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Social Networks and Environmentally Sustainable Land Management

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ACKNOWLEDGMENTS

The PUTTI project is a collaborative research initiative between the CSIRO and nominated NSW Catchment Management Authorities. The project is focussed on dryland farming and is funded by the Australian Government's former National Action Plan for Salinity and Water Quality/National Heritage Trust Program (NAP/NHT) and CSIRO

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EXECUTIVE SUMMARY

Natural Resource Management (NRM) in Australia has moved to a model of regional and local management where centralised control systems had previously been favoured. The regional model of NRM and participatory NRM in general, rely on the involvement, cooperation and collaboration of the catchment community, government organisations and key stakeholder groups. The collaborative co-management approach intrinsic to the regional NRM model relies heavily on the development and use of social capital. As "…connectedness, networks and groups" are identified as one of the four principle components of social capital (Pretty and Ward, 2001; p. 211), both formal and informal networks play an important role in this endeavour.

The Partnerships and Understanding Towards Targeted Implementation (PUTTI) project is a multifaceted research project, utilising qualitative methodologies, quantitative behavioural modelling, and network analysis to better understand the links between NRM and social processes influencing land management behaviours. The project consists of three stages; a behavioural modelling component examining the main factors influencing individual land management behaviours within two sub-catchments in the Central West area; a behavioural modelling component within sub-catchments in the Lachlan region, and; a final stage consisting of a monitoring and evaluation component with research investigating community requirements for change in both the Lachlan and Central West. The Social Network Analysis (SNA) outlined in this report was an additional activity introduced to provide further insight into the role of social structure and networks on the flow of farming information and the uptake of sustainable land management practices (SLMP) within the study region.

Data collection for the SNA commenced in the Central West catchment. Twenty four participants who had taken part in previous research were first asked about their sources of agriculturally related information. From here, a snowball sampling technique was used to identify further participants, with up to the first three agriculturally related information sources from the initial 24 cases followed up on. This process was repeated three times, with a resultant four rounds of interviews, and a total of 134 participants. Data gathered from participants was used to identify all links between the 134 participants relating to information seeking, and a behavioural questionnaire assessed each individual's level of SLMP. Analysis based on social influence models was performed to identify the importance of social structure on the adoption of SLMP. Previous research indicates that the development of social capital is a key component of collaborative NRM and can influence the uptake of sustainable practices. Given social capital is reliant, in part, on social networks and in particular, connectedness (see Glossary), it was hypothesised that increased levels of connectedness between people where at least one member of each tie had SLMP would be related to the implementation of more SLMP among those they were connected to.

The results of the network analysis indicated that the only significant predictor of SLMP relating to information networks was the number of properties owned. Specifically, those people connected to owners of multiple properties were significantly more likely to undertake more SLMP, but owning multiple properties itself, did not lead to more SLMP directly. However, a number of factors emerged as increasing the chance of less SLMP. Specifically, older farmers were more likely to have less sustainable practices, as were people connected to older farmers. Being isolated from others, that is, having few sources of information also significantly increased the chance of less sustainable practice.

The results from this exploratory study indicate that fostering increased connectedness within agricultural communities is not likely to significantly increase the adoption of SLMP. However, with reduced connectedness the likelihood of *un*sustainable practice is significantly increased. Therefore, increasing connectedness – for example, by encouraging the formation of information sharing, or social groups - may be an effective mechanism to break cycles of unsustainable behaviour. The importance of multiple property owners and age suggest that diversity of information sources might play a role in reducing the incidence of less SLMP. Again, while diversifying people's sources of information across age groups and property numbers may not increase the adoption of SLMP, it could reduce less sustainable management. These results are interesting and suggest the need for further research to investigate the importance of connectedness in the adoption of more SLMP.

This report is one of a series that provides details of findings from the PUTTI research. In addition to the reports on the first and second phases of the project (Porter et al 2007; Bates et al. 2008) the following research reports including the current one, are available:

1. Leviston, Z., Price, J., Tucker, D., Bishop, B., Bates, L. E., & Nicol, S., (2009) Partnerships and Understanding Towards Targeted Implementation – PUTTI: Attitudinal modelling and monitoring of factors influencing land management practice in the Central West and Lachlan Catchments. CSIRO: Water for a Healthy Country National Research Flagship.

2. Green, M. J., Dzidic, P.L., Tucker, D.I., Nicol, S.C., Bates, L.E., Bishop, B.J., Leviston, Z. & Price, J., (2009). Partnerships and Understanding Towards Targeted Implementation – PUTTI: Landscapes and Livelihoods: Community requirements for sustainable change. CSIRO: Water for a Healthy Country National Research Flagship.

3. Tucker, D. I. Lusher, D., Green, M. J., Dzidic, P. L., Bates, L. E., Leviston, Z., Robins, G., & Pattison, P. (2009). Partnerships and Understanding Towards Targeted Implementation - PUTTI: Social networks and environmentally sustainable land management. CSIRO: Water for a Healthy Country National Research Flagship (this report)

4. Bates, L. E., Leviston, Z., Green, M. J., Tucker, D. I., Price, J., Dzidic, P.L. & Nicol, S. C. (2009) Partnerships and Understanding Towards Targeted Implementation – PUTTI: Final report - Conditions underpinning the voluntary adoption of sustainable land management practice. CSIRO: Water for a Healthy Country National Research Flagship.

1. INTRODUCTION

1.1. Overview of Natural Resource Management in Australia

Since the 1990's Natural Resource Management (NRM) in Australia began moving away from a traditional focus on centralised control, to management systems based more regionally and locally. For example, the establishment of the National Landcare Program, National Heritage Trust in 1997 (NHT), NHT2 (second generation NHT) and more recently the National Action Plan for Salinity and Water Quality (NAP; extending until 2007-08) supported the devolution of responsibility for NRM to regional levels. The aim of these policies was to foster a sense of shared responsibility in addressing environmental issues, involving farmers and other community members. Catchment Management Authorities (CMAs) represent the operationalisation of the NRM program in NSW (see Robins and Dovers, 2007, for the equivalent NRM bodies established in other states and territories of Australia).

In NSW, Catchment Action Plans (CAPs) are the principle mechanisms to achieve catchment level targets related to biodiversity, native vegetation, water and aquatic systems, land management, people and the community. The NSW Natural Resources Commission states that

> "…a key part of the CMAs' role is to engage with their communities, gain their trust, build their ownership of the regional CAP and targets and then 'help them to help themselves' by voluntarily adopting sound NRM practices and acting as stewards of the natural resource assets on their land."
> (Natural Resources Commission 2008, p. 3)

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1.2. The importance of informal social processes and collaborative management in NRM

The concepts of partnerships, collaborative management (or co-management), collaborative governance, adaptive co-management, social capital, social learning and social networks, are closely inter-related in participatory NRM (Pero, 2005; Pahl-Wostl, 2002: Pahl-Wostl and Hare, 2004; Lockie, 2006). The processes are particularly relevant with the regional model of NRM being promoted in rural Australia.

Collaborative management is "a situation in which one or more social actors (see Glossary) negotiate, define and guarantee amongst themselves a fair sharing of the management functions, entitlements and responsibilities for a given territory, area or set of natural resources" (Borrini-Feyerabend, Farvar, Nguinguiri & Ndangan, 2000, p1). The efficacy of collaborative management initiatives depends on both the resolution of power sharing arrangements between stakeholders (such as public agencies and private individuals or entities) as well as on the establishment of mechanisms to maintain collaborative governance arrangements. While formal processes are often utilised in establishing collaborative management arrangements, Carlsson and Berkes (2005) caution against a focus on formal aspects suggesting that co-management should be understood as "…an approach to governance, and not merely as some kind of formalised power sharing arrangement." (Carlsson and Berkes, 2005, p66). In not overemphasising the formality of such collaborative structures, the role and prominence of informal networks within these structures can be acknowledged.

To a large extent, NRM in Australia follows an adaptive co-management paradigm, whereby multiple public and private stakeholders engage in collective management of natural resources. While the increased resources, knowledge and ownership that might be expected to come with adaptive co-management are attractive, there are practical and operational realities that need to be understood. For example, with multiple stakeholders and actors come multiple agendas, variation in knowledge and variability in motivation or capacity to respond to different and often changing circumstances.

The concept of social capital is common in research around community resilience. As Pretty and Ward (2001) succinctly state, the term social capital "…captures the idea that social bonds and social norms are an important part of the basis for sustainable livelihoods" (p. 210). Social capital facilitates cooperation between actors, reducing the costs of working together and increasing confidence to invest in collective action. Individuals are also less likely to engage in private actions that may lead to degradation of resources (Pretty and Ward). Pretty and Ward cite the four main components of social capital as; relations of trust; reciprocity and exchanges; common rules, norms and sanctions; and connectedness, networks and groups (Pretty and Ward, 2001, p211).

1.3. Social Networks and NRM

Concepts of social capital have increasingly been seen as important in facilitating the uptake of improved land management practices both in Australia and internationally (see for example, Svendsen and Svendsen, 2000; Alston, 2002; Woodhouse, 2006; Pahl-Wostl et al 2007). It is clear that social networks are also an important element in the successful collaborative management of natural resource management.

Social networks are a familiar concept in everyday life as people form relationships of various strengths and value with relatives, friends, colleagues and others over time. Social Network Analysis (SNA) is a way of examining these relationships to understand the structure, functionality and importance of the connections between people (agents) and organisations. In SNA, the patterns or regularities in the relationships among social entities whether they be individual people, groups or organisations are the focus of analysis. SNA provides a way of thinking about and describing the social environment through the provision of a set of well defined concepts encapsulated in structural variables that capture relational features among entities within a network.

The history of interest in social networks stretches over hundreds of years and has accelerated since the 1970's with advances in the analytical methodologies of graph theory and sociometry. Network theory has been applied in fields as diverse as politics, business, health, biology, economics, anthropology, psychology and sociology to name a few (see Wasserman and Faust, 1994). While social network data is often collected at an individual actor or agency level regarding each individual's relationships with the other actor in the network, the combination of these relationships creates a single network from which we can make inferences about emergent social structures of networks. SNA identifies the links between social entities (which can be individuals or collectives), referred to as ties (see Glossary) between actors. Formal networks (for example Landcare groups, the Kondinin Group) are utilised in an attempt to spread the uptake of desirable NRM practices, Additionally, informal networks (e.g. sporting clubs, church groups) are an important part of rural communities. SNA is an appropriate method for examining these relationships. As Knoke and Kuklinski (1982) noted "the structure of relations among actors and the location of individual actors in the network have important behavioural, perceptual and attitudinal consequences both for the individual units and for the system as a whole" (p13).

Importantly, SNA is specifically adept at exploring and understanding the structural properties of informal social networks, which evolve from the bottom-up rather than being imposed from the top-down (as is the case with formal structures). Attention on the role of either formal or informal social networks in NRM, has only been a focus of research since 2000. In an analysis of twenty case studies in Europe, Assouline, Bernaud, David and Roque (2000) as well as Oerlemans and Assouline (2004), highlighted the importance of concentrating on management aspects of groups involved in networking activities. They identified a series of barriers farmer networks encounter, including insufficient effort expended on ensuring that farmers develop shared perceptions and goals; limited capacity for self management; and a need for mechanisms to facilitate collective learning. Furthermore, research by Kallstrom and Ljung (2005) points to the need for agencies to assume a supportive role for relationships and networks among farmers to facilitate collaborative learning.

Murdoch (2000) proposed the potential utility of considering rural development in network terms, where the provision of services including skills, training and other initiatives from agencies like catchment management authorities could be managed through the development of networks. Building on his earlier research and that of Campbell (1994) calling for the need to build networks at multiple scales to support co-ordinated action and learning among farmers, Lockie assessed the significance of network analysis and two related approaches, actor network theory (see Callon and Law, 1995) and the network society thesis (see Castells, 2000) in explaining the impact of networks on the adoption of improved land management practices, with particular reference to the Landcare movement. He found that networks were important with a slight association between membership of formal and informal agri-environmental groups and the implementation of more sustainable practices (Lockie, 2006).

1.4. The PUTTI project, social networks and sustainable natural resource management

The PUTTI project comprises qualitative and quantitative studies of land management behaviours, as depicted in Figure 1. The analysis of social networks provides further insight into the importance of networks and structural properties such as connectedness, on SLMP behaviour. In line with Pretty and Ward's (2001) concept of social capital, it is hypothesised that increased connectedness between farmers, agribusinesses and other NRM related professionals will lead to increases in adoption of sustainable practices. Sustainability of land management practices is evaluated and social influence networks are analysed to assess whether they significantly impact management practices. Further exploratory analysis is conducted to identify if other network structures or demographic factors are impacting on the adoption of sustainable practice.

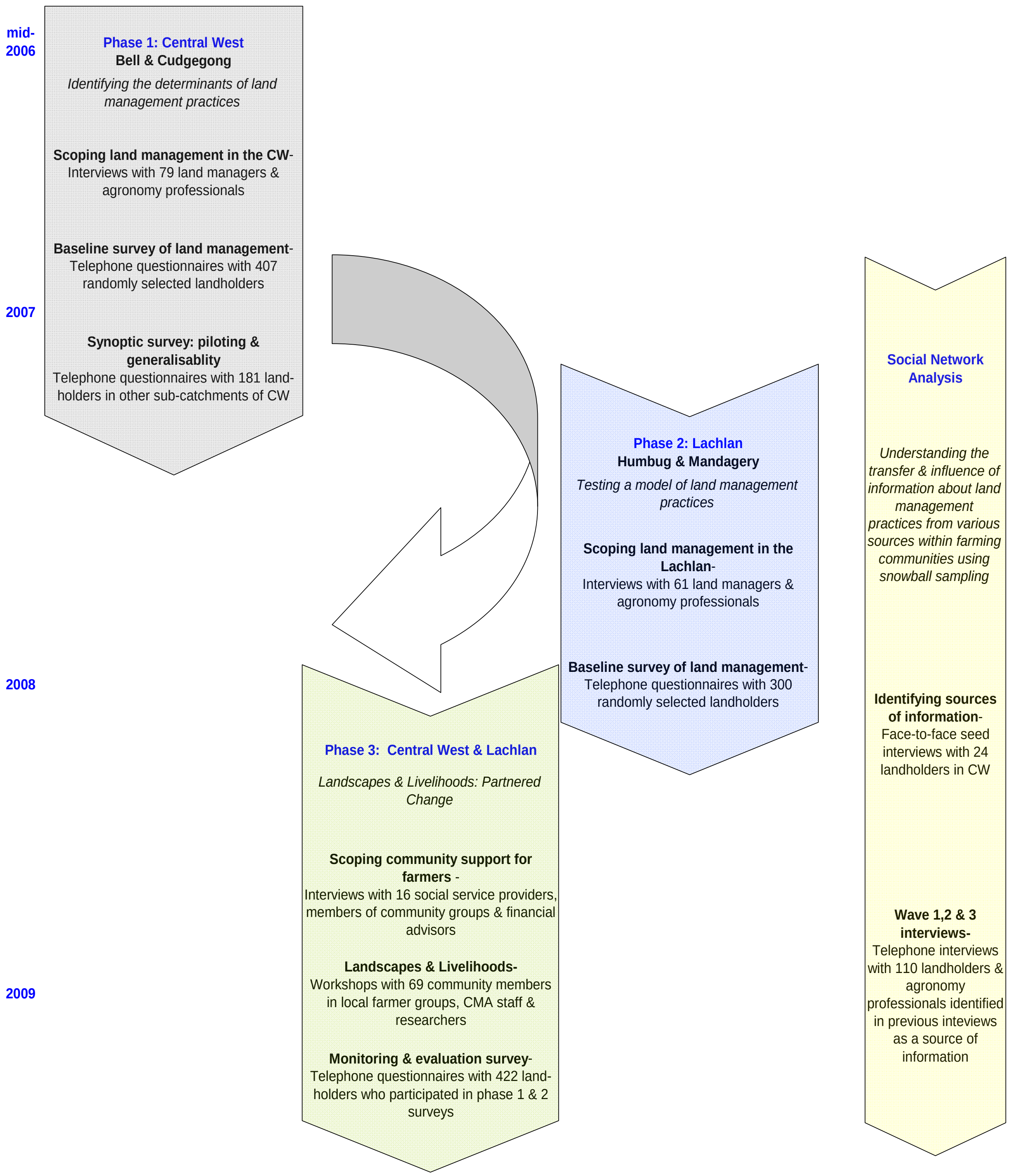

Figure 1 Components and timeline of the PUTTI project

2. METHODOLOGY

2.1. Overview

Social network analysis requires the collection of detailed data relating to individuals connections to others. The type of connections depends on the analysis being conducted. In this instance, the primary goal was to attain data relating to peoples information networks, specifically, who landholders and agri-business professionals approach for information relating to farm management. In addition, the research was exploratory to determine if and how social networks impact on land management practice. Along with information networks, data was collected about decision making networks, discussion networks and family networks, discussed in more detail below.

The principle method of data collection was through semi-structured interviews, with initial seed case interviews conducted face to face, in order to better assess the appropriateness of the data collection methods. Subsequent interviews were conducted via telephone.

Ideally in social network analysis, a network is studied in its entirety, to avoid the potential confounds of missing data. It would therefore be ideal in this instance to have spoken to all dryland agriculturalists in connection with one another, both within and outside of our study region. Pragmatically this was not possible, due to resource constraints, and also due to difficulties in identifying all possible members of the network. A snowball sampling technique was therefore utilised, whereby a number of ‘seed’ cases were selected, and a predetermined number of their referrals were contacted, with the process repeated in succession a specified number of times. (Daraganova, 2009).

There are principally two forms of social network modelling. These are *social selection* models, and *social influence models.* Very simply, social selection models attempt to predict the presence of a connection between actors, based on known attributes, whereas in social influence models, the ties between actors are already known, and the process attempts to predict the presence of a dependant variable. In the case of the present research, social influence models were used, as the aim was to understand the influences of social ties within the agricultural community in the study area and on behaviour (SLMP). For an in depth presentation of social influence and social selection statistical models see Robins, Pattison and Elliot (2001) and Robins, Elliot and Pattison (2001), respectively.

2.2. Participant Selection

Twenty four initial seed cases were selected from 407 landholders who participated in the PUTTI Behavioural Survey in phase one of the project which considered land management practices. Participants were selected from the Bell and the Cudgegong sub catchments of the Central West. Selection criteria were based on participants’ behavioural scores from the Behavioural Survey, with specific attention to participants were scored at the two extremes of the behavioural measure i.e. those whose land management behaviour was assessed as more sustainable and those whose land management behaviour was less sustainable at that time. This ensured a range of behaviours for which to assess the impact of social networks. All of the participants in wave 0 (the first wave) were either landholders or land managers engaged in dryland farming (see Figure 2).

The snowball sampling technique requires network boundaries to be defined. In conjunction with research collaborators at Melbourne University, it was decided that for each participant, the first three information sources specific to agricultural practice would be contacted to form each wave of interviews (Daraganova, 2009). A total of three interview waves were conducted in addition to the initial seed cases. Not all participants provided three referrals who were engaged in agricultural practice. Figure 2 summarises the snowballing approach.

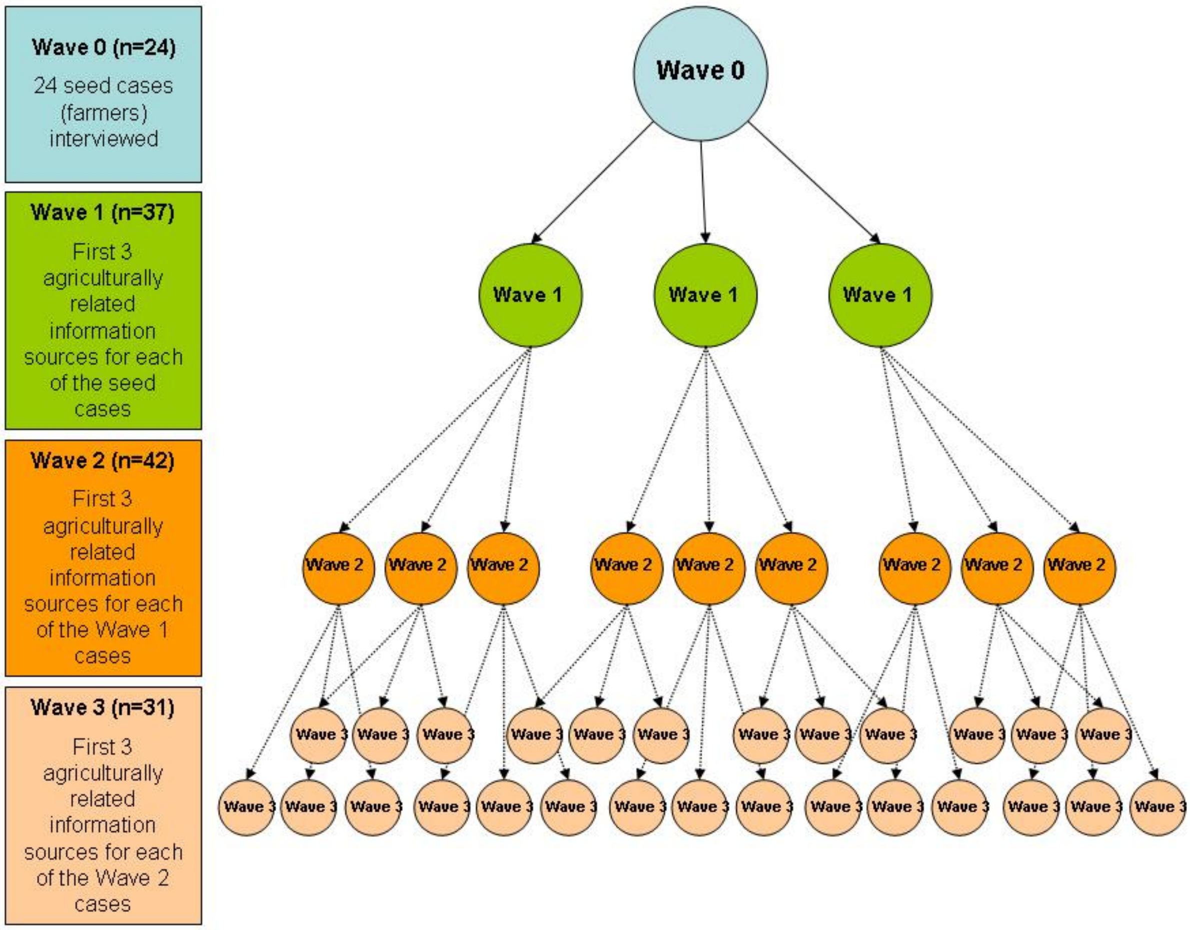

Figure 2 Schematic of the snowball sampling technique, including actual number of participants in each wave

Participants in waves one through three were not constrained by location. This meant that participants from these waves could come from anywhere in Australia or internationally.

2.3. Questionnaire development and implementation

2.3.1. Overview

Given that not all participants in the SNA had taken part in previous research, two questionnaires were designed to elicit information comparable with previous behavioural data collected. Two questionnaires were designed for this purpose. The first, entitled the *Network Questionnaire,* aimed to identify connections to others within the network. This questionnaire principally asked participants to identify who they approached for agricultural information, who they discussed management and decision making on their property with, and who they consulted when making final decisions on the property. The second questionnaire, entitled the *Behavioural Questionnaire* was used to garner information to measure environmental SLMP (the dependant variable of the statistical network models). To this end, the questionnaire contained items around various land management practices consistent with the behavioural survey utilised in other components of the PUTTI research. Landholders and agribusiness professionals were presented with slightly different questionnaires, as detailed below.

2.3.2. Network Questionnaire

Table 1 summarises the items included in the Network Questionnaire. In addition to covering sources of information, discussion and decision making, farmers were also asked to identify family in the area, and to provide basic demographic information. Subsequent to initial seed case interviews, the questionnaire was adapted slightly. The most prominent change included the removal of social tie items. Initially, participants were asked to nominate those in the community who they interacted with on a social basis. These questions were met with some resistance, with many participants feeling uncomfortable about providing this information. Questions within the network questionnaire were slightly different for farmers and non-farmers (see Table 1 for differentiation). The topic of the questions were the same for both groups (e.g. sources of information) however for farmers they related to practices they used on their farm, whereas for agribusiness professionals they related to where they gained information that informed their professional practice.

Table 1. Network Questionnaire Items

Topic	Items: Farmers	Items: Non-farmers (Agriculturally related professionals)	Description
Information sources	*"Where do you go or who do you talk to for information about what you do on your farm?"*	*"Who do you talk to, or where do you go for information relating to your profession and agriculture?"*	Participants prompted to name a person but all forms of information were accepted (e.g books, internet etc). Detail on that information source provided referrals for use in the snowball sample. For example: if a person was referred to as a source of information then the respondent would be asked to give their name, address, gender, age, occupation, type of information, topic area and the value of that information rated on a scale of 1 - 5. For other information sources as much detail as possible was gathered on the above points.
Individuals involved in discussions	*"If you are going to make a big decision on the farm, who do you discuss this with before deciding what to do?"*	*"Who do you discuss this information with to make sure you are giving the best advice?"*	Participants were prompted to name a person, which could be the same as mentioned previously. The person's group (eg CMA, scientist etc) and the importance of that person in discussing the information (on a scale of 1 -5) was asked.
Individuals involved in decision making	*"After discussing the information, who makes the final decision about what will be done on the farm?"*		Participants were prompted to give the name of the person and their relationship to the respondent.
Family	*"What family do you have on the farm and/or in the area or catchment?"*		Participants were asked to give names of family members, their relationship to the respondent and to note whether they live or work on the farm.
Demographics			Participants were asked to provide their name, address, occupation, age and gender.

2.3.3. Behavioural Questionnaire

The Behavioural Questionnaire contained items relating to five main areas of land management. A score determined through the aggregation of the five sub-components was used as a measure of SLMP in subsequent Social Network modelling. As indicated in Figure 1, baseline surveys were conducted in both the Central West and Lachlan study areas. The questionnaire was designed to be comparable to behavioural measures utilised in previous behavioural modelling endeavours conducted within the broader research program. This questionnaire was only administered to participants who had not previously participated in the Behavioural Survey, and hence seed cases were excluded. The questionnaire was administered via telephone.

The areas, or sub-components examined, were chosen in line with a number of criteria and assessment. This included alignment with Catchment Action Priorities (CAPs), results from qualitative interviews with landholders and workshops/discussions with catchment managers. The measure was used as the dependent variable in subsequent social network modelling. The five sub-components were:

- Soil testing
- Native vegetation management
- Perennial pasture management
- Weed control
- Stock management

Two behavioural questionnaires were constructed specifically for the SNA, one for landholders asking about current behaviours, and one for other professionals involved in agricultural practice (e.g. agronomists, agribusinesses). The intention of these questionnaires was to understand current land management practices (for farmers), and to gauge opinions about these practices (for agribusiness participants). The questionnaires contained the same items, differing only in framing. For example, where farmers were asked, *what weed control techniques do you use?* Participants who were agribusiness professionals were asked *what are the most appropriate weed control methods for farmers to use?* Table 2 outlines the questions in the behavioural questionnaire, used to calculate each of the sub-component scores used to create a SLMP score for each participant.

Table 2. Behavioural Questionnaire Items

Subscale	Questions from the behavioural survey
Soil Testing	Do you have regular soil testing done on your property?
	How often do you test your soil?
	What do you test for?
Perennial Pasture Management	What perennials do you have planted?
	Why do you have it?
Native Vegetation Management	Is native vegetation management part of your property planning?
	What proportion of your property is currently under native vegetation?
Weed Management	What weed control techniques do you use?
Stock Management	Have you reduced stocking rates?
	Have you erected fences to exclude stock from revegetation areas?

2.3.4. Data management and analysis

A final behavioural score was calculated for each respondent using the above questions. The score was continuous ranging from a possible 0 through to 10. Statistical analysis necessitated the use of a binary dependent variable. To this end, the sample was split into three even groups. The top third were considered sustainable land managers, the bottom third less sustainable land managers with the middle non-classified. Splitting the sample in this way ensured that those near the middle of the sample in reference to behaviour were not inappropriately labelled. Two models were run on this data, the first modelled sustainable behaviour, comparing the top third of participants with all others, while the second modelled sustainable behaviour comparing the bottom third with all others.

Assessment of responses to the individual land management questions was undertaken utilising expertise within the Lachlan CMA. A workshop was held with a number of staff from the Lachlan Catchment Management Authority (LCMA) in March of 2008. This, in conjunction with ongoing assistance and communication allowed for confidence in the validity of the land management score.

2.3.5. Interview protocol

Twenty three of the 24 seed case interviews were conducted in person at the participant's property. Two members of the project team were present at all interviews, with one person facilitating the interview and the other acting as interview scribe. The final seed case and all other subsequent interviews were conducted over the telephone by a trained field interviewer. Telephone interviews were decided on as the best method for Waves 1-3 as the network was not spatially bounded (that is, referrals were not restricted to living or working in a specific area). Referrals were classified as no-contact after 10 calling attempts across different days and times. If this occurred the next referral on the participants list was contacted. Interviews took between 30 minutes to an hour to complete.

2.3.6. Participant details

One hundred and thirty-eight farmers and agribusiness representatives took part in the social network study. Of these, 134 were used in analysis. Insufficient data was obtained from four participants so they were subsequently excluded. Table 3 shows the breakdown of participants in each wave, according to classification as farmers or agribusiness. In some cases, referrals were considered to fit both farmer and agribusiness categories. In these instances participants were interviewed in accordance with their referral category. For example, if an individual was given as a source of information, and referred to as an agribusiness representative, then they were interviewed as an agribusiness professional despite also being a landholder.

Table 3. Social network participants from each wave of interview

Wave	Farmers	Agribusiness professionals	Total
0 (seed)	24	0	24
1	19	18	37
2	7	35	42
3	1	30	31
Total	51	83	134

While all 24 seed cases were located in the Central West catchment, referrals were not constrained by location. The majority of participants were from NSW (94.8%); however, there was one participant from each of Victoria, Western Australia, South Australia and Queensland, and three from the ACT.

3. RESULTS

3.1. Summary of participant demographics

Full information on demographics is provided in Appendix A. The following represents a summary of key features. It is important to note that the sample was not intended to be representative of the general, or farming community. It was intended only to represent those people who are sought out to provide information about land management practices.

The majority of participants were males aged between 45 and 64. Furthermore 83.7% of participants overall were male. Nearly two thirds of the participants (62.2%) reported having no other family in the region. The most common occupation was farmer (31.3%) and agronomist (17.9%).

Of the 135 participants, 55 were identified as belonging to a particular organisation or group. The most common affiliation was the Department of Primary Industries (DPI) followed by a Catchment Management Authority.

3.2. Details of information sources

Participants were asked to provide details about their information sources such as people, organisations and literature. It was not possible to follow up all categories of information source, with some participants citing groups or organisations rather than individuals. It was also possible for multiple respondents to refer to the same information source. Further detail on information referrals are provided in Appendix B.

Most sources of information were within the Central West Catchment (56.1%). Many information sources that were outside of the catchment were still within the state of NSW (31.1%), with few interstate or overseas information sources cited (12.5% and 0.3% respectively).

Most informants either worked (agribusiness professionals) or lived (farmers) in Orange or Mudgee. Males were more frequently asked for information than females (85.5% and 14.5% respectively). Most informants were over the age of 45 (70.6%), with almost a quarter aged between 35 and 44 (22.5%).

Over 35 informant occupations were given, the most common being scientist/ researcher, followed by agronomist and then farmer. Most people sourced information from people working in government organisations (for example the Department of Planning and Infrastructure), other farmers or people working in an agribusiness (for example Elders).

Participants sought information on a total of 44 different topics, the most common being stock management, crop management and everyday farm management. Soil testing and pasture management were also highly cited

3.3. Details of discussion sources

Participants were asked to nominate who they discussed ideas with, either for deciding what to do on the farm (farmers) or regarding what information to give people (agribusiness related participants). The combined results showed that government departments (18.5%), family (17.6%) and agribusiness (16.7%) were the most common groups. Other commonly cited groups were other farmers (10.2%), agronomists (7.4%) and business/financial/legal (6.9%) groups. Full detail of discussion sources is provided in Appendix C.

Discussant groups for farmers and agribusiness participants were compared. While farmers discussed most commonly with family (41.8%), other farmers (16.5%) and business/financial/legal sources (15.4%), agribusiness were more likely to discuss with government (30.4%), other agribusiness (22.4%) and agronomists (12.0%).

3.4. Comparison between sources of information and those involved in discussions

While participants were asked about both information sources and discussion sources, only information networks were examined in the social network analysis. The figure below illustrates that, while sources of information and discussion were quite similar overall, there were some discrepancies. Most notably, as discussion partners, family were listed more frequently, as were Business/financial/legal sources. Science and research was mentioned more frequently for information sources (see Figure 3).

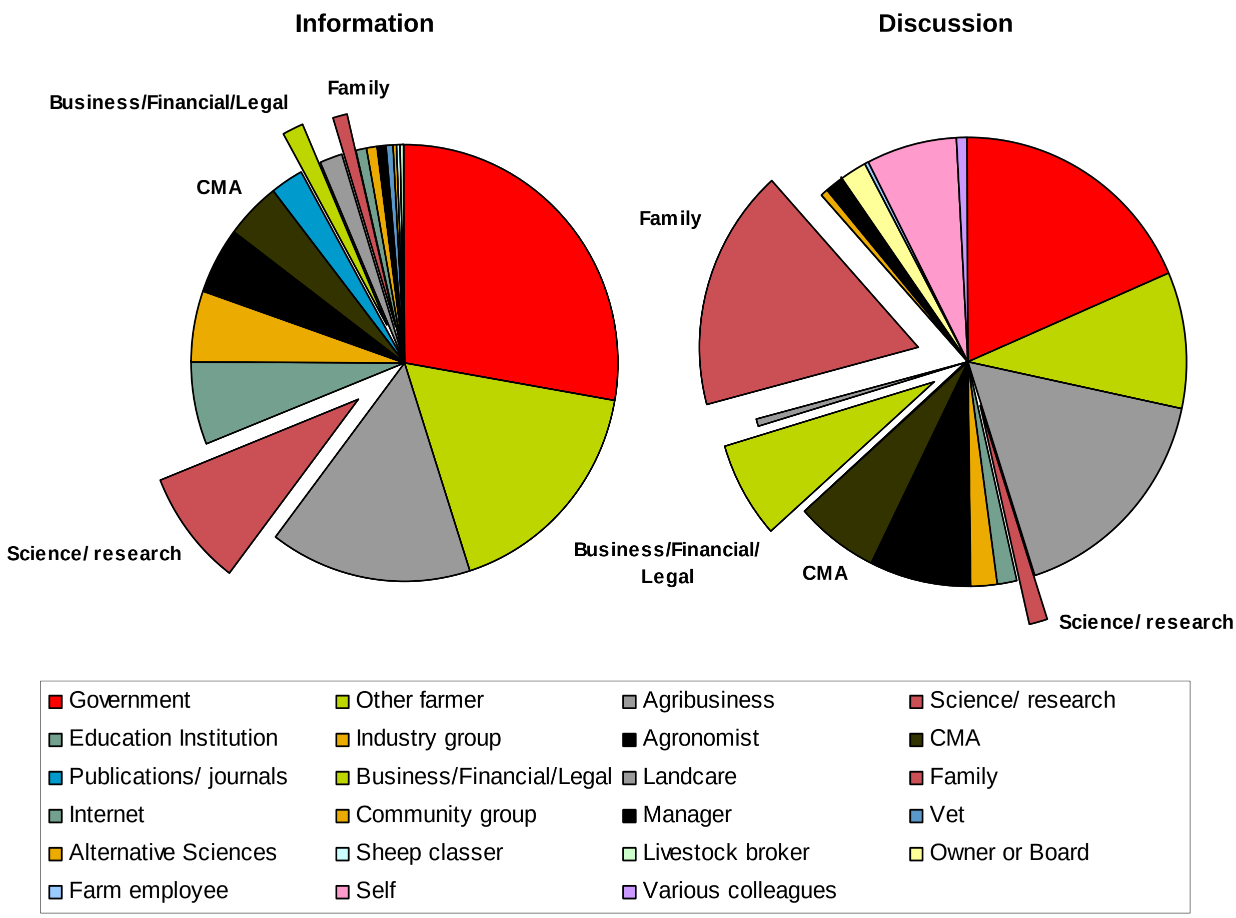

Figure 3 Similarities and discrepancies between sources of information and discussion partners

3.5. Decision making

The decision component of the network questionnaire was directed only towards farmers to identify who made the final decisions about what to do on the farm, after information had been sourced and discussed. Not all farmers interviewed provided an answer to this section.

Personal reflection i.e. no discussion with another person or family members was the most frequent response (69.6% and 54.3 % respectively) See Appendix D for further details.

3.6. Sustainable land management practices

This section provides information on the results of the behavioural questionnaire. Results for farmers and agribusiness participants are discussed separately. Full details of results are found in Appendix E.

3.6.1. Soil testing

Farmers and agribusiness participants agreed on all facets of soil testing. Farmers were asked whether they undertook regular soil testing (a simple yes/no item). Over half of the farmers (51.9%) undertook regular soil testing. Agribusiness participants were similarly asked if regular soil testing was an important part of land management, to which nearly all (94%) responded yes. Most farmers did at least part of this soil testing themselves (85.1%) and again nearly all agribusiness participants thought this was appropriate (98.7%). Soil testing was undertaken most commonly up to every 3 years (81.4%) and again most agribusiness participants agreed that this was appropriate (55.7%).

3.6.2. Native vegetation

Farmer and agribusiness participants agreed on the importance of native vegetation, with most farmer participants (73.1%) indicating vegetation management was part of their property planning, and 86.7% of agribusiness saying this was an important part of sustainable land management. The majority of farmers (56.8%) had less than 40% of their property under native vegetation and most agribusiness (65.31%) thought up to 20% of a property under native vegetation was appropriate.

3.6.3. Perennial pastures

The most common perennials planted by farmers were White Clover (47.9%), Phalaris (43.8%) and Lucerne (39.6%). Lucerne and Phalaris were also commonly cited as best to plant by agribusiness participants (77.6% and 55.3% respectively). When asked as to the rationale of planting perennials, most farmers stated it was for feed or pasture (58.3%), which was consistent with agribusiness (36.6%).

3.6.4. Weed control techniques

A large proportion of both farmers and agribusiness participants thought that a larger focus on weed management was appropriate (43.1% and 39.2% respectively). While most farmers thought that chemical sprays were the best form of weed control (49.0%), agribusiness participants thought grazing was most appropriate (57.1%). Grazing was however the second most utilised weed control by farmers (29.4%). Other methods employed by farmer participants were spot spraying and boom spraying (29.4% and 19.6% respectively). The most common responses by agribusiness other than grazing, included competing pastures (45.5% of participants), herbicides (44.2%) and chemical sprays (28.6%).

3.6.5. Stock Management

More than two thirds of farmers (69.2%) said that they had reduced stocking rates to ease the environmental impact of their stock and a similar number of agribusinesses thought that this was an important part of land management (79.3%). Farmers thought that erecting fences was important, with over half of farming participants erecting fences to keep stock from waterways (53.8%) or revegetation areas (65.4%). Agribusiness participants also thought that fencing was important, with almost all believing fences to keep stock from waterways (87.8%) or revegetation areas (90.2%) was important.

3.7. Analysis of Social Networks

3.7.1. A Cautionary Note on the Interpretation of Social Network Results

The social network data is not longitudinal, with data being collected at a specific time point during each wave. The existence of connections between individuals or groups is not evidence of a causal relationship, rather they can be thought of as associations. Additionally, the social network models we use are non-directed – that is, these models cannot, for example, differentiate whether Jack goes to Tom for information, or the reverse. Rather, we only know that information sharing goes on between Jack and Tom, but we cannot model the direction of that information[1]. As a result of this, multiple valid interpretations of the analytical outcomes are possible because we are not sure of the direction of the information flow in the network relation.

Importantly, in this study comparisons were made between (1) sustainable management and the remainder of cases, and (2) less sustainable management and the remainder of cases. Therefore, it is important to note that if a set of relationships in the network leads to a likelihood of SLMP, this *does not* imply that an individual for which that relationship does not hold is likely to have less sustainable land management behaviour. In other words, bad behaviour isn't just the opposite of good behaviour, or vice versa. For example, if having few connections is shown to lead to 'less sustainable' land management behaviour, this does not necessarily suggest that having many connections to others leads to sustainable land management behaviour, rather that it reduces the risk of less sustainable land management behaviour.

The following represents the authors' interpretations of how the results of the analysis might be explained. Those with different experiences may have alternate interpretations.

3.7.2. Interpreting Social Networks and Sociograms

Social Network Analyses focuses on the "*relationships* among social entities, and on the patterns and implications of these relationships" (Wasserman & Faust, 1994, p. 3).

In this research we have utilized the innovative research techniques of a particular class of statistical model for social networks (known as exponential random graph models, or ERGM – see Robins, Pattison, Kalish & Lusher, 2007 for an introduction). In ERGM, the network data is examined statistically– thereby allowing us to determine if social network structures (or network effects) occur at greater or less than would be expected by chance. By network effects, we refer to patterns in the ways that people interact. For instance, reciprocity (see Glossary) is a network effect, representing mutuality (i.e. you scratch my back, I'll scratch your back; see Glossary). A further network effect is the formation of triads (i.e. a friend of a friend is a friend).Through the analysis we can identify if these network effects (these ways of forming social ties) are present or absent from the social network we are investigating.

[1] This is a current limitation of these statistical social influence models. Future work on these models hopes to be able to model the direction of social network ties and move beyond this limitation.

Importantly, we also like to include network effects that relate to the personal qualities of individuals in the network. For instance, we investigate whether people with certain behaviours (e.g. sustainable soil testing behaviour) are connected to many other people in the network, or whether their connection to others in the network a result of some other personal characteristic.

As indicated previously, social influence modelling is used in this research, which predicts people's behaviours from their social network ties to others and also from their own individual characteristics. This approach allows us to compare a number of network effects, concurrently, and rule out competing explanations of behaviour. A range of possible explanations for behaviour are considered simultaneously, and principled inferences about which are the most important predictors of behaviour are made.

The results of the models produce a parameter estimate for each network effect included. There is for example, a parameter estimate for reciprocity, another for triadic formations (see Glossary), and another for whether being connected to for example males is important, and perhaps still another for whether being male predicts behaviour. This allows an understanding of which components of a network are important, as well as which individual-level characteristics, and whether they might significantly influence the dependent variable. Parameters that are more than twice the size of the standard error are considered to be statistically significant – that is, statistically they occur at greater than chance levels and have predictive capacity for our dependent variable (e.g. environmentally sustainable farming behaviours). The models are akin to logistic regression, with differences explained in Robins, G *et al* (2007). In summary, parameter estimation allows us to assess if certain structural or personal characteristics of the network members have occurred in the observed network at a greater rate than we would be expected by chance. In the results below, each of the significant network parameter estimates are explained. More detail of these network effects is included within the discussion and implications section of the report.

The network diagrams presented within the results allow for a visual representation of the observed network, including the ability to focus on different network components. Network diagrams are called sociograms (see Glossary). In each, the circles (which are farmers) and squares (which are agri-business people) are representative of participants, and connecting lines are indicative of a tie between participants. In this case, ties represent information seeking behaviour, and are non-directional, meaning that the presence of a tie between person A and person B could mean person A nominated person B or vice versa. Network diagrams are a useful analytic tool because they do provide considerable information. However, when inferences are required from network data, statistical models are required (for example, when predicting behaviours from networks).

3.8. Social networks and overall land management behaviour

The following social network analyses and models examine the impact of different variables on SLMP. While both farmers and agribusiness participants are included in this analysis, the dependent variable is the SLMP behaviour score of farmers. The connections between participants in the analysis refer to information seeking behaviour. A connection between two participants indicates that one of these people has approached the other for information related to agricultural practice.

3.8.1. Influence of networks on Sustainable Land Management

Statistical analysis indicated that SLMP could be explained in part by social structures with agricultural information connections between participants, explaining aspects of both sustainable and less sustainable land management practice. Full details of the statistical results are available in Appendix F.

SLMP's were more likely for farmers with connections to owners of multiple properties. Conversely, poor practices were more likely if participants had few connections to others, were older; or were connected to older people

Figure 4 illustrates the information network model. Farmers are represented by circles and agribusiness by squares, with higher overall scores (i.e. better land management practices) highlighted in red. The larger circles indicate a greater number of properties managed by the participant. It is clear here that the number of properties does not directly impact on SLMP scores, despite leading to better scores for those with connections to them. Note that the arrows between members are non-directed i.e. they do not signify that there are *reciprocal* links between people, simply that one of the pair referred to the other.

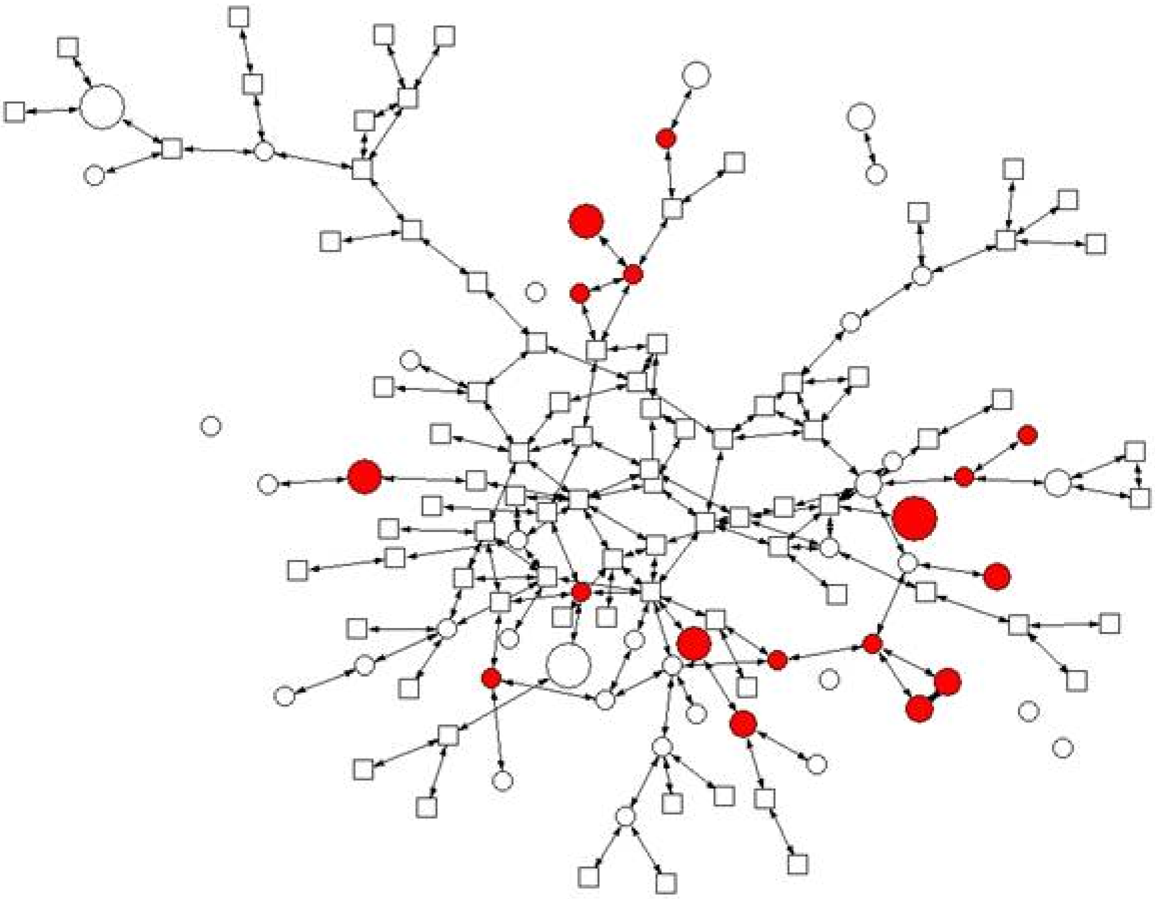

Figure 4 Information network of farmers (circles) and agribusiness (squares) with SLMP (red circles) and number of properties owned (indicated by size of a circle)

3.8.2. Sub-component behaviour models

In order to further explore the effects of social networks on behaviours, models were examined for each of the five sub-components (soil testing, native vegetation, weed management, perennial pastures and stock management) of the overall SLMP score. As with the overall behaviour, each of the 5 component scores were converted to binary form to be suitable as dependent variables in the modelling process. No significant effects were identified for perennial pasture management in this exploratory modelling process. Full details of the statistical results are available in Appendix F.

Soil Management

Participants who owned multiple properties and those who were connected to others with multiple properties were engaged in more sustainable soil management practices. Additionally, participants with connections to agribusinesses identified as promoting SLMP also performed better on soil testing measures. Conversely, those with fewer properties were more likely to engage in poor soil testing practices.

Native Vegetation Management

Participants were more likely to engage in sustainable native vegetation management if they were connected to other farmers. However, participants who were connected more generally within the network (not specifically to farmers) were likely to engage in poor native vegetation management.

Weed Management

Connections to others in the *same geographical region* were important for sustainable weed management. Sustainable management was more likely by those connected to other sustainable managers in the same area. That is, being connected to a sustainable manager only significantly increased the chances of 'better' weed management if participants were located close together. Conversely, those with ties to others who were geographically removed from them were more likely to receive poor scores on weed management measures.

Connections to others in the network was important to sustainable weed management with active people more likely to score well, and inactive people more likely to score poorly. However, there appears to be a point at which people can have too many connections, with participants who were very active in the network less likely to engage in sustainable weed management

Stock Management

Connections to males and to agribusiness professionals increased the chance of sustainable stock management, while those connected to females and not affiliated with government agribusiness received 'poor' scores. Connections to others in the network more generally were also important; with participants not particularly active in the network less likely to have sustainable stock management .

4. DISCUSSION AND IMPLICATIONS

4.1. The importance of network connections and information on sustainable land management

The aim of the social network analysis was to assess the extent to which agricultural information networks influence SLMP. While the research was exploratory in part, it was also hypothesised that, in light of literature on collaborative management, increased network connections would result in higher prevalence of SLMP. The SNA results failed to demonstrate this, although a number of interesting results highlighting the importance of network connections in other ways were revealed. These results have substantial implications on best practice for catchment managers and are discussed in detail below.

4.1.1. Sustainable management and number of properties

Results from the network analysis in this study indicated that the only significant factor increasing the likelihood of SLMP was a connection to others with multiple properties. However, owners of multiple properties did not necessarily score better on SLMP. The discussion below represents two possible interpretations of this result, though alternative explanations are also possible. The interpretations presented here are largely based on the findings from the other components of the PUTTI research project (as outlined in the executive summary of this report).

Biophysical features (e.g. soils, hydrogeology) of a region can differ markedly across relatively small geographic distances. This can have a substantial impact on a farmer's ability to look to other properties for examples of sustainable practice, as even nearby properties could be operating under extremely different conditions. Those with multiple properties are likely to be operating under a greater variety of conditions than those with single properties. It is possible, given these differences, that owners of multiple properties represent the most efficient source of information about farm management across a broad set of circumstances. For example, rather than one farmer talking to five different farmers, he/she can instead go to one farmer with multiple properties and gain information on a range of topics and experiences. In this sense then, SLMPs are related more directly to efficiency of information seeking, of which being connected to multiple properties is indicative.

Another possibility is that farmers with multiple properties may be perceived, by other farmers, to be more successful. In this scenario, those farmers who are effective at establishing connections with the most 'successful' farmers are more likely to engage in SLMP. This possibility relates to a number of assumptions inherent in the research methodology as well as mythology within the farming community. In regards to research assumptions, the questionnaire and subsequent dependant variable in the analysis are very specifically related to environmental sustainability as indicated by farming practice. However, it is clear from other components of research (see Green et al. 2009) that perceptions of farming sustainability are more complex and intricate to farmers, including aspects such as economic viability and community wellbeing. This would explain why, although environmentally sustainable farmers have connections to multiple property owners, the owners of multiple properties do not necessarily exhibit sustainable practices themselves. The perception that those farmers with multiple properties are the most successful could be related to aspects of mythology in the farming community. Perceptions of 'bigger is better' and multiple properties being seen as measures of economic viability could lead others to value information from these sources.

In both of the above scenarios, it is the information seeking behaviour that is assumed to be influencing SLMP. In the first case, those with the most efficient information seeking behaviours are more sustainable, and for the second, those who identify and seek out those seen as 'successful' are the sustainable practitioners. The effect related to the number of properties in the results may be more of a proxy measure for some other phenomena, perhaps a personality type, or information seeking efficiency.

4.1.2. Information connections and less sustainable practice

The social network analysis results indicated that people with fewer connections were more likely to have a lower measure of SLMP. The original hypothesis that increased information networks would result in more SLMP was not supported by the results. While this result appears very similar to the hypothesis, there is a subtle difference. Increased information connections are important in reducing poor behaviour, but do not necessarily promote sustainable behaviour. Again, there are multiple interpretations for this. The first is an issue of causality. It is possible that farmers who isolate themselves from others, and do not seek information about their practices become less sustainable managers; that failing to have a variety of information sources leads to less sustainable behaviour. The converse of this is the possibility that these farmers are seen to be poor managers to begin with and are then isolated by others; that better land managers do not want to associate with those who are perceived to be 'bad' or less successful. This is in keeping with the multiple property interpretations for sustainable land management behaviours. If sustainable farmers are more inclined to seek information, and connect with those perceived as successful, then those perceived as unsuccessful are more likely to be isolated.

A lack of information seeking behaviour could also be related to locus of control. Related research (Leviston et al.) identified that people with an external locus of control were more likely to have less SLMP. An external locus of control means that people are more likely to believe that they do not have the capacity to make changes, or undertake activities in light of other external factors. Given the drought in many of the regions participants were from, it is possible that participants with fewer connections felt that there was little point in seeking information, as there was little chance of implementing changes during the drought.

4.1.3. Age and poor sustainable practice

The network analysis indicated two results relating to age. The first, that older farmers are more likely to score poorly on measures of SLMP, the second that seeking information from older farmers increases the likelihood of scoring poorly on the sustainability measure. One possibility for this result relates to age and conservatism, phenomena highlighted through associated qualitative research (Green et al., 2009). Older farmers have sometimes been identified as more conservative and less inclined to adopt new practices. Further, there is an evident resistance to management concepts that are seen as overly environmental, or too 'green', as was identified in a number of qualitative interviews conducted by the research team. This pattern appears to be more evident in older land managers and may account for poor scores for SLMP.

There is the possibility that being connected to older farmers indicates that someone is only receiving information about potentially outdated methods and therefore is not undertaking the current best management practices related to sustainability.

4.2. Implications of snowball sampling approaches in network studies

The snowball sampling technique was used in this research because it was more appropriate as discussed earlier. Having an initial ‘seed set’ of 24 participants, and contacting three referrals for each participant up to a total of four iterations, the total number of potential participants is 960. The total number of participants in our research however was only 134. While, in part this is due to non-agriculturally related referrals (and referrals to organisations or other information sources like the internet, newspapers) and some participants having less than three referrals, there is still some question as to why we might have only managed to contact 13.95 percent of the potential participants. One reason for the relatively low actualisation might be the inclusion of agribusiness, and the lack of subsequent referrals back to farmers. While many farmers sought advice from agribusiness, far fewer agribusiness participants sought advice from farmers, or indeed other agriculturally related sources. This may have implications for future research, where researchers may want to consider asking for separate referrals for agribusiness and farming sources.

4.3. Information seeking and sources of discussion

The SNA component of the PUTTI project made assumptions about the importance of social networks, based on research suggesting a positive impact on the adoption of SLMP. To assess this, the research focused on one aspect of social connectedness in particular, information networks. Data was also collected for other network ties, though this represented an exploratory component of the research, and as such these were not statistically analysed. Specifically, participants were asked about who they sought to have discussions with when making decisions, prior to implementing changes. Interestingly, for the most part, both sources of information and discussion were very similar (see Figure 3), with some notable exceptions. The first of these was science and research connections. Participants were much more likely to seek information from these sources than they were to have discussions regarding farm management. Many participants were more likely to have discussions with family members than seek information from them. The last of the larger discrepancies related to business/financial/legal sources. Again, participants were more likely to discuss management with these sources than go to them for information. While these differences make some intuitive sense (particularly with respect to family) the question raised is related more to the type of connections assessed. That both discussion and information sources were not analysed is a possible limitation of the study and in future, it may be interesting to analyse both types of connections and see if the different connections have differing impacts on land management behaviours.

4.4. Implications for NRM and future research

The central tenet of this research rests on the assumed inter-relationship between social capital, co-management approaches, and the importance of connectedness and networking within communities. The assumption was that increased connectedness would enhance the uptake of SLMP, highlighting the operation of collaborative management approaches to NRM in Australia. This was not found to be the case, and as stated previously, although assigning causality is not possible, there are still a number of possible implications.

Firstly, while connectedness in networks did not show increased likelihood of SLMP, the converse, being isolated from others, did decrease the likelihood of SLMP. In this sense, while fostering networks within agricultural communities cannot be espoused to promote SLMP in this study, disruption of the flow of information from those who have ‘poor’ land management behaviours, could perhaps be seen as an intervention of sorts. If the results of this study are able to be generalized to other contexts (and this is an open question), one policy implication is clear: for intervention with landholders demonstrating ‘poor’ or unsustainable behaviour to be effective, you need to ensure that people are not socially isolated from others on farming information.

Other results indicate that, where there are mechanisms to assist with both the promotion of SLMP or discouraging less sustainable land management, these seem to hinge on diversity. It may be that encouraging existing or new learning, information seeking, or even social groups in an agricultural setting to encompass a range of ages, gender and managers of single and multiple properties may be essential in promoting SLMP and negating the less sustainable practices. Certainly more research is needed here.

As with any self reporting in research, there are potential issues of recall accuracy, maybe somewhat confounded by both dependant and independent variables being self reported. Further, while we spoke specifically to participants about SLMP, there appears to be a distinction between sustainable and successful when discussing farming practice. It is possible that while we were assessing sustainable practice, we were being told about information sources of more traditionally measured successful practice, which may have further confounded the results.

In any case, this research highlights the importance of social structure on behaviour, while this is limited in the promotion of sustainable behaviour.This being the case, it should be noted that while social connectedness might be encouraged, it is not necessarily something that can be forced or mandated. There are potential implications for NRM related to the assumption that social capital is reliant on connectedness, and further that it contributes to the success of collaborative management by promoting behaviour change or continuity of sustainable behaviour. More research is needed to clarify the relationships between connectedness, social capital and the adoption of SLMP.

5. APPENDIX A

Demographic details of participants

Table 4 Gender and age of participants

Age	Gender (number of participants)		Total
	Male	Female	
25 to 34 years	8	1	9
35 to 44 years	23	3	26
45 to 54 years	27	4	31
55 to 64 years	28	2	30
65 to 74 years	8	1	9
More than 75 years	4	0	4
Total	98	11	109

Table 5 Number of other family in the region

Number of other family members	Number of participants	Percentage of participants (n=134)
0	84	62.7
1	4	3.0
2	9	6.7
3	10	7.5
4	8	6.0
5	5	3.7
6	7	5.2
7	2	1.5
8	2	1.5
9	1	0.7
10	2	1.5

Table 6 Participant affiliation with groups

Affiliation	Number of participants	% (n=134)
Department of Primary Industries	21	15.7
CMA	7	5.2
Elders	3	2.2
Department of Agriculture	2	1.5
CSIRO	2	1.5
Charles Sturt University	2	1.5
Landmark	2	1.5
Wagga Agricultural Institute	2	1.5
Ag & Vet	2	1.5
Electrical company owner	1	0.7
Department of Environment and Climate Change	1	0.7
Sydney University	1	0.7
Little River Landcare	1	0.7
Rural Lands Protection Board (Central Tablelands)	1	0.7
S.A Research and Development Institute (SARDI)	1	0.7
Back Paddock Co.	1	0.7
Bayer Crop Sciences	1	0.7
WHK	1	0.7
Dow Chemical Company	1	0.7
Delta Agribusiness	1	0.7
Tablelands Livestock Health & Pest Authorities	1	0.7

Table 7 Closest town to participant's place of business or residence

State	Town	Number of participants
NSW	Molong	12
	Rylstone	14
	Mullion Creek	3
	Euchareena	1
	Gulgong	3
	March	1
	Mudgee	15
	Orange	16
	Cumnock	3
	Bogee	1
	Cowra	10
	Kandos	1
	Yeoval	2
	Bathurst	5
	Tamworth	4
	Wagga	5
	Wellington	7
	Dubbo	5
	Geurie	1
	Coonabarabran	1
	Sydney	1
	Norwood	1
	Yass	1
	Young	1
	Bowral	1
	Narromine	1
	Gooloogong	1
	Kew	1
	Wyalong	1
	Fingle Bay	1
	Parkes	1
	Condobolin	1
	Queanbeyan	1
	Trundle	1
	Glen Innes	1
	Eugowra	1
	Harden	1
South Australia	Adelaide	1
Western Australia	Bunbury	1
Queensland	Cleveland	1
Victoria	Horsham	1
ACT	Canberra	3

6. APPENDIX B

Information source details

Table 8 Age of information sources

Age Category	No. of Responses	% (n=249)
25 to 34	17	6.8
35 to 44	56	22.5
45 to 54	75	30.1
55 to 64	71	28.5
65 to 74	20	8.0
more than 75 years	10	4.0

Table 9 Occupation of information sources

Informant Occupation	No. of Responses	% (n=311)
Scientist/ research/ academic	71	22.8
Agronomist	63	20.3
Farmer	56	18.0
Agribusiness employee/manager	14	4.5
Consultant	13	4.2
Livestock broker/officer	11	3.5
Catchment manager/coordinator	11	3.5
Alpaca stud owner/breeder	8	2.6
Retired	6	1.9
Department of Agriculture employee	6	1.9
Wool broker	6	1.9
Technical officer	6	1.9

Table 10 Information source groups

Group	No. of Responses	% (n=414)
Government	115	27.8
Other farmer	71	17.1
Agribusiness	63	15.2
Scientist/ research	36	8.7
Educational institution	25	6.0
Industry group	22	5.3
Agronomist	21	5.1
CMA	17	4.1
Publications/ journals	11	2.7
Business/financial/legal	7	1.7

Table 11. Classified topic area of information sourced

Topic Area	No. of Responses	% (n=406)
Stock management/ breeding	59	14.5
Crop management/ crop agronomy	41	10.1
Everyday farm management	41	10.1
Soil testing	27	6.7
Pasture management	26	6.4
Animal Health	18	4.4
Weed control	17	4.2
Everyday farm decision making	14	3.4
Crop disease	14	3.4
Soil degradation management	12	3.0
Agricultural research/ new ag technology	12	3.0
Fertiliser/ plant nutrition	12	3.0

7. APPENDIX C

Affiliations of people involved in discussions

Table 12. Combined farmer and agribusiness affiliations of discussants

Discussant affiliation	Number of responses	% (n=216)
Government Department	40	18.5
Family	38	17.6
Agribusiness	36	16.7
Other farmer	22	10.2
Agronomist	16	7.4
Business/financial/legal	15	6.9
Self	14	6.5
CMA	13	6.0
Industry group	4	1.9
Owner or board	4	1.9
Science/ research	3	1.4
Educational Institution	3	1.4
Manager	3	1.4
Various colleagues	2	0.9
Community group	1	0.5
Landcare	1	0.5
Farm employee	1	0.5

Table 13. Farmer only affiliations of discussants

Farmer discussant affiliation	Number of responses	% (n=91)
Family	38	41.8
Other farmer	15	16.5
Business/financial/legal	14	15.4
Agribusiness	8	8.8
Industry Group	3	3.3
Owner or Board	3	3.3
Manager	3	3.3
Educational Institution	2	2.2
Government Department	2	2.2
Community Group	1	1.1
Agronomist	1	1.1
Farm employee	1	1.1

Table 14. Agribusiness only affiliations of discussants

Agribusiness discussant affiliation	Number of responses	% (n=125)
Government Department	38	30.4
Agribusiness	28	22.4
Agronomist	15	12.0
Self	14	11.2
CMA	13	10.4
Other farmer	7	5.6
Science/ research	3	2.4
Various colleagues	2	1.6
Industry Group	1	0.8
Landcare	1	0.8
Educational Institution	1	0.8
Owner or Board	1	0.8
Business/financial/legal	1	0.8

8. APPENDIX D

Details of people involved in making final decisions

Table 15 Referrals for decision making

Decision Makers	No. of Responses	% of participants (n=46)
Self	32	69.6
Family Member/Relative	25	54.3
Property Owner	1	2.2
Farm Manager	4	8.7
Agronomist/advisor	5	10.9
CMA	2	4.3

9. APPENDIX E

Sustainable land management item details

Soil Testing

Table 16. Farmer participants: frequency of soil tests and who carries them out.

Who tests the soil	How often is soil testing undertaken			
	Up to once every 3 years	Every 3 to 4 years	less than once every 4 years	Total
Self	11	2	1	14
Professional	4	0	0	4
Both	7	1	1	9
Total	22	3	2	27

Table 17. Agribusiness participants: timing for soil tests and who should conduct them.

Who should test the soil	How often should soil testing undertaken			
	Up to once every 3 years	Every 3 to 4 years	less than once every 4 years	Total
Farmer	44	13	21	78
Professional	0	0	1	1
Total	44	13	22	79

Native Vegetation

Table 18. Farmer participants: proportion of properties currently under native vegetation.

Percentage of land under native vegetation	Number of participants	Percentage (n=44)
Up to 20%	15	34.1
21 to 40%	10	22.7
41 to 60%	8	18.2
61 to 80%	5	11.4
Greater than 80%	6	13.6

Table 19. Agribusiness participants: proportion of a property that should be under native vegetation.

Percentage of land under native vegetation	Number of Participants	Percentage (n=49)
Up to 20%	32	65.3
21 to 40%	3	6.1
41 to 60%	4	8.2
61 to 80%	2	4.1
Greater than 80%	8	16.3

Perennial Pastures

Table 20. Perennial pastures planted by farmers

Perennial	Number of responses	Percentage of cases (n=48)
White clover	23	47.9
Phalaris	21	43.8
Lucerne	19	39.6
Cocksfoot	18	37.5
Sub clover	12	25.0
Rye grass	12	25.0
Clover - unspecified	9	18.8
Clover - Seaton Park	8	16.7
Red grass	7	14.6
Clover - Nungarin	6	12.5
Clover - Balansa	5	10.4
Pitted blue grass	5	10.4
Native grasses/Clovers unspecified	4	8.3
Red clover	4	8.3
Microlaena	4	8.3
Kangaroo grass	3	6.3
Tall Fescue	3	6.3
Wallaby	3	6.3
Warrigo grass	3	6.3
Mt Barker Mahra Clover	2	4.2
Stipa grass	2	4.2
Trefoil	2	4.2
Wheat crop	2	4.2
Millet	1	2.1
Arrowleaf - Zulli Clover	1	2.1
Summer grasses	1	2.1
Foxfoot	1	2.1
Narrow leaf clover	1	2.1
Curly / windmill grass	1	2.1
Jemalong clover	1	2.1
Native trees	1	2.1
Glucenes / ciders	1	2.1
Oats	1	2.1
Salt bush	1	2.1
Peas / Legumes	1	2.1
Consol Love Grass	1	2.1
Bambatsi Panic	1	2.1
Button Grass	1	2.1
Everlasting Daisies	1	2.1
Danthonia	1	2.1

Table 21. Farmers: reason for planting perennial pastures.

Reason	Number of responses	Percentage of cases (n=48)
Feed / pasture / stock / grazing / fodder	28	58.3
People doing well have large variation in species	24	50.0
Improve soil health / productivity / fertility / nutrients	7	14.6
Already there / grows naturally / self germinating	6	12.5
Groundcover / minimise dust	5	10.4
Natives are naturally suited for conditions / soil	5	10.4
Most productive	5	10.4
Environmental reasons / sustainable / natural habitat	3	6.2
Cost advantage	3	6.2
Improved / better root systems / hold soil together	2	4.2
Want to leave property in natural condition	2	4.2
Maintain moisture / minimise evaporation	2	4.2
Cleaner streams	2	4.2
Nitrogen fixation / improve nitrogen levels	1	2.1
Hay making	1	2.1
Suited to conditions / area / resilient / drought resistant / grows well	1	2.1
For sale as feed	1	2.1
Balance pasture / crop	1	2.1
Maximise stock productivity	1	2.1
Rotational system of paddock	1	2.1
Weed control	1	2.1
Control water table / deep rooted	1	2.1
Reduce salinity	1	2.1
Variation in soil type (more types of soil)	1	2.1
Variety is advantageous across seasons	1	2.1
Water use efficiency	1	2.1

Table 22. Perennial pastures suggested as appropriate by agribusiness participant

Reason	Number of responses	Percentage of cases (n=74)
Lucerne	59	77.6
Phalaris	42	55.3
Cocksfoot	30	39.5
Rye grass	28	36.8
Sub clover	12	15.8
Kangaroo grass	12	15.8
White clover	7	9.2
Red grass	7	9.2
Wallaby	7	9.2
Native grasses/Clovers unspecified	7	9.2
Microlaena	7	9.2
Millet	5	6.6
Peas / Legumes	5	6.6
Depends - no single answer	5	6.6
Clover - unspecified	4	5.3
Bambatsi Panic	4	5.3
Native grasses - unspecified	3	3.9
Red clover	3	3.9
Digit Grass	3	3.9
Danthonia	3	3.9
Clover - Seaton Park	2	2.6
Chicory	2	2.6
Summer grasses	2	2.6
Warrigo grass	2	2.6
Curly / windmill grass	2	2.6
Rhodiums	2	2.6
Unsure	2	2.6
Wheat crop	2	2.6
Corkscrew grass	1	1.3
Pitted blue grass	1	1.3
Stipa grass	1	1.3
Rose clover	1	1.3
Haifa - white clover	1	1.3
Forbes	1	1.3
Oats	1	1.3
Consol Love Grass	1	1.3
Arista Austrastya	1	1.3
Forage	1	1.3
Tropical pastures	1	1.3
Panic Grass	1	1.3

Table 23. Agribusiness: reasons for planting perennials.

Reason	Number of responses	Percentage of cases (n=71)
Feed / pasture / stock / grazing / fodder	26	36.6
Suited to conditions / area / resilient / drought resistant / grows well	26	36.6
Groundcover / minimise dust	21	29.6
Environmental reasons / sustainable / natural habitat	11	15.5
Nitrogen fixation / improve nitrogen levels	10	14.1
Maintain moisture / minimise evaporation	9	12.7
Improved / better root systems / hold soil together	7	9.9
Control water table / deep rooted	7	9.9
Improve soil health / productivity / fertility / nutrients	6	8.5
Minimise / prevent / improve / control erosion	6	8.5
Most productive	6	8.5
Reduce salinity	6	8.5
Maximise stock productivity	5	7.0
Not Applicable	5	7.0
Natives are naturally suited for conditions / soil	4	5.6
Weed control	4	5.6
Balance pasture / crop	3	4.2
Cost advantage	3	4.2
Balancing productivity	2	2.8
Combination of Summer and Winter growing	2	2.8
Organic matter - carbon	2	2.8
Rotational system of paddock	1	1.4
Cleaner Streams	1	1.4
recommended (by DPI)	1	1.4
Matches goals/enterprise type	1	1.4
Gives disease break for root diseases	1	1.4
ease of management	1	1.4
Increase biodiversity	1	1.4
Nutrient cycling	1	1.4
Quality same all year round	1	1.4
Stops nitrate leaching	1	1.4
Tolerate acidity	1	1.4
People doing well have large variation in species	1	1.4

Table 24. Focus on weed control

	Focus on Weed Control (%)				
	No focus	2	Some focus	4	Large focus
Farmer (n=51)	3.9	7.8	25.5	19.6	43.1
Agribusiness (n=79)	0	3.8	29.1	27.8	39.2

Table 25. Farmers: weed control techniques employed.

Weed control technique	Number of responses	Percentage of cases (n=51)
Chemical spray	25	49.0
Grazing	15	29.4
Spray – Spot	15	29.4
Spray – Boom	10	19.6
Digging	6	11.8
Chipping	5	9.8
Manual	5	9.8
Competing Pasture	5	9.8
Hoeing	4	7.8
Slashing	4	7.8
Biological (pest species) grubbing	4	7.8
Spray – aerial	2	3.9
Herbicide	2	3.9
Improve soil fertility	2	3.9
Cultivation	1	2.0
Burning	1	2.0
Goats	1	2.0
Crop rotation	1	2.0
Mechanical removal	1	2.0
Sustainable management of stock	1	2.0

Table 26. Weed control techniques advocated by agribusiness

Weed control technique	Number of responses	Percentage of cases (n=77)
Grazing	44	57.1
Competing pasture	35	45.5
Herbicide	34	44.2
Chemical spray	22	28.6
Cultivation	18	23.4
Crop rotation	14	18.2
Integrated	13	16.9
Spray – Spot	10	13.0
Biological (pest species) grubbing	9	11.7
Slashing	5	6.5
Crop rotation	5	6.5
Depends on the species	5	6.5
Harvest for hay	4	5.2
Burning	4	5.2
Spray – Boom	3	3.9
Tillage	3	3.9
Sileage	3	3.9
Awareness	3	3.9
Sustainable management of stock	3	3.9
Chipping	2	2.6
Ploughing	2	2.6
Goats	2	2.6
Improve soil fertility	2	2.6
Weeds can be beneficial	2	2.6
Pasture cropping	2	2.6
No till sowing in one location	2	2.6
Hoeing	1	1.3
Manual	1	1.3
Chop it out	1	1.3
Persistence	1	1.3
Quarantining incoming animal	1	1.3
Imported hay in one location	1	1.3

10. APPENDIX F

Parameter estimates for SNA

Table 27. Sustainable land management behaviour social network, *p model parameter estimates [a]**

Structural parameters	Parameter estimates	SE
Attribute density	-3.847090	2.69760
Activity	1.326912	1.26346
Star 2	-0.925829	0.66200
Contagion	0.083076	0.86312
Actor-relation parameters		
Geographic homophily	-0.014247	0.03614
Number of properties	0.633828	0.34124
Connection to people with multiple properties	0.953302	0.41041*

[a] The *p** model parameter name is included in Column 1 and the model estimate is included in Column 2, with Column 3 indicating the Standard Error (SE) of the estimate.

Table 28. Less sustainable land management behaviour social network, *p model parameter estimates[a]**

Structural parameters	Parameter estimates	SE
Attribute density	-0.355837	2.89899
Activity	-7.148464	2.50153 *
Contagion	-5.682289	3.87794
Actor-relation parameters		
Geographic homophily	-0.101038	0.05512
Number of properties	1.184592	0.88530
Connection to people with multiple properties	1.660736	0.55593 *

[a] The *p** model parameter name is included in Column 1 and the model estimate is included in Column 2, with Column 3 indicating the Standard Error (SE) of the estimate.

Table 29. Parameter estimates for *sustainable* soil management network models

Structural parameters	Parameter estimates	SE
Attribute density	- 8.569773	3.11263*
Activity	-1.453861	1.07152
Contagion among partners	-1.045513	1.65849
Contagion	1.671053	1.21449
Actor-relation parameters		
Geographic homophily	0.025699	0.03991
Number of properties	1.618804	0.56778 *
Connection to people with multiple properties	1.861772	0.82716 *
Connection to sustainable agribusiness	0.486936	0.21651 *

[a] The *p** model parameter name is included in Column 1 and the model estimate is included in Column 2, with Column 3 indicating the Standard Error (SE) of the estimate.

Table 30. Parameter estimates for *less sustainable* soil management network models

Structural parameters	Parameter estimates	SE
Attribute density	3.165353	2.58389
Activity	-0.579729	0.82539
Contagion	0.142739	0.75403
Star 2	-0.096441	0.41383
Actor-relation parameters		
Geographic homophily	-0.004275	0.02458
Number of properties	-0.843922	0.42043 *
Connection to people with multiple properties	-0.163395	0.26828

[a] The *p** model parameter name is included in Column 1 and the model estimate is included in Column 2, with Column 3 indicating the Standard Error (SE) of the estimate.

Table 31. Parameter estimates for *sustainable* native vegetation management network models

Structural parameters	Parameter estimates	SE
Attribute density	-1.852819	2.25118
Contagion	-0.900818	0.68763
Star 2	-0.706193	0.38376
Actor-relation parameters		
2 path equivalence	0.656276	0.33469
Geographic homophily	-0.011667	0.02655
Connection to other farmers	1.811060	0.88139 *
Connection to Agribusiness	1.359207	0.88139

Table 32. Parameter estimates for *less sustainable* native vegetation management network models

Structural parameters	Parameter estimates	SE
Attribute density	0.239009	2.79013
Contagion	-1.642278	0.82386
Activity	-1.275375	0.88083
Star 2	0.888270	0.41189 *
Actor-relation parameters		
Geographic homophily	0.030769	0.02246
2 path equivalence	-1.596615	0.60119 *

Table 33. Parameter estimates for *sustainable* weed management network models

Structural parameters	Parameter estimates	SE
Attribute density	-3.463832	2.07504
Contagion	0.680052	0.61712
Activity	1.651471	0.66265 *
Star 2	-0.603808	0.27482 *
Actor-relation parameters		
Geographic homophily	0.015929	0.01467
2 path equivalence	-0.516719	0.22842 *

Table 34. Parameter estimates for *less sustainable* weed management network models

Structural parameters	Parameter estimates	SE
Attribute density	3.479834	2.54582
Activity	-2.163198	0.80251 *
Star 2	0.373391	0.37690
Actor-relation parameters		
Geographic homophily	-0.027701	0.03188
Remoteness to partners	0.322692	0.12358 *

Table 35. Parameter estimates for *sustainable* stock management network models

Structural parameters	Parameter estimates	SE
Attribute density	-0.417841	2.91687
Contagion	0.287929	0.56139
Activity	-1.047971	0.55721
Actor-relation parameters		
Geographic homophily	-0.008074	0.02548
Gender	1.014932	0.83190
Connection to Gender	1.378919	0.66532 *
Connection to Agribusiness	2.980730	1.47346 *

Table 36. Parameter estimates for *less sustainable* stock management network models

Structural parameters	Parameter estimates	SE
Attribute density	4.849394	2.92936
Activity	0.583168	0.78142
Contagion	-0.290112	0.74416
Actor-relation parameters		
Geographic homophily	-0.042396	0.03101
Remoteness to partners	0.256413	0.12830
Connection to gender	-1.686186	0.73708 *
Connection to Agribusiness	-2.720358	1.32222 *

11. GLOSSARY

Actor – Is the individual or group of individuals that is studies using network analysis. With respect to the research in this report, each actor represents an individual farmer, or an individual involved in some type of agribusiness.

Connectedness – is indicative of the amount of ties, or connections, between actors. A high level of connectedness would indicate an actor has a number of ties to other actors.

Contagion – a contagion effect refers to instances whereby connections are more likely between actors exhibiting similar responses on the dependent variable. It therefore refers the the 'spread' of a variable through a network.

Geographic homophily – a geographic homophily occurs when a similar pattern of responses, or observations are identified in a group of participants closely located geographically. This homophily is independent of ties between these actors. For example, if a geographic homophily was identified in a social network model where intelligence was the dependent variable, it would suggest that people of higher intelligence are more likely to be located closely in an area, though not necessarily more likely to be connected to one another.

Mutuality – both actors in a pair choose the other

Reciprocity – the tendency for one actor to interact with another, if that actor has chosen them

Sociograms – Are visual representations of social networks, principally representing actors and their ties, though sometimes also showing other variables such as age and gender.

Ties – are connections between actors. In the case of the network analysis conducted in this report, ties indicate that an actor, or participant, seeks information from another about agricultural practices

Triadic formations – a group of three actors and all ties between them

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