelands, New South Wales

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Abstract

The 21st Century is destined to be dominated by the effects and implications of global anthropogenic climate change. In the Central Tablelands changing climates will almost certainly impose extra pressures on an already degraded and fragmented landscape. Recent climate modelling for NSW (NARCliM) demonstrates that there is very high confidence that all temperature indices (max, min, seasonal, annual, extremes) will continue to increase over the coming decades. Both mean maximum and mean minimum temperatures are expected to rise in the Central West of NSW by around 0.7 degrees C by 2030, and 2.1 degrees by 2070. This represents a significant acceleration in the rate of temperature rise by comparison to 20th Century increases. This, coupled with the likelihood of changes to the frequency, intensity and seasonality of rainfall will impact on the survival capacity of many species, especially those already at the margins of their ranges or independently vulnerable. Due to its central location and high relative altitude the Central Tablelands will experience a net inflow of a) people (climate refugees from hot areas west and north; lifestyle migrants; retirees to get closer to medical services); b) native species (range expansion or shifting); c) broadacre agriculture (shifting into the region as cold winters become milder); d) weeds, pests and diseases (known, and previous unknown in the landscape). Managing the inevitable land use conflicts will require a multi-faceted response from Natural Resource Management (NRM) agencies and local councils.

Introduction

Modern anthropogenic climate change refers to the medium to long term modification of global climate caused by increases in the concentration of greenhouse gases (GHGs), primarily carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (IPCC, 2013). These increases are derived from global emissions of GHGs from a range of sources including fossil fuel combustion, cement production, transport exhausts, removal and burning of vegetation, degradation of soil organic matter, and agricultural sources such as CH_4 from ruminant livestock. As a result of these extra emissions, the global carbon cycle is out of balance to the extent that emissions outweigh natural storage (or sequestration) mechanisms (such as in vegetation, soils and the oceans), leading to a continued increase in GHG concentrations in the atmosphere. The consequence is a rise in overall average atmospheric temperature, and a disruption of natural climate processes.

Many global, national and State agencies have characterised the modern trend in climate due to increased GHG emissions. These include the Intergovernmental Panel on Climate Change (IPCC), CSIRO, Australian Academy of Sciences, Bureau of Meteorology and NSW State environmental agencies. Regardless of global and national efforts to mitigate these emissions, some change is inevitable due to legacy GHG levels in the atmosphere. Therefore all regions will require some level of adaptation to projected changes in climate and will need to manage consequent impacts. Climate change can interact and impact on all social-ecological systems within the region. Opportunities do, however, exist within a changing climate, and the Central Tablelands of NSW may benefit economically due to its relatively high elevation compared to surrounding areas. Managing the expected impacts and potential opportunities will be a key role for national, state and regional NRM and agricultural agencies as well as the public.

The Central Tablelands region contains several high elevation plateaus, e.g. Oberon plateau (mostly above 1000 metres ASL), and the western Blue Mountains as well as other high ground associated with Mt Canobolas (elevation 1397m ASL) and its lava plains south-east of Orange (approximate elevation 900–950m ASL). This provides a predominantly mild climate relative to adjoining regions to the north, west and south. The interfluve of the Great Dividing Range passes through the eastern third of the region, with the majority of rivers flowing into the Murray-Darling Basin to the west and north. The region has a relatively high rainfall by comparison to neighbouring regions to the north, west and south, and is a critical source location for water resources along the Macquarie and Lachlan river catchments. Therefore changes to climate and hydrology in the region will likely impact on communities and ecological systems downstream.

The Koeppen climate classification for the entire Central Tablelands region is Temperate with no dry season, with warm summers on the western and northwestern slopes, and mild summers in the tablelands proper (BoM, 2015). Being an inland tablelands region, there is a marked seasonal and diurnal variation in temperature, with cold winters and warm to hot summers. Rainfall is distributed fairly evenly throughout the year, with a slight summer increase. However, there is a wide year to year variation driven largely by ENSO (El Niño Southern Oscillation) fluctuations (El Niño = hot, dry; La Niña = cooler, moist). Many of the higher plateau regions experience snowfalls in winter.

Observed climate change

Global climates have been changing for more than a century, primarily due to previous increases in the concentration of atmospheric greenhouse gases (IPCC, 2013). Many long term temperature records have been broken in recent years (Coumou et al., 2013; BoM and CSIRO, 2016). The Bureau of Meteorology/CSIRO State of the Climate 2016 Report outlines the key changes that have already taken place in Australia:

Temperature (Figure 1)

- Australia's climate has warmed by 1.0°C since 1910, and the frequency of extreme weather has changed, with more extreme heat and fewer cool extremes
- nine of the ten warmest years have occurred since 1998
- global mean temperature has risen by 0.85°C from 1880 to 2012. Note: 2016 was globally the hottest year on record (NOAA, 2016), the third year in a row that the heat record was broken.
- All of the warmest 20 years on record (globally) have occurred since 1990.

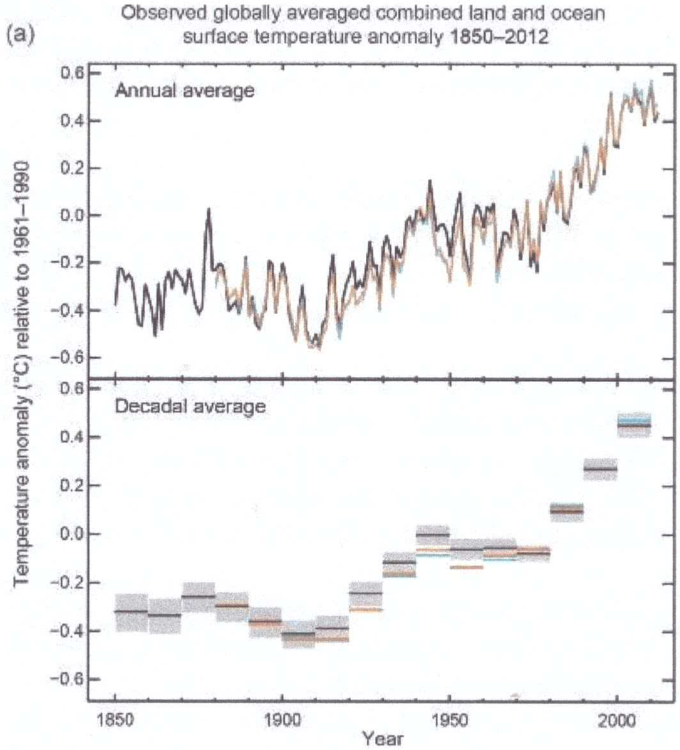

Figure 1 Global mean surface temperature change since 1850

Source: Colman et al., (2015)

Rainfall

- Rainfall averaged across Australia has slightly increased since 1900, with the largest increases in the northwest since 1970.
- Rainfall has declined since 1970 in the southwest, primarily due to reduced winter falls
- Autumn and early winter rainfall have mostly been below average in the southeast since 1990.

Related Phenomena

- Extreme fire weather has increased, and the fire season has lengthened, across large parts of Australia since the 1970s.
- Current global atmospheric carbon dioxide concentrations have reached approx. 406 ppm (February 2017) and are rising at an average rate of between 2-3 ppm per year. 2015 saw the largest carbon dioxide growth rate on record (to 2.96 ppm/year), indicating that atmospheric carbon dioxide concentrations are still accelerating (ESRL, 2018). Concentrations of the other major greenhouse gases are at their highest levels for at least 800,000 years.

Future climate change

Introduction

Attribution of the causes of modern climate change and their relationship to human emissions of greenhouse gases is now well established by successive iterations of the Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC). These reports summarise the now substantial scientific literature on climate change processes, causes, impacts, and adaptation responses. The latest (5th) report, published in late 2013/early 2014, reiterates with greater confidence the conclusions of previous reports that humans have had a considerable impact on the climate of the planet. The IPCC (2014) states:

- 'Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems.
- Warming of the climate system is unequivocal, and since the 1950s, many of the observed
changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen.
- The effects of Anthropogenic greenhouse gas emissions, together with those of other anthropogenic drivers, have been detected throughout the climate system and are *extremely likely* to have been the dominant cause of the observed warming since the mid-20th century.
- Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems.
- Cumulative emissions of CO2 largely determine global mean surface warming by the late 21st century and beyond. Projections of greenhouse gas emissions vary over a wide range, depending on both socio-economic development and climate policy.
- Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise'.

Modelling the Future

Future projections of climate change are contingent on changes in the global greenhouse gas emissions profile. Future net emissions are therefore dependent on population changes, emissions intensity, fossil fuel usage, land management, technological improvements, potential efficiencies in energy generation and global efforts to curb emissions of the primary greenhouse gases. Previous iterations of the IPCC Assessment reports have presented a range of socio-economic scenarios that underpin climate modelling. There are around 40 General Circulation Models (GCMs) currently used to simulate the Earth's climate.

Figure 2 shows that since the beginning of the 21st century, global emissions have increased dramatically to a level of approximately 10 Pg carbon per year. This is equivalent to 10 trillion kilograms per year and places the current emissions trajectory along or above the RCP8.5 line, which would see an increase of 4.0-6.1 degrees C in global mean temperature by 2100. Again, to put this into perspective, this change is equivalent to the difference in temperature between an interglacial (e.g. current climates) and a glacial era (ice age). The change would, however, occur over a century, rather than the many thousands of years usually taken between ice age cycles. As a result, many earth system and ecological processes will receive change at a pace that is unprecedented and places many communities and ecosystems at great risk.

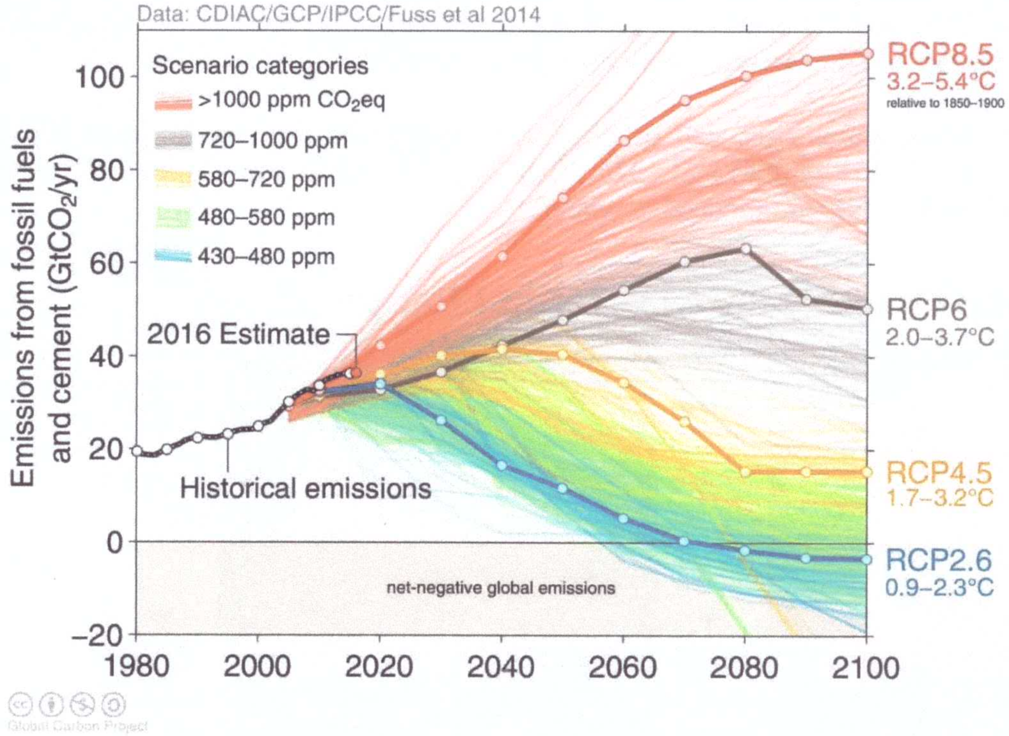

Figure 2 Possible Trajectories of global carbon emissions

Source: Global Carbon Project (2016)

Even if global mitigation efforts increase substantially over the coming decades, Figure 2 indicates that the Earth's atmosphere and oceans will continue to heat at an unprecedented rate. Ultimately, global temperature levels in the latter half of the 21st century will be determined by mitigation actions now.

Model Projections for the Central Tablelands (CT) region

The following is a summary of climate change projections for the CT region based on:

- IPCC 5th assessment reports (IPCC, 2013)
- CMIP3 NARCliM outputs for the Orana/Central West Region obtained from AdaptNSW (Evans et al., 2014; OEH, 2014a,b).
- CSIRO/BoM Central Slopes and Murray Basin Cluster Reports containing mostly CMIP5 modelling for the SE Aust Region (Ekström et al., 2015; Timbal et al., 2015)
- Climate Change adaptation tools and outputs via the Terranova (2015) website, in particular, biodiversity planning modelling (Drielsma et al., 2014).

Please note that all the following maps incorporate both Central Tablelands and Orana regions.

Temperature

There is very high confidence that all temperature indices (maximum, minimum, seasonal, annual, extremes) will continue to increase over the coming decades. Both mean maximum and mean minimum temperatures are expected to rise in the Central West of NSW by around 0.7 degrees C by 2030, and 2.1 degrees by 2070 (OEH, 2014b). This represents a significant acceleration in the rate of temperature rise by comparison to the 20th-century rises.

Daily maximum temperatures rises will be greatest in spring and summer for the Central Tablelands for both 2030 (Figure 3) and 2070 (Figure 4). Minimum temperatures will also rise, although this will be less pronounced in winter.

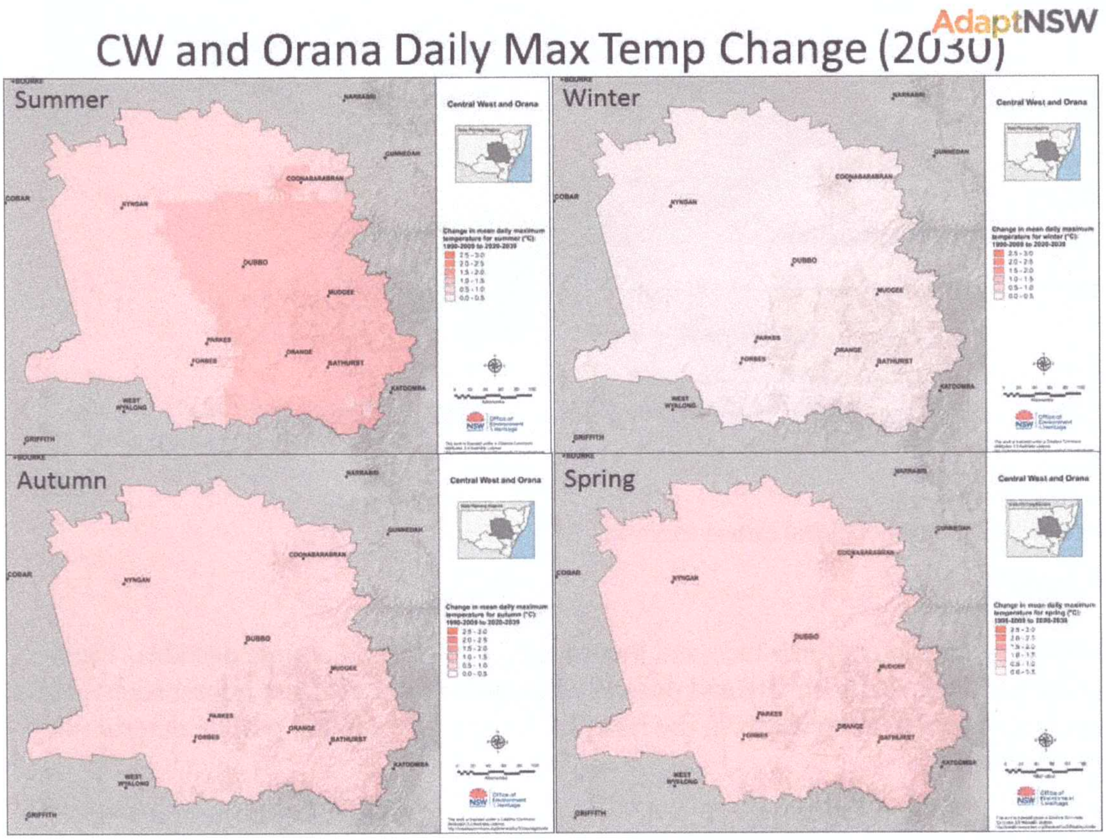

Figure 3 Central West and Orana daily maximum temperature change 2020-2039 (2030)

Rainfall

There is less confidence in projections for rainfall change, due to the highly complex nature of atmospheric processes that govern specific rainfall totals, timing and intensity. On average, a global increase in atmospheric temperature should lead to a slight increase in atmospheric humidity and ultimately to increases in precipitation. However, global climate changes also impact on processes that govern rainfall distribution patterns. For example, a combination of global warming and ozone depletion may be shifting circulation and atmospheric pressure patterns leading to a sharp decline in rainfall in southwestern Australia (CSIRO and BoM, 2015). For the SE Australian region, a 15% decline in rainfall across late autumn- early winter has been noted (BoM and CSIRO, 2014), however its direct attribution to anthropogenic climate change is still to be determined.

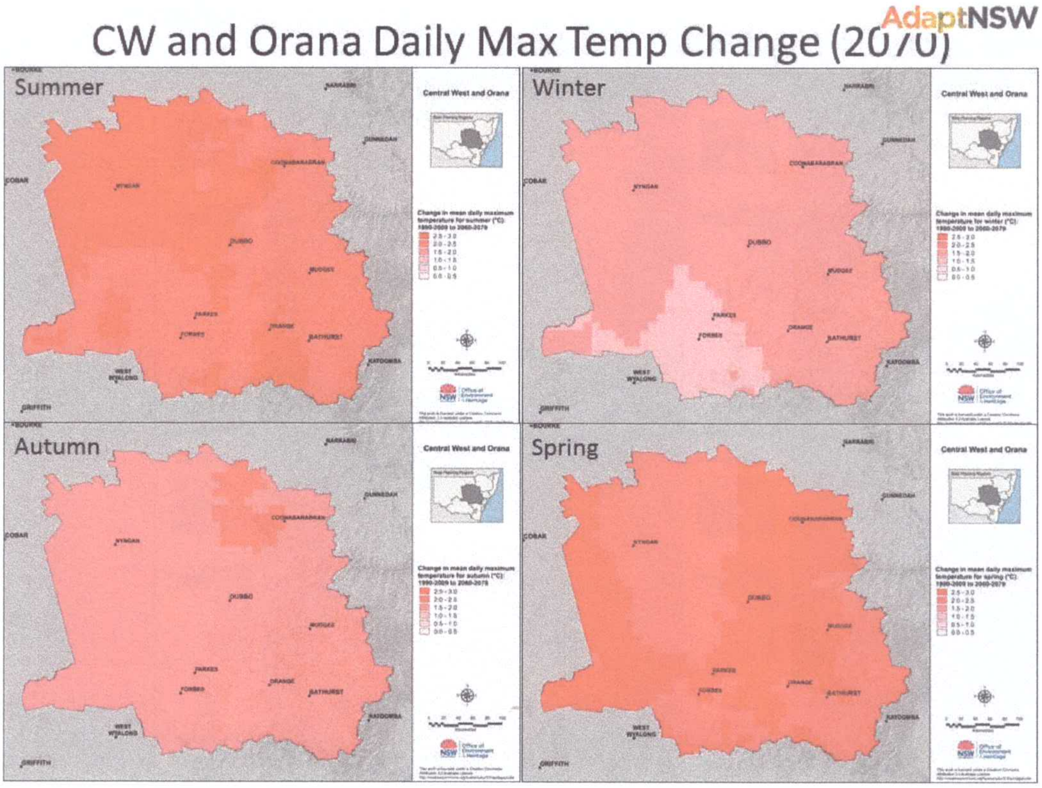

Figure 4 Central West and Orana daily maximum temperature change 2060-2079 (2070)

For the Central West region of NSW, there is medium confidence that mean rainfall will decrease in spring and increase in early autumn (Figure 5) although annual totals will remain similar to current. By 2070, a clear shift towards summer/autumn dominance will become evident (Figure 6), with a possible slight increase (5–10%) in annual totals. The extra rainfall in summer and autumn is projected to be associated with increased intensity events (e.g. storm cells), which are likely to increase the risk of hail and wind damage. Flash flooding risk from these events is also likely to increase.

Potential Evapotranspiration

There is high confidence that potential evapotranspiration will increase in all seasons as warming progresses (Ekströmet al., 2015; Timbal et al., 2015).

Relative humidity

A decline in relative humidity is projected for winter and spring (high confidence) and summer and autumn (medium confidence), although changes in the near term are projected to be small (Ekström et al., 2015; Timbal et al., 2015).

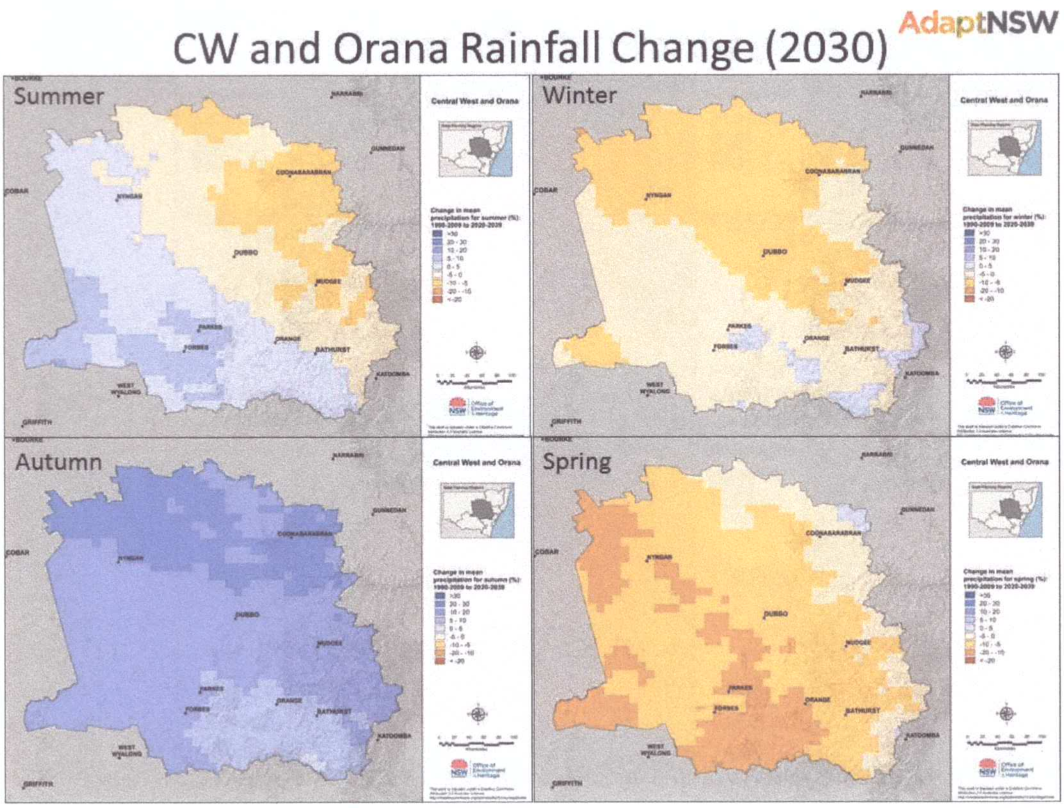

Figure 5 Central West and Orana seasonal rainfall change 2020-2039 (2030)

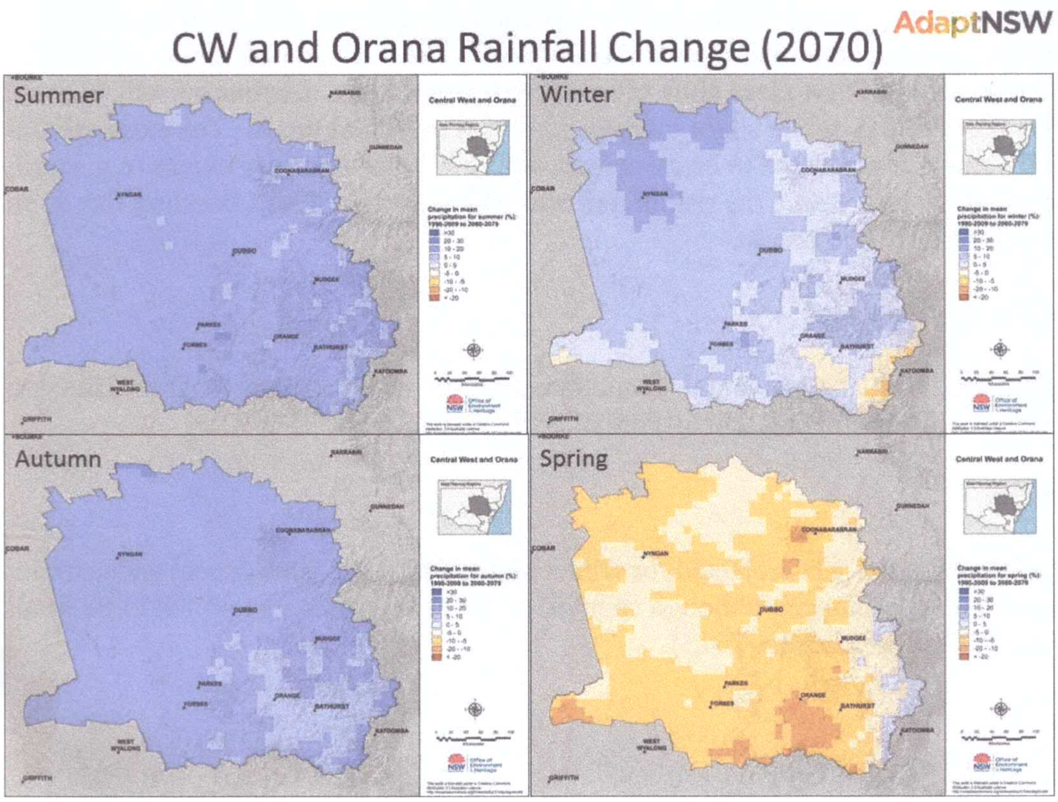

Figure 6 Central West and Orana seasonal rainfall change 2060-2079 (2070)

Drought and soil moisture deficit

Increased temperatures, coupled with increases in potential evapotranspiration (PET) and changed the distribution of rainfall have been shown at a global scale to indicate an overall landscape drying trend (Dai, 2011), which may lead to a worldwide agricultural drought by mid-century. Increased effective aridity (e.g. soil moisture deficit) is projected by most global climate models primarily due to a global PET amplification effect (Cook et al., 2014; Scheff and Frierson, 2015), although prospects for eastern Australia are yet to be determined. Landscape aridity not only impacts on the ability to maintain agricultural production but has also been shown to affect the long term survival of many vulnerable fauna species in the Central West of NSW (Kerle et al., 2014).

Extreme weather and fire

The number of potential frost days in the Central Tablelands is projected to decrease significantly in the long term, although in the near term (the next decade or so) the prevalence and intensity of frosts may be determined to some extent by winter humidity levels. At some stage, broader temperature increases will overwhelm this effect and frost prevalence will decrease in line with global change. This matches the long term trend over the latter half of the 20^{th} century towards fewer and less significant snowfalls across the region. Snowfalls are now an irregular event in the region and mainly confined to the highest mountain or plateau locations (e.g. Mt Canobolas, Blue Mountains, Oberon Plateau, Yetholme, Orange). Reductions in winter frost may impact on the viability of stone and pome fruit production in areas outside the highest plateau locations.

NARCliM modelling (Evans et al., 2014; OEH, 2014a,b) indicates that the majority of the tablelands will have increases in extremely hot days. However, the percentage increases are significantly less than areas to the north and west. Within the region, the western slopes are most at risk for significant increases in extremely hot days (i.e. maximums >35^{o}).

Extreme hot days are often associated with fire hazard, and in Australian conditions, this risk is usually determined by the McArthur Forest Fire Danger Index (FFDI), which is based on indices for dryness (calculated from rainfall and evaporation) and likely weather conditions (temperature, wind speed and humidity). This is a weather-based index and does not explicitly consider fuel loads. Bradstock (2010) demonstrated that climate change might alter the four key ‘switches’ (biomass growth, availability to burn, fire weather and ignition) that lead to increased fire activity. He concluded that in some semi-arid regions a drying climate might reduce fire hazard due to a reduction in available fuel, however, in moist temperate forests (i.e. most of the Central Tablelands forested areas), fire hazards will increase. Maps of projected changes in mean and extreme fire weather conditions, based on NARCliM projections for 2030 and 2070 are available from the AdaptNSW website (OEH, 2014a) and not repeated here. These demonstrate that the most significant increases in fire weather will be in summer and spring, with potential reductions in FFDI in autumn. These results are consistent with a recent trend towards the earlier onset of the fire season (now early-mid spring) in eastern Australia. Significantly higher fire weather risks projected by NARCliM for areas north and west of the Central Tablelands region must be tempered by the potential for reduced fuel loads due to landscape drying in these regions (cf. Bradstock, 2010).

Challenges for natural resource management

The majority of the region has seen a long history of human activities and consequently is considered a highly disturbed landscape, especially since European occupation. Habitat fragmentation, loss of landscape function, changes in soil condition and the overall drying of the landscape are seen as key driving processes for species loss and degradation since European occupation (Kerle et al., 2014). Sixty-four per cent of vertebrate fauna in the broader Central West and Lachlan catchments are considered to be declining (Kerle et al., 2014). Changing climates will almost certainly impose extra pressures on an already degraded and fragmented landscape. Changes to the frequency, intensity and seasonality of rainfall, coupled with the high likelihood of increased temperatures across the region will impact on the survival capacity of many species, especially those already at the margins of their ranges or independently vulnerable.

Climate change and biodiversity

Being centrally located in NSW, the Central Tablelands is a critical region for species migration in all directions. Recent biodiversity adaptation modelling (Drielsma et al., 2014) has indicated that high elevation parts of the tablelands will become critical habitat and potential refugia for vulnerable species affected by rising temperatures, and links to lower elevations on the western and NW slopes will become important corridors in the future. Both structural and functional connectivity of the natural landscape will become increasingly important under changing climates (Doerr et al., 2011), and local NRM bodies will need to prioritise these linkages as part of their regional revegetation policies.

The imposition of climate change itself will undoubtedly increase the value of these revegetation and corridor expansion initiatives. The biodiversity adaptation modelling (Drielsma et al. 2014) has highlighted the overall value of cool, moist regions across central parts of the NSW tablelands for biodiversity adaptation to climate change.

The NSW Register of Threatened species lists 130 species, populations, communities or habitats threatened by anthropogenic climate change in NSW. Many of these exist in the Central Tablelands or may rely on the region for migration. Key endemic populations that are listed include *Eucalyptus canobolensis* (Canobolas Candlebark) and the *Xanthoparmelia* Lichen Community on Mt Canobolas. Mt Canobolas State Conservation Area (SCA) alone contains at least 50 species of flora and fauna that are at the margins of their range, and hence are potentially vulnerable to any change in the climate. This SCA will also become increasingly important as a refuge for species migrating from hotter conditions elsewhere, and management for conservation there must be of the highest priority.

Critical habitats such as montane swamps and swampy meadows (Mactaggart et al., 2008) are similarly listed as vulnerable. It is expected that as climates change, further species, communities and habitats will be listed as vulnerable, endangered or critically endangered. Interactions between specific Key Threatening Processes (KTPs) as a result of changing climates will further exacerbate risks. For example, weed, disease and pest invasion, all KTPs that affect the region's biota, can expand under climate change. Cascading impacts are likely, where changes in one KTP will exacerbate others. Compounding of impacts will furthermore increase the rate at which species will become vulnerable.

Biological responses to climate change will include:

- Species extinction (affecting specialists, vulnerable and isolated communities)
- Migration (mobile species, generalists, often weed species)
- Evolution (mainly rapid reproducers; includes many insects including locusts)
- Withstand climate change (generalists, weeds, pests, large, widespread populations)

Significant further research is required to define locally specific responses to changing climates, especially in high montane areas and reserves where species are reliant on cooler climates and often moist conditions.

Soil erosion

A combination of a drying landscape reduced groundcover and increased erosivity of future summer storms will cause an increased likelihood of sheet, rill and gully erosion in many areas of the State (Rawson and Murphy, 2011). The Central Tablelands are particularly vulnerable to increased gully erosion due to extensive areas of sodic subsoils (Figure 7) which are prone to dispersal when wet.

Figure 7 Vulnerable sodic soils promote the expansion of gullying. This example is near Lewis Ponds.

Photo: A. Rawson

Significant post-fire erosion is also likely when a severe wildfire is followed by summer thunderstorms (McInnes-Clarke et al., 2014). Rawson and Murphy (2011) also highlighted the increased risk of salinity under future climate projections, primarily due to changes in soil water balance across seasons, and a more dynamic wetting/drying regime. Known occurrences of dryland salinity in the region are considered most at risk of reactivation and expansion.

Biosecurity

Projected climate changes for the entire country will fuel the spread of tropical and sub-tropical species into regions further south. Many of these will be pest and weed species, including insects, insect-borne livestock viruses, cane toads, cattle ticks, and ferals. Incidences of zoonotic diseases (e.g. Hendra virus, leptospirosis) are projected to increase in future as the movement of humans, livestock and wild animals is affected by changing climates (Australian Academy of Science, 2015). The rate at which these pests and diseases are likely to move south is largely unknown.

A recent report from the Australian Academy of Science (2015) indicates that Australia's risks of disease spread will be significantly increased under climate change projections. The types and frequencies of outbreaks will increase, especially many vector-borne diseases (e.g. dengue fever borne by mosquitoes), and heat-related food-borne diseases such as *Salmonella*, *E.coli* and *Campylobacter*. Waterborne diseases such as Cholera and *Giardia* are also projected to rise in response to changes in water availability and temperature. Algal blooms in both rivers and reservoirs are projected to increase as water temperatures rise.

Projected climate change will affect the risk of weed threats in two ways: a) the suite of weed species in the region will change; and b) some weeds will become more invasive (Scott et al., 2014). In the case of the Central Tablelands, pest and weed invasion is expected via migration from warmer regions to the north and west. It is likely that species previously unrecognised in the tablelands will begin to invade in the coming decades, and previously naturalised species may become increasingly difficult to control as climate changes (Scott et al., 2014). Current dispersal mechanisms (including accidental dispersal via human activities) will remain the same. However, the ability of some species to take root and reproduce will increase in the region, especially those species where cold weather is a current limiting factor. Increased CO_2 in the future atmosphere may also preferentially advantage certain C4 plants (species with a more efficient method of converting CO_2 to biomass carbon), many of which may become weeds within the region.

Extreme climatic events

All models suggest an increased risk of fire, flooding, storm damage (excess wind/hail/rain), heatwaves and drought for many regions within NSW, including the Central Tablelands. The key increases in climate-derived risks on a seasonal basis will be:

- summer: flood, fire, heatwave, storm damage, hail, drought
- autumn: flood
- winter: drought
- spring: drought, fire, heatwave

Public awareness and management of weather-related extremes should focus on the understanding of heightened risks under climate change conditions, including changes to drought severity and fire behaviour that increase the risk of injury or death. For example, the 2009 Black Saturday fires in Victoria were driven by weather conditions not previously experienced in Australia, which were likely to have been exacerbated by climate change. The subsequent inquiry into the fires instigated a range of new management strategies, including the creation of a new fire risk category of 'Catastrophic'. Under this category, fire behaviour is said to be directly life-threatening, and the best response is to leave the area promptly. Previous best management practice involved a 'stay-and-save' strategy under Extreme conditions. Identification of the correct response is, therefore, critical to survival.

Summary and conclusion

Much of central NSW (in particular the Central Tablelands) is a relatively cool climate location that will likely become increasingly attractive as climates continue to warm. The region is likely to receive an increase in net migration of:

- people (climate refugees from hot areas west and north; lifestyle migrants; rural retirees to get closer to medical services in large centres like Orange)
- native species (range expansion or shifting)
- broadacre agriculture (shifting into the region as cold winters become milder)
- weeds (known and previously unknown in the landscape)
- pests (as above)
- diseases (as above)

It is envisaged that managing this net migration will eventually become the key activity of all NRM, regional development and local government agencies in the region. Land use conflicts are an inevitable consequence of increased net migration into the region, and all agencies must play a key role in helping to preserve the natural and cultural amenity of the landscapes where conflicts occur. For example, increased opportunities for agricultural expansion in the Tablelands must be balanced against the need to maintain adequate native vegetation corridors for species migration, and water resources for all. Soil erosion risks will continue to increase, and careful management of new land uses and users will be critical to ensure the sustainability of soil resources. Of particular concern is the expansion of lifestyle blocks where the owners may not have the land management experience necessary to restrict land degradation or for adequate pest and weed control.

A summary of the cascading or 'emergent risks' impacting biodiversity in the Central Tablelands is shown in Figure 8. It is clear that global climate change influences many individual processes that determine the longevity and resilience of species and ecological communities. In combination with indirect effects such as human population and land-use changes, climate change will undoubtedly affect native habitats and increase the risk of species decline and community failure in the coming century. It is not sufficient to focus on one particular climatic element, e.g. temperature rise, when assessing risk, as the whole suite of changes and impacts will combine to produce cascading change in ecological communities.

Further research needs include:

a) specific details about interactions between environmental change and ecological needs of vulnerable species within the region, including:

- threshold heat and water stresses
- reproductive capacity and limitations
- evolutionary capacity
- preservation potential of habitat

b) detailed modelling of specific habitats within the region, both for their refugia and temporary corridor potential

c) an inventory of the degradation status of all high-value habitats, with options for their rehabilitation

Overall Impact = f (

Current conditions;
already fragmented landscape, declining species, declining communities, high level of endemism, disturbed and degraded soils (low nutrient and OC status), drying landscape, fewer swampy meadows, gullied watercourses

Direct Impacts;
shifting habitat conditions, heat stress, water stress, fire, predation, reproductive limitations

Indirect Impacts/emergent risks;
mismatching environmental conditions, corridor breaks, cascading habitat loss, weed competition

Social Changes;
Human land-use change, food security pressures, population change)

= (the perfect storm?)

Figure 8 Climate Change impact on biodiversity in the Central Tablelands (expressed as a function f(a,b,c,d)=x)

d) the use of fire as a management tool requires further investigation in the region. Fire ecology is a primary driver of biodiversity in the region (Graham et al., 2013), and can also be used as a weed reduction and land rehabilitation tool (Milton Lewis, personal communication, 2015). Aboriginal cultural use of fire is receiving increased recognition in recent years, and many local rehabilitation projects are starting with cool cultural burns (e.g. Parissi et al., 2015). Projected changes in FFDI will also undoubtedly influence the available window for fuel reduction burns and therefore require a rethink of fire hazard reduction strategies.
e) as a corollary of d) above there should be a renewed effort into understanding and implementing Aboriginal cultural land management practices that arguably had a better appreciation of the intrinsic capability and resilience of the land under management, and made better use of the available natural resources. European practices have largely reshaped the Australian environment to permit the imposition of European crops and animals onto a land largely unsuited to it. Native flora, fauna and soils have all declined as a result. With the spectre of further impacts from global climate change on the horizon, alternative land management practices that are better attuned to the intrinsic capabilities of components of the natural landscape are essential.

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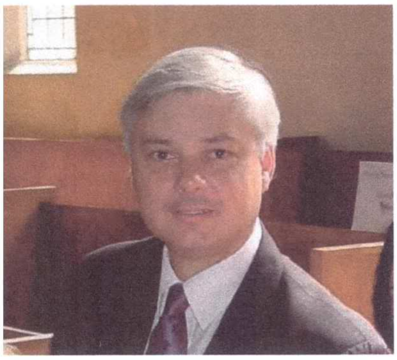

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