OPTIONS FOR IMPROVED EFFICIENCY IN THE BEEF INDUSTRY OF NON-ARID TROPICAL AUSTRALIA

L. 'T MANNETJE[1], M. R. E. DURAND[2], R. F. ISBELL[3] AND J. D. STURTZ[4]

ABSTRACT

The economic situation and characteristics of the beef industry in northern Australia, its physical environment and its feed resources are outlined. The various options open to improve efficiency of production are considered, together with the past and future role of research and extension in this process.

INTRODUCTION

This paper is based on a contribution to the National Conference of the Australian Institute of Agricultural Science held in Canberra in August 1976. This conference had as its themes "Limits to Growth" and "Options for Action". In the first part there were discussions on population projections and physical resource limitations. The second part consisted of contributions concerning the options for agricultural and pastoral producers and the role of agricultural scientists and extension workers. We were asked to deal with the livestock industries of Queensland, the Northern Territory and the Kimberley region of Western Australia from the coast to the 500 mm isohyet (Fig. 1). The main livestock industry of this area is beef cattle, but there are nearly 1.5 million sheep confined to southern Queensland, principally for wool, with some fat lamb production on the Darling Downs. There are also about 476,000 dairy cattle on 5100 holdings, but they are found almost exclusively in limited areas of coastal eastern Queensland. Solely on the basis of numerical

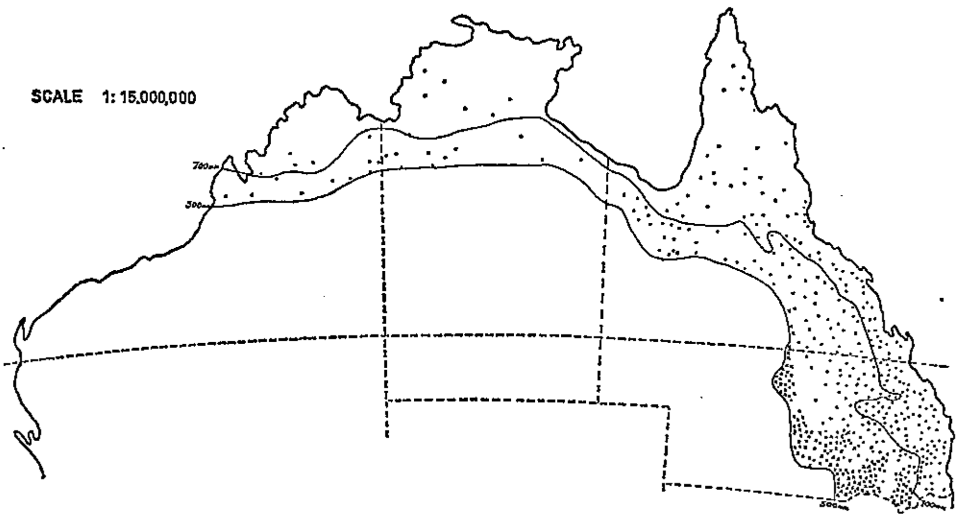


FIGURE 1. DISTRIBUTION OF CATTLE AND SHEEP ABOVE 500mm ISOHYET
each dot = 25,000 cattle (QLD. 1974, N.T. and W.A. 1971)
each cross = 25,000 sheep (1974)

1. C.S.I.R.O., Division of Tropical Crops and Pastures, St. Lucia, Qld. 4067.
2. Queensland Department of Primary Industries, Brisbane, Qld. 4000.
3. C.S.I.R.O., Division of Soils, Davies Laboratory, Townsville, Qld. 4810.
4. Department of the Northern Territory, Darwin, N.T. 5790.

dominance this paper will concentrate on the beef cattle industry. At present beef producers receive little return for their produce and this paper does not attempt to offer a solution for producers to alleviate their problems, which are caused by restrictions in international trade. We shall give a resumé of the economic situation of the beef industry, followed by brief descriptions of the physical environment, the industry itself and the feed resources. Then we shall deal with the options open to producers to improve efficiency of production and with the past and future role of agricultural research and extension in this process.

THE ECONOMIC SITUATION OF THE BEEF INDUSTRY

About 70 to 80% of beef produced in this area is exported so that future prospects are tied to world beef market conditions. This market has lately shown to be rather unstable and a look at world production, consumption and trading figures would indicate that future prospects are equally subject to large fluctuations in demand and price. Reeves and Hayman (1975) collated data for the period 1971-3 (Table 1).

TABLE 1

Mean annual production, consumption, imports and exports of beef carcass from 1971 *to* 1973 *inclusive* (after Reeves and Hayman 1975)

	Production		Consumption		Imports (I) or Exports (E)		
	'000 tonnes	% of world total	'000 tonnes	kg/ head	'000 tonnes	% of world total	
Importing countries					I		% of consumption
U.S.A.	10115	29·5	10741	53	873	34·5	8·1
E.E.C.	5387	15·7	6399	25	899	35·6	14·0
Japan	279	0·8	393	4	111	4·4	28·2
Canada	890	2·6	933	43	94	3·7	10·1
Total	16671	48·6	18466		1977	78·2	
Exporting countries					E		% of production
Australia	1306	3·8	566	44	716	26·2	57·0
Argentina	2117	6·2	1540	65	562	20·6	23·1
New Zealand	407	1·2	134	46	274	10·0	69·0
Brazil	2100	6·1	1883	19	185	6·8	8·3
Total	5930	17·3	4123		1737	63·6	

Total world production calculated as 34·3 10^6 tonnes

Several interesting points emerge from these figures:

(a) Australia is second only to New Zealand in relying on exports for its beef sales;
(b) two political blocks, the USA and EEC, control 70% of the world trade in beef;
(c) only 8% of the world's beef production is traded;
(d) Australia has the greatest proportion of the total beef export.

These observations lead to the conclusion that Australia's beef production, and particularly that in the north, is extremely vulnerable and very dependent on world market trends. Only small fluctuations in beef trading will have much enlarged effects on income of beef producers.

As the U.S.A. and E.E.C. countries rely for their own beef production to a large extent on grain feeding or overwintering, and as the world's grain shortage will tend to raise grain prices, this will mean sharp increases in beef prices in these countries if imports are restricted. Australia's hope for the future as far as beef exports are concerned lies in consumer pressure in these countries for cheaper imported beef. There may well be a case for undertaking publicity campaigns in the U.S.A. and the E.E.C. (and other countries) for Australian beef, showing how this is produced without great inputs of energy and fertilizer, on land that cannot be used for other food production, and how this production therefore adds rather than detracts from the world food supply.

Other avenues for greater export of Australian beef are new markets. At present the best prospects for Australia are Japan, the U.S.S.R. and the Middle East. The BAE (1976) predicted that the chances for beef exports from Australia should improve over the next few years.

In the short term there does not appear to be much scope for greatly increased beef production, but, given increased world population, increasing buying power and increasing shortages of energy and food grains, the long-term outlook is one of greater demand for beef from low energy-input production systems on land that has no alternative use for food production. In this respect northern Australia is well situated and for the rest of this paper we will discuss the technical aspects of the efficient use of the resources available for beef production in this region.

THE ENVIRONMENT

We are dealing with the humid and sub-humid sub-tropics and tropics from the coast to the 500 mm isohyet (Fig. 1). This region covers about 1.75 million sq. kilometres and has an extremely wide variety of land forms. The main ones are extensive plains, coastal and riverine lowlands, and undulating lands interspersed with some mountain ranges in sub-coastal Queensland and in the Kimberleys; in addition there are some tablelands and rugged dissected plateaux (Mabbutt and Sullivan 1970).

The vegetation is mainly tropical and sub-tropical sub-humid woodlands, brigalow forests and grassland. Small areas of rainforest occur in coastal Queensland (Moore and Perry 1970).

The basic climatic features of the region (Fitzpatrick and Nix 1970) are:

(i) solar radiation is never less than 350 cal/cm^2/day, in summer going up to 550 in the more inland parts;

(ii) mean January maximum temperatures range from 30° to 35°C and mean minimum July temperatures from 4°C in southern Queensland to 18°C in the far north; frosts are a significant feature in southern, central and northern inland Queensland (Coleman 1964);

(iii) most of the region receives about 750 mm of rainfall, which is summer dominant, with the dry period generally becoming longer and drier with decreasing latitude; the highest mean annual rainfall is about 1500 mm which is only recorded along the very eastern coastline of Queensland, except for a small area of 3500-4000 mm near Tully and Innisfail. Variability is high in many parts of eastern Queensland and droughts are common.

Most places in our region have a growing period of about four months. The main difference between northern and southern Australia in terms of pasture growing conditions is that in the north moisture and temperature peaks coincide, whereas in the south they do not. In northern parts growing conditions are mainly determined by moisture, but with increasing latitude the importance of temperature increases until it in turn becomes the determining factor.

Edaphically the region varies widely and particularly in eastern Queensland there is a very complex pattern of soils. The inherent nutrient status and certain physical properties of the soils have important influences on the kind and quality of the native pastures and the potential of the soils for improved pastures or cropping. The two most widespread limiting plant nutrient deficiencies are nitrogen and phosphorus (Williams and Andrew 1970). The chief exceptions are most of the black cracking clays in eastern Queensland, many of the grey and brown cracking clays originally supporting brigalow or gidgee (*Acacia* spp.) in the same region, and the euchrozems in north-eastern Queensland. The occurrence of other nutrient deficiencies is less well known, particularly in the Northern Territory and Kimberley regions, but marked responses have been found to sulphur, potassium, copper, zinc and molybdenum in a number of localities. Cobalt deficiency in cattle has been recorded near the tip of Cape York Peninsula (Winter, Siebert and Kuchel 1977).

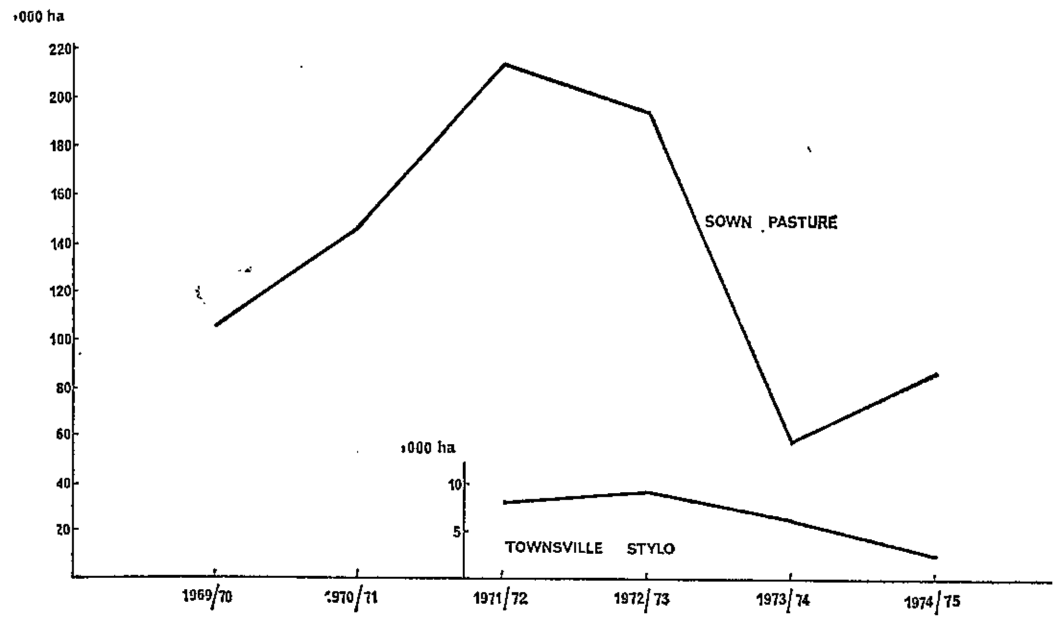
LAND USE CAPABILITIES

At present there is little land use conflict between the pastoral and agricultural industries. In southern Queensland cropping extends to as low as 550-600 mm mean annual rainfall, and in central Queensland to about 650 mm. In both regions most cropping is on self mulching clay soils and there are large unused areas, particularly in central Queensland, of at least moderately fertile clay soils suitable for cropping, provided appropriate anti-erosion measures are taken. However, rainfall variability is such that a relatively high proportion of crop failures is inevitable in the lower rainfall situations. Areas south of the Tropic have more flexibility as both winter and summer crops may be grown. In coastal areas of north Queensland there is a limited amount of land available for expansion of sugar production, and this could take place at the expense of existing beef cattle areas.

Although there have been some unsuccessful or unprofitable attempts, there is currently no cropping in the Gulf region, the Northern Territory, or the Kimberleys on any scale. The main limitations have been low fertility soils, lack of suitable crop varieties, pests and diseases, logistic problems of dealing with large areas of cultivation and harvesting in an uncertain climate, and particularly enormous distances which put transport costs for inputs and outputs at very high levels.

In summary, it is highly improbable that large areas of land presently used for grazing would be taken up for cropping purposes. Most of the land under consideration is suitable only for extensive type pastoral industries.

Fig.2 ANNUAL PASTURE ESTABLISHMENT IN EASTERN ZONE



GRAZING LANDS AND PASTURES

Nearly all animal production in the area we are concerned with is based on native pastures of low productivity (grazing lands in the sense of Moore (1970)). These are commonly the understorey of open forests or woodlands, and open plains. The main exceptions are in areas formerly covered by dense forest, e.g. the brigalow region of southern and central Queensland, and rain forest areas in northern and southern Queensland. In addition, there are small areas of fully sown pastures on the Wallum and on open forest country, particularly in south-eastern Queensland. Altogether, the Queensland Department of Primary Industries (1975) estimated the total area of effective sown pastures in Queensland at 3.6 million ha, of which about 2.6 million ha is in the area of our concern and of which 0.5 million ha is Townsville stylo oversown into native pastures. Whereas the rate of increase in pasture sowing was low during the 1960's, there was a marked increase in the years 1970 to 1972 (Fig. 2). There was a sharp reduction in 1974 and 1975, which reflects the slump in the beef industry at that time. The total improvable area in north-eastern Australia was estimated by Davies and Eyles (1965) at 60 million ha and by Ebersohn and Lee (1972) at 40 million ha. If we accept 50 million ha as potential area for pasture improvement in Queensland (assuming it is all in the region of our concern) the area improved comprises 5% and the maximum rate of increase was 0.4% per annum in 1971-72, which dropped to 0.2% in 1975.

In the Northern Territory, Sturtz, Harrison and Falvey (1975) estimated that 138,000 ha were improved pastures, of which 90% is under Townsville stylo. Fitzgerald (1975) stated that there was no pasture improvement outside research stations in the North Kimberley region, although good potential had been shown.

THE BEEF CATTLE INDUSTRY

In describing the livestock industries and future development we may divide the area into two zones, one including the Kimberleys, the Northern Territory and the Gulf and Peninsula regions of Queensland (northern zone) and the other the east coast of Queensland (eastern zone). The cattle distribution within these regions is shown in Fig. 1. The total number of beef cattle is about 7.6 million. There are about 680,000 in the Kimberley region, about 1 million in the Top End of the Northern Territory and the Barkley Tableland, about 675,000 in the northern zone of Queensland and about 5.2 million in the eastern zone. This shows the relative importance of the eastern zone in terms of animal numbers and density, particularly in central and southern Queensland.

In the northern zone holdings are very large with minimal development and stocking rates varying from about two to ten head per square kilometre. In the eastern zone the holdings are much smaller, management is more intensive and the infrastructure of roads and townships is well developed.

In the northern zone cattle are either finished within the zone at an age of 3½ to 4½ years, or sold as stores in the case of higher rainfall northern coastal areas and Cape York Peninsula.

In the eastern zone the standard of property development and management is very variable, ranging from highly intensive enterprises with sown pastures and high stocking rates (from 0.5 to 2 head per ha) in southern coastal areas, to properties that are run along similar lines as those in the northern zone. Most properties breed and fatten and the average age of slaughter is under 3½ years. Despite other forms of rural activity in this zone (viz. dairying, sugar, grain production) 75% of the cattle are on holdings which derive more than 50% of their income from beef cattle.

Cattle turnoff as a percentage of the total herd is low by comparison with southern states. Westerman (1966) reported that in the Kimberleys annual sales were only 12% of the total herd. However by 1972 this figure had risen to 17% partly as a result of the construction of beef roads. Similar developments in the

Northern Territory and Queensland have raised the percentage turnoff, which was estimated by the BAE (1974) at 14% in Cape York Peninsula and Gulf region, compared with 27% for Queensland as a whole.

According to the 1973 cattle census in Queensland, of the 5.2 million head in the eastern zone, 1.6 million were Herefords, 235,000 Shorthorns, 175,000 Brahmans, about 2.2 million zebu crosses and nearly 1 million other breeds and other crosses. It follows that about 46% are at least part *Bos indicus.* This contrasts with the northern zone, particularly the Kimberleys, where it is estimated that more than 95% are Shorthorns. The Northern Territory, as far as it is within our region, is estimated to have about 15% *B. indicus* or its crosses, the remainder being Shorthorn. In the Queensland part of the northern zone about 50% of the cattle are *B. indicus* or its crosses, the rest being mainly Shorthorn.

IMPROVING EFFICIENCY OF PRODUCTION

Efficiency of production is defined as the ratio of output of products to input of production factors on a monetary basis. It does not refer to the total amount of output or input by itself nor to the level of intensity of production. The economic situation in terms of price of product, mainly determined by demand, and of costs of inputs such as labour and fertilisers, are the factors a producer must consider in deciding on the level of intensity of production.

In the current economic environment of rising costs, inflation and unstable markets, the producer needs to take management decisions aimed at increasing net returns. We do not profess to know how this can best be done, but we will discuss some options of increasing production and of reducing cost per unit of output, both being important factors in determining efficiency of production.

The most obvious way of achieving this is by increasing herd size without increasing labour input. Herd size can be increased by obtaining more land, which may improve overall net returns, but if the enlarged property will be operated along the same lines as the original one, this is not likely to improve efficiency. Realistic means of improving efficiency are to increase carrying capacity and to improve herd performance, because a big cost factor is labour, which is mainly used for mustering, animal handling and maintenance work. Improving the carrying capacity means that the same herd can be kept on a smaller area, or that a larger herd can be kept on the same area, both resulting in labour saving per unit of output. Improving herd performance allows for greater output from the same herd or the same output from a smaller herd, both without the need for increased operating costs.

To what extent carrying capacity can be improved depends on the existing stage of development and this will vary with the property and within the property. In the northern zone most properties would benefit from better management generally and from the provision of more watering points, further subdivision and clearing. If the property is already fully fenced and at least partly cleared, the next step for development would be pasture species improvement, both by oversowing a legume, e.g. Townsville stylo, and by the establishment of sown pastures. To obtain the most benefit from property improvements, herd performance should also be improved. Here again the options depend on the type of herd and the level of management. Change-over from a *B. taurus* breed to a *B. indicus* cross-breed would be a logical move in the tropics to improve herd performance and to reduce costs because of better adaptation to the environment and the reduced need for dipping. General selection and control of pests and diseases can contribute substantially to improved performance, particularly in terms of reproduction. Finally, controlled mating and weaning would improve efficiency and output in some areas (Strachan and Rudder 1971) and some form of herd recording would rationalise culling procedures.

When the producer has decided to improve the land, the question is which type of land should be dealt with first, how it should be improved and what area should be included.

In most instances it is logical to improve the better classes of land first and where it concerns establishment of fully sown pastures this should be done on land which is already cleared. The question of how much land to improve must be discussed on a percentage basis, not a given area, because 1000 ha may be all or half of some properties but only 1% of another. For any land improvement to be effective it must have an impact on overall productivity. This applies to all stages of development, whether it be fencing, tree thinning or pasture sowing. It is not known what proportion should be improved as a minimum and this would depend on the type of improvement. In the case of tree thinning or pasture improvement the impact would be felt if this were more than 10%. Also, once a large property has been improved to say 80% of its area, it is doubtful if the last 20% would make very much difference, particularly as it is likely that the cost of improvement would increase, because it would be the least productive type of country that is left.

Another important consideration at this stage is the labour supply. The average labour input over Queensland as a whole is one full-time employee in addition to the owner or manager for each holding. If these two are already fully employed, any extra work to be done requires another man. This will, in many cases, increase the labour input by 50% and the improvement carried out must more than pay for this extra labour cost. As there is an inevitable period of lag before an extra man would be fully employed and also before the new improvements would result in increased output, it follows that labour requirements can be a severe limitation to property development.

Property development in some cases may lead to a different type of production enterprise. In many parts of northern Australia some forms of improvement, e.g. tree killing, fencing and water supply would only affect the quantity of available feed and therefore carrying capacity. But others, such as oversowing, pasture establishment or fodder cropping, improve both quantity and quality of feed. This can change breeding-only country into breeding-and-fattening country. It also adds flexibility to an enterprise as the producer may choose to vary the classes of stock depending on market conditions.

THE CONTRIBUTION OF RESEARCH AND EXTENSION

In this section we shall outline research activities of the past, particularly with regard to new species and better cattle, and state what we think are important issues for the future.

Pasture plants

Although Townsville stylo, the main success story of the northern pastoral industry, was a chance introduction and is now widely naturalised, its widespread use for oversowing into native pasture in tropical Australia can be attributed to research into production levels (e.g. Norman and Arndt 1959, Shaw 1961, Shaw and 't Mannetje 1970) and to extension articles on establishment methods (Graham 1963).

Although other chance introductions were successful, a large number of grasses and legumes has become available as a result of plant introduction and selection by research organisations (see Davies and Hutton 1970). This has led to a new outlook for tropical pasture development, particularly because of the success of legumes. The one outstanding example of tropical pasture plant breeding is Siratro (Hutton 1962), now widely used in sown pastures in Queensland and other countries. Although a first requisite is to have the plants, the so-called tropical pasture revolution would not have been possible without research on plant nutrition (Andrew and Fergus 1976) and legume bacteriology (Norris and Date 1976), nor without an active extension program.

Cattle

Apart from the introduction of zebu cattle by the early settlers, which did not leave a lasting trace in the cattle population (Pattie 1973), "exotic" breeds were first imported into Queensland in 1933 from the U.S.A., under an agreement between C.S.I.R. (forerunner of CSIRO) and cattle breeders (Turner 1975). From 1950 to 1954 more zebu cattle were imported and work started at the National Cattle Breeding Station "Belmont" near Rockhampton.

We have already stated that approximately 46% of beef cattle in Queensland now have *B. indicus* ancestry to some extent. Early reports by Alexander and Chester (1956), later confirmed by Kennedy and Churcher (1971), indicated better liveweight gains for zebu crosses than for the traditional British breeds. A very important advantage of zebu cross-bred cattle is their greater tick resistance and heat tolerance. The cost of ticks in Australia to governments and producers was estimated at $42 million per annum (Anon. 1975). With selection for tick resistance within cross-bred herds it is possible to reduce greatly and perhaps eliminate the need for control measures, whereas the level of tick resistance in *B. taurus* breeds is too low to achieve practical results in an acceptable time span. (Seifert, pers. comm.)

Frisch (1973) demonstrated the greater resistance of Brahman crosses to drought conditions. Brahman-cross cattle were found to be less affected in weight gains by gastrointestinal worms than were Hereford × Shorthorn crosses (Seifert 1971). *B. indicus* crosses are also less troubled by blight (Frisch 1975) and by dystocia (Wythes, Strachan and Durand 1976).

Studies at Belmont have resulted in the establishment of a new breed, Belmont Red, which is ½ Africander, ¼ Hereford and ¼ Shorthorn. Rudder, Seifert and Vercoe (1976) have shown that this breed has higher fertility, a slightly lower rate of weight gain and a more equable temperament than Brahman-cross animals.

Animal husbandry practices such as controlled mating and strategic weaning have been shown to be beneficial in southern and central Queensland (e.g. Rudder and McCamley 1972). However, Alexander and Carraill (1973) pointed out that in northern Australia controlled mating would have to be combined with early weaning and improved nutrition, otherwise many cows would fail to produce a calf each year.

Future research

The main efforts in the past have been directed towards such immediate problems as finding suitable species for pasture improvement, their nutritional and *Rhizobium* requirements, their feeding value and production potential. Similarly, in the animal field the work has concentrated on genetics, disease and pest control, nutrition and husbandry practices. Land research has mainly dealt with the description of soils and landscapes. Although more effort will still have to be put into these fields in the future, the overall research effort needs to be shifted towards less tangible fields such as the ecology of whole ecosystems, with particular reference to landscape stability. Also, much more work will need to be done in the sociological and economic spheres. It is important to find out what governs the adoption of new practices and how efficiency of production can be improved.

Ecosystem research is being undertaken on a small scale at present. For instance, it is known that inclusion of Townsville stylo and superphosphate in northern pastures has led to the invasion of annual grasses at the expense of perennials (Torssell 1973). This reduces animal production in the Northern Territory where these pastures are deferred for winter grazing, but so far it has not affected animal production in north Queensland. In contrast, in climatically milder central coastal and subcoastal southern Queensland native perennial grasses grow vigorously with good stands of Townsville stylo (Shaw and 't Mannetje 1970, 't Mannetje unpublished).

Efficiency of production may be improved if inputs can be reduced without affecting the output to any large extent. Two areas deserve special attention, viz. fertilizer use and establishment cost. Fertilizer use can be reduced if pasture species can be found that have a lower requirement for certain nutrients. Jones (1975) has found that a number of *Stylosanthes* introductions fall into this category. Research is also underway with regard to maintenance fertilizer requirements. Research on sown pastures has usually concerned sowing into cleared, cultivated soil and this constitutes a major part of the cost. Work is in progress to investigate oversowing both grasses and legumes onto undisturbed ground.

The most important factor influencing plant growth in northern Australia is moisture, which is determined by climatic factors and soil properties such as infiltration rates and storage capacity. There is a need to extend the application of simulation research for the prediction of site × yield relationships, growing-season lengths and year to year variation, such as has been attempted by McCown (1973) and by McCown, Gillard and Edye (1974).

Other aspects requiring further attention are the fertility status of the soil, the nutrient tolerances of new pasture plants and the role of legumes in building up soil nitrogen levels. There is a need for a better understanding of the nitrogen and phosphate pathways in the ecosystems to be able to increase efficiency of production. This applies equally to the infertile soils as to the relatively fertile soils; a knowledge of how the rundown of this fertility can be avoided would be of great economic and ecological significance.

In most animal production studies under grazing it has not been possible to relate the animal response to specific attributes in the pasture system. However, it is necessary to reach an understanding of the main processes involved in the animal-plant-soil-climate complex before we can make more rapid advances. Examples of the sort of studies that are needed are those of Stobbs (1973), and of 't Mannetje (1974) which relate animal responses to herbage attributes, and those of Kennedy and Siebert (1972) and of Rees, Minson and Smith (1974) aimed at unraveling the role of individual elements in the case of supplements and fertilizers.

Animal research is moving more towards fundamental aspects of disease and pest control. For example, it has been recognised that tick control by chemicals is a lost battle in the long run and emphasis is now placed on tick resistant cattle, strategic dipping and pasture spelling (Anon. 1975). As far as diseases are concerned, there are still practical problems to be solved. Ephemeral fever causes severe losses in production, but there are advanced studies in obtaining effective immunisation (Spradbrow 1975). Eye cancer in Hereford cattle is of concern to graziers in central and southern Queensland, although the defect may be overcome by simple operation. There are still many diseases that affect reproduction, such as vibriosis, leptospirosis and trichomoniasis, but the problem lies mainly in that many properties are not managed at a sufficiently intensive scale to eradicate them by vaccination. Of even greater economic significance is the widespread occurrence of tuberculosis and brucellosis, not so much for the losses they cause in the cattle, but because overseas markets may ban imports from areas where these diseases are prevalent (Muirhead 1973, Carpenter 1976), in the same way as countries with foot and mouth disease are barred. We can only reiterate what many others have stated (e.g. Henzell 1974), that Australia as a whole must tighten its quarantine measures and prepare itself to combat any outbreaks of catastrophic diseases like foot and mouth disease, or blue tongue.

Not enough research has been done in the fields of economics and very little in sociology. Economic studies have been restricted to case studies of pasture improvement in southern and central Queensland (e.g. Moyle and Haug 1965 and Firth, Bryan and Evans 1974), in northern Queensland (Robinson and Sing 1975) and in the Northern Territory (McLintock 1970). These investigations are of great value because they provide necessary information for extension workers and they may be used by research administrators to indicate future research needs.

Socio-economic research as carried out by Crouch and Chamala (1974) and by Chamala and Crouch (1974) give an insight into motivation for and success of technical property development, but these papers were the only ones encountered in this field for northern Australia. This type of research is basic to the development of extension services which were criticised by a visiting sociologist (Coughenour 1972).

Adoption of new practices

The main role of extension services is to bring new knowledge to the notice of producers, to show how it may be implemented and to indicate the likely effect on productivity and profitability. For this information to flow unimpeded the extension officer must have access to research findings and the research worker must publish his findings in accessible journals and be willing to give it freely, even before publication at meetings, field days, etc. Finally, the farmer must be receptive to new ideas and he must be in a position to apply them.

The farmer's attitude will depend in the first instance on the state of the industry. If demand and price for beef are good, the grazier is more easily interested in development than when demand and price are low. Provided he is interested it is then a matter of finance and knowledge.

Most effort of research and extension has been put into pasture development in areas with better rainfall distribution, where the scope for improvement is greater. A dollar spent on pasture development in a humid area must have a better return than in a semi-arid area. This follows from the relative productivity per unit area from the two environments.

The technology for the so-called tropical pasture revolution has been inspired and developed by research, before a real demand for innovations had become evident. This has at times given rise to cynicism and low morale among pasture research and extension workers, because they could see little practical application for their findings. Indeed, with only 5% of the Queensland area and a negligible proportion of the northern zone under effectively improved pasture it would seem that the considerable research and extension efforts have largely been in vain. Although it is difficult to put a figure on the economic worth of the improvements that have been effected, we can approach it by the assumption, based on research findings, that sown pastures in this area produce about five times more beef than unimproved pastures. The annual mean beef production on unimproved pastures can be taken as about 15 kg per ha, which would put a potential increase due to pasture improvement at the equivalent of 156 million kg of beef per year. However, much of the improved pasture area is on land previously not available for grazing (e.g. brigalow), or it is in use for milk production and we cannot claim that 50% of beef produced in Queensland can be attributed to pasture improvement.

Nevertheless it should be of major concern that the adoption of new practices is so slow, reasons for which cannot easily be found. There are some papers recording the level of adoption, but none offering explanations. Thus Chamala and Crouch (1974), in a survey of sheep management practices in north-west Queensland, found that pasture improvement had been carried out on 10% of properties, but 50% had not even tried. The level of improvement was not related to property size. Hall and Bryant (1976) found that only 7% of properties in central Queensland practised recommended mating and only 9% recommended weaning procedures. The level of implementation was only related to stage of property development, not property size. However, they did note a big change in cattle husbandry practices, because 20 years earlier there was no controlled mating and only male calves were weaned, and now 39% of properties had controlled mating and 96% weaned. It was suggested that property development receives higher priority than cattle husbandry practices.

However, the role of extension in the future is probably more one of aiming at improved efficiency and profitability than the encouragement of pasture improvement and improved animal practices *per se*. With the likelihood of continued uncertainty in beef markets and prices, one of the principal roles of extension might be to help producers offset the effects of fluctuations in income, by advising on consolidatory measures to be taken in periods of good incomes in order to be able to weather the poor periods.

CONCLUSION

We have reviewed the potential and difficulties of the pastoral industries in northern Australia. The main conclusion from this is that future development of the industry is uncertain, because it depends to a large extent on overseas markets. If the demand for beef rises, there is considerable future for the industry and development will be steady towards increased production and increased efficiency. Because of the difficult environment, research and extension play a vital role, as production and efficiency of production cannot be increased much without the adoption of new technologies such as pasture improvement, disease and pest control. Greater sociological research effort is required to find out what motivates producers in their decision making on the adoption of new practices.

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