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From extension to distributed learning: the embedding of agricultural scientists in farmer-knowledge networks

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Abstract

This paper reports on the social structures of an ongoing learning group in which 17 farmers and five agricultural scientists are collaboratively undertaking a three-year farmlet experiment that investigates the performance of 'herb mix' pastures. Network analyses have been undertaken of the history of prior contact between the group's 22 members and of the 223 contacts made by the participating farmers to develop their herb pasture knowledge. The results show that networking by farmer members radically increases the ability of science to reach other farmers. These farmer networks have distributed structures characterised by dense, decentralised and equitable ties between the participants. The power to authorise agricultural knowledge is pluralised by numerous self-reinforcing relationships grounded in everyday farming practices. The paper concludes by discussing the relevance of such distributed learning for current attempts to replace linear extension with a more productive approach to agricultural knowledge.

Keywords: agricultural science; distributed networks; extension; farmer learning

Introduction

In mid-2011, the authors established an ongoing learning group to explore the knowledge-sharing opportunities created by improved interaction between farmers and agricultural scientists. Group activities have centred on a three-year farmlet experiment that investigates lamb finishing on herb and legume-based pastures composed of red and white clovers (*Trifolium pratense* and *T. repens*), chicory (*Cichorium intybus*) and plantain (*Plantago lanceolata*). The experiment was launched with 19 farmers and the authors, an interdisciplinary group made up of five agricultural scientists, two educationalists and a sociologist. The farmers were personally invited to join the project by the five agricultural scientists in the group. The farmers have visited the farmlet four times a year and have participated in the experiment's grazing management decisions; they have also attended various science-oriented workshops and visited a number of each other's farms. The project has included frequent opportunities for informal socialising. The significance of these small-group interactions is considered elsewhere (Sewell et al. 2014). Here we present the results of our research into the learning group's network structures, focusing in particular on relationships between the five agricultural scientists and the 17 farmers for whom network data has been collected (data could not be obtained for two of the group's farmer members).

The learning group is a gathering of 22 individuals that aims to collectively produce agricultural knowledge. The group has been convened to determine the lamb finishing performance and grazing management requirements of some new forage species whose value potential is assumed from research on ewes and lambs over one season (Golding et al. 2011; Hutton et al. 2011) but, to date, has not been scientifically established in a year-round farm system. Moreover, the learning group has also been convened to speak directly to more general and pressing concerns of the sector. Many have argued that we need new forms of agricultural knowledge and that traditional extension has failed to deliver (e.g. Beef+Lamb 2013). According to the old linear model, new agricultural techniques are developed by scientists in their laboratories and research stations and then passed on to specialised intermediaries such as consultants and industry good representatives, who in turn pass the new knowledge on to farmers. It has long been argued that linearity produces an abstract knowledge poorly suited to the grounded complexity and riskiness of farming; small wonder then that such traditional extension models have foundered on the so-called problem of 'farmer uptake' (Pretty & Chambers 1994).

Rather than being treated as the passive recipients of wisdom generated elsewhere, farmers need to be actively involved in the production of new knowledge (for an early NZSAP statement along these lines, see McRae 1993). A number of overseas rural development projects have sought to sponsor this farmer involvement by encouraging closer ties with production scientists (e.g. Richards 2009). Although a handful of similar initiatives are underway in New Zealand, these are typically *ad hoc* exercises that lack both systematic data collection and a sustained focus on developing new approaches to learning that can replace linear extension. This is the gap we aim to fill. As the results presented in this paper show, production scientists are socially embedded in extensive contact networks that farmers construct in order to grow their knowledge. The analysis of these networks suggests a new model of distributed learning that radically departs from the traditional practices of agricultural extension.

Materials and methods

A range of network data has been collected from the 22 learning group members. Using a mix of name-generator and roster formats (Prell 2012), four surveys have been undertaken. Prior to the first farmlet visit in mid-2011, each farmer was interviewed to identify their pre-existing contacts for herb pasture knowledge. The farmers were also asked to select from this initial list the 'top 3' contacts they had found 'the most useful to talk to in order to get hold of or share information and ideas' about herb pastures. Immediately following the first farmlet visit, the 17 farmers and five scientists were surveyed individually to identify whom of the learning group members they knew personally before the project began. In December 2012, the farmers were re-interviewed to identify who they had talked to about the pastoral experiment over the preceding 18-month period. The two sets of farmer interviews identified 223 herb pasture contacts in total and it is this combined population that is analysed here. Finally, in early 2013, learning group members were presented with a roster of the 223 individuals named in the farmer surveys and asked to identify all those they knew personally. The network data generated by these four surveys have been analysed with Ucinet software (Borgatti et al. 2002). The various metrics used are described in context below.

Results

The learning group's prior contact network

The history of prior interpersonal contact may be viewed as a learning resource that is distributed between the learning group's 22 members. Table 1 reports six summary indicators of the network structure generated by these prior contacts (for a full account of these indicators see Prell, 2012).

Table 1 Six structural indicators of the learning group's prior contact network.

Network density	0.44
Average shortest path	1.6
Betweenness centralisation	11.6%
Number of farmer-farmer dyads	48
Number of farmer-scientist dyads	44
Number of scientist-scientist dyads	10

Network density measures a group's structural cohesion as the number of actual ties divided by total possible ties, with scores varying between 0 (no actors are tied together) and 1 (all actors are directly connected). There were 102 prior ties between the learning group's 22 members, giving a density score of 0.44. This result suggests a relatively cohesive network in which, on average, each individual already knew nearly half the membership when the group first gathered in 2011. Cohesiveness is also indicated by the length of the average shortest path. Members who already knew each other directly are one degree apart; if they knew of each other only indirectly through another, then they are two degrees apart and the more others it takes to connect them the further apart they are. In network terms, the shorter the path between two members, the more efficiently they can communicate. The average shortest path between all pairings of the 22 members is a low 1.6, suggesting that everyone is close together.

Group cohesion can be sustained by a range of network structures. For example, a small subgroup may hold the majority of ties (collectively, they already knew many more of the learning group than did the others). Here cohesion is sustained by a centralised structure that hierarchically privileges a few over the many. The extent to which the learning group conforms to such a structure is indicated by its betweenness centralisation. Betweenness centrality refers to the frequency that an actor is positioned on the shortest path linking two other actors together. Falling between otherwise unconnected pairs indicates the structural power to act as a knowledge 'gatekeeper'. At the level of the whole network, betweenness centralisation is calculated as the average difference between the score of the most 'between' member and all the others, with the index varying between 100 (one member holds all ties) and 0 (everyone is directly connected and thus there is no betweenness centrality in the network). The learning group's prior contact score is 11.6%, suggesting a decentralised network whose cohesion does not rely on a few highly pivotal players to connect otherwise isolated members.

Table 1 also reports on dyadic distributions of the learning group's prior contacts. Dyads are an elementary structure produced when two actors are directly tied together. As noted above, prior contact generated 102 ties between the group's 22 members, meaning that there are 102 pairs in the network. Of particular interest is the extent to which these dyads are organised by the group's two member identities: scientist and farmer. Member identities create three possible dyads: (1) farmer-farmer, (2) farmer-scientist and (3) scientist-scientist. Although the five scientists make up only 22.7% (5) of total membership (22), we might nevertheless expect them to dominate the dyadic structures. For example, the scientists all knew each other before the learning group formed and thus their dyadic count is the maximum possible for five actors (10). More significantly, the 17 farmer members were recruited by the scientists; they did not enrol themselves in the group. Given scientist-centred recruitment, we might expect farmer-scientist dyads to substantially outnumber farmer-farmer dyads. In the event however, this was not the case. Farmer-farmer pairs make up 47.1% (48) of all dyads, marginally ahead of farmer-scientist pairs at 43.1% (44). To put the same point alternatively, the 17 farmers belong to 92 dyads and half (52.2%) these prior contacts are with each other.

The 17 farmers' herb pasture network

The 17 farmers were interviewed prior to the learning group's first meeting to identify their existing herb pasture contacts. They were also asked to identify their 'top 3' contacts from the resulting roster of names. Eighteen months later, the farmers were re-interviewed to identify individuals with whom they had discussed the farmlet experiment over the intervening period. In total, the two interviews identified 223 contacts made by the 17 farmers. Table 2 cross-tabulates these 223 individuals by occupational role. Note that multiple 'top 3' nominations of the same individual have been aggregated. It is also notable that learning group farmers and scientists received two 'top 3' nominations apiece; these 4 intra-group nominations are excluded from analysis. An authority index has been calculated as the percentage of each occupation's contacts who received 'top 3' nominations. The index indicates the relative power of each role to convert network presence into highly valued knowledge (with scores varying between 100, where all role contacts received 'top 3' nominations, and 0, where no role contacts were nominated)

Table 2 Farmer herb pasture knowledge contacts by occupational role (%).

Contact occupation	All contacts	Top 3 nominations	Authority index
Accountant	0.4	0.0	0.0
Banker	2.2	0.0	0.0
Consultant	4.0	8.5	44.4
Contractors	6.7	4.3	13.3
Farmer	59.6	31.9	11.3
Industry good	4.0	2.1	11.1
Merchant (fertiliser)	2.7	6.4	50.0
Merchant (seed)	10.8	42.6	83.3
Other	2.7	0.0	0.0
Scientist	2.2	0.0	0.0
Veterinarian	4.5	4.3	20.0
Total	100 (n = 223)	100 (n = 47)	

The learning group's 17 farmers make most of their contacts for herb pasture knowledge with fellow farmers (59.6%). In distant second place are seed merchants (10.8%), followed by an assortment of rural professions at approximately 2-7% apiece (bankers, consultants, contractors, industry good representatives, fertiliser merchants, scientists and veterinarians). The 'top 3' nominations are distributed unevenly across these occupational contacts. Fellow farmers are second placed (31.9%) behind seed merchants (42.6%). Consultants, contractors, fertiliser merchants and veterinarians cluster below at approximately 4-9% apiece. The authority index shows that some occupations convert network presence into valued knowledge at higher rates than others. Index scores divide the occupations into three distinct groupings. Seed merchants are well ahead of all other roles (83.3%), followed by fertiliser merchants and consultants at approximately 40-50% each. Bringing up the rear at approximately 10-20% apiece are contractors, fellow farmers, industry good representatives and veterinarians.

Triadic structures in the learning group network

A final survey assembled a roster of all the individuals named as a knowledge contact by one of the 17 farmers. Learning group members were asked to identify who of the listed individuals they also personally knew. These data indicate the extent to which the learning group shares its 223 contacts. Analysis indicates that such sharing is common; 91.0% (203) of the contacts are personally known by more than one of the 22 learning group members. When a contact is known by two members, a triadic structure is created. These structures have three distinct forms. The contact can be shared (1) by two of the 17 farmers, (2) by two of the five scientists, or (3) by a farmer and a scientist. These three triadic forms have been identified using Ucinet's brokerage routine (Borgatti et al. 2002). Table 3 cross-tabulates the three triads by the occupation of the 203 shared contacts.

The sharing of personal contacts embedded the learning group in 4109 triads. These social structures create opportunities for contacts to be informed about the farmlet experiment by two of the group's 22 members. Table 3's results thus suggest that the learning group is strongly positioned to deliver messages from multiple sources. Nearly ten times as much contact sharing takes place between the 17 farmers (2334) as between the five scientists (257). On average, each farmer shares a contact with one of the other 16 farmers 137.3 times, one and a half times more frequently than with the five scientists (89.3). Each scientist shares a contact with another scientist 51.4 times, six times less frequently than with one of the farmers (303.6). These results evidence the communication power gained by the scientists through their relations with the group's farmer members. The significance of farmers is also evident in the distribution of contact occupations. Farmers make up 51.9% (2136) of total shared contacts, four times the score of the second-placed private consultants (532). Across all three triadic

Table 3 Learning group triads by contact occupation.

Contact occupation	Shared by 2 farmers	Shared by 2 scientists	Shared by mixed pair	Total
Accountant	1	0	0	1
Banker	15	1	4	20
Consultant	253	42	237	532
Contractor	77	16	53	146
Farmer	1263	116	757	2136
Industry good	102	25	115	242
Merchant (fertiliser)	52	0	9	61
Merchant (seed)	240	2	52	294
Other	36	0	0	36
Scientist	96	32	128	256
Veterinarian	199	23	163	385
Total	2334	257	1518	4109

forms, farmer contacts are shared three to five times more frequently than any other occupational role. The results also reveal some minor differences between the scientist and farmer group members. Relative to the farmer-only triads, the scientists are less likely to share merchant contacts and more likely to share consultants, industry-good representatives and fellow scientists. In general however, the sharing of farmer contacts by the 17 farmers is clearly the learning group's dominant triadic form.

The learning group's power to deliver multi-sourced messages extends beyond triadic structures. Contacts may be shared by more than two group members and, for example, a contact shared by three has one more possible source than a contact shared by two. Table 4 reports the distribution of contacts by the number of group members who know them personally.

Table 4 The distribution of learning group contact sharing.

Number of group members who share the contact	Number of contacts
2	42
3 to 5	79
6 to 8	47
9 to 11	18
12 to 14	9
15 to 17	6
18 to 20	2
Total	203

Table 4 shows that only 20.7% (42) of the 203 shared contacts are embedded in simple triadic structures with two learning group members. The majority are more widely known. Over one third (34.3%) are known by 3-5 members and nearly another third (28.3%) by 6-11. On average, each of the shared contacts is known by 5.7 learning group members. One is known personally by 20 of the group's 22 members.

Discussion

The results reported above indicate that the learning group's five agricultural scientists are deeply embedded in knowledge networks made and maintained by the group's 17 farmer members.

The history of prior contact between the learning group's 22 members may be viewed as a valuable learning resource given that people who already know each other personally are well placed to share knowledge. The analysis of prior contacts indicates a network that is densely tied together. Group members are positioned relatively close to each other in a social structure that is decentralised and sustains little in the way of hierarchically privileged 'gatekeeper' roles. Dyadic analysis shows that prior contacts are equitably distributed between farmers and scientists. Significantly, the learning group's recruitment process, in which farmer members were nominated by the participating scientists, resulted in a network in which many of the farmers were already acquainted with each other.

Analysis of herb pasture contacts made by the group's farmers indicates the presence of a wider knowledge-sharing population made up of 223 individuals. Substantially more of these contacts (59.6%) are with fellow farmers than with any other occupation. This result indicates the power of farmer networking to move knowledge between farmers. The analysis of 'top 3' nominations reveals the occupational authority constructed when farmers share herb pasture knowledge. Seed merchants are the most valued partners, with fertiliser merchants and consultants also figuring as powerful secondary sources. Significantly, although fellow farmers are the most common occupational contact, they are second placed in 'top 3' nominations and sixth placed on the authority index. Aside from those present in the learning group, individual scientists are not identified as authoritative sources. Farmer networking thus does not simply reproduce the learning group's exclusively farmer and scientist membership. Interaction with the 17 farmers certainly gives the group's five scientists considerable reach to other farmers, but it does so by pluralising authority across a defined spectrum of rural professions.

Analysis indicates that the farmers' 223 knowledge contacts are extensively shared across the learning group as a whole. Some 91% of these contacts are known personally by more than one member. The 203 shared contacts are embedded in 4109 group triads and on average each is known personally by 5.7 group members. The dominant triadic structure links two farmer members with a shared farmer contact. These results show that the learning group is strongly positioned to deliver multi-sourced messages. Farmers are both the most likely source and recipient of such messages. The group's ability to deliver multi-sourced messages creates numerous opportunities to reinforce knowledge about the herb pasture experiment.

The learning group's power to reinforce knowledge highlights the extent to which it departs from traditional extension approaches. The ability to reinforce messages is produced by what is called the redundancy of network ties (Burt 1992). For example, using a strict efficiency calculus, we may assume that it should take no more than one tie to move knowledge from someone who knows to someone who does not. If there are two ties with someone not in the know, then one of these ties is redundant. By this count it should take the group no more than 223 ties to move knowledge about the experiment to its 223 contacts. In the event the group has 2322 ties with its contacts, meaning that 90.4% (2099) of these ties are redundant. Such redundancy indicates a social structure that can deliver multiple versions of 'the same' message. Moreover, the ability to deliver multi-sourced messages is also the ability to collectively receive them. The abundance of redundant ties thus indicates the learning group's power to reinforce communication both to and from the 223 contacts. Such extensive feed-back loops mean that the group is strongly positioned to produce a responsive knowledge adapted to highly differentiated contexts (Tsouvalis et al. 2000).

Conclusion

The social embedding of science in farmer knowledge networks signals an opportunity to develop learning systems that can address the perceived shortcomings of traditional approaches to agricultural extension. Although the search for extension alternatives is ongoing, it would clearly benefit from a more sociological focus on the structures that sustain agricultural knowledge. Structurally, traditional extension relies on central agencies with the hierarchical authority to produce a knowledge that holds true irrespective of local circumstances. Specialised intermediaries relay this knowledge to farmer learners. Such extension systems are designed to span great distances, with people located far apart from each other, and their efficiency is typically measured as the most consistent and numerous farmer contacts gained for the least central resources. Polemically, we might dub these centralised and linear systems 'the Wellington model'. We believe that such command-and-control extension not only fails to empower learning but is simply out of step with the post-MAF, commercialised culture faced by New Zealand farmers.

It is certainly the case that farmers face a fragmented knowledge system filled with 'too much noise and mistrust' (Beef+Lamb 2013). However, these days no central authority can be established that has the power to dispel this fragmentation with consistent and hierarchically aligned messaging. The only realistic option facing New Zealand agriculturalists is to make good the fragmented world we inhabit. This is the large learning we seek from our experimental learning group.

The learning group's 22 farmers and scientists are co-producing agricultural knowledge in relationships that are decentralised and equitable. The group's members are embedded in networks that are both densely tied and authoritatively pluralist. This social structure self-organises around locally available resources and operates largely independent of materials shipped in from elsewhere. Rather than the efficient minima produced by specialist intermediaries and unusual occasions, the social structure exhibits an abundance of self-reinforcing relationships grounded in the everyday routines of farming. Taken as a whole, these attributes identify the learning group as one participant among many in what is called a distributed network. The capacity of such resource infrastructures to produce resilient, locally attuned and action-changing innovations has been well documented in numerous fields (Biggs et al. 2010). We thus suggest that current attempts to replace linear extension with more productive approaches to agricultural knowledge should take stock of the distributed learning powers sustained by farmer-scientist networks.

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