PROCEEDINGS OF THE AUSTRALIAN RANGELAND SOCIETY BIENNIAL CONFERENCE
Official publication of The Australian Rangeland Society

Copyright and Photocopying

Form of Reference

The reference for this article should be in this general form;

Author family name, initials (year). Title. *In*: Proceedings of the nth Australian Rangeland Society Biennial Conference. Pages. (Australian Rangeland Society: Australia).

For example:

Anderson, L., van Klinken, R. D., and Shepherd, D. (2008). Aerially surveying Mesquite *(Prosopis* spp.) in the Pilbara. *In*: 'A Climate of Change in the Rangelands. Proceedings of the 15th Australian Rangeland Society Biennial Conference'. (Ed. D. Orr) 4 pages. (Australian Rangeland Society: Australia).

Disclaimer

The Australian Rangeland Society and Editors cannot be held responsible for errors or any consequences arising from the use of information obtained in this article or in the Proceedings of the Australian Rangeland Society Biennial Conferences. The views and opinions expressed do not necessarily reflect those of the Australian Rangeland Society and Editors, neither does the publication of advertisements constitute any endorsement by the Australian Rangeland Society and Editors of the products advertised.

The Australian Rangeland Society

FRAGMENTATION OF AUSTRALIAN RANGELANDS: RISKS AND TRADE-OFFS FOR LAND MANAGEMENT

C.J. Stokes [1], A.J. Ash [2] and R.R.J. McAllister [1]

[1] CSIRO, Sustainable Ecosystems, Davies Laboratory, PMB PO Aitkenvale Q 4814
[2] CSIRO, Sustainable Ecosystems, 306 Carmody Rd, St Lucia Q 4067

ABSTRACT

Land policy and legislation have been the major factors driving fragmentation of Australian rangelands. At the regional scale, fragmentation of rangelands has facilitated the development of private land rights, promoted the development and intensification of the pastoral industry, and encouraged settlement and growth of rural communities. But these changes have also had negative consequences in disrupting ecosystem functions associated with spatial connectedness, compromising enterprise economics and putting pressure on rangeland resources. Declining terms of trade and current pastoral property sizes, are both constraining the viability of present-day cattle production enterprises, leading to pressures to consolidate enterprises and intensify production systems. We explore some of the benefits that are expected from increased infrastructure development together with the trade-offs from the unintended consequences of internal property fragmentation.

INTRODUCTION

Arid and semi-arid landscapes, such as Australia's rangelands and savannas, are characterized by low levels of resources for plants and animals, and these resources are usually patchily distributed in time and space. This presents challenges for those seeking a livelihood in these systems. Traditionally, humans and herbivores have been able to exploit spatial heterogeneity to offset temporal variability in resource availability, with animals migrating to make use of favourable patches in the environment and human cultures adopting similar nomadic behaviour. The adoption of western-style, sedentary, intensified land uses has disrupted these large-scale spatial processes and landscapes have become fragmented into discrete parcels of land with diminished interactions between them. This has increased the exposure of land users to risks of temporal variation by denying them the opportunity to take advantage of more favourable parts of the landscape when local conditions are adverse (Boone and Hobbs 2003). Climatic variation in Australia's rangelands is particularly high and presents a major challenge to land managers. In addition to biophysical variation, the socio-economic climate is also in a continual state of flux with changing agricultural markets, changes in societies' values and expectations for rangelands and changes in agricultural practices (Holmes 1996, Ash and Stafford Smith 2003). In fragmented landscapes, land managers have to deal with these continually shifting challenges within the confines of their individual land units.

PROCESSES OF RANGELAND FRAGMENTATION

Land fragmentation, which has accompanied the pastoral development of rangelands, is defined here as the process by which spatial connectivity within a landscape is eroded and discrete land units become increasingly disassociated from each other. The fragmentation of rangelands, following settlement and subsequent development, can be thought of in terms of five elements (Fig. 1):

Resource Excision - Early land development is restricted to favourable regions in the landscape within which key resources are concentrated (such as permanent water sources, riparian areas and pastures with good forage). These are appropriated first, with land that is suitable for intensive uses being removed for other uses, while key grazing resources are commandeered to effectively provide exclusive access to surrounding, poorer-resource areas. Initial land use is therefore concentrated around naturally-occurring key resources in the overall landscape, much of which remains unutilized

or lightly utilized. At this stage, utilized patches of land are fragmented within the landscape, with the patchiness of land use reflecting the heterogeneity in resource distribution and access to transport networks and markets.

Land Use Homogenisation - With development of regional and property infrastructure (especially artificial water points), resource access and land use across the region becomes more uniform, providing greater opportunities for regional fragmentation of pastoral properties (see Abbott and McAllister 2004, these proceedings).

Regional Scale Fragmentation - As development across the region provides a more uniform spread of resources, it becomes possible for larger properties to be subdivided, with the increase in infrastructure development offsetting the smaller sizes of the new properties.

Property Scale Fragmentation - Economic pressures to intensify production lead to the increased development of water points and fencing, with internal fragmentation of properties into smaller paddocks.

Consolidation - Properties are combined together into larger enterprises when individual properties are no longer large enough to support a viable business (because of excessive subdivision and/or declining terms of trade) (Ash *et al.* 2003).

These elements of land fragmentation could be considered to follow a rough sequence, with each in turn becoming progressively dominant over time (Fig. 2).

The development of Australia's rangelands, with accompanying land fragmentation, has lead to steady gains in pastoral production. But associated with this, land managers have also been exposed to greater risk from climatic variation, environmental degradation, and changing social and economic conditions. Here, we look at fragmentation in rangelands, using the Dalrymple Shire as an example, to assess the drivers of land fragmentation, the benefits and risks that arise, and the responses of land managers to these challenges and opportunities.

LAND FRAGMENTATION IN THE DALRYMPLE SHIRE

Shire Description

The Dalrymple Shire is situated in northeast Queensland and covers 66,709 sq km of the Burdekin River catchment. Weather patterns are affected by El Niño - Southern Oscillation cycles, which contribute to a high interannual variation in rainfall (CV% 30-48). Soils vary from infertile sandy duplexes to relatively nutrient-rich, self-mulching clays reflecting the heterogeneity in underlying geology, drainage patterns and other topographic features. This heterogeneity supports a variety of vegetation communities that differ in species composition, seasonality and forage production.

The Shire is predominantly state leasehold land (87%), with most freehold land restricted to urban centres and surrounding small rural residential and non-commercial grazing lots. The vast majority of the Shire is used for extensive beef production and cattle disposals in 1992/3 were valued at $51 million (Rogers 1998). Most pastoral enterprises are independent, family-run businesses that combine cattle breeding and fattening operations (Bortolussi *et al.* 2004a). The largest economic sector is mining (gold, base metals and dolomite), valued at $232 million.

Since European settlement, patterns of land use and tenure in northern Queensland have been strongly influenced by government policies and by events at local to global scales. Below, we briefly review how some of the factors associated with pastoral development have affected landscape fragmentation, the scale of land use and land requirements for viable enterprises.

Land Policy, Legislation & Tenure

The dominance in the Shire of leasehold land, with property rights dictated by lease conditions (QNRM 2001), has meant that land legislation, especially that pertaining to lease terms and conditions, has been a major policy instrument for influencing land use. Australian land legislation has historically been aimed at orderly allocation of land, encouraging settlement and land 'improvement', generating revenue, preventing monopolies, promoting social equity, and developing the rights of landholders in relation to the state (Hannam 2000).

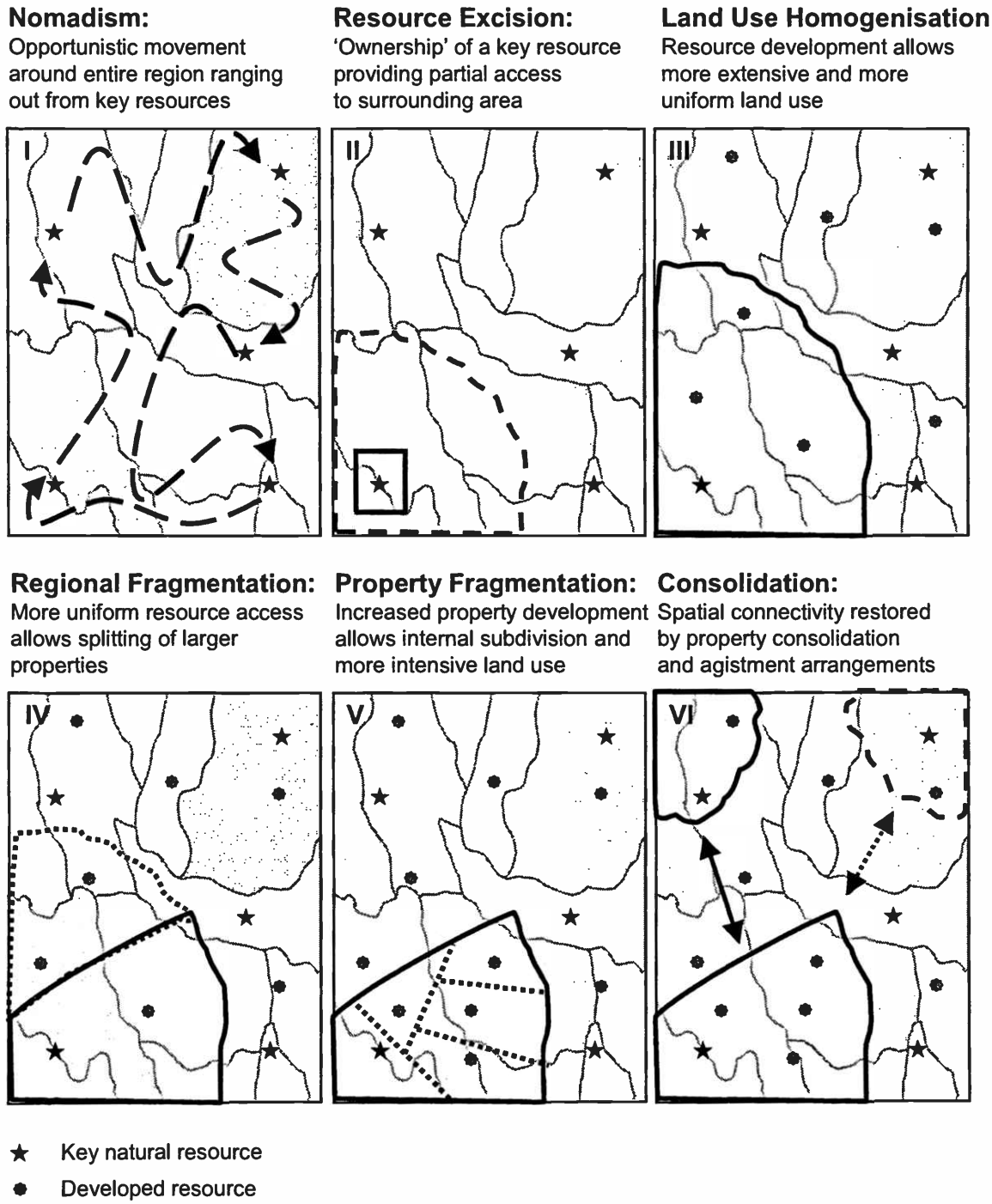

Figure 1. Processes of fragmentation and modes of land use in a heterogenous landscape during pastoral development.

European settlement of the Dalrymple Shire coincided with two events that stimulated early pastoral development; the discoveries of gold in the 1860s and 1870s and the separation of Queensland from New South Wales in 1859 (Holmes 1963). The Queensland Land Act 1860 promoted settlement by providing leases of 14 years with minimal lease fees. While the runs were relatively small, 6,600 to 26,700 ha, there was no limit on the number that could be held, as long as they were stocked to a quarter of their carrying capacity within nine months. The Crown Lands Act 1884 was enacted to promote a policy of closer settlement and it provided for parts of leases to be resumed. As a result, many small runs around Charters Towers and Ravenswood were acquired by ex-miners for dairying. A new Land Act was introduced in 1894 and, with subsequent revisions, it continued to support a policy of 'closer settlement', favouring the creation of smaller land lots for allocation to family-operators. One goal of the policy was to encourage the growth of rural communities.

During the 1950s, the Queensland 'populate or perish' strategy developed from a review of land settlement policy (Land Settlement Advisory Commission 1959). This review recognized the influence of property size on financial security, but sought to balance this against the requirement for increased rural population density for regional community viability (Day 2001). The expectation at the time was that agricultural enterprises would require assistance during establishment, but that they would later become self-sufficient as development and 'improvement' of the land increased its production potential. As an incentive for land development, lease terms were extended, security of tenure was emphasized, and costs of land development were recognized. This applied especially to the Brigalow Belt, which extends into the southeast of Dalrymple Shire, where land 'improvement' involved expensive tree clearing and sowing of pasture. The last notable fragmentation of properties in the Shire occurred during the post World War II period, when resumptions of land from large leases created several new smaller leases that were allocated by ballot. These properties generally remained large enough (40,000 - 50,000 ha) to support viable enterprises at the time.

REGIONAL FRAGMENTATION – IMPACTS & ADAPTATION

Property Size Constraints

The beef and sheep industries have been characterized by boom and bust cycles affected by changes in local and international markets and climatic variation. Favourable periods for the pastoral industry have often been characterised by overoptimistic expectations of the land's production potential (Allingham 1976), pressures for more intensive development, closer settlement and property subdivision. Downturns in the markets and weather have exposed the vulnerability of small enterprises. It has been proposed that fragmentation in rangelands continues until financial, ecological and social dysfunction become severe enough to initiate structural adjustment towards consolidated enterprises (bottom of the curve in Fig. 2), and that rangelands are most vulnerable to degradation at the time of these changes when stresses associated with rangeland fragmentation and small enterprise size are greatest (Passmore and Brown 1992, Ash *et al.* 2003). These pressures and consequent resource degradation have been well documented for the region (De Corte *et al.* 1994, Mortiss 1995). The Dalrymple Shire has not been suitable for sheep and has therefore avoided the excessive level of fragmentation, largely associated with the wool booms, that has been seen in some of the pastoral areas further south. Nevertheless, current property sizes in the Shire are still some of the smallest among the extensive beef producing areas in northern Australia (Bortolussi *et al.* 2004a).

Cost-Price Squeeze

In addition to declining property sizes, economic factors have contributed substantially to the reduced viability of pastoral enterprises. Estimates of the number of cattle required to maintain an economically viable, extensive pastoral enterprise have been steadily increasing over the past decades.

It is currently estimated that cattle properties in the Shire need to be able to carry 1,500 to 3,000 adult equivalents (Caltabiano *et al.* 1999, Roth *et al.* 1999). This reflects the declining terms of trade for the beef industry: while output prices for pastoral production have remained unchanged, input costs have risen by 1.9%/yr relative to the consumer price index (Centre for International Economics 1997). Hinton (1993) reported average rates of return for beef properties in the Dalrymple Shire of -1 to 3%, although beef prices were relatively low at the time of Hinton's report. In adapting to this cost-price squeeze, enterprises have little control over product prices and many have already streamlined input costs and production practices (Landsberg *et al.* 1998). There are thus strong pressures for enterprises to consolidate properties and/or intensify production systems (Fig. 2) (Ash *et al.* 2003).

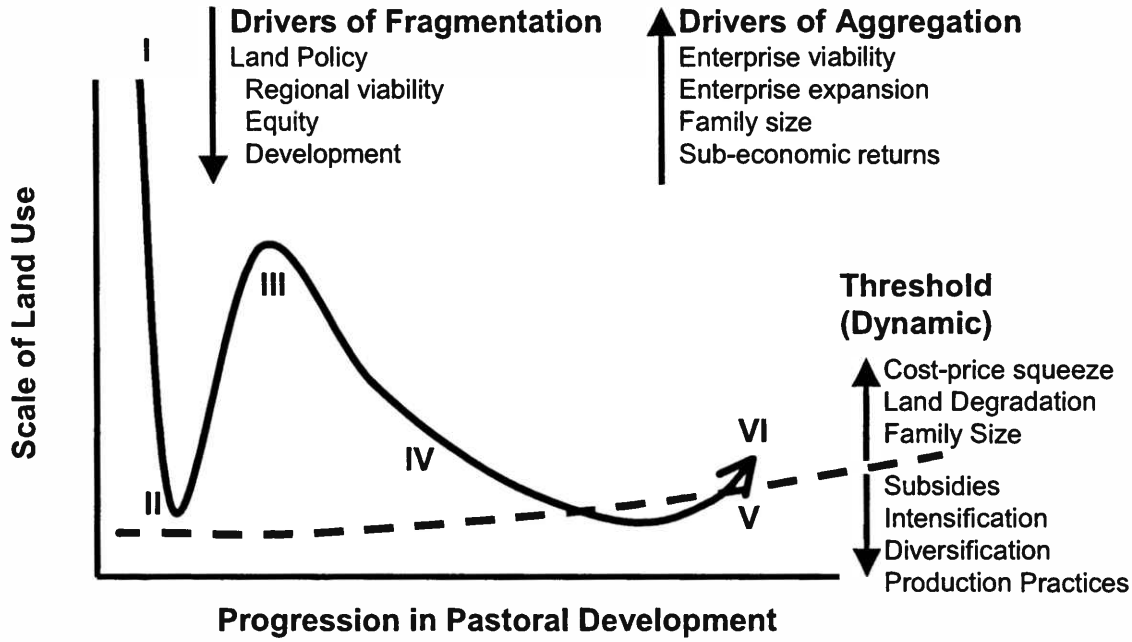

Figure 2. Effect of pastoral development on landscape fragmentation and the scale of land use (solid line). In recent times, there has been a general upward trend in the threshold for the minimum property size required to sustain a viable pastoral enterprise (dashed line). Roman numerals indicate when processes listed in Fig. 1 are dominant.

Business Consolidation

One of the main drivers for aggregating properties into larger enterprises is to generate efficiencies from the increased scale of production. There is evidence of increasing consolidation of pastoral properties across northern Australia, even amongst owner-operated (non-corporate) enterprises (Bortolussi *et al.* 2004a). Discussions with land managers in the Dalrymple Shire show that there is a wide range of reasons for combining pastoral properties into a single enterprise. Family size is an important driver for consolidation, and pastoralists with more than one child often want to expand their enterprises to provide opportunities for their children. In these cases, succession planning becomes an important consideration in structuring the business. Business partnerships between property owners (whether related or not) have at times been a useful means of pooling human and financial resources for mutual benefit. Careful selection of complimentary properties allows specialisation of production activities according to land type. There may be similar benefits if there are differences in weather patterns between properties, since stock can be moved between properties to match differences in forage availability, such as in the case of localized droughts. Ownership of

several properties also offers the chance for opportunistic real estate transactions and personal business/lifestyle differences can affect preferences for multi-property or single property management structures.

Hinton (1993) found the 271 commercial grazing properties in the Dalrymple Shire to be amalgamated into 196 pastoral business entities. Properties ranged in size from 10,000 to 50,000 ha and carried 2,000 to 5,000 head of cattle (Rogers 1998). A recent survey showed that more than half of landholders in the Shire currently own more than one property, with an average of 2.2 properties each (Greiner *et al.* 2003). The average property size of those running a single property is 13,471 ha whereas the average individual property size in jointly-run properties is 40,259 ha, i.e., it appears that the larger properties are the ones being consolidated together. This is consistent with indications from owners of multiple properties that their preference for maintaining flexibility in their business structure is to deal only in properties that are tradeable as standalone entities. This would suggest that property units that have been over-subdivided are effectively removed from efficient, sustainable pastoral production.

PROPERTY FRAGMENTATION & INTENSIFIED PRODUCTION

Benefits of Property Infrastructure Development

The other response to pressures facing the pastoral industry has been a move towards more intensified production systems involving increases in property infrastructure, particularly water points and fencing (Bortolussi *et al.* 2004a). There are numerous benefits that are expected to flow from these developments, but the main aim has usually been to achieve more uniform utilization of pastures across the landscape. The availability of permanent water has been a major limitation on the spatial extent of land use by livestock, especially for European breeds of cattle that did not venture far from water points and riparian areas. On most properties today, the limited coverage of water sources contributes to uneven spatial utilization of paddocks (Pickup and Chewings 1988) and restricts the options for installation of new fences. Development of new water points remains a top priority for many land managers as a means to provide more uniform livestock access across properties.

Aside from distance to water, selective grazing by livestock in patches or preferred vegetation communities has also contributed to uneven grazing. Selective overgrazing can initiate a sequence where livestock progressively degrade one preferred vegetation type after another. In the past, most fencing was done for animal management reasons: to separate stock by type, to match stock types to the quality of pasture, to assist with mustering animals, to keep stock owned by different people apart, to manage cattle diseases and to control animal pests. But grazing, vegetation and land management objectives are starting to become more important considerations for fencing. With the development of new water infrastructure, opportunities are arising for fences to be used in more strategic ways. Much of this fencing has concentrated on controlling access to heavily-utilized riparian areas as a means of limiting land and pasture deterioration and controlling weeds. Fencing according to land type allows the intensity of use of preferred pastures to be controlled to prevent overgrazing, with stock being shifted to make better use of underutilized land types. For some sensitive vegetation types, controlling the timing of grazing can limit the impacts of grazing, while in other cases, periods of intensive grazing can be used to positive effect to control undesirable plants and promote desirable species. Internal subdivision of properties also allows for strategic spelling of pastures, and other stock movement systems for controlling the intensity, duration and timing of grazing. Where paddocks are small enough, this can be incorporated with strategic use of fire in management, by allowing fuel loads to build up and controlling when livestock are reintroduced after pastures start to grow again. Management systems based on these principles have been used to address the problem of patch grazing (Andrew 1986), and are also being tested for controlling undesirable plants.

We have described how the subdivision of properties into smaller paddocks and associated increased control over animal movement create a range of options for positive intervention in the management of rangelands. But with these opportunities come the requirement for increased management action in planning infrastructure development and stock movements. This has given rise to the development of a range of grazing and management systems within which to plan and exercise these options. While views on the merits of various intensive management systems are often passionately held, they have proved difficult to validate (Holechek *et al.* 2000). There are a number of factors associated with intensified production systems that could all be beneficial to overall enterprise management: water point development provides the possibility of more uniform livestock access across a property, even without additional fencing; fencing provides opportunities for greater control of the location, intensity, duration and timing of grazing, and smaller paddock sizes may improve utilization even without elaborate rotational grazing systems (Hart *et al.* 1993); formalized management and grazing systems provide decision-making principles for stock movements and other aspects of enterprise planning and evaluation (Earl and Jones 1996); and closer interaction of managers with enterprise resources (livestock, land, financial and human) can improve their familiarity with the overall state of their enterprise making it easier to detect warning signs of problems and intervene earlier. It is difficult to determine the relative contributions of these different elements to overall enterprise performance, but doing so would be extremely valuable for planning, implementing and improving efficient and sustainable intensified production systems.

Risks Associated with Rangeland Fragmentation

If a 100 ha paddock can sustainably support 10 head of cattle, how many head of cattle can a 10,000 ha paddock support? This question is deceptively simple, but exposes the complex nature of the effect of the scale of land use on spatial interactions of herbivores with their environments (Roshier and Nicol 1998). We have already looked at the ways in which smaller paddock sizes may benefit livestock production and other aspects of enterprise management, but now we address some of the possible trade-offs and unintended negative consequences of intensification that should also be taken into account.

Where herbivores are free to exploit landscapes at large scales, heterogeneity has the potential to act as a spatial buffer to offset seasonal dry periods and droughts (Boone and Hobbs 2003). This spatial buffering would be expected to be strongest where the mix of vegetation patches within a paddock responds differently to weather events (such as seasonal cycles, droughts, frosts or wet periods) and in

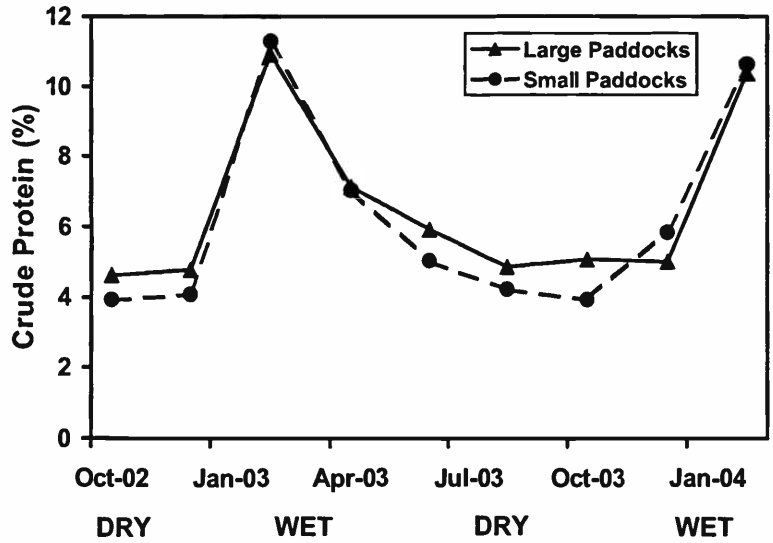

Figure 3. Seasonal variation in cattle diet quality (as measured by faecal near infrared spectroscopy) for 30 large (> 2200 ha) and 30 small (< 2200 ha) paddocks in the Dalrymple Shire.

a manner that alters the relative values of the different patches as forage sources for herbivores. These spatial interactions would be lost with fragmentation. Restrictions on animal movement could potentially have negative consequences for animal nutrition by reducing the accessible diversity of vegetation for selection and diet maintenance when forage quality is poor. Preliminary, illustrative results from a study in the Dalrymple Shire are consistent with this predication (Fig. 3). If this is the case, animal performance would suffer in smaller paddocks, or costs would be incurred in the requirement for extra feed supplements. It has similarly been suggested that heterogeneity in large paddocks acts as a buffer against the effects of increased stocking rate, with a reduced density-dependent decline in individual animal performance in large, complex paddocks than small or homogenous ones (Ash and Stafford Smith 1996, Roshier and Nicol 1998).

There are also biodiversity implications for intensified land use. Current patterns of land use provide a diversity of utilization rates ranging from very heavily grazed patches that promote disturbance- and grazing-adapted species near water points, to very lightly used areas with poor water access that provide refugia for grazing sensitive species (James *et al.* 1999). With intensified land use, these refugia could be lost and other arrangements would have to be made for the conservation of these species. The increased availability of water sources could also contribute to increases in populations of native and introduced animals, increasing utilization pressure on pastures and creating other management problems.

Intensified grazing systems pose a set of risks too. The level of improvement in long-term, sustainable beef production is uncertain and the level of infrastructure development at which development costs exceed the returns on investment is not clear (Holecheck *et al.* 2000). This poses financial risks, and the short-term financial impact of the costs of development and increased herd size need to be carefully managed, even if future gains are assured. Increased property development provides the means to greatly increase stocking rates in the short-term, even though these stocking levels are not sustainable in the long-term, increasing the potential for environmental damage if proper management restraint is not exercised. Even when a property as a whole is not overstocked, the distribution of animals needs to be constantly managed according to the changing conditions in each paddock; otherwise individual paddocks can be overgrazed. The spatial interactions of freely-moving herbivores with heterogenous landscapes result in complex movement patterns as vegetation is produced and consumed across the landscape (Bailey *et al.* 1996). In fragmented landscapes, these 'automatic' movements are lost, but there are increased opportunities for them to be controlled 'manually'. This increases both the opportunities for positive management intervention and the damaging consequences of incorrect decisions, requiring a greater level of skill and understanding from land managers: development of human capacity would have to match efforts to improve the productive capacity of the land. There have been warnings of unforseen negative outcomes of some high-risk management strategies aimed at intensifying production (Holecheck *et al.* 2000). Many of the elements of intensified production systems are, in effect, equivalent to 'disabling the environmental safety switches' so that environmental processes can be switched from 'automatic' to 'manual' to gain some extra performance. Do we know enough to decide which switches we can flip and how to work with them off? A holistic regional approach to intensification also needs to consider the human dimension of the risks associated with our capacity to manage the environment 'with the safety switches off'.

CONCLUSIONS

Policies governing the development of Australia's rangelands have had to strike a balance between achieving sustainable communities and economies at the regional level, and achieving sustainability at the enterprise level. These goals have often been viewed to be in conflict, with the legacy of 'closer settlement' contributing to the challenges faced in achieving sustainability at the enterprise level today. An added complexity is that there are continual fluctuations and changes in the biophysical and socio-economic climate so, to stay viable, even enterprise structures that are currently successful

cannot remain rigid. Small and/or heavily utilized properties have less flexibility to adjust to these changes and are therefore exposed to greater risk compared to larger enterprises with moderate utilization rates. Many pastoralists may be more concerned about managing risk and maintaining flexibility than optimizing production for the prevailing conditions (Bortolussi 2004a).

With the current trend towards intensification of production, it is important to acknowledge some of the accompanying uncertainties and trade-offs, such as the disruption of spatial buffering provided by landscape heterogeneity. There are a number of important questions that need to be answered. Which elements of landscape heterogeneity, connectedness and fragmentation are beneficial for pastoral systems? Landscape patchiness could have both positive and negative implications for land management (Ash *et al.* 2003). It may be that heterogeneity provides a benefit only when there is complementarity in seasonal livestock preferences and forage values of different vegetation types. Whereas, in situations where there is a consistent animal preference for a particular vegetation type through all seasons, it could be better to subdivide the different vegetation types into simplified management units for separate, specialised management. What is the optimum level of fragmentation and internal development within properties? What are the relative positive and negative contributions of the different elements of intensification (water points, fencing, management systems and resource familiarity) to overall enterprise performance and sustainability? And what role can social networks, such as agistment arrangements, play in restoring connectedness and resilience to pastoral regions?

Better understanding of these benefits and trade-offs could allow some of the negative effects of fragmentation to be minimized in intensified production systems, while some of the positive effects of heterogeneity and connectedness could be restored, contributing to the robustness of pastoral enterprises and their capacity to adapt to changes in the future.

ACKNOWLEDGEMENTS

Many of the concepts relating to rangeland fragmentation have been developed in collaboration with our research partners in the SCALE project. The project is supported by the US National Science Foundation Biocomplexity Program. We are grateful to the landholders participating in this study for their involvement and for sharing their knowledge of the history of pastoral development in the Dalrymple Shire and on their properties.

REFERENCES

Allingham, A. (1977). "Taming the Wilderness": the first decade of pastoral settlement in the Kennedy District. PhD thesis. James Cook University.

Andrew, M.H. (1986). Use of fire for spelling monsoon tallgrass pasture grazed by cattle. *Tropical Grasslands* 20: 69 – 78.

Ash, A., Gross, J. and Stafford Smith M. (2003). Scale, heterogeneity and secondary production in tropical grasslands. Proceedings of the VIIth International Rangelands Congress, pp 569 – 579.

Ash A.J. and Stafford Smith, M. (1996). Evaluating stocking rate impacts in rangelands: animals don't practice what we preach. *The Rangeland Journal.* 18: 216 – 243.

Bailey, D.W., Gross, J.E., Laca, E.A., Rittenhouse, L.R., Coughenour, M.B., Smith, D.M. and Simms, P.L. (1996). Mechanisms that result in large herbivore grazing distribution patterns. *Journal of Range Management.* 49: 386 – 400.

Boone, R.B. and Hobbs, N.T. (2003). Lines around fragments: effects of fencing on large herbivores. Proceedings of the VIIth International Rangelands Congress, pp. 580 – 591.

Bortolussi, G., McIvor, J.G., Hodgkinson, J.J., Coffey, S.G. and Holmes, C.R. (2004a). The northern Australian beef industry, a snapshot: 1. Regional enterprise activity and structure. *Australian Journal*

of Experimental Agriculture. In press.

Bortolussi, G., McIvor, J.G., Hodgkinson, J.J., Coffey, S.G. and Holmes, C.R. (2004b). The northern Australian beef industry, a snapshot: 4. condition and management of natural resources. *Australian Journal of Experimental Agriculture.* In press.

Caltabiano, T., Hardman, J.R.P. and Reynolds, R. (1999). Living area standards. Queensland Department of Natural Resources, Coorparoo.

Centre for International Economics. (1997). Sustainable natural resource management in the rangelands. Centre for International Economics, Canberra & Sydney.

Day, D. (2001). *Claiming a continent: a new history of Australia.* Harper Collins, Sydney.

De Corte M.W.M., Barry E.V., Bright M.J., Cannon M.G. and Scanlan J.C. (1994). Land degradation in the Dalrymple Shire, a preliminary assessment. Methods and results. Project report Q093023, Queensland Department of Primary Industries, Brisbane.

Greiner, R., Stoeckl, N., Stokes, C., Herr, A. and Bachmaier, J. (2003). Natural resource management in the Burdekin Dry Tropics: social and economic issues. CSIRO, Townsville.

Hannam, I. (2000). Policy and law for rangeland conservation. *In* 'Rangeland desertification.' (O. Arnalds and S. Archer). Kluwer Academic Press, Dordrecht.

Hart, R.H., Bissio, J., Samuel, M.J., and Waggoner, J.W. Jr (1993). Grazing systems, pasture size, and cattle grazing behavior, distribution and gains. *Journal of Range Management.* 46 : 81-87.

Hinton, A.W. (1993). *Economics of beef production in the Dalrymple Shire.* Queensland Department of Primary Industries, Brisbane.

Holechek, J.L., Gomes H., Molinar, F., Galt, D. and Valdez R. (2000). Short duration grazing: the facts in 1999. *Rangelands* 21: 18-22.

Holmes, J.H. (1997). Diversity and change in Australia's rangeland regions: translating resource values into regional benefits. *The Rangeland Journal.* 19: 3 – 25.

Holmes, J.M. (1963). *Australia's open north.* Angus and Robertson, Sydney.

James C.D., Landsberg, J. and Morton, S.R. (1999). Provision of watering pints in the Australian arid zone: a review of effects on biota. *Journal of Arid Environments.* 41:87-121.

Land Settlement Advisory Commission (1959). *Report on progressive land settlement in Queensland.* State of Queensland, Brisbane.

Landsberg, R.G., Ash, A.J., Shepher, R.K. and McKeon, G.M. (1998). Learning from history to survive in the future: management evolution on Trafalgar Station, north-east Queensland. *The Rangeland Journal.* 20: 104 – 117.

Mortiss, P.D. (1995). The environmental issues of the Upper Burdekin catchment. Project Report Q905017, Queensland Department of Primary Industries. Brisbane.

Passmore, J.G.I. and Brown, C.G. (1992). Property size and rangeland degradation in the Queensland mulga rangelands. *The Rangeland Journal.* 14: 9 – 25.

QNRM (Queensland Department of Natural Resources & Mines) (2001). *Managing State rural leasehold land: a discussion paper.* State of Queensland, Coorparoo.

Rogers, L.G., Cannon, M.G., and Barry, E.B. (1998). *Land resources of the Dalrymple Shire.* Queensland Department of Primary Industries, Brisbane.

Roshier, D.A., and Nico, H.I. (1998). Implications of spatio-temporal variation in forage production and utilisation for animal productivity in extensive grazing systems. *The Rangeland Journal.* 20: 3 – 25.

Roth, C., Aldrick, J., Ash, A., Hook, R., Novelly, P., Orr, D., Quirk, M. and Sallaway, M. (1999). The North Australia Program: NAP Occasional Paper No. 4. CSIRO, Townsville.