Net zero for agriculture

Oxford Martin Programme on Climate Pollutants

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To design effective policies to stop global warming, we need to know the impact of different measures on temperature. This has long been a challenge for action involving short-lived climate pollutants such as methane. CO_2-warming-equivalent (CO_2-we) emissions provide a simple but accurate way of assessing the global temperature outcomes of different mitigation options, avoiding well-known problems arising from the use of conventional CO_2-equivalent (CO_2-e) emissions.

Like every sector of the global economy, agriculture must play its part if we are to succeed in achieving the overarching goal of the Paris Agreement: to limit global warming to well below 2°C and pursue efforts to keep the rise below 1.5°C. What does this mean in practice? One thing is certain: net emissions of long-lived greenhouse gases – in particular carbon dioxide, but also nitrous oxide – must come down to zero. This is because these gases accumulate in the atmosphere, so even a small annual emission of CO_2 would build up over time. The sooner we reduce these emissions to net zero, the lower we can keep the temperature.

Net zero means that all remaining ongoing emissions are offset by removing an equivalent amount of greenhouse gas from the atmosphere. Agriculture generates emissions of nitrous oxide (N_2O) from fertilisers, manure and rice production, and methane (CH_4) from ruminants and rice production – all of which are difficult to completely abate.

If you are removing CO_2 from the atmosphere (by afforestation, for example) to compensate for N_2O emissions, then conventional CO_2-equivalence (multiplying N_2O emissions by GWP_{100}, the 100-year Global Warming Potential, to give CO_2-equivalent emissions) provides an appropriate method for working out how much CO_2 needs to be removed to offset the warming impact of N_2O emissions.

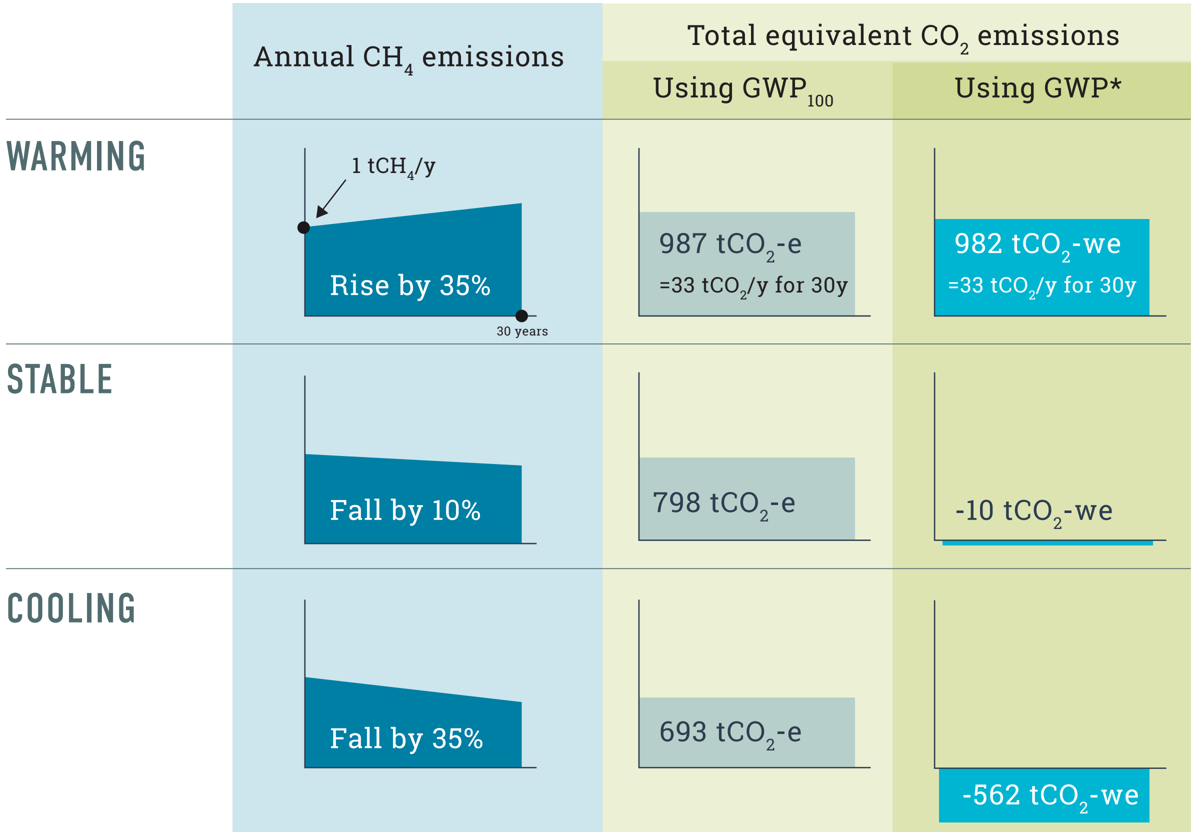
Methane is the other main agricultural greenhouse gas. Unlike CO_2 and N_2O, methane is short-lived. Methane emitted into the atmosphere is removed by chemical reactions, known as "sink" processes, so that only about half will remain after a decade. This means that a steady level of methane emissions leads to a steady amount of methane in the atmosphere. Reducing methane emissions rapidly enough would cause the amount left in the atmosphere to go down, as the methane sink outweighs the source, leading to near-term cooling. As net zero CO_2 targets are being set for mid-century, methane is one of the most powerful levers we have to slow global warming until the economy is decarbonised. In order to capitalise on this, we must be able to accurately assess the impact of ongoing or changing methane emissions on global temperatures. For this reason, we have come up with a new way to apply GWP_{100}, called GWP*, which can be used to calculate ***CO_2-warming-equivalent*** (CO_2-we) emissions[1] .

Methane scenarios

This method is demonstrated in the figure by three idealised methane emission scenarios (dark blue), all of which start from 1 tonne of methane per year. In the first, methane emissions increase over time by just over 1% per year. This leads to more methane in the atmosphere (the source outweighs the sink) and causes warming. Using conventional GWP_{100} suggests these methane emissions are equivalent to over 30 tonnes of CO_2 per year (grey), which happens to be similar to the CO_2-we emissions (light blue) calculated using GWP*. But this is just a coincidence: if methane emissions much rise faster than 1% per year, GWP_{100} substantially underestimates the warming they cause.

In the second scenario, methane emissions are decreasing by 0.3% per year. If all other emissions were zero, this would lead to approximately stable global temperatures. But using conventional GWP_{100}, it would be equated with a large continued emission of CO_2 – which would imply warming. GWP* equates this scenario with close to zero CO_2 emissions, because that is what is needed to deliver a temperature outcome equivalent to the actual impact of this methane scenario.

[1] Cain, M., Lynch, J., Allen, M. R., Fuglestvedt, J. S., Frame, D. J., & Macey, A. H. (2019). Improved calculation of warming-equivalent emissions for short lived climate pollutants. *npj Climate and Atmospheric Science (2019)2:29 ;* https://doi.org/10.1038/s41612-019-0086-4



Calculation of CO_2-we
To calculate warming-equivalent emissions in the example above, first calculate total emissions of methane over the 30 year period measured in tonnes of CO_2-e calculated using GWP_{100} and multiply by 0.25. Then add the *change* in emission rate (also measured in tonnes of CO_2-e per year) multiplied by 75. This calculation is based on equation 1 from reference 1.

And in the final scenario of a more rapid reduction in methane emissions, where the sink outweighs the source to cause cooling, the mismatch is even more stark. Conventional GWP_{100} equates this scenario to emitting a substantial amount of CO_2, which implies warming. Other ways of calculating CO_2-e emissions, such as GWP_{20} or GTP_{100} would equate these emissions with larger or smaller amounts of CO_2, but all positive, and hence all causing different amounts of warming. All these conventional methods break down when methane emissions are falling because none of them take into account the impact of changing methane emission rates. Methane emissions falling at this rate have the same impact on global temperature as active removal of CO_2 from the atmosphere: correctly indicated as negative CO_2-we emissions under GWP*.

Defining net zero

Another example of how equivalence metrics are relevant for the Paris Agreement is in working out what CO_2 removals are needed to offset continued methane emissions for *net zero greenhouse gas emissions*. If we use the conventional GWP_{100} to define the offsets we end up with cooling under typical future scenarios[2]. Under different emissions scenarios, you could end up with warming under conventional net zero emissions. We have defined GWP* so that the required CO_2 removals would lead to warming neutrality. Net zero emissions of all greenhouse gases aggregated under GWP* would mean net zero warming.

[2] Fuglestvedt, J., Rogelj, J., Millar, R. J., Allen, M., Boucher, O., Cain, M., Forseter, P. M., Kriegler, E., Shindell, D. (2018). Implications of possible interpretations of 'greenhouse gas balance' in the Paris Agreement. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 376(2119), 20160445. https://doi.org/10.1098/rsta.2016.0445

Implications for farmers

As an example of the practical implications of GWP*, consider the methane emissions associated with a single cow. Assume for simplicity this cow belches out 100kg methane every year. (Note that for a full assessment of the climate impacts of livestock, we would also need to consider the N_2O and CO_2 emissions associated with the cow's production system, but for this briefing note we focus on methane alone). Under conventional GWP_{100}, this methane would be equated with 2.8 tonnes of CO_2 per year, or a large SUV being driven 15,000km per year. Under GWP_{20}, these emissions would be equated with 8.4 tonnes of CO_2, or a luxury Hummer. But if that cow is part of a herd built up in the last century and now stable, its actual CO_2-warming-equivalent emissions calculated using GWP* are only 0.7 tonnes of CO_2 per year, equivalent to a plug-in hybrid.

There is, however, a catch: if the farmer were to increase her herd size by a single additional cow, the resulting increase in methane emissions would have the same impact on global temperatures as a one-off emission of 210 tonnes of CO_2, or over 50 return flights from the UK to New Zealand. Conversely, if the farmer were to reduce her herd by a single cow, or make equivalent reductions in methane emissions through, for example, feed additives or improved manure management, the benefits would be equivalent to removing 210 tonnes of CO_2 from the atmosphere. Reducing the herd's methane emissions by 0.3% per year gives zero CO_2-warming-equivalent emissions, meaning that in aggregate they would not be causing any further global warming at all.

The overwhelming importance of changing methane emission rates means that these must to be taken into account in assessing the impact of agriculture on global climate, and GWP* allows us to do this.

For further details please see
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