Likely climatic changes and their impact on the northern pastoral industry

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Abstract

Global warming is predicted to have less impact on northern than southern Australia due to temperature increase being least at the equator and increasing polewards.

Estimates for northern Australia suggest an increase in temperature of 1 or 2 °C in northern coastal areas and 2 to 4 °C inland by the year 2030. Summer rainfall could increase by + 10 to + 20%.

Warming in inland regions could result in a southwards shift of the northern limits of the sheep industry, the frost zone and the winter growing species. The shift could be of the order of 1.5 degrees of latitude for 1 °C increase in temperature.

The seasonality and monsoonal nature of rainfall in northern Australia will increase the importance of soil characteristics, especially for the Vertisols. Within regions, day length and solar radiation will not change but rainfall and temperature will change, creating new climates to which indigenous and introduced species may not be adapted. Increased water use efficiency due to higher CO_2 levels and stomatal closure during the day could offset the predicted negative effect of higher temperature on plant growth. Pasture legumes, being C_3 plants, could benefit from increased atmospheric carbon dioxide levels.

Research is needed to develop more comprehensive pasture-plant models and to provide better predictions using regional climate model output.

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Resumen

Se ha predicho que el calentamiento de la tierra tiene un menor impacto en el norte que en el sur de Australia debido a que el incremento de la temperatura es menor en el ecuador y aumenta en dirección a los polos.

Las estimaciones para el norte de Australia sugieren que para el año 2030 habrá un incremento de 1 o 2 °C en la temperatura de la región costera del norte y 2 a 4 °C en el interior del país. La lluvias de verano podrían incrementarse en 10% a 20%.

El calentamiento de las regiones del interior podría resultar en un cambio hacia el sur del limite norte de la industria borreguera y de la zona de heladas así como de las especies de crecimiento de invierno. El cambio podría ser en el orden de 1.5 grados de latitud por cada 1 °C de incremento en la temperatura.

La naturaleza estacional y de monzón de las lluvias del norte de Australia incrementarán la importancia de las características del suelo, especialmente los Vertisoles. La duración del día y la radiación solar no cambiarán en las regiones, pero sí la lluvia y la temperatura, lo que creará climas nuevos a los cuales las especies indígenas y las introducidas podrían no estar adaptadas. El incremento en la eficiencia en el uso del agua, debido a los mayores niveles de $C0_2$ y al cierre de estomas durante el día, podría reducir el predicho efecto negativo de las elevadas temperaturas sobre el crecimiento de las plantas. Las pasturas de leguminosas, por ser plantas C_3, podrían beneficiarse con el incremento en los niveles de bióxido de carbono.

Se necesita más investigación para desarrollar modelos más completos de planta-pastura y para proporcionar mejores predicciones utilizando los resultados del modelo climatológico regional.

Introduction

A feature of the Australian environment is the high variability in rainfall resulting from the quasi-periodic drought-flood cycle that dominates the climate in eastern and northern regions of the continent. Mostly we have learned to adapt to this variable climate although extreme events can still be damaging to the environment and financially painful to individual land holders.

With the Greenhouse Effect associated with the build-up of carbon dioxide and other greenhouse gases in the atmosphere we are faced with a completely new situation. Climatic change will occur but such changes will be effectively irreversible. This is in contrast to past change when there has always been the expectation that such change is essentially above and below a long term mean and is cyclical and reversible.

In spite of high level political scepticism and the publication of arguments questioning the reality of changes in climate due to increasing greenhouse gases in the atmosphere (e.g. Daley 1989) there is broad scientific consensus that predicted effects are based on sound theories and supporting data. The outcome is likely to be a critical global problem. Recent temperature analyses (IPCC 1990) suggest that a real warming of the globe of 0.3 to 0.5 °C has already taken place over the last century (Figure 1); any bias due to urbanisation is estimated to be less than 0.05 °C. Nevertheless there are many uncertainties in our understanding of climate and hence our ability to predict the magnitude of climate change. Also it should be noted that the observed changes so far could be largely due to natural variability and are not conclusive evidence of the Greenhouse Effect.

In discussing future climatic change caused by global warming we are talking about scenarios rather than predictions of substance. The atmosphere-ocean-land-biosphere is complex and there are a number of areas where significant deficiencies occur in our understanding of climate.

Likely climate change in northern Australia

Global warming is likely to have less impact on northern than on southern Australia. This is because temperature increases are expected to be least at the equator and to gradually increase polewards. Given the economic importance and wide distribution of the pastoral industry in northern Australia it is necessary to anticipate likely changes and, where possible, to direct research towards ameliorating negative effects.

Predictions of global warming and changes in temperature and rainfall are calculated from global climate models (GCMs) which use standard physical equations to describe the behaviour of the earth's atmosphere under different conditions. Although most of the physical processes are well known there are significant deficiencies of knowledge in five areas (IPCC 1990). These are:

- the sources and sinks of greenhouse gases, particularly carbon dioxide, methane and nitrous oxides;
- cloud influence on the magnitude of climatic change;

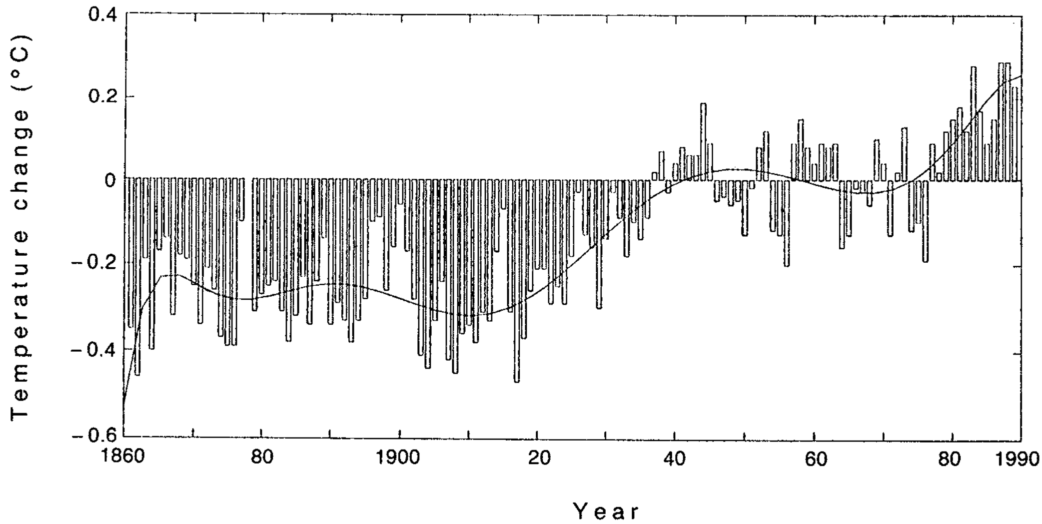

Figure 1. Global mean of combined land-air and sea surface temperatures, 1861-1989 relative to the average for 1951-80 (IPCC 1990).

- ocean influence on the timing and location of climate change;
- polar ice sheets and their effect on sea level rise;
- the effect of land surface hydrology.

In Australia a critical factor affecting regional climate could be changes in El Nino – Southern Oscillation (ENSO) events which are largely responsible for our quasi-periodic droughts and floods (Allen 1988). With global warming there could be more frequent drought/flood events or the main influence could move further eastwards into the Pacific Ocean resulting in less intense events. Current GCMs do not simulate this effect satisfactorily and scenarios involving drought/flood events have to be treated with caution.

The first detailed estimates of the likely effect of global warming in Australia were developed for the 'Greenhouse 87' conference held in Melbourne in December 1987. This 'working scenario' appears as an appendix in the book entitled 'Greenhouse: Planning for Climatic Change' (Pearman 1988). Many of these values were based on a conference held in 1985 at Vallach.

A more recent scenario (Table 1) for Australia has been prepared by Pittock (June 1990). It recognizes both improved Australian estimates using the CSIRO4-level model and data from the Intergovernmental Panel on Climate Change (IPCC 1990). By 2030 temperature in northern Australia could increase by 1 or 2 °C in coastal areas and 2 to 4 °C in inland areas. These changes will be higher in winter and lower in summer. There could also be an increase of +10 to +20% in summer rainfall and possibly a decrease in winter rainfall. Overall warming could lead to increased evaporation of 5 to 15%; however there is insufficient information for meaningful predictions of changes in cyclone activity in the Australian region (Holland *et al.* 1988; Evans 1990).

Table 1. Scenarios of changes in climate in Australia by 2030 AD[1]

Temperature	+1 or 2 °C in northern coastal areas +1 to 3 °C in southern coastal areas +2 to 4 °C inland More in dry season, less in wet
Rain	+10 to 20% in summer rainfall region −10% in winter rainfall (south west) More intense rainfall events Monsoon more intense
Evaporation	5 to 15% increase
Sea Level	Global average up to 20 cm by 2030 3 to 10 cm rise per decade

[1] Recommended for sensitivity studies only.

Latest estimates of likely global changes in temperature and rainfall were also prepared this year by the Intergovernmental Panel on Climatic Change (IPCC 1990). Five regions (Figure 2) each with several million square kilometres in area were selected for detailed study. One of the regions was the Australian continent although no distinction was made between northern and southern Australia.

Temperature and rainfall estimates for Australia are similar to those of Pittock (1990). Estimation of soil moisture levels showed a highly variable pattern for Australia and no general conclusions could be made.

In contrast, large changes are anticipated in some of the other regions of the world. Temperature increases of up to 3 to 4 °C are expected in central North America with soil moisture decreasing in summer by 15 to 20%. This could be offset by higher winter rainfall. In southern Europe, decreases in summer soil moisture of 15 to 25% are projected. On the other hand in southern Asia, mainly the Indian subcontinent, increases of 5 to 15% summer rainfall are expected with increases of soil moisture of 5 to 10% (Table 2).

These scenarios are useful in indicating the likely direction of changes especially in temperature and soil moisture. They also indicate broad scenarios that can be modelled with land-system models.

Impact of climate change on the pastoral industry of northern Australia

Regional estimates of climatic changes in the northern Australian environment have not been developed in detail. Increases in inland temperatures could result in a southwards shift of the northern limits of the sheep industry, the frost zone and winter growing species such as medics. The likely rate of change of land use frontiers in central North America has been estimated at several hundred km/1 °C temperature rise (Parry and Carter 1988). Expressed in terms of the north/south shift in Australia this is equivalent to about 1.5 degrees of latitude/1 °C temperature rise.

The distribution of sheep and cattle in Australia in 1988 is shown in Figures 3 and 4. The sheep and cattle population densities for local government areas (LGA) were drawn using MAPINFO

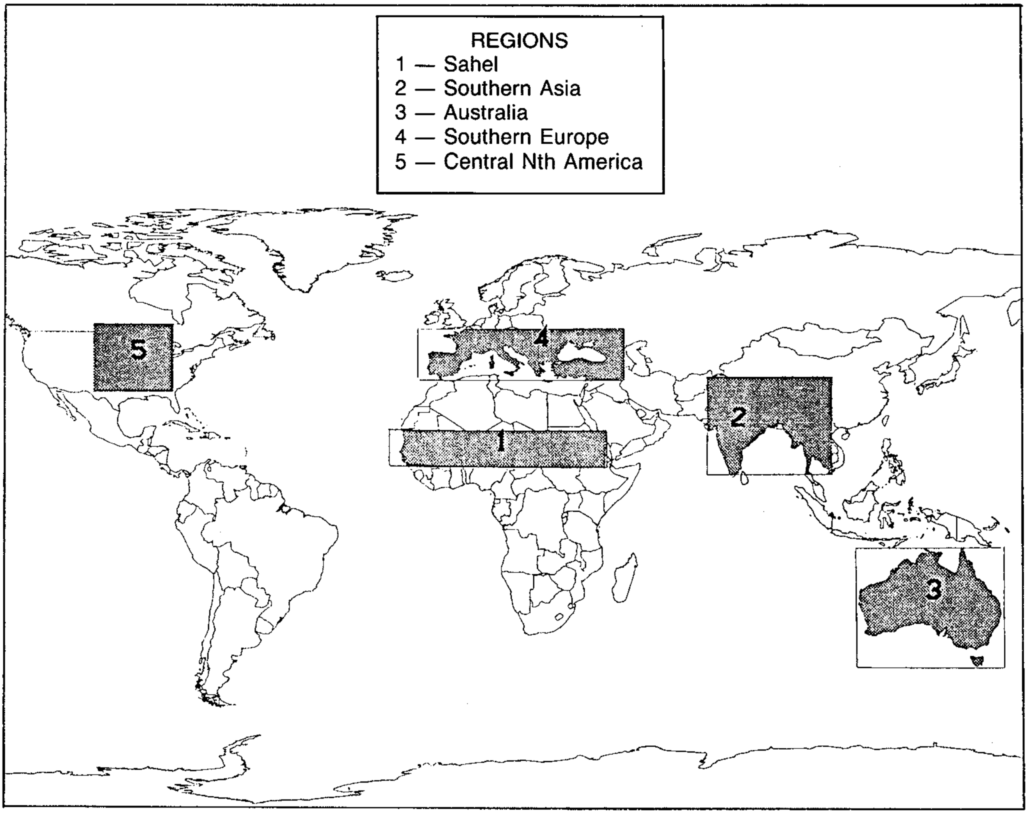

Figure 2. Map showing the locations and extent of five areas selected by IPCC.

(1989). These diagrams are very accurate in the high population areas especially in south-eastern Australia. However they are less useful in the inland and northern areas where LGAs can include very large areas of arid desert, with no sheep or cattle.

Figure 3 shows that the sheep population density in the large region north of latitude 30 °S is low in comparison with that in southern Australia. The northern limit in Queensland is about 19 °S and an increase of 3 °C in temperature by the year 2030 could lead to a retreat to 23.5 °S. An extension of lower density sheep populations into northern New South Wales is also possible.

Figure 4 shows a quite different pattern for cattle distribution in Australia with a significant proportion of the cattle in northern Australia. No large scale changes are seen in this pattern by the year 2030 but with the retreat of the winter rainfall influence there could be some decrease in the higher cattle intensities evident in latitudes 20 to 23 °S.

The impact of climatic change on pastoral production in Queensland was considered in detail by McKeon *et al.* (1988) but their analysis was based on a 50% increase in summer rainfall whereas latest estimates are for a 10 to 20% increase. Nevertheless their findings are worth repeating. Firstly they pointed out that the possible decrease in winter rainfall could result in a retreat of the annual medics (*Medicago* spp.). This could significantly influence animal production in the inland areas from 24 °S (the approximate northern limit of medics (Clarkson 1977) to 29 °S.

Secondly the increase in summer rainfall could expand the potential areas of legumes and reduce establishment and long term survival constraints. However there could also be an increase in disease problems, especially anthracnose on *Stylosanthes* species. One of the effects on grasses could be a decrease in buffel grass (*Cenchrus ciliaris*) as this plant has shown itself to be poorly adapted to high rainfall areas. On the other hand, *Leucaena*

Table 2. Predicted changes in climate in five global regions by the year 2030. Source: IPCC (1990)

Region	Latitude	Expected warming °C		Rainfall change (%)		Soil moisture effects
		Summer	Winter	Summer	Winter	
Sahel	10-20 °N	1-3	1-3	increases	increases	decrease marginally in summer
Southern Asia	5-30 °N	1-2	1-2	+5 to +15	no change	summer increases +5 to +10%
Australia	12-45 °S	1-2	2	+10	—	highly variable between regions
Southern Europe	35-50 °N	2-3	2	−5 to −15	slight increase	summer soil moisture decreases −15 to −25%
Central North America	35-50 °N	2-3	2-4	−5 to −10	0 to +15	summer soil moisture decreases −15 to −20%

spp. and *Lotononis* spp. could expand their current areas with a more favourable water regime and reduced frost incidence could assist *Leucaena*.

Thirdly, McKeon *et al.* suggested that there could be significant effects on native grasses. This could result in botanical changes, shrub invasion and tree growth in southern spear grass areas (*Heteropogon contortus*).

McCown (1980) considered the effect of the length of the wet season in northern Australia in terms of a green season and a dry season. The consequences of global warming would depend on whether the green season was extended or not. Initial analysis of climate models (A.B. Pittock and B. Hunt, personal communication) has shown little change in the mean monthly latitude of the summer monsoonal trough in northern Australia. This suggests that the main climatic change will be increasing rainfall during the current green season rather than extending the length of the season.

Key role of plant growth and livestock productivity models in understanding and ameliorating negative effects

There is little question that in the future there will be a continuing stream of climatic scenarios from GCMs such as CSIRO4 and its successors. This information will be focussed more and more on regional areas. If the impact of global warming is to be assessed accurately in the wide range of climate niches in northern Australia a key component will be the development of robust and sophisticated pasture plant models. Much progress has been made in the last 20 years in the development of crop models. In comparison, the modelling of pasture systems has made less progress because of the complexity of pasture plant systems, i.e. more than one main species, competition between species and variable life cycles, plus an overlay of grazing pressures. It is important that research attention be given to both plant and animal models separately as well as the interaction between them.

A computer search of the international literature over the period 1972 to 1990 showed that 61 papers had been published on various aspects of pasture models including pasture growth as affected by climate, soils and nutrients. Thirty-eight percent of these papers came from Australia. A comprehensive review of recent developments of pasture models and decision support systems in northern Australian savannas has been presented by McKeon *et al.* (1990).

In the long term however what is required is the development of a broad-spectrum pasture model similar to that achieved with crop models (e.g. CERES.MAIZE, Jones and Kiniry 1986) or land system models (e.g. EPIC Sharpley and Williams 1990, Williams *et al.* 1990a).

The land system model EPIC and its successor ALMANAC, already have the ability to handle pure grass and pure legume systems satisfactorily (Williams *et al.* 1984). The recent development of an EPIC sub-model simulating competition between two crops grown in an intercrop situation can be extended to simulate systems such as grass-legume pastures (Williams *et al.* 1990b). Since EPIC also has the capacity to model trees the potential is there to model grass-tree and legume-tree systems and agro-forestry systems generally.

Given the complexity of pasture systems it is unlikely that pasture models will, in the short

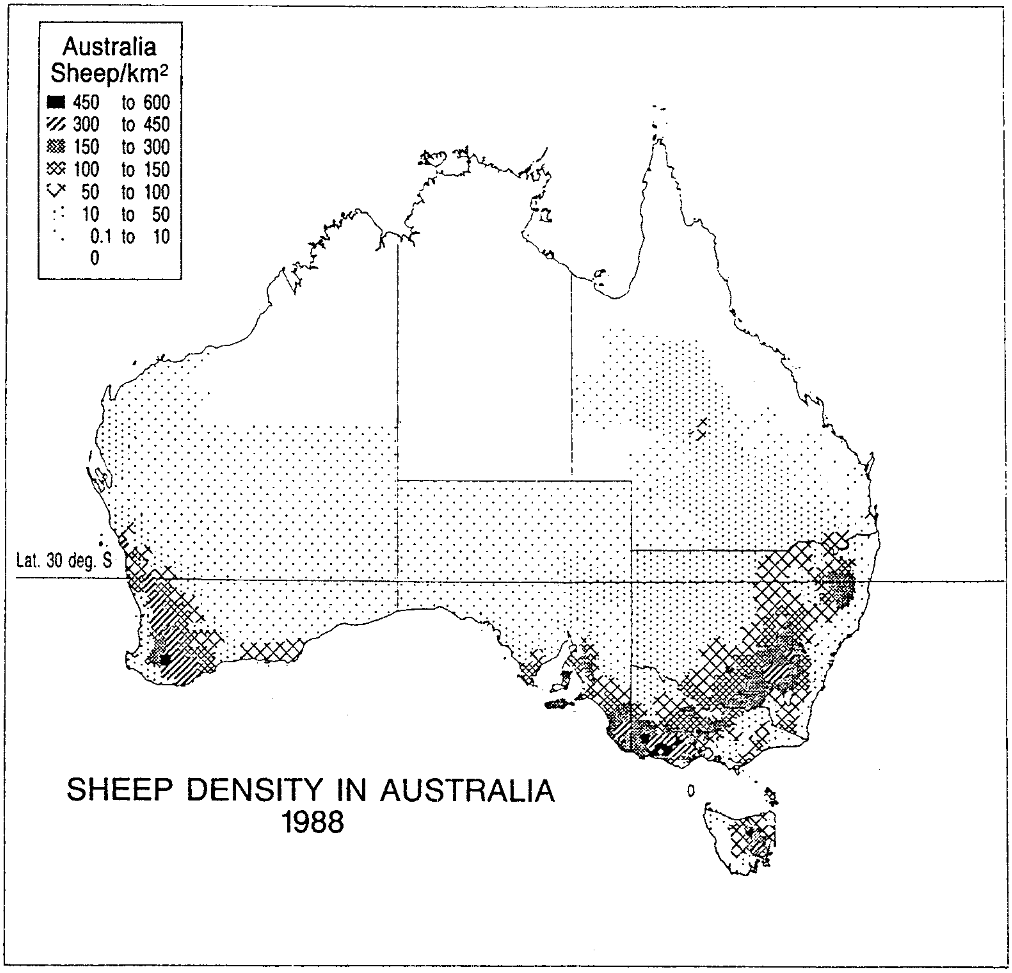

Figure 3. Distribution of sheep in Australia (Source: ABS Statistics).

term, have the ability to match the simpler single-species crop models in mimicking actual crop performance. After all, even the best crop models are only cartoons of a very complex climate-soil-biological system. It has taken nearly 25 years to develop useful and robust crop models and refinement is still continuing. The gains in this area have been very worthwhile in terms of our understanding of plant productivity, our ability to integrate available information and our capacity to develop decision support systems for crop management. Development of land system pasture models will take longer, but considering the large areas of native and improved pastures in northern Australia, and the economic contribution of the beef industry, this approach offers the best option of matching the substantial gains achieved with crop models. It also offers the best hope of providing better scenarios of the effects of global warming on pasture systems and animal productivity in northern Australia.

The behaviour of the main economic pasture plants needs to be examined in relation to a number of factors. Firstly, within regions, day length and solar radiation will not change but changes in rainfall and temperature are likely. This will create climates unlike those that have occurred previously and to which indigenous and introduced species are not necessarily adapted.

Secondly, the greater seasonality and monsoonal nature of rainfall in northern Australia, and the decline in winter rainfall, will place a high

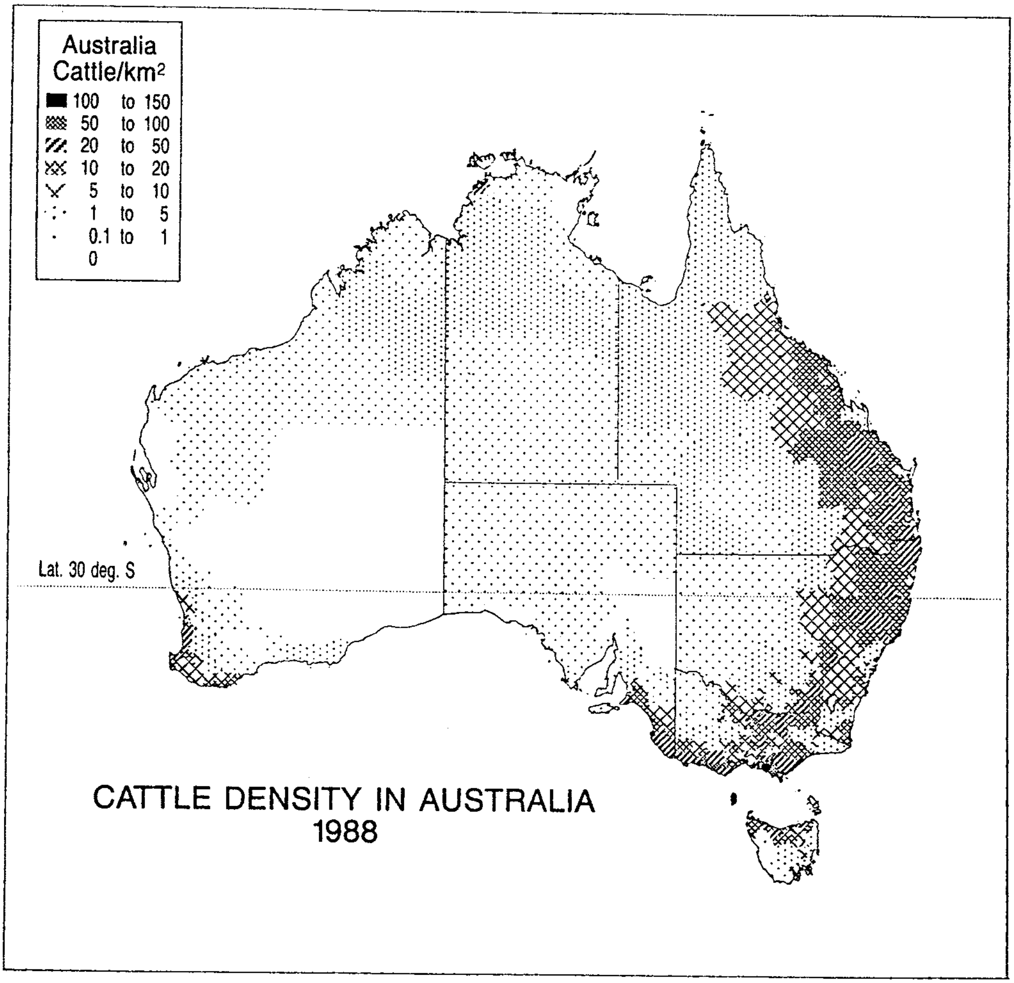

Figure 4. Distribution of cattle in Australia (Source: ABS Statistics).

premium on soil characteristics. Vertisols are likely to be much more productive than other soils due to their high water holding capacities and fertility. If rainfall increases significantly it is possible that the potential cropping areas will be extended westwards where large areas of these soils occur in northern Australia. This will create opportunities for forage cropping and mixed enterprises.

Thirdly, although the emphasis is mainly on the negative effects of global warming on plant productivity there will also be positive effects. On the one hand, higher plant productivity will be achieved with higher carbon dioxide levels in the atmosphere. This effect will be greater with C_3 than C_4 plants. These benefits will be greater in southern than in northern Australia due to a predominance of C_3 plants in the former but pasture legumes are C_3 plants and will benefit in the north.

On the other hand there is evidence that increased carbon dioxide levels will result in stomatal closure resulting in an increase in plant water use efficiency (Surano and Shinn 1984). Muchow and Sinclair (1991) found in simulation studies on data from maize experiments at Katherine in the Northern Territory that while an increase in temperature and lower rainfall decreased grain yield the positive compensating effect of increased water use efficiency offset these changes causing little or no decrease in grain yield overall within the range of water levels considered.

Fourthly, there may also be quite unexpected changes in climate in the future due to global warming. For example there are indications from GCMs that much more extreme temperature events could occur than at present. With the already high soil and air temperatures (more than 60 °C for soil) in northern Australia even small increases could have damaging effects on many pasture plants.

Conclusions

There is evidence that a temperature increase of 0.3 to 0.6 °C has occurred globally over the period 1861-1989 which could be related to the increase in greenhouse gases. A further increase of 1 or 2 °C (coastal) and 2 to 4 °C (inland) can be expected in northern Australia by the year 2030. Much uncertainty exists in the prediction of regional climatic change. Negative effects of global warming are associated with the higher temperatures and positive effects with slightly higher plant productivity and higher water use efficiency. The latter are due to higher carbon dioxide levels in the atmosphere. With the prediction of increased summer rainfall and higher water use efficiency in northern Australia it is possible that plant productivity could be increased generally with predicted changes occurring to the year 2030. The diminution of winter rainfall could extend the classical dry-wet monsoonal climate further southwards resulting in a retreat of winter growing species such as medics. Also, the northern limit of the sheep industry and frost zone could retreat southwards.

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