Trust And Cooperation In Natural Resource Management: The Case Of Agistment In Rangelands

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EXTENDED ABSTRACT

Reciprocal altruism is paradoxical; theoretically the more one is trusted, the better the outcomes from one-shot prisoner's dilemmas, although for individuals the best outcomes are when trust is not reciprocated. Most real life games are not one-shot, but iterated where trust develops through past actions (Cárdenas and Ostrom, 2004). Furthermore, in social-ecological systems outcomes are driven by the biophysical context. In rangelands, our focus, low levels of biophysical variation limit the returns from trusting others and vice versa (McAllister et al., in press). Regardless of context, individuals who are too trusting always loose out.

We explore trust and cooperation using agistment of livestock in Australian rangelands as an example, which is a human response to variation in rangeland resources in time and space. Agistment interactions are essentially iterated interactions, where livestock is transferred between pastoral enterprises in a commercial arrangement. The interaction occurs between a pastoralist with a shortage of forage (whether induced by rainfall deficiencies or management practices) and another who have an excess. Agistment may facilitate stock movements between pastoralists when it is not possible to maintain an economically viable herd in the long-term on a single management unit and where attempts to do so can lead to the loss of income or capital (livestock or landscape function) (Goodhue and McCarthy, 2000).

We use the model of McAllister et al. (in press), which combines a landscape, with variable resourse disbribution in time and space, and humans, who have the ability to build networks for facilitating agistment.

Our results show that fostering a climate of trust is critical in cooperative action. However, from an individual's point of view, one can be worse off if too much trust is placed in others (Figure 1). Even though if the need arises, trust is generally likely to develop as part of a informal institution, non-cooperative action experienced by otherwise trusting individuals implies that the informal institutions may be insufficient and formal polices which support those of an informal nature may be effective in improving outcomes from cooperative actions in rangelands.

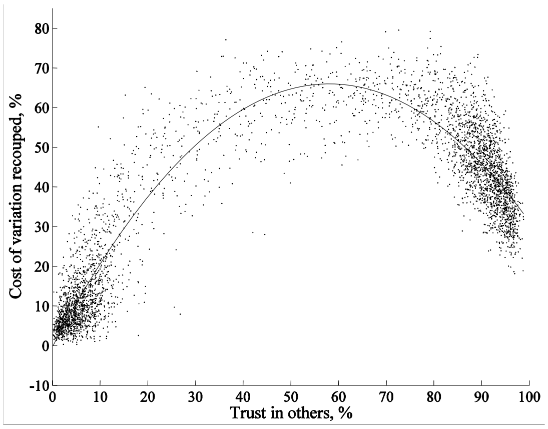


Figure 1. Relationship between the trust placed in others and the percentage of the "cost of variation" recouped by agistment. The vertical axis shows the percentage of the cost of variation a pastoralist recovers through agistment. The horizontal axis shows how much trust, on average, an individuals trusts others in their network. Trust is measured as the mean trust placed in others at the end of the game, weighted by the total number of times an opponent is encountered.

1. INTRODUCTION

Reciprocal altruism is common in humans (Niamir-Fuller, 1998, Gurven, 2004), however, its evolution is paradoxical; theoretically the more one is trusted, the better the outcomes from one-shot prisoner's dilemmas, although for individuals the best outcomes are when trust is not reciprocated. Most real life games are not one-shot, but iterated where trust develops through past actions (Cárdenas and Ostrom, 2004). Furthermore, in social-ecological systems outcomes are driven by biophysical context. In rangelands, our focus, low levels of biophysical variation limit the returns from trusting others and vice versa (McAllister et al., in press). Regardless of context, individuals who are too trusting always loose out.

We explore trust and cooperation using agistment of livestock in Australian rangelands as an example, which is a human response to variation in rangeland resources in time and space. Agistment interactions are essentially iterated interactions, where livestock is transferred between pastoral enterprises in a commercial arrangement. The interaction occurs between a pastoralist with a shortage of forage (whether induced by rainfall deficiencies or management practices) and another who have an excess. Agistment may facilitate stock movements between pastoralists when it is not possible to maintain an economically viable herd in the long-term on a single management unit and where attempts to do so can lead to the loss of income or capital (livestock or landscape function) (Goodhue and McCarthy, 2000). Pastoralists will note that agistment is about people because it is the human relationships which facilitate agistment which either make it fails or succeed.

Human responses to spatio-temporal rangeland variation are well documented in the African context (Perevolotsky, 1987, Scoones, 1992, Thébaud, 2001), but much less is known about such institutions in more formally governed societies like Australia (McAllister et al., in press; Janssen et al., in press). To gain further understanding of agistment we conducted semi-structured interviews with 14 pastoralists in the cattle-grazing dominated rangelands of north-eastern Australia (Dalrymple Shire, see Stokes et al., in press, for descriptive account). Interviews took place during 26-29 July 2004 and typically lasted between 1 and 2 hours, and we used the information collected through these surveys to guide our hypothesis development.

Anecdotally, it now appears that agistment is common practice in Australian rangelands. However the development of agistment has only occurred in its present form at least since the 1960s when transport technology and road network development allowed cheaper and more efficient movement of stock over long distances. Also at this time land-use intensified, largely due to technological advances such as additional water points and cattle breed. Such advances reduced the systems' natural drought buffering capacity (Walker et al., 1987) which increased the impact of climatic variation.

To further our understanding of agistment, 14 semi-structured interviews with north Queensland pastoralists (26-29 July 2004, Dalrymple Shire.) We found that agistment is driven by multiple objectives, including buffering of biophysical variation, strategic behaviour and even social conscience. Within our sample, drought mitigation (69%) and strategic stock building to stock future planned land purchases (31%) were the two most discussed drivers for agisting cattle (with 23% discussing both). For accepting agisted cattle, strategic land acquisition with future cattle purchases to follow (31%) was the most common driver. Taking advantage of unexpected or patchy rainfall (23%) and strategic designation of land to generate agistment fee cash-flows (15%) were also drivers for accepting agistment cattle. We found a paradox in the distance over which cattle are agisted. While distance represents a major financial cost of agistment, pastoralists spoke of the need to travel 200 km in order to take advantage of landscape and climatic heterogeneity. On average agisted stock travelled along 375km of road or 270km in a straight line. The greatest distance travelled was recalled to be 1,200 km by road. We also found that most agistment agreements were rather informal, and that trust and reputation are central. Despite this reliance on trust, and despite pastoralist being reluctance to give details on dishonoured trust, we found ample evidence that dishonoured trust was not uncommon. Pastoralists used a range of indicators in selecting agistment counterparts; two common themes were reputation and indicators such as the condition of land and livestock on the landowner properties. Even though climatic variation and its interaction with pastoral land and stock underpin agistment activity, pastoralists will point out that agistment is about people. Most pastoralists relied predominantly on hand-shake or verbal agreements (46%). Many also relied predominantly on a written but not legally binding agreement (31%) but few relied predominately on a legally binding agreement (8%).

We hypothesise that in natural resource management, where mutual cooperation is required to help buffer the variation in rangeland resources, that even though increasing the level of cooperative behaviour improves outcomes, individuals in the system can lose out if they trust too much. To study this we employ game theory, where pastoral agents play games in a landscape that shows characteristics of resource variation in rangelands.

2. METHODS

This paper uses a model published by McAllister et al. (in press) to explore and develop theory. We summarise the model here, but refer to McAllister et al. (in press) for detail.

The core aspect of the model of agistment activity is the strategic behaviour of pastoralists, where the opportunity for pastoralists to interact is determined by a highly variable biophysical landscape. Game theory models are used to explore strategic behaviour, particularly where social facets are important (for a review see Gotts et al., 2003). In our problem, agistment involves the interaction between two pastoralists; when pastoralists interact they "play" a prisoner's dilemma game. We know that cooperation between selfish individuals can evolve when players repeat a game (Axelrod, 1984). When interactions are only one shot, there is no strategic reason for an egoist to cooperate. However, experiments show that people do cooperate to a certain degree in one-shot social dilemmas (Frank et al., 1993). This may happen when a reliable reputation score of an opponent (Wedekind and Milinski, 2000), or other pieces of information are available, perhaps based on prior face-to-face communication. Our model explains cooperation between strangers based on the ability of players to learn who to trust (based on Janssen, in press). Players learn to recognise trustworthiness using symbols which we represent as a sequence of zeros and ones. (see McAllister et al., in press, Ahn et al., 2004) Our field interviews indicated that in agistment interactions, pastoralists look for symbols such land and livestock condition, infrastructure development, and management approaches as indicators how trustworthy an opponent may be in terms of adhering to agistment obligations.

The model consists of a population of 400 players. Players wishing to supply land for agistment interact with players who demand land. When players interact, individuals have three possible actions to choose from: cooperate (C), defect (D), or withdraw (W). The payoffs from agistment depend not only on what action a pastoralists takes, but also what action the pastoralist's "opponent" takes. If both players cooperate, they each get a payoff of R (reward for cooperation). If both players defect, they each get a payoff of P (punishment for defecting). If player A defects and B cooperates, A gets a payoff of T (temptation to defect), and B gets S (sucker's payoff). If at least one of the players withdraws from the game, both players get a payoff of E (exit payoff). An attractive feature about our application is that the actions have direct interpretation in terms of agistment. When a player supplying land defects, stock may go missing through theft or as a result of poorly maintained fences. Stock may also lose condition because supplementary feed is not managed as agreed. When the owner of the stock defects, they may agist stock poorly bred for temperament, damaging infrastructure on the land owners property. It is also possible that, with few legally binding contracts (pers. observation, see above), payment expectations (timing or amount) may not be met. The most important cost of agistment, however, is the opportunity cost of not agisting. If you are in a position to supply land, then the opportunity cost is that of lost revenue from not agisting. If pastoralists seeking agistment land fail to agist stock, then the opportunity cost is that of overstocking; leading to mortality, loss of stock condition and increases in supplementary feeding costs. Our interpretation of how the payoff matrix relates to agistment is that biophysical variation incurs a cost to pastoralists of R, and that agistment activity allows pastoralists to (to varying degrees) recoup those losses, but in some cases agistment may incur costs in addition to the cost incurred with biophysical variation. The pay-off matrix for the game in this article is defined using T = 2, R = 1, E = 0, P = -1, and S = -2 (see Janssen, 2006.

The probability of a player not withdrawing from the game and thereafter co-operating with an opponent is based on the likelihood of trusting the opponent (see McAllister et al., in press). If both parties agree not to withdraw from the interaction, each player chooses either to cooperate or defect in order to maximise their expected returns from the game, but their objective functions are biased by an individual's aversion to exploiting others and an individual's degree of altruism (i.e. behavioural preferences.)

We assume, in line with experimental evidence (Ahn et al., 2003), that there is a difference between material payoffs and the experienced utility of the monetary payoffs. The rational choice made by the players in maximizing the expected utility is based on the expected utility for cooperating and defecting.

Given the two estimates of expected utility, the player is confronted with a discrete choice problem which is addressed as a stochastic decision process. Players learn who to trust by learning to recognize symbols. Weights applied to the symbols estimate trustworthiness. If an agistment game is played, each player receives feedback on the experience. The weights of symbols associated with positive experiences increase, while the weights of those associated with negative experiences decrease, reducing discrepancies between the amount of trust placed in an opponent and that opponent's trustworthiness.

The key to representing our agistment problem is splitting the population of players into groups representing pastoralists who, in a given time period, either demand agistment land, are in a position to supply land for agistment, or neither supply or demand land for agistment. Splitting players into those not active in the agistment market, and those supplying and demanding land respectively is achieved using a simple model of a rangeland with patchy distribution of rainfall (hence it is assumed patchy forge distribution). The basic design of the rangeland model is that in each period, the systems dries uniformly across the landscape but hydrates non-uniformly through patchy rainfall. It is this patchiness which creates demand for agistment (dry properties seek to agist their stock on wetter proprieties. Unlike the McAllister et al. (in press) here we use analyse only one case of variation.

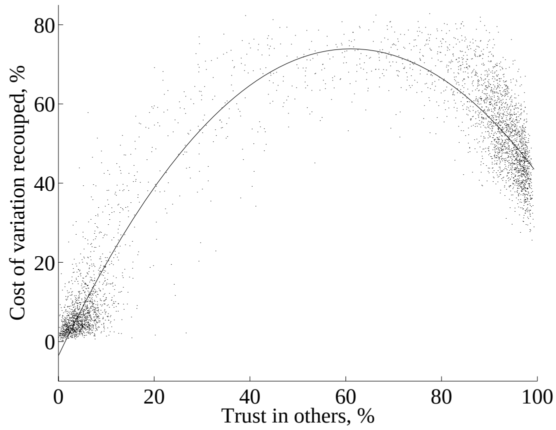
TABLE 1. List of parameters and their default values.

Parameter	Value
Number of players n	400
Number of symbols s	100
Number of generations	20,000
Iterations of game	10
Cooperation parameter α_i	[0, 3]
Cooperation parameter	$[0,\alpha_i]$
Max conditional para. α_{MAX}	3.0
Learning rate λ	0.5
Steepness γ	1.0
Spatial variation para. v_S	160
Spatial co-var. para. v_C	3

Specific assumptions used in this paper are presented in Table 1. The demonstrative lines shown in figures are statistically derived using a 2nd degree polynomial in Figure 1, and a cumulative gamma distribution in Figure 2.

3. RESULTS

We found that generally, in agistment interactions, the relationship between how much trust an individuals build in others is not linearly related to how successful agistment is for that individual (Figure 1). Up to some point, individuals with increasing amounts of trust in others tend to achieve better outcomes from agistment. Past some point, individuals with increasing amounts of trust in others tend to achieve worse outcomes from agistment. Further, this "threshold" point appears to be different for different degrees of spatial variation.



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Two issues underlying this result. One, how much an individual's degree of cooperative behaviour impacts on how much cooperation that individual experiences. Two, an individual's degree of cooperative behaviour impacts on how frequently they are able to enter into an agistment arrangement when required.

An individual's degree of cooperative behaviour experienced is positively related to an individuals own degree of cooperation action taken (Figure 2.) An individual's degree of cooperative behaviour and how frequently they are not able to enter into an agistment arrangement when required is negative related (Figure 3).

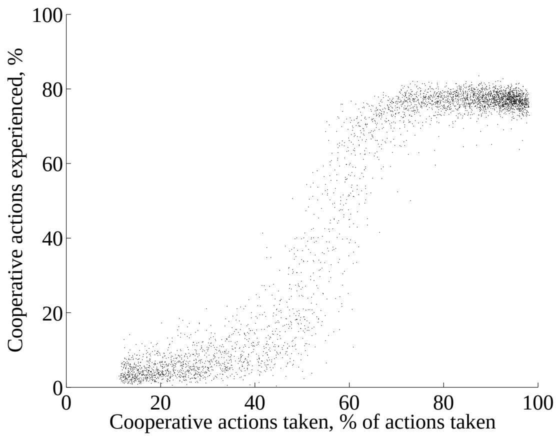

Figure 2. Relationship between the degree of cooperative action taken by an individual takes and the degree of cooperation that individual experiences. The degree of cooperation taken is measured as the ratio of the number of cooperative actions taken by an individual to the total number of actions taken by that individual. The degree of cooperation experienced is measured as the ratio of the total number of cooperative actions experienced by an individual to the total number of actions experienced (equal to the number of actions taken).

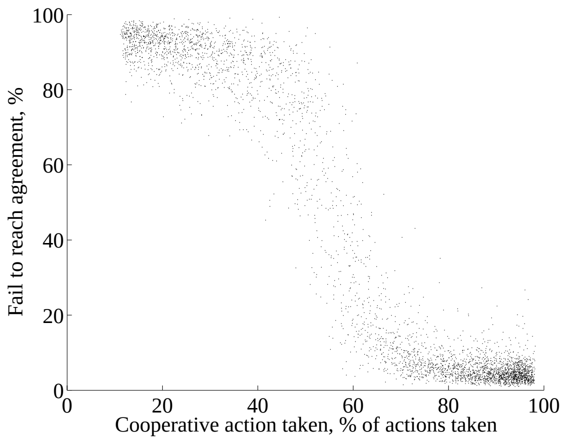

Figure 3. Relationship between the degree of cooperative action taken by an individual takes and the number of times an individual failed to enter into an agistment arrangement. The degree of cooperation taken is measured as the ratio of the number of cooperative actions taken by an individual to the total number of actions taken by that individual. An individual is deemed to have failed to reach an agreement when they were in the market for agistment (supply or demand) but did not have a single interaction where either player did not withdraw. In this figure, this is expressed as a percentage of the number of times and individual is in the agistment market.

4. DISCUSSION

In our model if all agistment interactions were mutually cooperative, then agistment would alleviate the total costs induced by variation. But "human" nature generally prohibits this outcome, even though, from an individual pastoralist perspective, being trusted has an economic value. The issue is that one can trust too much, and this constrains the opportunity to exploit variation. This result is consistent with expectations based on previous work on reciprocal altruism. For example, experimental games have shown that individuals tended to trust altruistic individuals more than they did non-altruistic individuals, and contribute more to others in their group when they expected to play a two-part trust game afterwards (Barclay, 2004).

If an individual always cooperates, other individuals will not necessarily reward this behaviour with cooperation. Likewise if an individual always defects, then other individuals will not necessarily punish unremitting defectors. When the ties between individuals are weak, there is little value in being trusted by others. Individuals build relationships, but the sum of individual relationships has important system-wide implications because a network can be formed that either stifles or encourages trust. In a system with few mutually cooperative agistment interactions, individuals tend to be less trusting of others, and this behaviour can be self-reinforcing. As a final point about spatial variation, because there are more people in the agistment market when spatial variation is high, an individual will have greater chance of finding a counterpart. The paradox of variation is that while, as a percentage, the cost of variation recouped increases as spatial variation increases, it is this variation that is the source of the cost in the first place. However, despite improved efficiency in the agistment network, overall costs always increase with variation (McAllister et al., in press).

The collection of trust network data collection is complex and expensive, and consequently we are faced with data limitations. These limitations have meant we have not tested our model with data, but the same limitations underpin its usefulness. In the face of data limitations our model uses theory to demonstrate how an individual's behaviour in agistment interactions is driven, in complex ways, by the behaviour in the system. While there is a tendency towards altruism in bi-lateral arrangements, the social institutions distort behaviour.

While our model is simple it allows us to consider possible implications for cooperative action in natural resource problems. Fostering a climate of trust is critical in cooperative action. However, from an individual's point of view, one can be worse off if too much trust is placed in others. Even though if the need arises, trust is generally likely to develop as part of a informal institution, non-cooperative action experienced by otherwise trusting individuals implies that the informal institutional may be insufficient and complementary formal polices may be effective in improving outcomes from cooperative actions in rangelands.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Ahn T.K., E. Ostrom, and J. Walker (2003), Incorporating motivational heterogeneity into game theoretic models of collective action, *Public Choice*, 117, 295-314.

Ahn T.-K., M.A. Janssen, and E. Ostrom (2004), Signals, symbols and human cooperation, in: (Eds.), Sussman, R.W. Chapman, A.R., *Origins and Nature of Sociality*, Aldine De Gruyter, New York.

Axelrod R. (1984), *The Evolution of Cooperation*. Basic Books, New York.

Barclay P. (2004), Trustworthiness and competitive altruism can also solve the "tragedy of the commons", *Evolution and Human Behavior*, 25, 209-220.

Cárdenas J.-C., and E. Ostrom (2004), What do people bring into the game: Experiments in the field about cooperation in the commons, *Agricultural Systems*, 82(3), 307-326.

Frank R.H., T. Gilovich, and D. Regan (1993), The evolution of one-shot cooperation: An experiment, *Ethology and Sociobiology*, 14, 247-256.

Goodhue R.E., and N. McCarthy (2000), Fuzzy access: Modeling grazing rights in sub-Saharan Africa, in: (Eds.), McCarthy, N., Swallow, B., Kirk, M., Hazell, P., *Property Rights, Risk, and Livestock Development in Africa*, International Livestock Research Institute, Nairobi., pp. 191-210.

Gotts N.M., J.G. Polhill, and A.N.R. Law (2003), Agent-Based Simulation In The Study Of Social Dilemmas, *Artificial Intelligence Review*, 19(1), 3-92.

Gurven M. (2004), Reciprocal altruism and food sharing decisions among Hiwi and Ache hunter-gatherers, *Behavioral Ecology and Sociobiology*, 56, 366-380.

Janssen M.A. (2006), Evolution of Cooperation in a One-Shot Prisoner's Dilemma Based on Recognition of Trustworthy and Untrustworthy Agents, *Journal of Economic Behavior and Organization*

Janssen M.A., Ö. Bodin, J.M. Anderies, T. Elmqvist, H. Ernstson, R.R.J. McAllister, P. Olsson, and P. Ryan (2006), A network perspective on the resilience of social-ecological systems, *Ecology and Society*

McAllister R.R.J., I.J. Gordon, M.A. Janssen, and N. Abel (2006), Pastoralists' responses to variation of rangeland resources in time and space, *Ecological Applications*, in press.

Niamir-Fuller M. (1998), The resilience of pastoral herding in Sahelian Africa, in: (Eds.), Berkes, F. Folke, C., *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*, Cambridge University Press, Cambridge, pp. 250-284.

Perevolotsky A. (1987), Territoriality and resource sharing among the Bedouin of southern Sinai: a socio-ecological interpretation, *Journal of Arid Environments*, 13, 153-161.

Scoones I. (1992), Coping with drought: responses of herders and livestock in contrasting savanna environments in southern Zimbabwe, *Human Ecology*, 20(3), 293-314.

Stokes C.J., R.R.J. McAllister, A.J. Ash, and J.E. Gross (2006), Changing patterns of land use and tenure in the Dalrymple Shire, Australia, in: (Eds.), Galvin, K.A., Reid, R., Behnke, R.H., Hobbs, N.T., *Fragmentation in Semi-Arid and Arid Landscapes: Consequences for Human and Natural Systems*, Kluwer.

Thébaud B. (2001), Sahel pastoralists: opportunism, struggle, conflict and negotiation. A case study from eastern Niger, *Global Environmental Change*, 1, 69-78.

Walker B.H., R.H. Emslie, R.N. Owen-Smith, and R.J. Scholes (1987), To cull or not to cull: lessons from a southern African drought, *Journal of Applied Ecology*, 24, 381-401.

Wedekind C., and M. Milinski (2000), Cooperation through image scoring in humans, *Science*, 288, 850-852.