Viewpoint from a Practitioner

Meat and Livestock Australia (MLA) works in consultation with producers to develop and implement research, development and extension aimed at creating an innovative and sustainable red meat industry in Australia. In order to achieve ongoing industry leadership, MLA promotes a *triple-bottom-line* approach to meat and livestock production, recognising that pastoral businesses need to be economically, environmentally and socially sustainable.

A large proportion of Australia's red meat and livestock are produced from the rangelands. Increasingly producers are faced with having to produce more meat at lower cost to remain economically viable. Increasing property size and rangeland consolidation is one response of producers to declining returns. However, pastoral businesses operate in a complex dynamic system, interacting with highly variable landscapes, climate, markets, prices, government policies and community concerns.

In this chapter the authors adopt a Complex Systems Science (CSS) approach to explore the pressures that influence land consolidation patterns in the rangelands. The utility of CSS in this context is that incorporating interactions between different rangeland sub-systems allows the emergence of global behaviour that may not be anticipated from the behaviour of the components in isolation. Using agent-based models, the authors show that land parcel sales were influenced strongly by seasonal variability and increased during periods of below average rainfall and drought when forage availability and profits were reduced.

Most importantly, model simulations for a range of initial property sizes demonstrated there was a non-linear relationship between the initial level of fragmentation and the degree of subsequent consolidation. In other words, in areas where initial property size was less than the threshold range for economic viability (< 20,000-25,000 ha), consolidation would proceed so a region would be dominated by a few very large enterprises. Similarities between consolidation patterns simulated from high, medium and low fragmentation scenarios were made with contrasting rangeland areas in south-west Queensland, the Dalrymple shire and the Victoria River District respectively. For policy makers these results demonstrate the need to understand the historical setting of land fragmentation in order to better understand rangeland consolidation responses.

Understanding rangeland consolidation process is important to the red meat and livestock industry because of the interactions with economic viability, and environmental and social sustainability. This knowledge may also assist agricultural policy formulation in areas of northern Australia where rangeland intensification and fragmentation is still proceeding. However, in addition to declining profits, there are complex demographic, social and psychological reasons many producers have for remaining on land that also need to be considered. Additionally, incorporating agricultural policy influences is also particularly important. Drought policy outcomes on one hand may distort economic signals promoting consolidation process, but also conflict with rural adjustment policy objectives on the other. Therefore an important challenge for future research is to incorporate non-economic and rural policy influences affecting rangeland consolidation patterns into CSS approaches.

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14. Rangeland Consolidation Patterns in Australia: An Agent-Based Modelling Approach

Ryan R. J. McAllister, John E. Gross and Chris J. Stokes

Abstract

In Australian rangelands, post-European pastoral land-use systems have been characterised by private-property regimes, which to varying degrees have created fragmented and disconnected landscapes. There are both environmental and economic risks associated with productive land fragments being too small. These risks necessitate an understanding of fragmentation's driving forces, made difficult because the problem involves social, economic and environmental factors, interacting over a range of temporal and spatial scales. We developed an agent-based model to help us explore the complex rangeland dynamics. In this paper we apply our model to the problem of landscape fragmentation and subsequent consolidation. Our simple model contains pastoralists, livestock, key ecological processes, and governance. Over the last century, declining enterprise sizes, increasing costs and declining returns have all contributed to increasing pressures on the viability of pastoral enterprises. We found strong regional variation is driven by localised historical and economic patterns which seed the consolidation process differently in different regions. Anecdotal evidence from South-West Queensland, Victoria River District, and Dalrymple Shire, show our model can explain regional variation. Our simulations represent a starting point for developing a more complete and insightful understanding of ongoing dynamics in rangelands, with the aim of informing policy.

Introduction

In most semi-arid and savanna ecosystems, extensive grazing dominates land use. European-style development of these ecosystems, with its privatised land tenure systems, has often profoundly altered the scale of land use through the subdivision of landscapes into discrete blocks of land that have been subdivided, traded and amalgamated to form enterprises of different sizes. In this chapter we take a complex systems approach to analysing the drivers of change in spatial scale of extensive rangeland enterprises, with the aim of informing policy. One working hypothesis is that development of rangelands is initially accompanied by fragmentation as land units are sub-divided, but later it is followed by a period of consolidation (Ash et al. 2004). We focus on the later process of land consolidation of cattle enterprises of northern Australia. While consolidation can occur at any stage during land ownership, in this later stage consolidation is the norm. This stage is characterised by external pressures that decrease profit margins, particularly for smaller enterprises. To remain viable, small or inefficient enterprises must increase profits by increasing the scale of operation, diversification and/or economies of scale (i.e., increasing in physical size). The point in the process where consolidation pressures begin to outweigh fragmentation pressures is important because at this point the environment is at most risk. An understanding of rangeland dynamics is necessary to guide development of wise policy, and it helps identify the causes of differences in regional patterns of consolidation. However, as we discuss below, different regions within Australian rangelands, despite sharing many aspects of governance and global economic trends, are presently experiencing polar differences in terms of consolidation/fragmentation pressure (Stokes et al. in press).

Since Europeans settled in Australia, land-use systems in rangelands have been gradually transformed from a semi-nomadic indigenous system to one characterised by a private-property regime. Private-property regimes are generally associated with the division of land for the exclusive use of individuals, often with boundaries clearly defined by fences. The expansive nature of production in rangelands, which is typically dominated by cattle and/or sheep production on enterprises over 20,000 hectares in area, has meant that the physical bounding of enterprises has, in some cases, taken over a century. The transition from semi-nomadic to the present day system has involved several stages (Stokes et al. 2004). These stages have generally seen rangelands initially pass through a period of fragmentation followed by a period of consolidation. The consolidation process is the focus of this paper, but the starting point of consolidation is a fragmented landscape, and we discuss the risks associated with fragmentation here. According to Stokes et al. (2004) there are two main risks of fragmentation: it allows the enterprise to fall below a minimum viable size; and it disconnects parts of the landscape limiting access to heterogeneity (Janssen et al. 2006). We discuss these risks in turn.

Rangelands are not suitable for intensive primary production and are generally managed as low-input systems. In such cases profits are generated from very small margins per area of land and, accordingly, very large enterprises are required to support a family. Policy has traditionally been an important driver of Australian rangeland fragmentation where land was allocated as parcels just large enough to support a family. The problem is that declining terms of trade (Macleod 1990) and increasing property prices have seen the minimum viable property size increase over time (Caltabiano et al. 1999). The threshold which defines a viable property size is dynamic, and if actual property fragments become too small because of a change in the viability threshold, then financial, environmental and social pressures seriously undermine the whole system's viability. Because of the inherent variability in the natural system, even highly fragmented landscapes can thrive in periods of above average rainfall, but when periods of unfavourable seasons coincide with downturns in markets, fragmented landscapes are at most risk (Stokes et al. 2004).

The second risk of fragmentation is that it disconnects large scale ecological processes. Most notably, rangelands are generally limited by having only patchy, irregular and infrequent rain events. When rangeland systems are not fragmented, herbivores can migrate around the landscape in pursuit of its patchy resources. However, fragmentation has bounded the movement of livestock, now the dominant herbivores in these landscapes. In rangelands throughout the world, institutions have developed that help human-managed herbivores move around the landscape, sometimes over massive distances, but such systems are imperfect (McAllister et al. 2006). The risk of fragmentation therefore, is that it bounds enterprises at a scale that is too small to buffer the systems high level of resource variability.

The negative effects that accompany over-fragmentation can be a strong motivator for change in rangelands (Landsberg et al. 1998). In practice, 2 adaptations to fragmentation are observed: production intensification and land consolidation.

The benefits of intensification have become more numerous since technological advances have made intensified production cost effective. Most innovations have sought a more uniform utilisation of pastures across the landscape. European breeds of cattle, which dominated Australian rangelands until the 1970s, did not venture far from water sources, creating heavy utilisation in some parts of the landscape and light utilisation in others. In this regard, production has been intensified by incorporating Indian cattle breeds, which can travel much farther from water, and by increasing the distribution of available water (Abbot and McAllister 2004). A poor distribution of water points itself can be a source of fragmentation, so water point development can reduce fragmentation

Land consolidation is the focus of this paper and there is evidence of increasing consolidation of pastoral properties in some regions in Australia's rangelands, but not all regions (Stokes et al. 2004). Consolidation is generally driven by the economic desire for greater returns (not necessarily economies of scale), but many pastoral enterprises are owner-operated and personal circumstances often seem to dictate when consolidation is required (for example, succession planning). Strategic-business decisions can also drive consolidation, particularly when an enterprise is seeking to hold complimentary properties (breeding and fattening, for example). Nevertheless, the primary driving force for consolidation is simply that an enterprise with given economic and environmental conditions, is not sufficient in area to generate enough cash flow to support its owners. In other words the enterprise fragment is too small. The process of consolidation is ongoing. Furthermore, the fragmentation-consolidation story is experienced differently across Australia.

What we discuss next is how we employ complex systems science methods to inform policy on the difficult and important issue of land consolidation. We used an agent-based model, which included pastoral enterprise agents with the ability to sell and purchase land parcels, to test how the system responded to various pressures. This model was designed to provide a platform for supporting policy in rangelands (Gross et al. in press), and could be used to explore various other issues. Here we limit our analysis to the important problem of land consolidation. The results from this application of the model helped us to develop a theoretical model which explains why the process of land consolidation emerges differently across contrasting Australian rangeland regions. We first describe the issue of land fragmentation in Australian rangelands, and then explore the issue using an agent-based model, and finally present the core results and findings.

Methods

Both the biophysical and human-dominated components of rangeland systems respond and adapt to system states, thus the processes of evolution and learning are critical in rangeland systems (Walker and Abel 2002). Such an adaptive system can be evaluated within the framework defined by the emerging science of complex systems, and the application of complex system science methods provides an alternative perspective on rangeland dynamics. In particular, agent-based models and computer-assisted reasoning show potential for gaining new insights into systems in which decisions are based on criteria with widely differing currencies, and where a multitude of individual decisions leads to emergent properties at a higher level (Levin 1998; Lempert 2002). We take a complex systems approach because these methodologies have already proved useful in exploring various aspects of rangeland dynamics (Janssen et al. 2000; Anderies et al. 2002; Walker and Janssen 2002; Janssen et al. 2004).

We developed a simple and quite general agent-based model of rangeland systems typical of northern Australia savanna. An earlier implementation of the model is described by Gross et al. (in press) and we embellished this model to more thoroughly explore land consolidation processes. In addition to the implementation described by Gross et al., our model considers: how costs and spatial heterogeneity drive consolidation; how different consolidation drivers affect land management practices; and how temporal heterogeneity affects the timing of consolidation. We summarise the important elements of our agent-based model here.

Pastoral enterprise submodel

Pastoral enterprise actions were represented by a strategy set that defined management actions and characteristics. This strategy set included criteria for setting a target stocking rate and making other financial decisions (sale of cattle, borrowing, destocking and restocking, etc.). Enterprises accumulated either debt or wealth depending on the overall success of their respective rules through time. The focus of this model was on the process of consolidation of Australian rangelands. To deal with this issue we needed our model enterprises to be equipped with rules for selling and buying sub-enterprise blocks of land. We did this using simple rules.

If an individual pastoral enterprise's debt position rose above 80 per cent (debt position is defined as debts or savings divided by the value of cattle and land assets) then that property was forced to sell one block of land. If that enterprise sold its last block of land, then it exited the system. If, in a given period, there were multiple enterprises with a debt position above 80 per cent, only the enterprise with the worst debt position sold land.

If a block was for sale, it was offered to the enterprise in the system with the highest estimated post-purchase debt position—i.e., what debt position an enterprise would have after purchasing the block. We assumed this enterprise bought the property with a probability of 50 per cent and if they did not purchase the property then it was not offered to other enterprises in the same month. If an enterprise had a positive debt position, then when the purchasing decision was made their debt position was weighted down by the total enterprise area (after purchase). This reflected a diminished desire for successful enterprises to change and grow.

The biophysical submodel was largely driven by precipitation, and each property received some random variation of the landscape-wide average reflecting spatial variability (details below). If a block was purchased, then the variation in precipitation applied to both the buying and selling enterprises was adjusted according the new total area of land owned.

The most important decisions that pastoralists have to make relate to how many cattle to stock. Stock numbers affect the biophysical condition of properties, which affects live weight gains. Also, seasonal depletion of forage affects live weight gains and/or supplement use. Live weight gain was the primary link between the biophysical agent (the property) and the pastoral enterprise agent. Live weight gains affected supplementary feed requirements, fecundity and mortality rates, and the weight of cattle sold.

We assumed that pastoralists made stocking decisions in May and that all cattle breeding (and mortality) occurred only in November. Simulated pastoralists had a target stocking rate that guided their cattle trading decisions. In the month when decisions were made, our model pastoralists sold and purchased cattle in order to maintain a target stock, but filtered their buying and selling rules by destocking during droughts (and subsequently restocking). Rates of destocking (or restocking) were estimated from forage utilisation (Littleboy and McKeon 1997) as:

$$\% \text{ Change} = 100 - a1 * \ln(\text{Utilisation}) \quad (1)$$

where Utilisation is the one-year average of forage utilisation (proportion of biomass production consumed by livestock) on a property;

and a1 is a shape parameter that determines how reactive individual pastoralists' stocking rates are to heavy utilisation (associated with low forage production under drought).

The parameter a1 varied for individual pastoralists in the system, reflecting heterogeneous approaches to dealing with drought. In these simulations, a1 varied (uniformly) from –35 to –25.

Cattle were purchased or sold in response to rates of forage utilisation (equation 1), and differences between target and actual stocking rates. If the achieved stocking rate was less than the target and % Change was positive, cattle were purchased. In this case, the number of cattle purchased was the lesser of the number needed to reach the target stocking level, or the absolute value of % Change (i.e., the number of cattle proportional to % Change). Cattle were always sold when the rate of stocking exceeded the target and cattle were always sold when % Change was negative. The number of cattle sold was the greater of the number needed to achieve the target stocking rate or the proportion of the herd equal to the absolute value of % Change.

The mass of each cow that was purchased was assumed to be 400 kg. The weight of cattle sold was taken as the total monthly live weight gains on a property over the past 3.5 years. These live weight gains included the effects of supplementary feeding, which bound the minimum monthly gains at 4.167 kg. Supplementary feeding incurred costs, which were related to what the gains would be without supplementary feeding, and we applied rules used by Macleod et al. (2004) to determine the level of costs incurred.

In our simulations, mortality and branding rates followed Gillard and Monypenny (1988):

$$\% \text{ Mortality} = 3.2 + 87.0 * e^{-0.03*(LWG+50)}, \quad (2)$$

$$\% \text{ Branding} = 0 \leq 15.6 + 0.488 * LWG \leq 80.0, \quad (3)$$

where LWG is the one-year average of live weight gains on a property. All births and deaths occurred at the same time each year.

Biophysical submodel

The underlying conceptual structure of the plant and livestock submodels was to define optimal growth rates, and then reduce these rates by factors that represented the most important constraints and stressors. Simulated plant growth could be limited by precipitation or seasonal changes in temperature. Plant growth varied seasonally in a manner consistent with growth of C4 species found in tropical Australia. Multi-year changes in potential plant growth resulted from changes in grass basal area, which responded on an annual basis to aboveground productivity and to utilisation. Maximum plant production (kg ha^{-1} mo^{-1}) was a function of basal area, thus the change in green vegetation (G, kg ha^{-1}) was:

$$dG/dt = B_a \, B_{gmax} \, M_{precip} \, M_{seas} - S \, G \qquad (4)$$

where B_a is basal area (percentage cover), B_{gmax} is maximum growth per unit of B_a (kg/ha), M_{precip} is a precipitation multiplier (0-1), M_{seas} is a seasonal growth factor (0-1), and S is senescent rate (proportion).

A key process in rangelands is degradation and the gradual run-down of production. A dynamic basal area function, based on that in the grassland simulation model GRASP (Littleboy and McKeon 1997), was used to represent the effects of heavy grazing or sustained drought. High rates of utilisation or low production (typically the result of drought) led to a reduction in B_a. We placed no restrictions on how rapidly B_a can decline, but increases in B_a were limited by averaging production over the previous 2 years, and by maximum growth rate. Consequently, rates of decline in basal area were usually more rapid than rates of recovery, representing the hysteresis that typically accompanies ecosystem degradation.

Grass was partitioned into pools of green and dry material (kg/ha). These pools varied in nutritional quality and were important to adequately represent livestock dynamics. Parameters in the plant submodel were calibrated to observations of biomass dynamics near Charters Towers, and to outputs from GRASP (Littleboy and McKeon 1997; parameter set Burdy11). The plant submodel we implemented reproduced patterns and quantities of forage that roughly matched observations from the black speargrass paddocks in the Charters Towers region.

Spatial heterogeneity was represented in the model by modifying precipitation as a function of property size. As property size increased, variation in precipitation declined according to equation 5. Equation 5 varies precipitation to property size to account for the observation that larger properties buffer spatial variation in precipitation (Perevolotsky 1987). Precipitation for each property was determined by multiplying average precipitations for all properties by:

$$1 + r(e^{-Area / 1000000}), \qquad (5)$$

where r is a random number drawn annually from a uniform distribution [-0.5,0.5] and Area is the total size of a property.

The livestock submodel partitioned cattle into 2 age classes. The model simulated live weight gain (LWG, kg) and it included simple diet selection and animal growth functions that interact with the plant submodel through selection and consumption of green and dry grass. Growth rates responded to forage availability and quality.

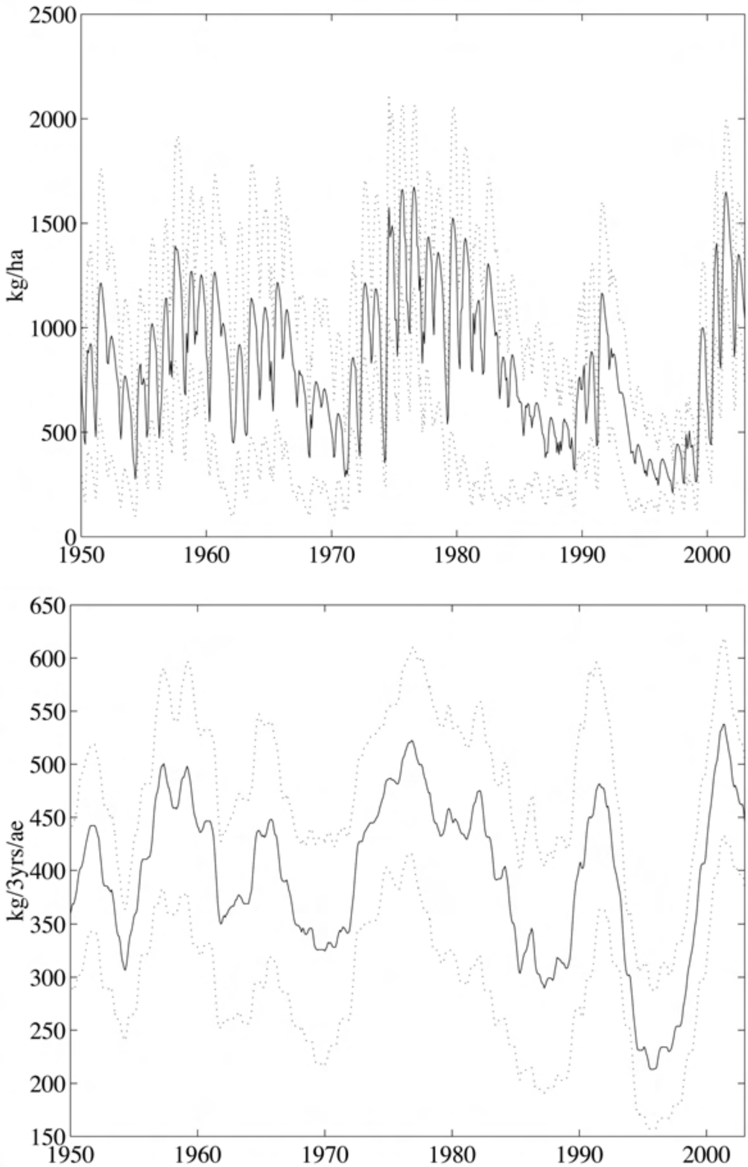
Diet selection is a key process in tropical pastures, and the quality of the diet consumed in our model was determined by the proportion of green forage in the diet. Diet selection was implemented following the basic conceptual model proposed by Blackburn and Kothmann (1991), but selection for green forage is driven only by the proportion of green in the sward and absolute biomass (Chacon and Stobbs 1976; Hendricksen et al. 1982). Diet quality was determined from the proportion of the diet composed of grass that grows in the current time step (highest quality green grass), green grass that grew in previous time steps (intermediate quality), and dry grass (lowest quality). Diet selection and diet quality are key drivers of animal growth and condition, which subsequently influences growth and survival of livestock in the absence of supplemental food. However, if average live weight gains fell below 4.167 kg for a given month, following MacLeod et al. (2004) we assumed that feed was supplemented at a level such that exactly 4.167 kg of weight was gained. The exact diet deficiency affected the amount of supplementary feed required (hence costs, see above) but not the minimum level of live weight gain.

Results

Reference conditions

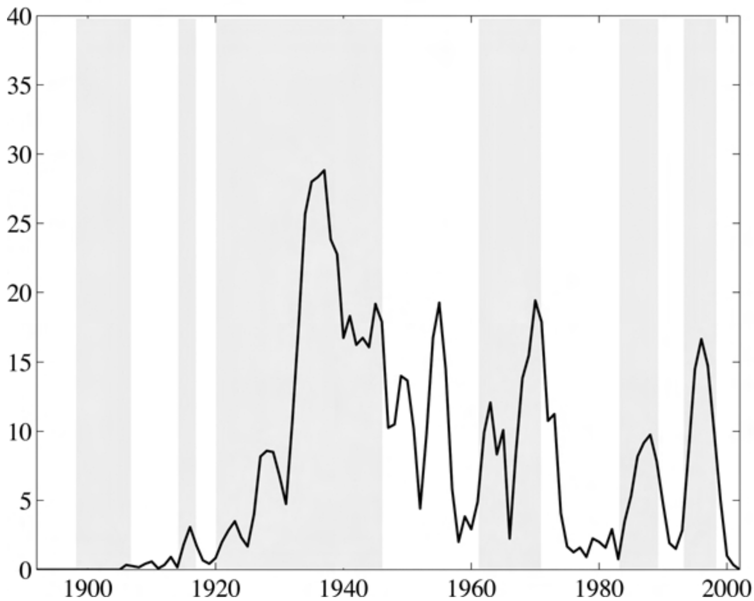
The simulations presented in this paper were based on 113-year simulations with a model time step of one month. The biophysical model was calibrated to output from GRASP, a grassland simulation model (Littleboy and McKeon 1997), to reflect characteristics of the Dalrymple Shire in North-East Australia. Our simulations were designed to mimic a hypothetical region consisting of 2.5 million hectares, which is a region approximately one-third of the size of the Dalrymple Shire. Our reference conditions used monthly precipitation observations from Charters Towers, Queensland, Australia, recorded between 1890 and 2003. For this case we used fixed cattle prices and fixed supplementary feeding costs and other variable cost prices, and did not allow trading of properties. Results are presented for simulations where property size was held constant at 20,000 ha (Figure 14.1). We then relaxed our constant size rule by dividing each property into 4 blocks of land and permitting land sales and purchases. These simulations indicated that land sales were related to weather patterns (Figure 14.2) and, after a sustained period of simulation, the distribution of property sizes was right skewed (Figure 14.3).

Figure 14.1. Results of reference treatment in a heterogeneous rangeland system



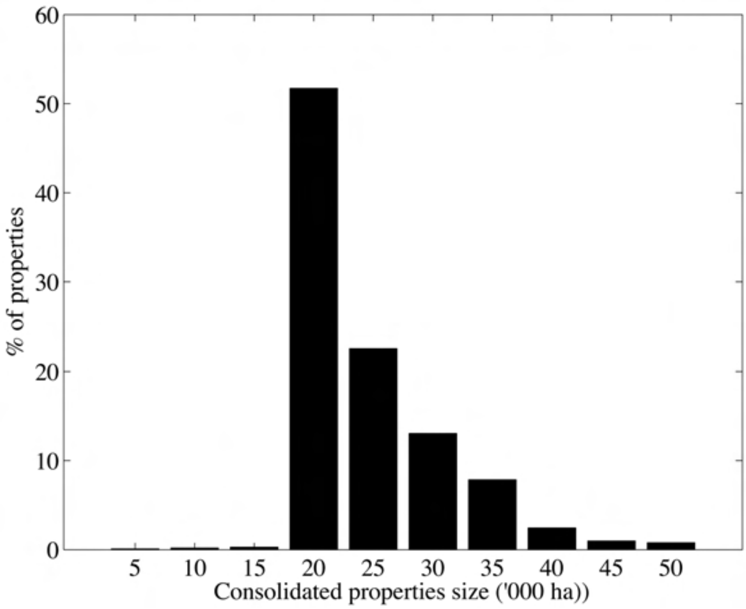
(a) standing dry matter; and (b) cumulative 3-year live weight gain per adult equivalent. The solid lines show the mean of all enterprises in the system, while the dotted-lines above and below represent 95 per cent confidence intervals for individual enterprises (percentile bootstrap method).

Figure 14.2. Number of block sales for the reference treatment (solid line)



Simulations were driven by observed monthly Charters Towers precipitation records. Shaded areas indicate periods where both the 3-year and 1-year average precipitation was below average (periods with below average precipitation separated by < 2 years were joined).

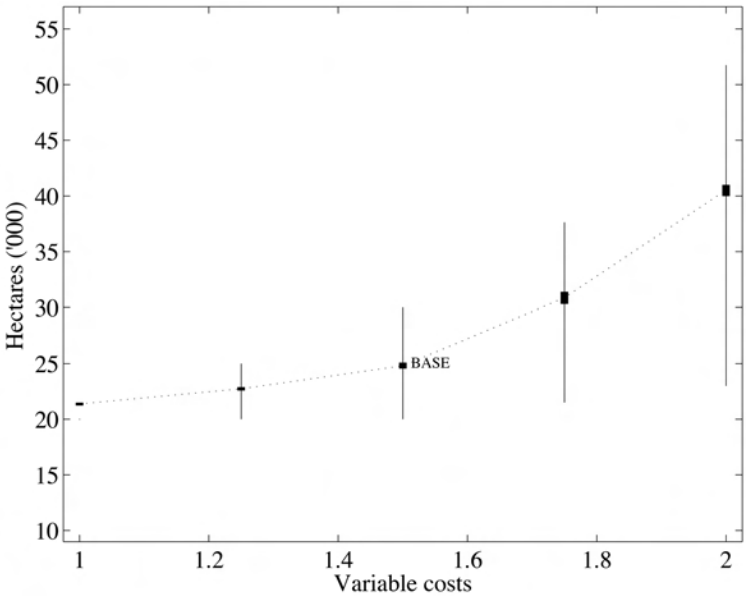
Figure 14.3. Consolidated property size distribution at the end of the simulations using reference conditions



Sensitivity analysis

Financial success was the only direct driver of consolidation in our model, though financial success was a function of property size, precipitation, management strategy and biophysical condition, as well as interactions of these factors. To explore the direct effect of financial pressure, we simulated treatments with different variable and fixed costs. In these simulations, monthly variable costs (other than supplementary feeding costs) per adult equivalent were fixed at \$1.00, \$1.25, \$1.50, \$1.75, or \$2.00 (Figure 14.4). In the same way, we also examined the effects of supplementary feeding costs and fixed costs. All changes in costs that we examined led to similar results: increased costs uniformly led to greater rates of consolidation. As an exemplar of these simulations, Figure 14.4 demonstrates how increased costs led to consolidation of properties.

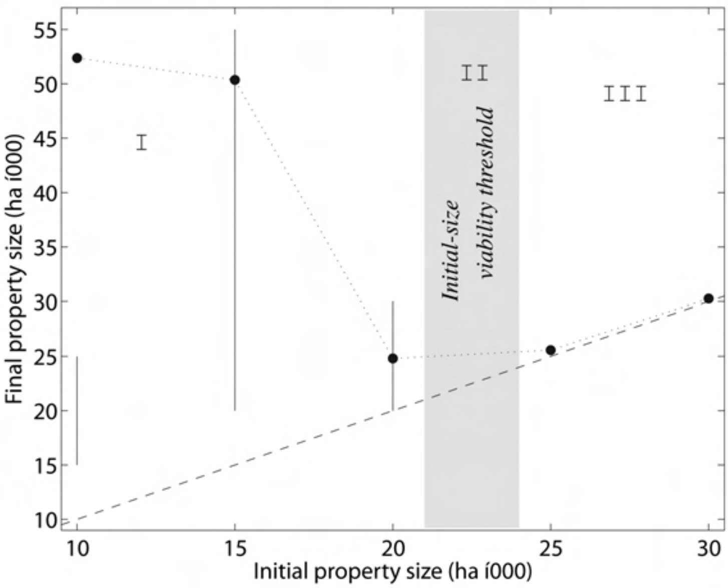
Figure 14.4. Average consolidated property size response to the variable costs



Thin vertical lines show percentile ranges (25 and 75 percentiles) for 100 repetitions, while the thicker bars show 95 per cent confidence intervals for individual enterprises (percentile bootstrap method).

We explored the effects of the initial distribution of property size on consolidation by maintaining 2.5 million hectares in the system, but dividing land evenly between various numbers of enterprises, hence varying the initial property size in the simulation. We compared 5 starting enterprise sizes: 10,000; 15,000; 20,000; 25,000 and 30,000 hectares (all divided into tradable units of 5,000 ha) and we repeated our simulations 100 times per treatment. Results from these simulations showed that the relationship between starting size and the mean size of enterprises at the end of simulation was convex (Figure 14.5). Also, the distribution of the resulting enterprise sizes for the treatment with the smallest assumed starting size was heavily skewed towards being small. This is shown by the percentile range; in particular, the upper percentile range fell below the mean result, indicating that consolidation activity was dominated by a relatively small number of enterprises. Clearly in a treatment dominated by sub-economic sized enterprises, any enterprise that took the initial step towards overcoming this was then in a relatively better position to succeed and continue to grow.

Figure 14.5. Mean consolidated enterprise size at the start and end of 113-year simulations



Thin vertical lines show percentile ranges (25 and 75 percentiles) for 100 repetitions. The dashed reference line marks points where the initial and final property size are equal. The shaded band indicates a threshold property size range for enterprise viability; property trading and consolidation only occurs when smaller, non-viable properties are forced to sell land.

Discussion

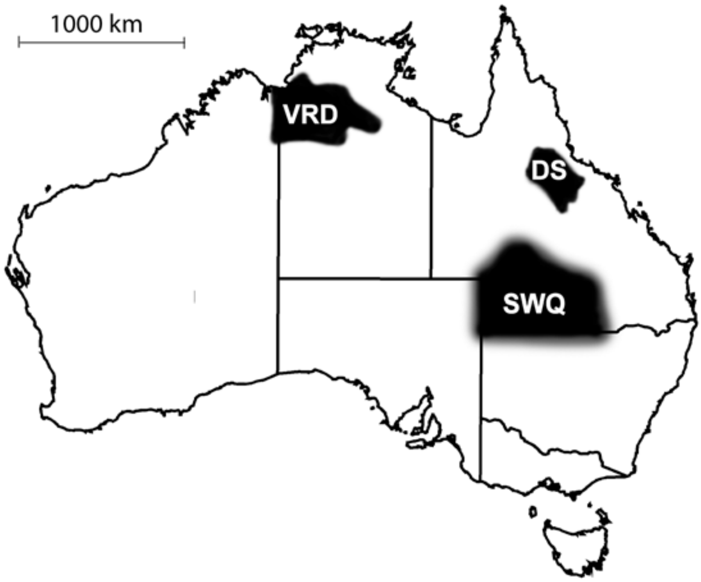
Consolidation is one reaction to decreasing returns from pastoralism (Figure 14.4). Consolidation requires both a demand for property by existing enterprises and a supply of land. In our simulations, supply was strongly related to weather conditions (Figure 14.2), which influenced forage availability and thus profits. Simulations reported here resulted in right-skewed distributions of property sizes after the consolidation process (i.e., the mean property size is larger than the median). This distribution is consistent with observations from Australian rangelands (Bortolussi et al. 2005).

There is a discernible threshold range of property size (20,000–25,000 ha: Figures 14.3 and 14.5) separating viable and non-viable enterprises. When simulations were initialised with enterprises too small to be economically viable (< 20,000 ha), the simulation usually ended with a few very large enterprises that skewed the final distribution of property sizes. When simulations started with very large enterprises (> threshold), these large enterprises were generally profitable enough to retain all their land and there was little opportunity for consolidation to occur. In this case, initial and final enterprise sizes were nearly the same.

There is some variation in the *initial-size viability threshold* between enterprises because properties are managed by heterogeneous agents, each with unique practices. This threshold would likely become less clearly defined if other sources of heterogeneity, such as differences in land resources between properties, were included in the model.

The model demonstrated that there is a non-linear relationship between the level of fragmentation in land-use systems, and the degree of their subsequent consolidation. We can compare our model results against historical observations from Australia. Three strongly contrasting scenarios of fragmentation in Australian rangelands, described by Stokes et al. (in press), serve as a useful basis for this comparison: the Dalrymple Shire (DS); the Victoria River District (VRD); and, south-west Queensland (SWQ) (Figure 14.6). From the late 1800s to the mid 1900s, land use in Australian rangelands was strongly influenced by policies of 'closer settlement'. Policies of this period were aimed at increasing rural populations, encouraging development of the pastoral industry and promoting equity in land distribution. This led to the subdivision of initially vast pioneering pastoral stations into progressively smaller enterprises. Over the last century, declining enterprise sizes, increasing costs and declining returns have all contributed to increasing pressures on the viability of pastoral enterprises. One of the consequences of these changes in recent decades has been pressure to consolidate pastoral enterprises. But there is strong variation between different regions of Australian rangelands in the extent to which enterprises became fragmented and in the subsequent consolidation of properties. South-west Queensland has had a long history of pastoral development, is relatively close to population centres, and has experienced several periods of strong profitability in the sheep industry. It was therefore very strongly influenced by policies of land subdivision. This corresponds to scenario I in Figure 14.5, where properties became subdivided to sizes well below the threshold for viability, and there has since been a growing trend towards enterprise consolidation. At the opposite extreme, the Victoria River District is remote from population centres, was amongst the last areas in Australia to be developed for pastoralism, and is only suitable for cattle, an industry that has not been as profitable as the sheep industry in the past. As a result this area has escaped the influence of policies of closer settlement and land fragmentation. This corresponds to scenario III in Figure 14.5. Initial property sizes were vast and have remained so, without being strongly influenced by pressures to consolidate. Dalrymple Shire represents an intermediate scenario, where rangelands only ever became moderately fragmented. Property sizes were probably viable at the time of the last subdivision, but were close to the viability threshold (Figure 14.5 II) and have subsequently become subject to consolidation pressures under the influence of rising costs of production (Figure 14.4).

Figure 14.6. Location of sites



Conclusions

To some degree, different regions within Australian rangelands demonstrate our simulated pattern, but localised historical and economic patterns have seeded the consolidation process differently in different regions. This process is ongoing and has various implications for regional Australia, in particular for social capital. If we seek to guide policy in rangelands we need to understand this process in a strong context of its historical setting. Enterprise size buffers against climatic variability and financial risk, and may improve economies of scale. But the drive to increase the scale of operations need not be met by consolidation alone. Anecdotal evidence suggests that kin-based networks may be important. Agistment networks also allow pastoralists to overcome spatial resource variability (Janssen et al., 2006; McAllister et al. 2005, 2006), which is more prominent for small enterprises. The size-related viability of rangeland enterprises portends important consequences for the social and environmental health of Australia's rangeland communities. In the past, small enterprises were more likely than large enterprises to perform poorly (Hinton 1995), and land consolidation was an effective response to the constraints imposed by small property sizes.

Our simulations represent a starting point for developing a more complete and insightful understanding of the dynamics of rangelands. This understanding is the key to interpreting events in the past and to forecasting consequences of policy into the future. Our model results, and equally the thought process involved in constructing the model, contributed to this understanding.

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