atmosphere

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CSIRO

Mapping methane emissions from livestock

CSIRO researchers have mapped latest estimates of methane emissions from livestock. By checking methane concentrations in air at the Cape Grim Baseline Air Pollution Station in Tasmania, scientists can 'back track' to check the accuracy of the estimates.

Results from this work will help in future to check Australia's national greenhouse gas inventory. Under the Framework Convention on Climate Change, countries are obliged to report on greenhouse gas emissions such as methane.

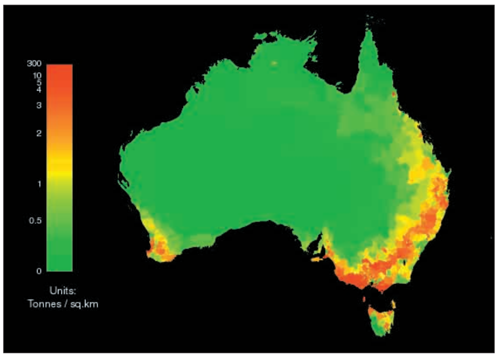
'The map is a tool to verify Australia's methane emissions,' says Mr Simon Bentley.

Livestock are responsible for about 90 per cent of Australia's methane emissions in the agriculture sector. Australia's cattle and sheep produce 3 million tonnes of methane each year. Other sources of methane are fossil fuel extraction and waste disposal, as well as natural sources such as wetlands and termites.

'Most of the livestock methane comes from cattle and sheep burps, with a small additional source being animal wastes,' says Mr Bentley.

A typical cow burps 280 litres of methane each day, the result of microbial digestion of fodder in its stomach. The type of food that the cow eats affects the amount of methane produced. Sheep produce about 25 litres of methane each day.

'To create the methane map, we calculated how emissions vary from place to place and between seasons,' says Mr Bentley.



Methane emissions from Australian livestock.

The map is based on livestock statistics from the Australian Bureau of Statistics for over 1300 different areas. Methane emissions from each area were calculated using data from Australia's national greenhouse gas inventory.

Methane emissions are converted to atmospheric concentrations within an atmospheric transport model run by Mr Bentley and colleague Dr Ying Ping Wang for verification against measured concentrations.

To help reduce livestock methane emissions, researchers at CSIRO Livestock Industries have been developing a vaccine that reduces gas release from animals while increasing liveweight gains.

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Australia's new hybrid cars will make a significant contribution to reducing air pollution in our cities. They are expected to be over 90% cleaner than the average petrol passenger car on the road today.

Cars to slash pollution and greenhouse gas

The vehicles could also lower greenhouse gas emissions by over 70% compared to average cars now on the road, says Dr Graeme Pearman, Chief of CSIRO Atmospheric Research.

'The aXcessaustralia car and the Holden ECOmmodore are an enormously positive development for the environment,' says Dr Pearman.

CSIRO and more than 80 industry collaborators developed the aXcessaustralia vehicle, which is powered by an electric motor and has a fuel-efficient engine to drive the generator that charges the batteries.

The Holden ECOmmodore includes state-of-the art CSIRO battery and capacitor technology.

Motor vehicles are responsible for much of the air pollution in our major cities. In Sydney, cars release 91% of the carbon monoxide in the air, 82% of the oxides of nitrogen and 49% of volatile organic compounds, such as benzene. Cars emit one-third of the dangerous tiny particles that are present in Sydney's air.

'The new cars emit just a small fraction of pollutants that cause smog,' says Dr Pearman.

'If we could have 20% of cars like aXcessaustralia or the ECOmmodore on the road, we could reduce people's exposure to pollution by 30%,' says Dr Pearman.

As well as offering air pollution benefits, aXcessaustralia is expected to generate just 80 g of the greenhouse gas carbon dioxide for each kilometre travelled compared with approximately 270 g per kilometre released by today's cars.

Like other cars, the hybrid cars release greenhouse gases such as methane as well as carbon dioxide. There are additional greenhouse gas emissions, due to the electricity needed to recharge the car.

'Taking everything into account, including generating the electricity to recharge the car, greenhouse gas emissions should drop from over six tonnes per year from the average car today to less than two tonnes per year from the hybrid cars,' says Dr Pearman.

As well as producing air quality and greenhouse benefits, the hybrid-electric car is far more economical than existing vehicles. At 28 km/L, the new car improves fuel economy by more than 300% compared with the average car on the road today.

The aXcessaustralia car.

'Anyone driving 15,000 km per year will save 1250 litres of petrol. This represents a saving of more than $1000 each year,' says Dr Pearman.

CSIRO's calculations of the impact on air pollution of hybrid cars were done using the newly developed air pollution model known as TAPM. Information on pollution emissions came from the Victorian EPA.

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Air pollution: size counts

A study of atmospheric particles in Australian cities has provided new information on tiny particles that are believed to be most dangerous to human health.

Dr Melita Keywood's research has identified for the first time in Australia the chemical make-up of different sized particles in the air. Tiny particles, which can penetrate deep into the lungs, contain toxic and cancer-causing chemicals. The chemicals include lead, black carbon and complex organic compounds.

The research compared atmospheric particles in Australian cities using the same measurement technique at all sites. In the past, comparisons of particle levels in air have been difficult as State and Territory agencies use different instruments and different techniques for measuring pollution.

Particles in the air come from motor vehicle emissions, domestic wood burning, industry and natural sources, and often contribute to haze as well as health problems.

Dr Keywood and colleagues measured levels of particles smaller than 10 micrometres in diameter in Sydney, Melbourne, Adelaide, Brisbane, Canberra and Launceston during seasons in which air pollution was expected to be most severe.

Sydney, Brisbane, Melbourne and Adelaide had average particle concentrations of between 20 and 25 micrograms per cubic metre. Despite the cities' smaller sizes, average concentrations in Canberra and Launceston were two- to three-times greater than in the other four cities, with smaller particles making up a larger proportion of the particle concentration in Launceston and Canberra.

'At times, particle levels in Canberra and Launceston are amongst the highest in Australia,' says Dr Keywood.

'Domestic wood fires in winter, combined with light winds and the locations of the two cities in valleys, produce high pollution readings,' says Dr Keywood.

Tiny particles are more likely than larger particles to be responsible for adverse health impacts, with elderly and children most at risk, along with people having existing respiratory illnesses.

Dr Melita Keywood's measurements have shown the chemical make-up of different sized particles in urban air.

The results of this work and those from other studies provide important input to the ongoing development of air quality standards, thus potentially reducing the health risk associated with exposure to air pollution.

Dr Keywood's research was sponsored by Environment Australia and performed in collaboration with ANSTO.

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Queensland warmer, with more downpours

Queensland is getting warmer, say scientists, continuing the trend that has occurred during the past 100 years.

Increasing levels of greenhouse gases in the atmosphere are likely to raise temperatures and increase the number of downpours. Tropical cyclones may also become more intense.

These findings are based on CSIRO research undertaken for the Queensland Government.

By the year 2100, CSIRO predicts that there will be more than twice the number of hot days between October and March and fewer than half of the cold days from April to September.

In addition, rainfall is likely to become heavier, although this does not necessarily mean greater annual rainfall.

‘We expect downpours to become heavier, which may mean more local flooding,’ says Dr Kevin Walsh.

‘We have also found a number of indications that El Niño events will become more common, although this finding is still uncertain.’

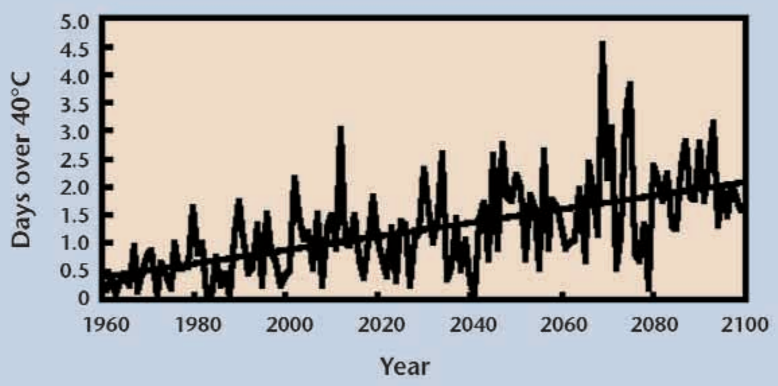
‘It is becoming more likely that tropical cyclone intensities will increase moderately in Queensland in future decades.’

Increases in tropical cyclone intensities, together with rising sea level, are likely to increase typical storm surge heights. A storm surge, which is a dome of water pushed ahead of a tropical cyclone by strong winds, is one of the most damaging aspects of tropical cyclones.

‘In Cairns, for example, predicted increases in tropical cyclone intensity, combined with predicted sea-level rise, are likely to raise 1-in-100 year storm surge events by about 0.4-0.7 metres,’ says Dr Walsh. ‘However, we have not yet established the full implications of this change.’

CSIRO climate modelling also shows an increase in drought frequencies in Queensland in the next century for most months, although there will be considerable variation from region to region.

Warmer seas are likely to cause coral bleaching in the Great Barrier Reef.



Simulated number of extremely hot days per month in central Queensland each year from October to March.

Bleaching is likely to become more common during the next 30 to 40 years, with the southern part of the reef affected first.

‘Unfortunately, bleaching leads to the death of coral ecosystems, although it is still not clear how fast the reef will be able to adapt to increasing temperatures,’ says Dr Walsh.

‘It is also possible that the reef will be damaged by increasing pollution and turbidity, fertilisers, pesticides, herbicides, and potentially by greater amounts of carbon dioxide absorbed by the ocean surface.’

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CSIRO's technology is being successfully marketed around the world by an Australian environmental company. Ecotech Pty Ltd, a Melbourne based equipment manufacturer, has manufactured and sold dozens of rainwater samplers and atmospheric particle samplers to environmental protection agencies and consultants in 17 countries.

CSIRO Atmospheric Research designed and developed both samplers. Ecotech sells them under licence to CSIRO, with royalties flowing back to research.

CSIRO and business export environmental technology

'We designed the rainwater sampler in the early 1990s,' says Dr Greg Ayers.

'We needed the sampler for our research, tracking acid rain and acidic particles in the air in Australia and overseas.'

The CSIRO rainwater sampler accurately records rainfall and collects and stores rainwater for subsequent chemical analysis. The device is designed to run unattended in remote locations.

'CSIRO developed the versatile particle sampler for measuring fine particles in air outdoors and indoors. We are especially interested in these fine particles because we know that they are the most damaging to human health,' says Dr Ayers.

CSIRO has used the samplers in a study of indoor and outdoor particle levels in air in Melbourne, Sydney, Newcastle and country regions of New South Wales.

'CSIRO has identified a number of areas where there is a clear need for sophisticated, versatile environmental monitors. Our relationship with CSIRO has been very strong and positive,' says Mr Steve Chamberlain-Ward, Ecotech's Marketing Manager.

'Sales of the particle sampler continue to rise, especially to industry. This is likely to be a very popular product,' he adds.

Ecotech's Microvol particle sampler, which collects particles and selected gases for subsequent analysis. The instrument has been developed from a CSIRO prototype.

Ecotech has sold rainwater samplers throughout Asia and to Europe and South America. More than 60 particle samplers have been sold in the USA, UK, Portugal, Mexico and Korea.

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El Niño and atmospheric carbon dioxide concentrations

Graeme O'Neill

This is an edited version of an article from CSIRO's Ecos magazine.

Researchers first noted a connection between carbon dioxide (CO_2) concentrations and El Niño and La Niña events in 1976. Analysis of 40 years of data has since revealed a complex but consistent relationship between these events and atmospheric CO_2 anomalies, in particular, a sharp decline in atmospheric CO_2 just before the onset of El Niño – Southern Oscillation (ENSO) events, followed by a 'rebound' effect.

Dr Peter Rayner says the initial, rapid response appears to be driven by the oceans, while the 'rebound' effect reflects the delayed response of terrestrial ecosystems to changes in temperature and precipitation.

In El Niño years the trace dips sharply downwards, then rebounds, while in La Niña years it swings violently upwards, before subsiding again. Both trends reflect the movement of several gigatonnes of carbon between sources and sinks in the oceans and on land (one gigatonne is one billion tonnes).

Between the extreme low of the 1982–83 El Niño event, regarded as one of the most severe this century, and the high of the La Niña event of 1988–89, the difference was equivalent to four billion tonnes of CO_2. Clearly, any model of the global carbon budget must factor in El Niño as a major player.

'We need to stress just how big these interannual variations in atmospheric CO_2 are,' Dr Rayner says. 'There is recent data suggesting that the 1996–97 ENSO event produced an even more dramatic swing than those of the 1980s and early 1990s.

'The interannual swings are equivalent to four gigatonnes of CO_2, or two-thirds of the emissions from fossil fuel burning.'

Currently, about half of the nearly six billion tonnes of CO_2 emitted by fossil fuel burning are removed from the atmosphere each year. Of this amount, about two billion tonnes is taken up by the oceans. On average, a somewhat smaller amount is stored in terrestrial ecosystems, as the difference between photosynthesis and respiration.

'Our quantitative understanding of this is severely limited by the much larger year-to-year variations associated with ENSO,' Dr Rayner says.

At first glance the CO_2–ENSO relation defies common sense: during ENSO events, the average global temperature increases slightly, so it might be expected that globally averaged heat transfer to the surface layers of the oceans would release more dissolved carbon dioxide into the atmosphere.

In fact, the reverse happens. During ENSO events, atmospheric CO_2 levels initially fall steeply, with the pattern reversing in La Niña years. Then a 'rebound effect' kicks in, partially correcting these sudden excursions from the norm.

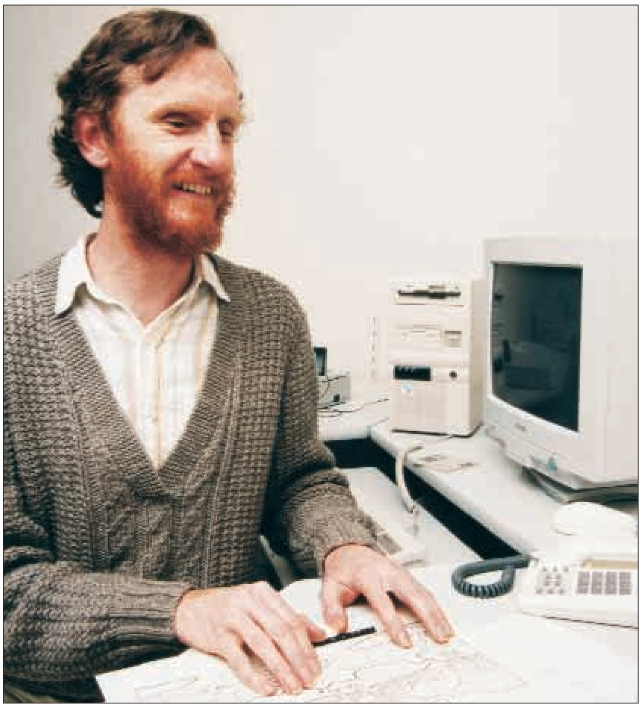
Scientists have learned that the interactions are rather more subtle and complex — the seasonality, timing and duration of ENSO events need to be considered.

Dr Rayner says the first and most immediate effect of an ENSO event is a change in the pattern of upwelling deep oceanic water in the eastern tropical Pacific Ocean. A huge pool of warm, low-salinity tropical water, usually centred in the equatorial Pacific north-east of New Guinea, flows eastwards towards the Pacific coast of South America.

The warm layer overrides the frigid, CO_2-charged waters that normally upwell in the oceans west of South America, throttling off the large amounts of CO_2 that normally diffuse into atmosphere in the region. In consequence, atmospheric CO_2 levels fall sharply over the eastern Pacific.

But this is not the only effect of an ENSO event, Dr Rayner says. ENSO also has dramatic impacts on land, through its effect on precipitation and temperature.

'It's difficult to know what the aggregate effect is, but it probably tends to drive



Dr Peter Rayner, studying the relationship between El Niño events and atmospheric concentrations of carbon dioxide.

increases in CO_2 and temperature over land, particularly in the western Pacific region,' he says.

ENSO events cause lower sea-surface temperatures in the western Pacific, resulting in reduced evaporation and precipitation.

The drier atmosphere leads to higher temperatures in Indonesia, accelerating decomposition of the litter layer of the region's tropical rainforest. At the same time, the plants become water-stressed and their growth slows.

Accelerated decomposition and reduced CO_2 intake for photosynthesis both tend to increase CO_2 in the atmosphere, and major forest fires in the parched forests, like those in Indonesia during the severe 1997–98 ENSO event, release even larger quantities of CO_2.

'Indonesia seems to start burning earlier in the ENSO cycle than one might expect, because the ocean starts to cool, and evaporation from the sea surface decreases, reducing precipitation and drying the land,' Dr Rayner says.

'Rainfall and temperature changes have integrated effects. They take time to bite, because the land takes time to get hotter and dry out.'

'There is also the effect of the underlying seasonal cycle: if the monsoonal rains arrive late, wildfires can suddenly become much more severe.'

'Modellers have no trouble making the terrestrial biosphere the big player, but the problem is that the atmospheric signal is not compatible with the timing and duration of ENSO events.'

Southern picture obscured by ice and algae

Dr Rayner says it is not yet clear how ENSO or other climatic cycles affect CO_2 sources and sinks in the Southern Ocean.

'We do know that the Southern Ocean is very active, and that it is probably a huge sink for CO_2, particularly between 20 to 50° South,' he says.

'But that's a major point of controversy, because while local measurements suggest it should be a strong sink, the atmospheric data don't confirm it.'

The frigid water and large algal biomass of the Southern Ocean should draw down large amounts of CO_2, but the picture is complicated by the presence of vast expanses of sea ice that develop in the zone between 55°S and the Antarctic coast each winter. The sea ice seals off the cold water, preventing CO_2 uptake, and shutting down algal photosynthesis: the ice blocks what little sunlight is available during the southern winter.

Dr Rayner says in the past the ocean was thought to be the major player in the large interannual fluctuations in atmospheric CO_2 concentrations. But the recent studies do not support this belief. Despite the dramatic changes that occur in the tropical oceans west of Peru, the atmosphere is seeing much more CO_2 than the oceans can generate, which implicates terrestrial processes.

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More than 870 students from 29 schools across Australia and the Asia Pacific made extensive weather and air pollution measurements as part of World Environment Day, 2000.

Students compare air quality across Australia

The students shared temperature, rainfall and cloud data via the Internet, giving a snapshot of the nation's weather. Students also tracked wind speed and direction, and haze levels.

'Students monitored weather and air quality for a fortnight,' says Ms Melissa McMahon, Australia Project Officer for GLOBE. GLOBE is an innovative, international Internet environmental education program.

The air pollution measurements came from the AirWatch program (see opposite page).

During the event, schools participated in a 'live' Internet Web chat, with scientists from CSIRO Atmospheric Research on duty to answer questions.

'The activity allowed students to learn more about weather and air pollution as well as giving them a taste for how scientists do research,' says Ms McMahon.

'It was a wonderful opportunity for schools to contribute to a worldwide environmental monitoring program and establish working links with other participating schools,' says Ms McMahon.

So far, through the international GLOBE Program, students have reported more than one million scientific observations in areas such as atmospheric, biological and soil science.

The GLOBE Australia Program is coordinated by CSIRO Education and jointly funded by the Department of the Environment and Heritage and the Department of Education, Training and Youth Affairs.

For more information:
http://www.erin.gov.au/net/ausglobe.html

CSIRO Business Manager retires


Mr David Slater

After a career spanning 34 years with CSIRO, Mr David Slater is retiring from CSIRO Atmospheric Research, where he has led the business team for more than 20 years.

David has experienced at first hand virtually all the tasks associated with supporting a world-class research laboratory.

'The biggest change I've seen over the years would have to be technology and the increase in our contract work. Computing power underpins everything we do and there is now so much more pressure on CSIRO to commercialise its research. We are constantly on the look-out for partners to help us apply our scientific advances,' says Mr Slater.

Mr Slater recently returned from a visit to the USA, where he had discussions with aerospace industries regarding development of a detector invented by CSIRO to monitor potentially lethal volcanic ash in a plane's flight path.

One of Mr Slater's proudest accomplishments was his role in the major site developments that CSIRO undertook at Aspendale in the late '80s and early '90s.

The award-winning air quality mural from Mowbray Heights Primary School, Tasmania.

AirWatch program national mural competition

AirWatch is a 'hands-on' environmental education program in which students learn about air pollution and its causes, and are encouraged to become actively involved in finding solutions to air quality problems.

Using methods developed for AirWatch by CSIRO, students measure fine particle and nitrogen dioxide levels, visual air quality and local weather conditions and contribute their results to a national database.

The Natural Heritage Trust funds Australia's AirWatch program, which has strong support from the Western Australian Department of Environmental Protection and CSIRO.

To celebrate World Environment Day this year, AirWatch launched a national mural competition. All primary and secondary schools in Australia were invited to enter.

Students were asked to create a mural that showed 'ways to keep our air clean'. The national primary school winner was Mowbray Heights Primary School in Tasmania. Their eye-catching, colourful mural with the slogan, 'Don't be mean, keep our air clean', illustrates ways in which the community can make a difference to its air quality.

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Selected publications

Here is a sample of the numerous papers published by staff of CSIRO Atmospheric Research during the past six months. For a full list of our publications, please visit http://www.dar.csiro.au/info/lib/pubsearch.html

Baines, P.G., and **Cai, W.J.** (2000). Analysis of an interactive instability mechanism for the Antarctic Circumpolar Wave. *Journal of Climate*, **13** (11): 1831–1844.

Boers, R., van Lammeren, A., and Feijt, A. (2000). Accuracy of cloud optical depth retrievals from ground-based pyranometers. *Journal of Atmospheric and Oceanic Technology*, **17** (7): 916–927.

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Gillett, R.W., **Ayers, G.P.**, **Selleck, P.W.**, Tuti, M.H.W., and Harjanto, H. (2000). Concentrations of nitrogen and sulfur species in gas and rainwater from six sites in Indonesia. *Water Air and Soil Pollution*, **120** (3–4): 205–215.

Grant, I.F., **Prata, A.J.**, and **Cechet, R.P.** (2000). The impact of the diurnal variation of albedo on the remote sensing of the daily mean albedo of grassland. *Journal of Applied Meteorology*, **39** (2): 231–244.

Hunt, B.G. (2000). Natural climatic variability and Sahelian rainfall trends. *Global and Planetary Change*, **24** (2): 107–131.

Jensen, J.B., **Lee, S.**, **Krummel, P.B.**, **Katzfey, J.J.**, and Gogoasa, D. (2000). Precipitation in marine cumulus and stratocumulus. *Atmospheric Research*, **54** (2–3): 117–155.

Jones, R.N., **Pittock, A.B.**, and **Whetton, P.H.** (2000). The potential impacts of climate change. In: *Climate change in the South Pacific: impacts and responses in Australia, New Zealand, and small island states.* A. Gillespie, and W.C.G. Burns (editors). (Advances in Global Change Research; 2) Dordrecht: Kluwer Academic. 7–32.

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Rotstayn, L.D., **Ryan, B.F.**, and **Katzfey, J.J.** (2000). A scheme for calculation of the liquid fraction in mixed-phase stratiform clouds in large-scale models. *Monthly Weather Review*, **128** (4): 1070–1088.

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Wang, Y.P. (2000). A refinement to the two-leaf model for calculating canopy photosynthesis. *Agricultural and Forest Meteorology*, **101** (2–3): 143–150.

Watterson, I.G. (2000). Southern midlatitude zonal wind vacillation and its interaction with the ocean in GCM simulations. *Journal of Climate*, **13** (3): 562–578.

Young, S.A., **Platt, C.M.R.**, **Austin, R.T.**, and **Patterson, G.R.** (2000). Optical properties and phase of some midlatitude, midlevel clouds in ECLIPS. *Journal of Applied Meteorology*, **39** (2): 135–153.

Maintaining milk yield in a warmer climate

Rising temperatures associated with climate change are likely to lower milk yield from cows, according to a CSIRO study. Milk losses will be minimised, say the researchers, if farmers adapt by providing shade and sprinklers for their herd.

The study uses a new approach, measuring future changes in terms of risk to farm productivity rather than in climatic terms.

The study was conducted in the NSW Hunter Valley. CSIRO is confident that the findings will apply elsewhere in Australia.

'Primary producers, who are users of climate information and often vulnerable to changes in the weather, want to know how climate change will affect their activities,' says Dr Roger Jones.

'We have analysed and presented the results of the study showing how much dairy farmers may need to adapt to the impacts of climate change to maintain their productivity.'

'Under current climate, dairy cows in the Hunter Valley that are kept out in the open produce about 3 per cent less milk than those kept under shelter.'

'This loss represents about 230 litres of milk per cow each year for a high-yielding herd. By adapting to hot weather by using shade sheds and sprinklers, milk losses can be reduced to about 50 litres per cow per year.'

However, because of climate change likely by the year 2030, milk losses are likely to be between 250 and 310 litres annually per cow, depending on the rate of warming.

'Importantly, the study has found that if farmers use shade sheds and sprinklers, each of their cows will produce 190 to 220 litres more milk per year than cows left exposed in paddocks. This would limit milk losses after adaptation to about 60-90 litres per cow per year. Our study shows that where measures limiting the effect of high temperatures on livestock are economical now, they will save even more money in future,' says Dr Jones.

Courtesy Simon Torok

CSIRO has discussed its findings with staff from government departments, conservation councils and the NSW Dairy Farmers Association.

'We studied hot cows because they were relatively simple to model,' says Dr Jones, 'and we wanted to demonstrate our methods of risk assessment to the government and community.'

The researchers are hoping to apply their methods to study the risk that climate change poses for integrated catchment management in the Hunter Valley.

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Profile — Cecelia MacFarling

A geologist with a degree from the University of New South Wales, Cecelia MacFarling recently began working towards a PhD at CSIRO Atmospheric Research. By extracting and analysing air trapped in Antarctic ice, Cecelia is studying natural variations in atmospheric greenhouse gas concentrations that occurred in the 1000 years prior to industrialisation.

'The main problem we have at the moment is too little data,' explains Cecelia.

'I am aiming for a measurement of gas levels for each decade — 100 measurements in total. This will give us a lot of information about atmospheric variations over this period.'

The measurements will include concentrations of carbon dioxide, methane, nitrous oxide and carbon-13 isotopes.

The Australian Antarctic Division, the University of Melbourne and CSIRO are co-sponsoring Cecelia's PhD scholarship.

Cecelia is keen to visit Antarctica if she gets the chance. 'The field work associated with locating, drilling and extracting cores would really help to put my research into perspective,' she says.

Cecelia MacFarling examines a section of ice core drilled from Antarctica at a cold storage facility in Melbourne.

Applying our research

Significant recent and ongoing projects

Assessment of TAPM for sulfur dioxide dispersion modelling	Pasminco Port Pirie Smelter Pty. Ltd.
Characterisation of emissions from domestic solid fuel heaters	Environment Australia
Development of a national greenhouse gas inventory database	Australian Greenhouse Office
Gas sampling and analysis	National Institute of Water and Atmospheric Research, New Zealand
Optical properties of cirrus clouds	Colorado State University, USA
Preparation of The Atmosphere chapter for the 2001 National State of the Environment report	Environment Australia
Review of expected air quality impact of emissions from the M5 East tunnel (collaborative with CSIRO Energy Technology)	New South Wales Department of Urban Affairs and Planning

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