Landcare Research
Manaaki Whenua

A dairy farm is not greenhouse gas neutral

The query "If cows eat pasture and recycle the carbon, why isn't a dairy farm carbon neutral?" is often asked. A corollary question is "Why isn't the carbon stored in pasture counted as a benefit to offsetting greenhouse gas emissions by farmers?" David Whitehead, Adrian Walcroft, Surinder Saggar and Warren Parker at Landcare Research address these issues in this article.

Increasing concentrations of greenhouse gases in the atmosphere are related to global warming. The three most important greenhouse gases are carbon dioxide (mainly from burning fossil fuels and deforestation), methane (mainly from ruminant animals and waste management) and nitrous oxide (mainly from dung, urine and nitrogenous fertilisers). In contrast to most industrialised nations, 50% of New Zealand's greenhouse gas emissions are attributable to methane and nitrous oxide, predominantly from agriculture. While the atmospheric concentrations of nitrous oxide (320 parts per billion) and methane (1.8 parts per million) are low compared with carbon dioxide (383 parts per million), on a mass basis their contributions to global warming, signified as 'global warming potential' (GWP) are much higher. Calculations show that over a 100 year time period, 1 kg of emitted nitrous oxide has the same greenhouse effect as 310 kg of carbon dioxide, while 1 kg of methane has the same greenhouse effect as 21 kg of carbon dioxide.

It is certainly true that carbon cycles through pastoral systems, and that farming ruminant animals does not add any 'new' carbon to the atmosphere. However, in the process of milk production some of the carbon in the atmosphere is transformed from a gas with a lower GWP (carbon dioxide) to a gas with a higher GWP (methane). For methane, the warming effect is much greater in the short term (over 20 years the GWP for methane is 72) and declines over time as the methane is converted back to carbon dioxide by natural processes in the atmosphere (about half the emitted methane is converted to carbon dioxide every 8 to 10 years).

Some dairy farmers believe that by increasing pasture production, this will lead to more carbon stored in the soil and that they may earn carbon credits or offset methane and nitrous oxide emissions. Is this possible? To answer this we need to consider how carbon is cycled and stored in pasture systems, how increased production will affect the carbon cycle, and also account for emissions of all three greenhouse gases.

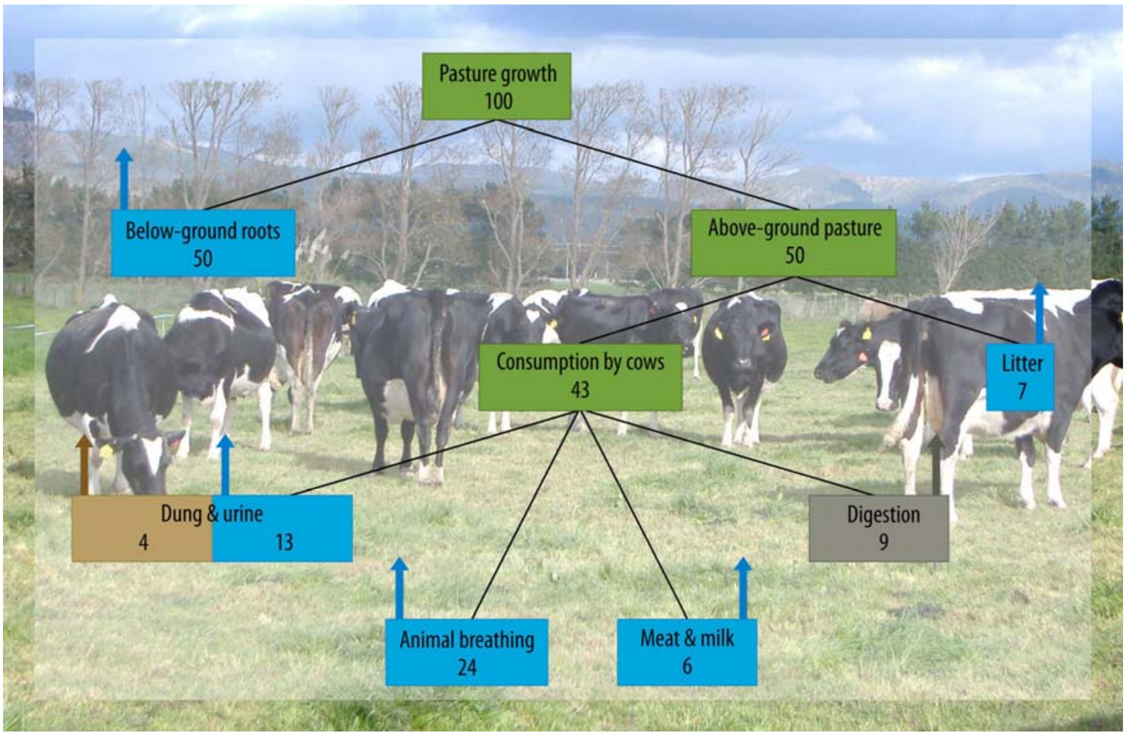
The average stocking rate for dairy herds in New Zealand is 2.8 cows per hectare. Carbon dioxide captured in the pasture biomass undergoes a series of cycles and overall, very little of this carbon is retained in the system. A hectare of pasture producing about 15,000 kg of dry matter per year above-ground will also transfer an equal amount of carbon to root growth. So, in total, pasture growth will remove about 50,000 kg of carbon dioxide from the atmosphere annually (dry matter is 45% carbon and carbon dioxide is 27% carbon by weight). Almost all the carbon transferred below ground is gradually returned to the atmosphere as carbon dioxide as the roots respire and decompose. About 85% of the above-ground pasture is consumed by the cows and the remaining 15% is left at the site as plant litter that rapidly decomposes, releasing the carbon back to the atmosphere as carbon dioxide. Over half (55%) of the pasture consumed by cows is breathed back to the atmosphere as carbon dioxide and about 30% is returned to the paddock as dung and urine that rapidly decomposes to carbon dioxide. About 12% of the pasture eaten by the cows leaves the paddock as meat and milk and about 3% of the pasture ingested is released as methane.

If pasture productivity was increased by 3000 kg dry matter per hectare per year by adding nitrogen as fertiliser, this would remove an extra 10,000 kg of carbon dioxide from the atmosphere per hectare per year. However, an extra half a cow per hectare would be grazed to utilize the extra feed. This would increase the rate of carbon cycling in the system (more cow respiration, more dung deposition, greater product removal and increased methane emissions per hectare), but have very little effect on carbon stored in the system. Increasing fertility can reduce root growth as the plants do not need to explore as much soil volume to obtain the required nutrients. Increased fertility also increases the decomposition of soil organic matter, returning carbon dioxide from the soil to the atmosphere at a faster rate. Recent data have shown that increases in dairy farming intensity have reduced soil organic carbon levels at some sites. By international standards, New Zealand intensive pastoral soils have high soil organic matter levels because of the relatively recent conversion from native forest to permanent pasture. Only a small area of land is under continuous cropping which depletes soil carbon. The potential for significant, permanent increases in soil organic matter in intensive pasture systems is therefore limited.

Emissions of methane and nitrous oxide must be considered in addition to the cycling of carbon dioxide. Ruminant digestion by a dairy cow produces about 80 kg methane per year or 220 kg per hectare. This is a small amount but, when multiplied by the GWP for methane, is equivalent to 4600 kg carbon dioxide emitted per hectare per year. Furthermore, a cow excretes about 120 kg of nitrogen per year in dung and urine. A very small proportion of this (about 1%) is converted to nitrous oxide, amounting to about 5 kg per hectare per year, but this emission is equivalent to 1600 kg of carbon dioxide per hectare per year because nitrous oxide is an extremely potent greenhouse gas. As an indication in terms of costs, at $25 per tonne for carbon dioxide these emissions amount to a potential liability of about $160 per hectare per year. However, this is likely to change by 2013 when liabilities for agricultural emissions start to take effect in the present Emissions Trading Scheme. To offset these emissions by an increase in soil organic matter would require the soil to absorb and permanently store 6200 kg of carbon dioxide per hectare per year. This is over half of the extra carbon dioxide removed by the potential increase in pasture productivity following fertiliser application, without considering that most of the carbon dioxide will be recycled back to the atmosphere anyway. Clearly, it is not possible to offset methane and nitrous oxide emissions by increasing pasture productivity.

Even if an increase in pasture productivity resulted in a permanent and measurable increase in carbon storage, under the current set of rules in the Kyoto Protocol that New Zealand adopted, this would not be eligible for credits. Carbon credits to offset emissions can only be recognised if a land-use change after 1990 results in a measurable and verifiable increase in carbon storage, such as afforestation of land that was previously in pasture. Storage of carbon in soils and vegetation that does not meet particular criteria cannot be counted for allocation of carbon credits. These criteria could be changed in future negotiations, but they stand at present.

In summary, carbon moves into and out of the farming system in a continuous cycle with little or no new carbon added to or removed from the atmosphere by grazed pastures (we have not considered carbon dioxide emissions from transport, energy use, waste management or other on-farm activities in this article). Dairy farms contribute to greenhouse gas emissions because of nitrous oxide and methane emissions. Further, it is not possible to offset these emissions by improving pasture productivity because the extra carbon gain will be balanced by increased carbon loss, resulting in no observable change in net soil carbon storage. Dairy farming provides many economic benefits but also contributes substantially to New Zealand's greenhouse gas liabilities. Modifying farm management practices to minimise gaseous nitrogen losses, e.g., the use of stand-off pads or herd homes during wet periods in winter, and storage of carbon in regenerating shrubland or planted forests are the most promising ways to reduce farm greenhouse gas emissions at present. Investment in research to develop cost-effective ways to reduce methane and nitrous oxide emissions is a high priority for the dairy industry.



Representation of the annual greenhouse gas removals and emissions for an average dairy farm with an above-ground pasture dry matter production of 15,000 kg per hectare and a stocking rate of 2.8 cows per hectare. The numbers shown are taken from the text but, for comparative purposes, all amounts are expressed on a carbon dioxide equivalent basis and as percentages of the total carbon dioxide uptake by the pasture. The green boxes represent carbon dioxide uptake by the pasture and the boxes with upward arrows represent greenhouse gas emissions, blue for carbon dioxide, grey for methane and brown for nitrous oxide. The sum of the percentage emissions from the boxes with upward arrows exceeds carbon dioxide uptake by 13% and this is attributable to the higher global warming potentials for methane and nitrous oxide compared with carbon dioxide. These calculations refer only to animal grazing and do not include emissions from transport, energy use, waste management or other on-farm activities.

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