[The Web link for this essay is here]

Net zero emissions by 2050

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Summary

- A brief potted history of Australia's LULUC&F[1] sector in the NGGI, draws on the author's extensive research experience targeting vegetation dynamics in our northern grazed woodlands. The discussion commences with the lead up to the Kyoto Protocol (KP) Agreement in 1997 and concludes with the implications, should the nation endorse a goal of achieving 'net zero (GHG) emissions by 2050'. There is a particular focus on 'vegetation thickening' and the evolving definition of 'managed' land, as both impact carbon accounting for the NGGI.
- In a Preamble the term 'net zero emissions' is explained and the fact that modern society cannot completely replace fossil fuel sources as feedstock for all of its energy or industrial products is highlighted. This in turn means that achieving net zero emissions will require some form of carbon sequestration (withdrawal from the atmosphere) to balance unavoidable human induced carbon dioxide (CO_2–e) emissions released into the atmosphere.
- The KP agreement is portrayed as a learning experience for many of the participating 'developed' and 'developing' countries. Most KP conference delegates had to accept at face value the often complex data shared with them on Carbon Accounting. This meant that available factual information was not always presented to the delegates – notably Australian data on C fluxes in the LULUC&F sector of our NGGI.
- A clear source of confusion for KP attendees was what actually comprised 'managed land'. It is pointed out that today this meaning has evolved such that nations with large LULUC&F sectors (e.g. Australia and the USA) have seemingly arrived at very similar definitions in line with evolving IPCC guidelines. As a result both the conterminous USA and virtually the entire Australian continent are now recognised by their respective governments as being "managed" for GHG accounting purposes.
- Given the size of the land mass involved it is impractical for any national Agency to measure biomass C or soil organic C and their fluxes over time, using ground based sampling alone. This has led to models such as FullCAM being developed for this task, but if the model outputs cannot be validated by field sampling at scale (e.g. for acceptable accuracy and precision) they are not fit for purpose. Such criticism is especially relevant to the estimate of fluxes in soil organic C (which comprises >50% of the combined above and below ground organic C pool in Australia's grazed woodlands).
- Fortunately satellite based spectral sensors, together with inverse modelling, now provide data that enables net CO_2 emissions to be determined with desired rigour – although a more extensive distribution of ground based calibration (validation) stations (e.g. the Total Carbon Column Observation Network) would give greater confidence in present outputs.
- Results are described that show both Japan's GOSAT and NASA's OCO-2 spectral sensors reveal the Australian land mass is an annual net C sink. And this is so under both *La Niña and El Niño* weather/climate conditions, with or without prescribed fossil fuel emissions included.
- The final conclusion is that there is very strong evidence to suggest that Australia already meets the aspirational goal of 'net zero emissions by 2050'! (This occurs because our 'managed' vegetated land area is very large, yet our human population is numerically smaller than for many individual world mega cities).The methodology that leads to this finding is outlined, while it is expected that fine tuning of the technology employed will give further certainty to the conclusions. But the pathway and procedures to follow are increasingly obvious. We would be derelict in our duty to our country, not to use them.

[1] Acronyms are defined at the essay's conclusion

Preamble

The call for net zero anthropogenic (GHG/CO_2–e) emissions to be released into the earth's atmosphere by 2050 is driven by those who believe that increasing quantities of CO_2 (and similar acting GHG gases) in the atmosphere are imperilling future life (and the climate) on the planet as we know it. There is also another cohort of people who promote net zero as a target, which they believe will enhance a multitude of personal, political and commercial agendas which may or may not have any bearing on future climate outcomes. A third group of sceptical people do not consider that 'additional' GHGs released into the atmosphere, as a result of mankind's activities, pose any unmanageable climate threat to humanity. Indeed they propose that a rising CO_2 concentration in the atmosphere is to be welcomed, as it significantly enhances plant growth and consequently world food production – *inter alia.*

What does 'net zero emissions' mean? The key words here are 'net zero'. This simply implies that GHGs may continue to be released by countries (as 'sources') into the atmosphere, provided that similar quantities are withdrawn from it (sequestered in GHG 'sinks') over corresponding timeframes. So the net effect is that sources and sinks, resulting from human decisions/activities in a country, are quantitatively balanced leading to more or less no change in that nation's contribution to atmospheric CO_2–e content.

The major human induced source of rising atmospheric CO_2 levels is the combustion of fossil fuels. Hence the concerted worldwide push to limit the use of such fuels and replace them by alternative energy supplies. Whether that is a realistic goal or not, the simple fact is that modern society cannot function without a multitude of material items that are ultimately derived from fossil fuel sources.

For example, industrial chemistry's use of petroleum accounts for 14% of all greenhouse gas emissions (https://www.sciencemag.org/news/2019/09/can-world-make-chemicals-it-needs-without-oil). And Rankin Energy Corp lists 144 items out of 6000 (and counting) of everyday items sourced from petroleum alone. See: https://www.ranken-energy.com/index.php/products-made-from-petroleum/ . It is claimed that many of these products will be made from alternative feedstock in future, but this is to be convincingly demonstrated in practice. Meanwhile there are some items e.g. jet aircraft fuel for which there seem to be no realistic/practical alternatives.

So, even in the very unlikely event that fossil fuels can be completely replaced as an essential energy source, there will remain a large requirement to sequester CO_2–e gases to have any prospect of achieving 'net zero emissions by 2050'. Carbon capture and storage, 'green hydrogen' and nuclear energy are frequently advocated as a means of limiting CO_2–e emissions into the earth's atmosphere, but the practicality or political constraints to their use at scale have yet to be overcome. Therefore, where there is sufficient land available many nations have focussed on sequestering GHGs in land based vegetation and within the soil supporting it.

The Kyoto Protocol

The Kyoto Protocol was the first agreement established under the United Nations Framework Convention on Climate Change which set out to limit future release into the atmosphere of GHGs resulting from human activities - as a means of curtailing the impact of 'global warming'. The major nations targeted by the Protocol were those included in the 'developed world' or Annexe 1 countries. Australia was in this grouping.

While the prime focus of the Protocol was on reducing fossil fuel use it was also recognised that extensive tree (land) clearing (e.g. Brazil, Australia) was an additional anthropogenic source of increases in atmospheric GHG concentrations. Thus many country delegates to the KP regarded reductions in worldwide tree clearing to be a desirable Protocol objective.

To assist negotiations all nations participating in the KP brought to the conference pro forma GHG accounting budgets (inventories) for their respective countries. The fossil fuel components of these budgets were generally accurate and had small uncertainties because the use of these fuels is closely monitored via well calibrated measuring devices (weighbridge scales, liquid and gas flow meters). On the other hand the Land Use Change and Forestry (LUC&F later to become LULUC&F) sector of country inventories (which included land clearing impacts) was far more problematic.

The latter situation arose because in the early-mid 1990s, when most countries represented at the KP talks compiled pro forma GHG inventories, available satellite imagery was still at a coarse resolution compared with that available today.   In Australia's case, while it was well known that extensive tree clearing was occurring (especially in Queensland and NSW) it was thought that no federal or State agency had definitive data on the area involved, nor of the carbon fluxes in the vegetation systems before or after clearing.

To address this problem the Australian Greenhouse Office (an agency within the Federal Department of the Environment. Sport & Territories) contracted the Bureau of Resource Sciences - to obtain the best data they could find to estimate the extent of annual Land Clearing in each of the States. Dr Michele Barson was given this task.

At this time the Queensland State Department of Primary Industries actually had a well set up grazed woodland monitoring/management research program in place. [That State's grazed woodland area alone (60+ M ha) exceeded all of the area allocated to agriculture (cropping/horticulture) and grazing in NSW]. So Dr Barson contacted me (as leader of the Qld DPI's woodland management program) to ascertain the extent of on-going land clearing in this State.

This was a protracted process because in the absence of definitive satellite data it meant obtaining information (often commercial-in-confidence) from a myriad of clearing contractors and landholders.   Dr Barson would contact me more or less on a weekly basis seeking progress reports on clearing estimates. At the conclusion of each conversation I would ask her who was calculating the CO_2 being withdrawn from the atmosphere via tree 'thickening' (increases in tree density, basal area, timber volume and/or canopy cover) in woodland areas not subject to clearing.   I was never given a direct answer. Yet this seemed strange from a carbon accounting viewpoint, since whether to clear or not clear land was surely a management decision affecting the carbon flux on both retained and cleared areas?

I also became aware that fluxes in soil organic carbon beneath grazed woodland communities were not being accounted for in our putative NGGI.   It is common for the organic C content of soil within the vegetation rooting zone of woodland trees to comprise >50% of the total C content in the woodland's above + below-ground biomass. Based on these observations I concluded that the whole carbon accounting exercise for our grazed woodlands was so full of potential errors, as to be useless/not fit for purpose.

Therefore I raised my concerns of these large C accounting deficiencies with the AGO.   Like Dr Barson the AGO believed that uncleared grazed woodland areas comprised remnant vegetation that was in equilibrium with its environment and therefore had a 'neutral' impact on C budgets. Nevertheless they asked Prof Ian Noble of the ANU to convene a meeting of some 13 national and international woodland ecologists to examine "The Contribution of "Vegetation Thickening" To Australia's Greenhouse Gas Inventory".   Several senior staff of the AGO also attended. The meeting took place at the ANU on 26 – 27 October 1996 – i.e. well before the KP conference in December 1997.

The Report of this meeting's outcomes was delivered to the AGO on 28 May 1997. The Executive Summary is included in a Submission I made to the Joint Standing Committee on Treaties, Parliament House, Canberra - Inquiry into the Kyoto Protocol - in August 2000. Link: https://www.aph.gov.au/Parliamentary_Business/Committees/Joint/Completed_Inquiries/jsct/kyoto/subslist and go to Individual Submission #38 (Dr Bill Burrows). Prof Noble's Executive Summary of his Report is Attachment 2 (q.v.). The following extract is of particular note: *It was concluded that there is a strong case to include the sequestration of CO_2 resulting from the management actions leading to "vegetation thickening" in the National Greenhouse Gas Inventory. The net effect, after allowing for the CO_2 losses through clearing affected areas would almost balance the emission from other activities relating to land-use change and forestry practices and is roughly a fifth of Australia's net greenhouse gas emissions (576 million tonnes of CO_2 in 1994).* (Italics inserted).

Despite the Conclusions of its own appointed Expert Panel the AGO's advice, at the time of the Parties signing the KP, was that the contribution of vegetation thickening to Australia's Greenhouse Gas Inventory in 1997 and for the First KP Commitment Period (2008-2012) should be ignored.   See: https://web.archive.org/web/20130517024601/http://www.aph.gov.au/parliamentary_Business/Committees/House_of_Representatives_Committees?url=jsct/kyoto/sub112_3.pdf. The implications/machinations behind this are discussed in more detail in another Submission I made to the Australian Government's Climate Change Policies Review in 2017. Link: https://web.archive.org/web/20181005144202/http://www.environment.gov.au/submissions/climate-change/review-climate-change-policies-2017/bill-burrows.docx

Extracts from this last linked Submission are especially relevant to future NGGI Accounts for Australia – notably if a target of "net zero emissions by 2050" is adopted by the Australian Government: 'For the first Commitment Period (2008 - 2012) of the Kyoto Protocol (KP) only c. 1% of Australia's land mass was actually taken into account in determining net emissions from the LULUC&F sector. In essence we restricted our accounting to estimates of land areas subject to deforestation, afforestation and reforestation. So, for example, in 2008 - 2012 the area contained within these inclusive categories only made up about 10% of the Australian forest estate and around 6% of Queensland's forest estate. Presumably all remaining areas in Australia's forest estate were considered to be not managed?' [For the purposes of the KP a "Forest" is a minimum area of land of 0.05 -1.0 ha with tree crown cover (or equivalent stocking level) of more than 10-30%, with trees having the potential to reach a minimum height of 2-5 m at maturity, *in situ*].

Then in December 2012 the Australian Government announced that – "it will include, in addition to the above, forest management, cropland management, grazing land management and re-vegetation activities so that for the second Commitment Period (2013 – 2020) virtually the whole (Australian) land mass will enter into the accounting framework [emphasis added]. (See page 3 in: https://web.archive.org/web/20200330062921/http://climatechangeauthority.gov.au/files/files/Target-Progress-Review/Australian%20land%20use%2C%20land%20use%20change%20and%20forestry%20emissions%20projections%20to%202030/Australian%20LULUCF%20emissions%20projections%20to%202030.pdf).

The managed land concept as a proxy for anthropogenic emissions and removals was introduced in the 2003 IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (LULUC&F), and incorporated into the 2006 IPCC Guidelines. The latter documents require full representation of land use in a country, with all land being subdivided into one of the following land-use categories: forest land, cropland, grassland, wetlands, settlements and other land. In addition, forest land, wetlands and grassland must be divided into managed and unmanaged sub-categories, and although there are no GHG reporting requirements for unmanaged lands, countries are encouraged to report their areas.

Subsequently Australia simplified its definition of managed land by considering all forest land, grasslands and wetlands as managed, while land in the 'other land' category (e.g., rock outcrops, barren areas) is considered unmanaged. https://doi.org/10.1186/s13021-018-0095-3 [See 'Defining managed land']

In its LULUC&F sector Annual Reports the USA notes that US emissions and sinks reported in (their) inventory are comparable to emissions and sinks reported by other countries (page 6.6). Yet from the preceding discussion such comparability was definitely not so in the case of Australia for 2008-2012. For example: The United States definition of managed land is similar to the basic IPCC (2006) definition of managed land, but with some additional elaboration to reflect national circumstances. Based on the following definitions (p. 5), most lands in the United States are classified as managed (emphasis added). Importantly, the IPCC (2006, Vol. IV, Chapter 1) considers all anthropogenic greenhouse gas emissions and removals associated with land use and management to occur on managed land, and all emissions and removals on managed land should be reported based on this guidance (see IPCC 2010 for further discussion). Hence managed land serves as a proxy for anthropogenic emissions and removals.

Managed Land in the USA: Land is considered managed if direct human intervention has influenced its condition. Direct intervention occurs mostly in areas accessible to human activity and includes altering or maintaining the condition of the land to produce commercial or non-commercial products or services (emphasis added); to serve as transportation corridors or locations for buildings, landfills, or other developed areas for commercial or non-commercial purposes; to extract resources or facilitate acquisition of resources; or to provide social functions for personal, community, or societal objectives (emphasis added) where these areas are readily accessible to society.

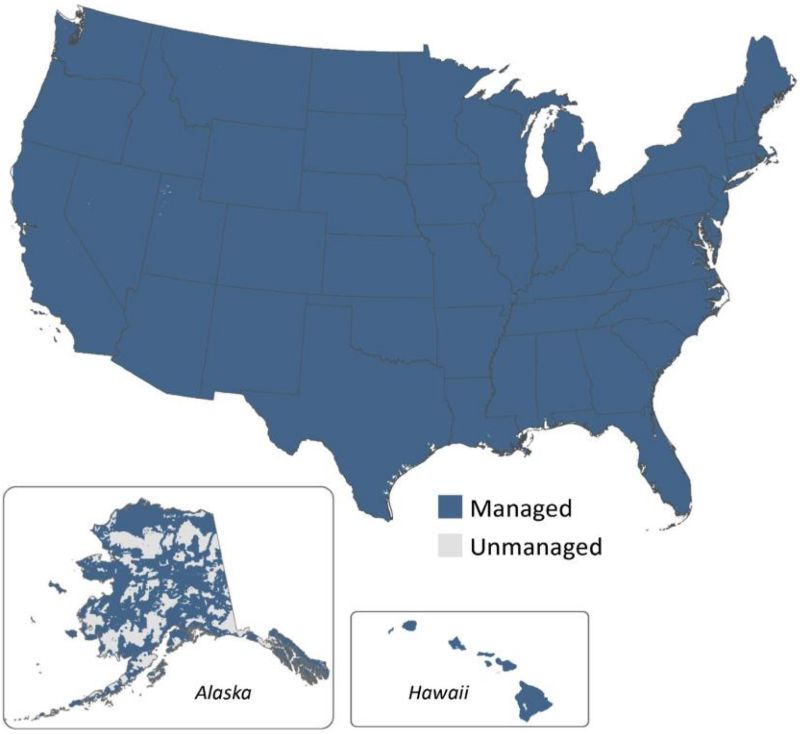

Figure 1 Distribution of managed and unmanaged land in the United States. The grey areas are unmanaged and the blue areas are managed   Link: https://doi.org/10.1186/s13021-018-0095-3

The total land area included in the U.S. Inventory is 936 million hectares across the 50 states. Approximately 890 million hectares of this land base is considered managed and 46 million hectares are unmanaged (Fig 1), which has not changed by much over the time series of the Inventory.

So considering our nation's stated intentions, both Australia and the USA will henceforth be including virtually their entire land mass in their respective GHG accounting frameworks. Indeed both countries need to do this if for no other reason than GHG accounting consistency. For Australia, this is a massive change compared with our limited (selective) LULUC&F accounting for the first KP Commitment Period. However it is entirely in step with vegetation community inclusions (e.g. mulga and poplar box grazed woodlands) accepted for GHG abatement purposes under the present Australian Government's Direct Action Plan.

Post Kyoto

The second Kyoto Commitment period concluded in December 2020. We have now moved to its successor, the Paris Agreement – for which the Australian government has already announced "that we will meet and beat the new 2030 Paris target". However this can only occur if we include fluxes in the LULUC&F sector of our reported inventory. And all pools and fluxes within this sector must be accounted for. We can't pick and choose. It would be preposterous if the huge soil organic C pool within vegetation rooting depth and its flux in the land mass was ignored in our GHG accounts - as it is responsible for at least 50% of the total biomass derived C pool within the above + below ground vegetation[A].

Yet it is impractical to accurately measure that flux with acceptable precision (uncertainty) for large paddock or landholding areas, let alone at a State or continental level. To address this major C accounting problem the NGGI places faith in its FullCAM model to derive changes in soil organic C pools. But such model outputs are essentially useless - unless they can be validated by objective field measurements.

You see the problem. We can't measure soil organic C flux at scale in field practice because the measurement error is larger than the flux being recorded. So we revert to modelling the putative outcomes but these estimates still have to be validated by field based measurements accompanied by statements of their accuracy and precision! That is a classic intractable, circular argument.

None of this is to say that there is not a significant CO_2 sink present in the LULUC&F sector of Australia's NGGI. {See: NOAA and NASA for supporting indications at a global level}. All it means is that alternative sampling methods need to be derived to determine its sign (source or sink) with accuracy and precision while targeting Australia's vegetated land area (c. 769 million hectares).

Net zero emissions by 2050?

It is the net CO_2-e flux in the atmosphere above the earth's surface which should be at the core of all global warming/climate change concerns of interest to government. Measures of atmospheric CO_2 concentrations integrate all sources and removals and do not distinguish whether this gas is of anthropogenic or natural origin – after all, any assumed GHG effects in the atmosphere are dependent on the molecule and independent of its source.

A focus on CO_2 concentrations in the atmosphere above the Australian continent would therefore seem to be highly appropriate before planning any future abatement actions. This is especially so given the stated intention to hereafter include 'virtually the whole (Australian) land mass ………. into the accounting framework' Burrows (2016) provides an overview of such an approach.

The evidence for substantial 'thickening'(increases in stem density, size or canopy) in the grazed 'intact' (uncleared) woodlands of northern Australia - since Europeans and their domestic livestock supplanted indigenous management on the continent - is compelling and overwhelming (see numerous illustrations, citations and discussion in:
https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Finance_and_Public_Administration/Completed%20inquiries/2008-10/climate_change/index {Submission # 297 – Bill Burrows}

A more recent example is the paper by Liu et al. (2015)[2]
https://www.researchgate.net/publication/281887147_Recent_reversal_in_loss_of_global_terrestrial_biomass - which documents an increasing trend in above ground biomass carbon (= sink) in our northern savannas over the 20 year (1993-2012) period, that included *El Niño* and *La Niña* years. [Vegetation biomass contains about 50% carbon]. This net biomass gain exceeded all concurrent losses in biomass due to tree clearing, woody plant deaths (drought related) and fires occurring during the monitoring period. Support for this statement is provided by ground-based observations of long term tree growth patterns in woodlands in CQ (Burrows et al. (2002) ; Back et al. (2009) - See Fig.1 therein); along with the many other examples cited in the Senate Inquiry Submission linked above.

The impact that thickening woody plant populations have on this country's GHG balance is magnified by the simple fact that Australia's land area approximates that of the USA, yet our human population barely matches that in many individual world mega cities. That this impact translates into a net CO_2-e sink (Anomalous carbon uptake in Australia as seen by GOSAT) is not surprising, although the extent of this Detmers *et al.* (2015) finding is astonishing. Hence the enhanced carbon sink these authors detected for 2011 amounted to some 2800 Mt CO_2-e. This contrasts with our reported NGGI emissions for the same year of just 552 Mt CO_2-e.

The strength of the Detmers *et al*. technique and analysis is supported by Marshall *et al*. (2015) Robustness of CO2 inversions . The huge advantage that Australia could enjoy in applying this approach, from the measurement standpoint of fortuitously having a comparatively small population, in a single country on a vast island continent, cannot be overstated.

And here are some supporting observations - as illustrated in a map (Fig. 2) of the most persistent carbon dioxide "anomalies" seen by NASA's Orbiting Carbon Observatory 2 [OCO-2] (i.e. where the carbon dioxide is always systematically higher or lower than in the surrounding areas).

[2] Brandt *et al.* 2017 found similar trends in their African study. See: 10.1038/s41559-017-0081

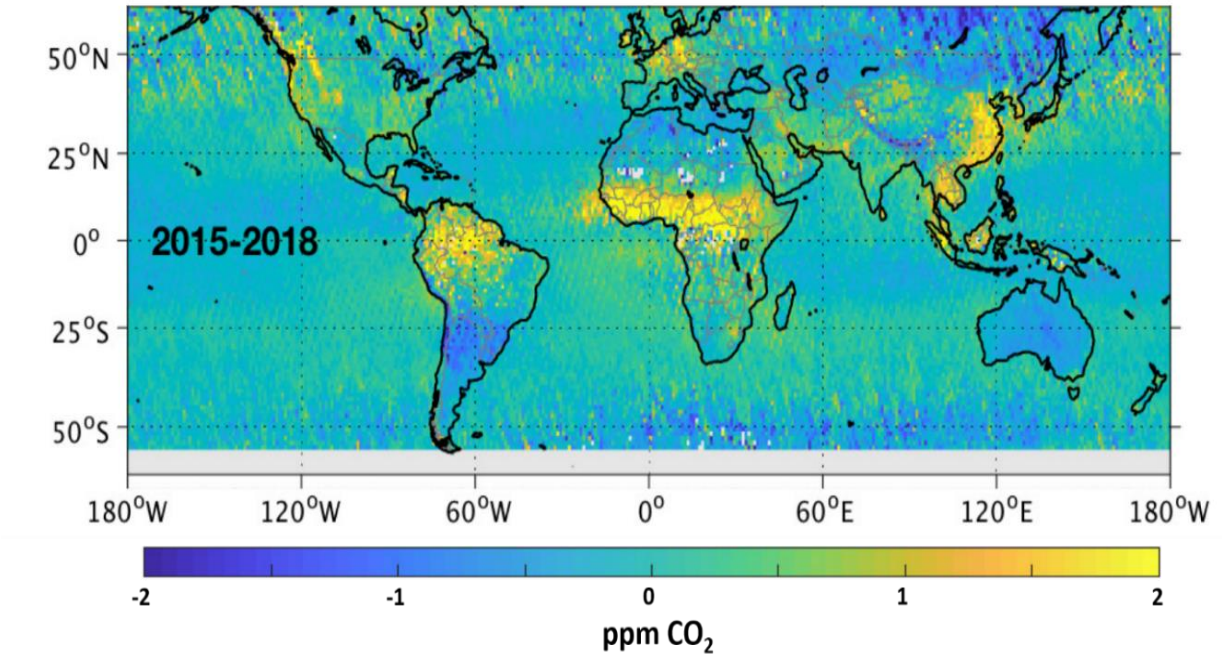

Figure 2 Positive anomalies are most likely **sources** of carbon dioxide, while negative anomalies (blue colourations) are most likely to be **sinks**, or reservoirs, of carbon dioxide. Credit: NASA/JPL-Caltech. (WHB - Emphases added). See: https://climate.nasa.gov/news/2915/the-atmosphere-getting-a-handle-on-carbon-dioxide/

Note that these data reflected most of the strong *El Niño* weather pattern in 2014-16 cf. the Detmers *et al.* observations { http://dspace.library.uu.nl/handle/1874/327830 } obtained in a strong *La Niña* weather pattern. Conclusion: *Irrespective of seasonal rainfall extremes the Australian continent is a net sink for* CO_2!).

A more recent paper by Chevalier *et al.* (2019) (Link: https://acp.copernicus.org/preprints/acp-2019-213/acp-2019-213.pdf) supports the combined Detmers + NASA data (see Chevalier *et al.'s* info for Australia - Fig 3, lower chart box, p. 21 in that paper - and note that GOSAT & OCO-2 values are all negative (= a C sink) for the 2010-18 period. Don't be put off by the Figure 3 annotation – "Time series of Inferred natural CO2 annual flux (**without the prescribed fossil fuel emissions**) between 2004 and 2017……..". Very little of Australia is identified as not being managed today. Whether we decide to use it or protect it, to make it a National Park or grazing land, forest plantations, mines or World Heritage etc we have made a conscious decision on its management. This is more or less identical with how the USA also classifies land as being "managed'' (Fig.1) for their GHG Inventory purposes. [See earlier discussion on what Australia and the USA now consider to be 'managed" in the Section on the 'Kyoto Protocol'].

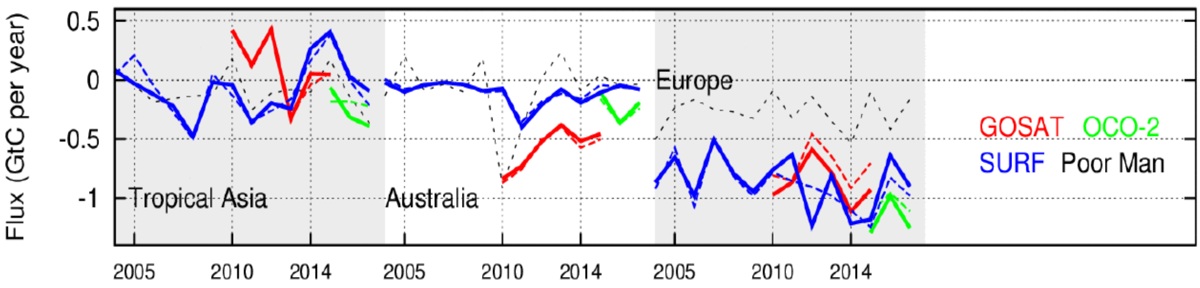

Figure 3 Time series (for Australia – centre graph) of Inferred natural CO2 annual flux (without the prescribed fossil fuel emissions) between 2004 and 2017, averaged over TransCom 3 land regions (see Fig. 4 below). Inversions with LMDz5A (LMDz6A) are shown in continuous (dashed) coloured lines. In the sign convention, positive fluxes correspond to a net carbon source into the atmosphere. [With negative fluxes corresponding to a net carbon (dioxide) withdrawal from the atmosphere - WHB]. The last year of the GOSAT inversions (2016) is not represented because of likely edge effects. Note that the prior fluxes are zero over land at this temporal 5 scale (see Section 2.2 in Chevalier link). [Chart extracted from Fig. 3, p.21 in Chevalier *et al.* 2019].

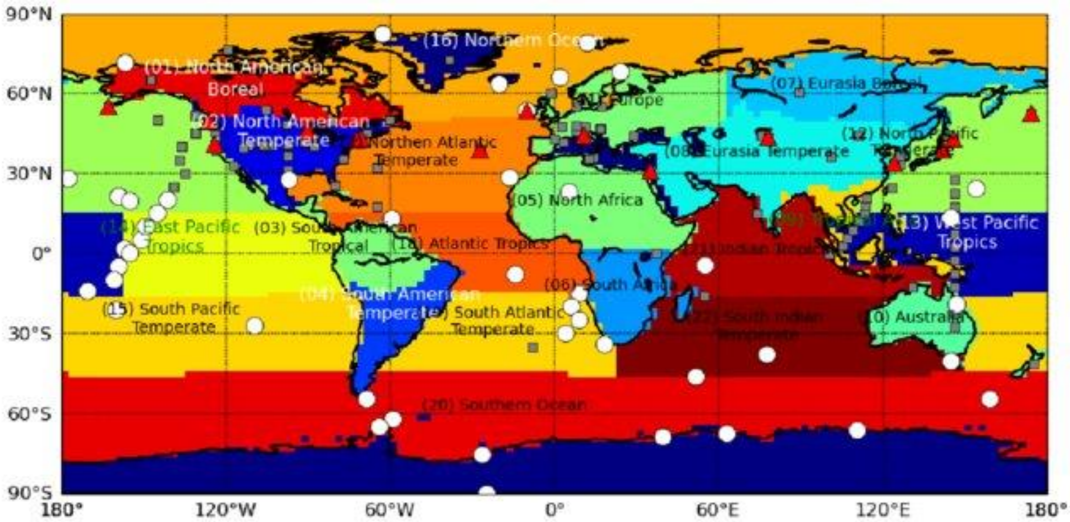

Figure 4 TransCom 3 land regions (See: https://acp.copernicus.org/preprints/acp-2019-213/acp-2019-213.pdf)

Australian fossil fuel emissions (not accounted for in Fig. 3) approximate 400 M t CO_2 per year [https://ourworldindata.org/co2/country/australia] or 110 M t C (as a component of molecular CO_2). Meanwhile the flux derived from OCO-2 sensors suggests that, excluding fossil fuel emissions, Australia was a net countrywide sink of c. 200 M t C in 2017 and when fossil fuel emissions were accounted for still remained a net sink for c. 90 Mt C (or 330 M t CO_2 equivalent). [In 2019 the LULUC&F sector of the USA was a net sink of c. 800 M t CO_2 - https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#land-use-and-forestry – but this only comprised 12% of total USA GHG emissions].

Europe (Fig. 4) is another example where the land sink for C from CO_2 emissions is surpassed by the CO_2 released into the atmosphere. Europe's annual emissions from the burning of fossil fuels for energy and cement production were c. 5.45 Gt CO_2 in 2019 (https://ourworldindata.org/co2-emissions). This contains c.1.49 Gt C per year. So while Europe was an inferred natural sink over the annual periods monitored (Fig. 3), C released into the atmosphere in 2019 (as a component of CO_2) exceeded this sink by c.500 Mt C.

There is no doubt that CO_2–e fluxes in the LULUC&F sector of Australia's nationwide GHG accounts are fraught with potential measurement errors and uncertainties, when based on field collected data. And modelled flux estimates suffer from the impracticality of validating the model outputs. This is especially true for soil organic C flux estimates, determined from sequential soil sampling that must also represent huge areas across the continent.

On the other hand measuring atmospheric flux inversions via satellite based spectral scanners should provide the robustness, spatial coverage and sampling density/frequency, as well as the accuracy and precision necessary to determine the Australia wide flux inversion of column–averaged CO_2. The main limitation to this in practice seems to be an inadequacy of ground based Total Carbon Column Observation Network (TCCON) stations with which to calibrate the satellite data inversions. Improving the number and distribution of such stations over the Australian continent (currently only at Wollongong and Darwin) could be more rewarding and less expensive than the government's $2.5 Billion investment in "Direct Action".

Despite present limitations there is still increasing evidence that Australia is already approaching or even exceeding net zero CO_2 emissions - today! Such an assessment draws on information (presented herein) that Australia as a whole is a net sink, coupled with decisions made identifying virtually the entire continent as being 'managed' – placing this nation in line with similar findings reached for the conterminous USA. The fact that Australia has a very small population relative to its huge vegetated (CO_2 absorbing) land area also contributes to its favourable net emissions outcome.

These conclusions may seem outrageous to many now wedded to a belief that we face "catastrophic climate change" or a "climate emergency". Personally I do not accept these descriptions, nor their implications. But if the world insists all nations adopt a goal of achieving 'net zero emissions by 2050' Australia need not be concerned by the challenge. Nevertheless our government needs to make a concerted effort to educate itself, its own people and the world why this goal is already quite attainable (achieved) for this country. Otherwise we may well be vilified for setting up another 'Kyoto Protocol' scam:

On the 29th September 2000 Senator Robert Hill, Leader of the Australian negotiating team for the Kyoto Protocol and past Minister for the Environment, Sport and Territories was quoted in the "Rural Weekly" as saying – "Reducing land clearance in Queensland would be one of the cheapest ways for Australia to lower its overall greenhouse (gas) emissions". The incentive for the Howard (Australian) and Beattie (Queensland) governments to promote land clearing bans lay in Article 3.7 (2nd sentence) of the KP – the 'Australia Clause'. This entitled Australia to credits for huge reductions in GHGs (no longer released) as a result of tree clearing bans put in place after the KP 1990 baseline (time of peak clearing) was set.

But to maximise its C accounting budget and political benefits, no acknowledgement could be given to C sinks that had been and were simultaneously accruing as a result of on-going woodland thickening in the grazed (= managed/intact) woodlands (e.g. mulga, poplar box, silver leaved ironbark) that were not being cleared; or from rainforest invading both wet sclerophyll (Atherton Tableland) and grasslands in Cape York, NQ. Nor were C sinks documented from regrowth on land cleared up to 50 years beforehand, or those sinks occurring from the human induced regeneration of permanent 'even aged' native forest (e.g. brigalow, gidgee, mallee and cypress pine); or from trees invading natural grassland (e.g. melaleuca, gidgee, mulga, blackwood, and in the VRD, NT and elsewhere). [Not forgetting, post Kyoto, the increased sinks generated in the vast areas of government mandated 'avoided deforestation' land – consequent to tree clearing bans legislatively imposed on rural holdings].

How ironic or deceitful is that? The very C sinks that would not be recognised, or admitted as to their size, in Australia's 1997 KP GHG budget are now very much identified as existing in 2021 to satisfy the needs of Direct Action – and by 2050 to presumably deliver net zero emissions. "Oh what a tangled web we weave, when first we practise - - - - - - - ."

Conclusions

Once a target of 'net zero emissions by 2050' is set it becomes self-evident that Australia needs to fully account for all sources and sinks arising from its LULUC&F sector, *inter alia*. This is for both reporting accuracy and to offset emissions emanating from those spheres of energy use and industrial production for which there are no alternative feedstocks (e.g. for jet aircraft fuel, many petrochemicals, crematoria, gas BBQs); other than to continue to depend on coal, oil or gas supplies.

The LULUC&F sector comprises almost all land in the Australian continent when delineated under present UNFCCC and IPCC Guidelines (now also accepted for this nation's NGGI). So from a C accounting perspective we must account for all pools and fluxes in the country which are potential sources or sinks of GHG's - to or from the atmosphere. We can't base our reports on (cherry picked?) partial budgets!

Yet it is impractical to determine GHG fluxes over the LULUC&F sector of the Australian continent with acceptable accuracy and precision when centred on ground based sampling alone, or by modelling which is dependent on similar ground based sampling for its validation at scale.

The best alternative methodology seems to be an atmospheric CO_2 inversion approach. Atmospheric CO_2 inversions estimate surface-to-atmosphere net carbon fluxes by employing atmospheric CO_2 concentration measurements (from satellite borne spectral sensors) and atmospheric transport models. Statistical methods are used to combine available information to estimate CO_2 fluxes in an optimal way. [In particular the information is exploited in a (top down) inverse procedure – incorporating observations of atmospheric trace gas concentrations, a priori knowledge of sources and sinks, and an atmospheric transport model to link sources and sinks to atmospheric observations. As explained at: http://www.globalcarbonatlas.org].

The crucial factor leading to an understanding that Australia is a net CO_2 sink, is that this country's land area approaches that of the conterminous USA, but our total population is no greater than that in a single world mega city. Thus our LULUC&F sector is a net sink that is derived from increasing vegetation growth (and land cover), as a result of post indigenous management. It is still more than sufficient to offset the emissions (sources) generated by tree clearing, decaying plant matter, fires etc., and changed land use. Further, this net sink transcends *El Niño* and *La Niña* years and confirms that a notional net zero CO_2–e emissions target has already been reached, with or without prescribed fossil fuel emissions included.

References

There are many cross reference Links provided in the main text to relevant explanatory publications. All these Links were accessible on a Firefox browser on 22.4.21. They are included to enhance understanding as well as providing citable sources If need be these Links should be perused by all readers not familiar with the LULUC&F sector of Australia's NGGI, or with its scientific and policy nuances.

Further reading

Prof Noble's Tree Thickening Workshop Report for DEST. Link

Changes in forest structure over 60 years: 'tree densities and basal area (biomass/C store) are increasing in the Pilliga forests, New South Wales, Australia' http://dx.doi.org/10.1071/BT11191

Acronyms

AGO: Australian Greenhouse Office

CO_2–e: Term for describing different GHG's expressed as a common equivalent unit of CO_2 based on respective 'global warming potentials'

FullCAM: Full Carbon Accounting Model

GHG: Greenhouse Gas

GOSAT: Greenhouse Gases Observing Satellite (Japan)

IPCC: Intergovernmental Panel on Climate Change

KP: Kyoto Protocol

LULUC&F: Land Use, Land Use Change & Forestry sector of the NGGI

NASA: National Aeronautics and Space Administration (USA)
NGGI: National Greenhouse Gas Inventory

NOAA: National Oceanic and Atmospheric Administration (USA)

OCO-2: Orbiting Carbon Observatory 2 (NASA)

TCCON: Total Carbon Column Observation Network

UNFCCC: United Nations Framework Convention on Climate Change

End Note

[A] Carbon accountants for the LULUC&F sector need to be mindful that (organic) carbon in vegetation and soil is part of a continuum. It is meaningless to estimate the flux in one component without taking account of the flux in the other. Thus carbon accumulating in above ground vegetation could be more than lost (gains offset) as a result of fire in the litter layer or erosion of this same layer and/or the soil beneath it. Some 50 years ago I recorded soil organic carbon (SOC) to 1 m depth in mature mulga (*Acacia aneura)*, mature mallee (*Eucalyptus socialis)* and 15 year old mallee regrowth in the infertile semi-arid woodlands of eastern Australia. The levels of SOC to 1 m were 88, 88 and 85 t/ha respectively. For convenience, say we have c. 100t/ha over the rooting depth. Importantly in semi-arid soils organic carbon builds up within the root zone and beneath tree canopies, requiring stratified sampling to determine its' per ha content. Anyone claiming less than 5-15% measurement error would have to be sampling very small plots – certainly nothing relevant to the paddock, property or landscape scale necessary for carbon accounting purposes. So our error is 5-10 tonnes/ha (likely much more) for each time we sample. Meanwhile carbon fluxes in tree biomass will be no more than 1-2 t/ha/year – usually much lower when average rainfall is under 750mm. No scientific auditor could honestly sign off on a carbon flux when the quantum of the error of measurement of the carbon pool in the system exceeds the quantum of the flux claimed! [Of course to avoid that pesky problem of statistical analysis we could just use the mean value of the carbon pool at time two, minus the mean value at time one. Or take the modern route of modelling the soil organic carbon flux without validating selected model outputs, against actual field measurements. Don't laugh, this is more common than you might think].

[This End note (Superscript A) refers to the last sentence, 1st para, **Post Kyoto** section, p.5].

[WHB – 23 April 2021]