A Burning Question

BY KARL-HEINZ WYRWOLL, MICHAEL NOTARO & GUANGSHAN CHEN

For thousands of years, indigenous Australians modified the landscape of the continent through regular and widespread burning of vegetation. Their use of fire was in part for hunting purposes and also for clearing pathways, for signalling other tribal groups and for promoting grass regrowth. Results from a recent climate modelling experiment suggest that these traditional burning practices may have been of sufficient magnitude to change the climate of northern Australia.

During the past few decades, human-induced climate change has been a persistent theme in the scientific literature. In more recent times it has been the subject of considerable argument in the public domain. Central to the discussion of human-induced climate change is the role of greenhouse gas emissions during the industrial era.

But in searching for a human signature in the atmosphere we can go much further back in time and follow the lesser-known idea, championed by W.R. Ruddiman, of the role that early farming played in global climate change over the last few thousand years. Ruddiman's research, while not without its critics, led to the "early anthropogenic hypothesis" – the idea that through land clearing, raising livestock and irrigating rice paddies, early agriculturalists caused a reversal in natural declines of atmospheric carbon dioxide 7000 years ago and methane by about 5000 years ago, thus steering the Earth into a different climate trajectory.

To this early anthropogenic hypothesis can be added the direct effects that human modifications to the land's surface may have had on the atmosphere. After all, humans have had a major impact on the Earth's land surface – specifically its vegetation – for thousands of years.

The extent and severity of global land surface changes has been long recognised in the scientific literature. It was emphatically highlighted by the classic 1955 volume *Man's Role in Changing the Face of the Earth* (W.L. Thomas – Editor), but it was the work of the late Jule J. Charney of Massachusetts Institute of Technology, who brought to the forefront the theme of land surface–climate interactions in 1975. Charney argued that land surface changes – such as vegetation clearing, grazing and burning – may have played a role in the devastating drought experiences of semi-arid areas such as the Sahel region of West Africa over the past century.

Since the early work of Charney there has been an increasing awareness of the fundamental role of land surface processes and states in the global climate system, and the part that vegetation plays. It can be inferred from basic atmospheric physics that changing vegetation types alters climate-controlling parameters such as surface roughness, evaporation and radiation characteristics. At a larger scale, numerous studies of past climates have demonstrated the pivotal role of vegetation feedbacks in the establishment and maintenance of regional climate states.

Fire has been an effective farming tool for traditional hunter-gatherer societies, and is generally thought to have led to extensive vegetation changes and wider modifications of the Earth's biological and physical environment. A central question of concern that follows is: what were the climate feedbacks that resulted?

The Australian Scene

A new book by Bill Gammage, *The Biggest Estate on Earth: How Aborigines Made Australia*, emphasises the ongoing concern that pre-historians and ecologists have had in understanding the effect of indigenous vegetation burning practices on Australian ecology. Some researchers claim a causal link between the extinctions of Australian megafauna such as the giant short-faced kangaroo and the marsupial lion following the arrival of the earliest people to the continent more than 50,000 years ago. It is thought that these burning practices changed the vegetation cover of the monsoon region of northern Australia from a closed woodland to a more open grassland type environment. This raises the question: was there also a significant climate response to the widespread vegetation changes that occurred in this region?

To address this question we can use the complex climate models that are now readily available to run experiments in which we change the vegetation and then look for any changes in climate, such as the stability of the atmosphere, air temperature, soil moisture and rainfall.

A Climate Experiment

In a recent study, our research group undertook a comprehensive examination of the influence of vegetation change resulting from traditional burning practices, on the northern Australian summer monsoon regime. For this we used a global climate model that incorporates interactions between the ocean, land, ice and atmosphere, and also includes vegetation dynamics and annual vegetation processes.

Climate models are imperfect representations of the Earth's climate system, a limitation that is often thoughtlessly emphasised by people who challenge the reality of human-induced climate change. Model limitations can be overcome, in part, through the use of ensemble techniques to cover the range of possible climate states that can be attained. In this approach a number of runs are undertaken with the same model but with minor differences in the initial conditions.

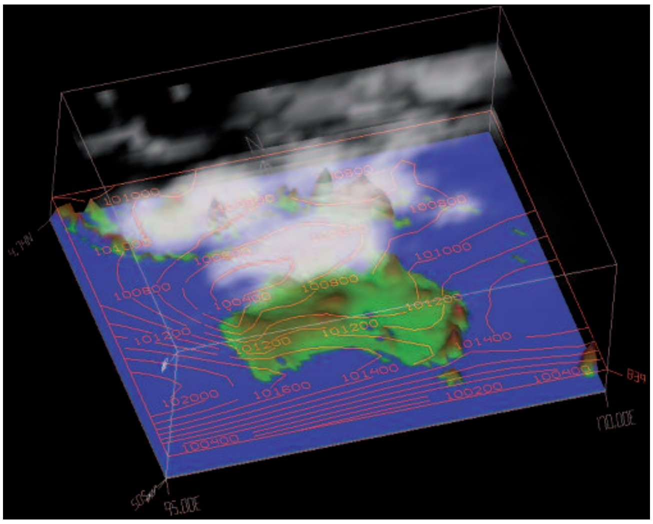

Figure 1. Three-dimensional model simulation of the northern Australian summer monsoon showing cloud cover and sea-level pressure contours during a typical summer monsoon month.

Before running a climate model it is first necessary to assess its ability to model present-day climate and, and in our study, vegetation conditions, of a region. Over the northern Australian monsoon region, approximately two-thirds of the annual rainfall occurs during the core monsoon season of January–March, primarily triggered through inflow from the northern Indian Ocean. Our model (Fig. 1) provided a reasonable representation of the spatial pattern and timing of monsoon precipitation, and a good representation of lower tropospheric winds that control monsoon inflow into north-western Australia.

The major vegetation types in the monsoon region of northern Australia are dominated by eucalypt woodland/grassland and tussock and hummock grasslands; some acacia shrublands and acacia forest and woodland; and open eucalypt forest in higher rainfall regions. Our model produced an idealised vegetation assemblage of grasses and tropical deciduous trees similar to the observed landscape of savanna/shrubland/grassland.

For our ensemble climate experiment we ran a modern-day, multi-century simulation for the entire monsoon season extending from November through to March, and we reduced the total vegetation cover fraction by 20% across northern Australia to simulate the effects of burning. The last 80 years were considered as the control simulation for comparison with the model results, and the impact of reduced vegetation cover on the climate of the monsoon region was determined.

The model results show that the climate response to reduced vegetation cover in the monsoon region was significant, but not during the height of the monsoon season. Rather, the climate response occurred during the pre-monsoon months of November and December, with decreases in total rainfall of more than 30 mm, higher surface and ground temperatures, and enhanced atmospheric stability. In other words, there was a decline in the strength of the early monsoon phase, effectively delaying the start of the monsoon.

While a decline in total rainfall of 30 mm in the pre-monsoon months may appear to be small, it is important to note that the dry season lasts for about 8 months, so the pre-monsoon rains are vital for the region's ecological recovery. Traditional indigenous burning practices occurred throughout the dry season, but were generally initiated in the early–mid dry season (May–August) under cooler, less fire-prone weather conditions. A prolonged dry season and higher temperatures during the pre-monsoon months could further promote the occurrence of late dry season "hot burns", which would carry significant ecological implications and could have induced additional land–atmosphere feedbacks.

The results of the experiment lead us to suggest that by burning forests and woodlands in northern Australia, Aboriginal people altered not only the ecology but also the climate of the region. They effectively extended the dry season and delayed the start of the monsoon. The findings that the impacts of vegetation burning practices were less significant during the peak monsoon season is not surprising given the global scale of the controlling climate mechanisms at that time of the year.

Our findings prompt the inevitable question: if Aboriginal land use practices have modified regional climates in the past, what has been the climate impact of the widespread land-surface/vegetation changes since the European occupation of Australia? The severity of European impact is highlighted by satellite images of south-western Australia (Fig. 2) that emphasise the extent of native vegetation clearing for agriculture over the past 100-odd years. Has there also been a climate response here?

The answer is a qualified YES! This region has experienced a reduction of the order of 20% in winter rainfall since the early 1970s. While much of this is undoubtedly due to circulation changes forced by global climate controls, local factors may also have played a role.

In the early 1900s a rabbit-proof fence stretching 3200 km from north to south was erected in south-western Australia to separate 13 million hectares of farmland to the west of the fence from native vegetation in the east. This fence provided an ideal opportunity for Tom Lyons and his research group at Murdoch University to assess the impact of land use changes on regional climate. Atmospheric data from both sides of the fence were recorded for more than a decade. The astounding results were twofold, with preferential cloud formation and higher rainfall recorded on the eastern side of the fence compared with the clear blue skies and lower rainfall to the west of the fence.

More recently Lyon's group was able to show that not only did this land cover change modify regional rainfall patterns, but with it may have come very significant changes in atmospheric circulation patterns. The climate implications of these findings are yet to be fully thought through.

Figure 2. Satellite imagery of south-western Australia, showing the extent of native vegetation clearing due to agriculture.
Source: Google Earth

Our model results provide an indication of how vegetation-shifts set up climate feedbacks over the monsoon region of northern Australia. The next step in our research will be to use higher resolution models to consolidate and extend these findings and include the impact of European land-use changes on the climates of north-western Australia.

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Our results bring further recognition of the fact that the climate impact of current land-use changes continues – although at a faster rate – a trend that extends over long time-scales. To be able to anticipate the resilience of the climate system to the ever-increasing rate of land surface changes will require an enormous effort, both through climate modelling and a more complete reconstruction of the climate record of the last few thousand years. From these efforts will emerge a better understanding of land surface–atmosphere interactions, and the wider climate feedback responses that these provoke, both at the regional and global scale.

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