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'In Local Collaboration we Trust': The Dynamics of Trust Network Relationships in Collaborative Natural Resource Management in Tanzania[1]

Mathew Senga
Department of Sociology and Anthropology, University of Dar es Salaam
E-mail: mathewsenga@udsm.ac.tz

Abstract
The existence of relational trust among network actors can facilitate collective action and enhance the successful collaborative practices of natural resource management. This paper uses a stochastic actor-oriented modelling approach to provide two simple models for dynamics of trust relationships in a network of Village Conservation and Development Committee (VCDC) in Amani Nature Reserve, Tanzania. By simultaneously modelling network (social selection) and behaviour (social influence) this paper tests the hypothesis of whether or not actors with similar attribute(s) tend to trust similar influential actors on the decisions about issues related to local collaborative practices of natural resource management. Results show that homophily (the tendency of individual network actors to associate and bond with similar others) effect for actor attribute and behaviour (influence on decisions of natural resource management) average similarity have an important role to play on selection, maintenance or dissolution of trust ties among VCDC actors in the context of collaborative practices of natural resource management. This paper contributes theoretically and methodologically to a discussion on importance of trust in interaction of actors involved in collaborative practices of natural resource management, particularly in developing countries such as Tanzania. The literature within such framework is still underdeveloped.

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Introduction

Collaborative natural resource management practices are characterised by trust relationships among actors in a social network. With trust relational ties, not only is it possible to enhance the sharing of various information, advice and support related to natural resource management (hereafter referred to as NRM), but also to facilitate the establishment of collaborative NRM priorities and tasks to address collective action dilemmas for effective management of natural resource.

Trust is a complex concept as there are many views and various types related to it. However, trust constitutes a vital form of social capital within social systems (Coleman, 1990; Putnam, 1993). According to Yamamoto (1990: 466), the decision to trust is based on evidence to believe, or be confident in, someone something's good intentions towards us. In the context of NRM, this paper considers two types of trust, similar to Pretty and Ward (2001: 211); the trust we have in individuals (hereby referred as actors) whom we (closely) know and the trust we have in those we do not (closely) know, but which arises because of our confidence in a known social structure.

Findings from research in NRM indicate that fostering a climate of trust is critical in co-operative action (McAllister *et al.,* 2005: 2334). Trust also constitutes a fundamental characteristic in social self-organising processes for ecosystem management (Brown *et al.,* 2001: 432). Moreover, Pretty and Ward (2001: 211) underscore the fact that trust lubricates co-operation, reduces transactional costs between actors, and so liberates resources.

Primarily, this paper intends to model simultaneously social selection (network) and social influence (behaviour) processes to gain insight into the dynamics of trust relationships and choice of influential actors on the decisions about NRM issues in the vertical network. Gender and age help to underscore whether homophily (the tendency of individual network actors to associate and bond with similar others) effect has any impact on actor attributes in the selection of a partner to trust, or in the maintenance or dissolution (termination) of the trust tie. The models work on an assumption that the decisions of actors in a network regarding their choices of influential actors and their attributes drive changes in the structure of trust network. As such, one hypothesis is derived: *Actors with similar attribute(s) tend to trust similar influential actors on the decisions about issues related to local collaborative practices of NRM*. Effects related to social selection and social influence are controlled, whereby for trust relationships structural effects of out-degree (density), reciprocity, transitivity and homophily (choice of network ties based on similarity of salient attributes) are controlled whereas for social influence, behaviour average similarity is also controlled.

Secondly, given the stated primary aim, this paper seeks to provide two simple models using a stochastic actor-oriented modelling (SAOM) approach for dynamics of trust relationships in a small vertical network of actors involved in local collaborative practices of NRM in Amani Nature Reserve (ANR), Tanzania. The network encompasses 23 actors who form the Village Conservation and Development Committee (VCDC). This is a platform of representatives from all surrounding villages and those at the enclaves of the ANR and other actors by virtue of their positions whose obligations include making sure that all the villages implement a Memorandum of Understanding (MoU) signed between villages and the ANR authority to ensure collaborative practices of NRM. The paper uses two waves (phases) of network panel and actor attributes data collected in the framework of longitudinal study design.

This paper is motivated by a desire to contribute to the discussion of the importance of trust in the interaction of actors involved in local collaborative practices of NRM. The paper assumes that similarly with other scholars (Singleton, 1998; Eamer, 2006) constructing an effective co-management arrangement is not only a matter of building institutions but also a matter of cultivating trust between the parties.

Whereas some research (Ostrom *et al.,* 1999; Beierle & Konisky, 2000; Conley & Moote, 2003) demonstrates the role of trust in NRM and decision-making, we are also witnessing a growth in literature focusing on trust in other contexts such as the functioning of teams and organisations (see, for example, McAllister, 1995; Jones & George, 1998; Dirks & Ferrin, 2001; Brass *et al.,* 2004: van de Bunt *et al.,* 2005). To the best of knowledge of the author of this paper, literature that pays special attention to trust network relationship in local collaborative practices of NRM remains underdeveloped in developing countries such as Tanzania. Testing a co-evolution of trust networks and behaviour (attitudes of actors) by means of SAOM approach would allow not only the joint representation of social selection and social influence (Steglich *et al.,* 2010) but also make it easier to distinguish causal relationships between actor-attributes and network structure. Additionally, it will allow for the clarification of whether attributes influence network structure or the other way around (Prell, 2012: 218). Methodologically and theoretically, this will contribute to literature of trust in the context of collaborative NRM.

This paper is structured as follows: section 2 describes the theoretical discussion; section 3 presents data and methods; and section 4 specifies the trust network models using the SAOM approach. Section 5 presents the results and discussion whereas section 6 concludes the paper.

Theoretical Discussion

As highlighted in the beginning, trust as a concept presents a difficulty in accurately defining, comprehending, measuring and applying it in different contexts. Gambetta (1988), for example, notes that the concept of trust has many theoretical origins and disciplinary homes; moreover, it has been described as a highly "elusive" concept. However, discussions by scholars such as Rousseau *et al.* (1998) and Möllering (2006) allow for a general agreement to be reached that trust is a foundational element of social relationship and, therefore, its characterisation needs to be understood as relational or interactional (in the sense of social network of actors).

Theoretically, perspectives of social capital, which is normally measured with questions related to levels of trust, have been used in the wide-ranging discussion on how social networks of actors may develop trust. This in turn facilitates the sharing of knowledge, information and reciprocal support among other aspects, in various contexts. Interpersonal trust represents an integral element of social capital (Labun, 2012: 103). In addition, it is a significant lubricant for successful collaborative practices of NRM. More specifically, trust and reciprocity are intangible aspects of social capital that would normally require an insider point-of-view.

Arguing on the importance of trust, Bodin and Crona (2009: 369) state that the "positive effect of bridging ties in NRM extends beyond the exchange of information, knowledge (and this paper adds other aspects such as advice and support), rather they can foster trust among previously unconnected groups which facilitates collective actions among different types of actors, such as farmers and government officials". This reflects the VCDC in ANR given its structure, which allows for the inclusion of both representatives from the local communities and government officials (conservators and councillors).

In such a context where a social network appears vertical to enhance participatory NRM, we normally expect the execution of formal rules, regulations and procedures for collective action interventions. However, some studies, for example, in ANR (Bildsten, 2002; Zulu, 2004; Vihemäki, 2005) identify challenges facing collaborative practices of NRM characterised by the increasing levels of defection. Krishna (2000: 80-88) precisely comment that where formal rules, procedures, roles and committees are working to support collective action but mutual trust is low and only little value is placed on collaborative initiatives, then collective action interventions are required to build trust and willingness to work together, and create relational social capital. This shows that in collaborative practices of NRM, high levels of mutual trust among network actors are required to enhance and promote the sharing of various aspects and confidence in collective action for a successful collaboration.

Theoretical and empirical literature in some parts of the world, other than Tanzania, demonstrates the significance of trust in NRM. The benefits of trust is highlighted in NRM aspects such as building a sense of fairness in NRM procedures (Lawrence *et al.,* 1997); facilitating learning for individuals and groups (Brechin *et al.,* 2002); enhancing NRM solutions in a creative manner (Wondolleck & Yaffee, 2000) and building relationships which are more positive for NRM (McCool & Guthrie, 2001), just to mention a few.

Trust does not only create social obligations and social exchange but it also builds reciprocal relationships among actors in the network and, as Coleman (1990) notes, such reciprocal relationships increase trust which can be useful in acquiring optimistic environmental consequences. For crucial vertical networks such as that of VCDC in ANR which is central to collaborative NRM decision-making, reciprocal trust is a prerequisite feature that encourages actors to participate jointly in various pertinent discussions for proper decision-making and, eventually, the development of the communities involved in collaborative practices of NRM and improvement of the natural resources in general.

This paper treats trust as relational, developing between two or more actors by mutually reinforcing repeated interactions that allow for a pattern of reliability in exchanging information, knowledge, skills, support, and advice as well as in accomplishing expectations. Within this context VCDC in ANR, which believes in local collaboration of NRM, fits in examining the dynamics of trust relationships. From a theoretical point-of-view, this paper derives the view that relational trust among actors allow each actor to engage confidently in various discussions that result in decisions for the betterment of local communities of ANR and successful collaborative practices of NRM in ANR.

Data and Methods

Data were collected in the framework of a longitudinal study design to cover network and actor attributes panel data of two waves. As already stated, the study population is regarded as a vertical network of 23 actors who form the VCDC. These are 19 actors from all the nineteen villages of ANR, two actors who are councillors from two districts (Muheza and Korogwe) that border ANR and two actors representing the ANR authority (the Conservator and his assistant). VCDC is an important platform for collaborative NRM and it conducts meetings to discuss and decide on all issues pertaining NRM. It also acts as a bridge between local communities and the ANR Advisory Board, which normally meets twice in a year or any time as needed.

All the actors (a rate of 100%) participated in semi-structured interviews using a social network questionnaire. As the number of actors in this vertical network is small, a

list of names of all VCDC members was obtained from the headquarters of the ANR authority, where VCDC meetings principally take place. Data collection commenced immediately after the meetings, whereby Wave 1 data was collected in June 2010 and Wave 2 data in December 2010. This was a time lapse for the consecutive VCDC meetings.

Among other social network questions, all the actors were asked to indicate in the list, the names of actors that they trust or feel free to report to for any matter related to NRM. They were given freedom to indicate as many actors as they could. On the basis of their answers, an N by N *adjacency matrix* for each wave was created, where N is the number of VCDC actors in the vertical network. Following Wasserman and Faust (1994), whenever actor i indicated to trust actor j, then in the matrix entry of i, j was 1 whereas for all the other entries were 0. Actor attributes were coded as: *gender* (1=female; 2=male) and *age* (1=18-28 years; 2=29-38 years; 3=39-48 years; 4=49-58 years; 5=59+years).

For behavioural dynamics, particularly the influence-related measure, actors were asked the following question: *With regard to this NRM issue… and considering other members of VCDC, which level of influence do you consider yourself to assume on the decisions of its outcome during the last VCDC meeting?* Responses to this question were coded as 1=low influence; 2=moderate influence; 3=high influence; 4=can't reveal. The NRM issue was the one, which caused a serious debate during the two meetings, of which a researcher was allowed to attend as a participant observer.

During the VCDC meeting in June, 2010 the issue about income management and sources of income was discussed among other issues. It was postponed until the next meeting in December for deliberations to be made. Serious arguments from the majority of VCDC actors were on villages' benefits on the payment from forest border management, forest and river sources restoration works. Given its weight on decisions, the study considered it important to understand the actors' levels of influence and treats it as a behavioural variable.

As noted earlier, this paper uses the SAOM approach as proposed by Snijders and van Duijn (1997) and Snijders (2001), with a tutorial presentation in Snijders *et al.* (2010) and a detailed application of the co-evolution of networks and behaviours (also referred to as social selection and social influence) in Steglich *et al.* (2010). Under SAOM, actors are assumed to control their outgoing ties and since SAOM is a continuous-time model, ties change only one at a time and the probabilities of changes depend on the total current network configuration, similar to the principles of Holland and Leinhardt (1977). This approach allows for the use of rate functions to allot network or behaviour as types of change for each respective actor.

In this paper, two distinct choice functions are recursively fixed. Firstly, partner selection in the trust network (selection of a partner[s] to trust or who is easily approachable to report to any matter related to NRM and dissolution/termination of a tie[s]) is fitted. Secondly, behavioural change (influence on the decisions about NRM issues) is also fitted. The result of these choices is an objective function of the various actors in a trust network, gender and age being their attributes, all aimed to maximise an objective function under certain constraints. According to Snijders and van Duijn (1997: 496) this objective function may be regarded as a utility or expected utility, and both the objective function and the constraints are actor-dependent. As the model is stochastic, actors in the trust network are expected to choose actions (selections and dissolutions) that yield larger or lower objective function values, irrespective of lesser probability.

The paper utilises method-of-moments[2] (Snijders, 2001) implemented with the Robbins-Monro algorithm applied to computer simulation outcomes to estimate the parameters of the model. Based on the parameters, the trust network, which is the dependent variable (changing covariate), and the attributes of gender and age, which are independent variables (constant covariates) and influence on the decisions (as behaviours) are simulated. Then the results are compared with the data observed. As in the Robbins-Monro process of stochastic approximation, the parameters of the model are adjusted and repeated simulations of the dynamic process are then performed to allow the values of parameters to get closer and closer to the moment estimates. The paper uses a score function method described in the manual for **RSiena** (Ripley *et al.,* 2012) to calculate the standard errors.

Trust Network Models Specification

Simple trust models are specified on the basis of the relevant effects, which are the explanatory variables for both the trust network and behavioural change. Specification is done to reflect the hypothesis stated earlier given the effects that are expected to drive the network and behavioural dynamics.

This paper defines X as the trust adjacency matrix and for social selection part of the model, the objective function for trust network state x for VCDC actor i based on covariates y and behaviour z is defined as:

[2]. The method-of-moments is an approach to estimating population parameters, for example, the population mean or the population standard deviation. The basic idea with this approach is that one takes known facts about the population, and extends those ideas to a sample.

$$f_i^{net}(x,y,z) = \beta_{density}\sum_j x_{ij} + \beta_{recip}\sum_j x_{ij}x_{ji} + \beta_{transTrip}\sum_{j,h} x_{ih}x_{ij}x_{jh}$$
$$+ \beta_{g,sim}\sum_j x_{ij}\left(sim_{g,ij}g, average\right) + \beta_{a,sim}\sum_j x_{ij}\left(sim_{a,ij}a, average\right)$$
$$+ \beta_{z,sim}^{net}\sum_j x_{ij}\left(sim_{z,ij}z, average\right)$$
(1)

where $density$ denotes out-degree density (number of ties between actors i (ego) and j (alters), $recip$ denotes reciprocity, $transTrip$ denotes transitive triplets. Moreover, g stands for gender, a for age and z is the behaviour variable (influence on NRM decisions). The paper treats x_{ij} as a dummy variable. It is coded 1 if actor i chooses actor j for trust, and it is coded 0 if otherwise. For reciprocity, the variable $x_{ij}x_{ji}$ is coded 1 if actors i and j choose each other (mutually) for trust and for transitivity, the variable $x_{ih}x_{ij}x_{jh}$ is coded 1 if actors i and j both choose another actor h for trust, and it is coded 0 if otherwise. All these terms (effects) when combined in a linear sense provide a product of $f_i^{net}(x,y,z)$, which is the objective function for actor i. The paper considers every model component carrying a parameter estimate β as the actor's weight on a certain characteristic of her ties on the network.

For the social influence part of the model, the objective function for trust network state x for VCDC actor i based on covariates y and behaviour z is defined as:

$$f_i^{beh}(z,x) = \beta_{linear}(z_i - z_{average}) + \beta_{quad}(z_i - z_{average})^2$$
$$+ \beta_{beh}[\sum_j x_{ij}(sim_{z,ij}sim_{z,average}) / \sum_j x_{ij}]$$
(2)

where $linear$ stands for linear shape effect $(z_i - z_{average})$ and $quad$ stands for quadratic shape effect $(z_i - z_{average})^2$ all of which are centred by subtracting the mean value of the behaviour $z_{average}$.

Results and Discussion

This section presents results of the VCDC trust models. Results are presented in such a way to reflect the hypothesis stated earlier for a co-evolution of trust network and behaviour.

Descriptive

The in-degrees of the 23 VCDC actors that responded to the interviews at the first and second wave vary from 0 to 13 for the first wave and from 1 to 14 for the second wave. The out-degrees for these actors vary from 2 to 11 for the first wave and from 1 to 10 for the second wave. The skewed distribution for both in-degrees and out-degrees in each wave is less strong as the gap between minimum and maximum values is not reasonable.

With regard to the Jaccard index, which is used to measure the amount of change in the network, over the two subsequent network waves the Jaccard index is 0.741. This is sufficient to estimate our models as the SAOM approach requires Jaccard indexes to be higher than 0.3 (Snijders *et al.,* 2010: 49). All the statistics in each model show good convergence indicated by the *t*-ratios that are close to zero, hence revealing a good fit. Good convergence under the SAOM approach indicates whether the simulated values deviate from the values observed. Figure 1 shows the topological structure of two waves of trust network of 23 VCDC actors:

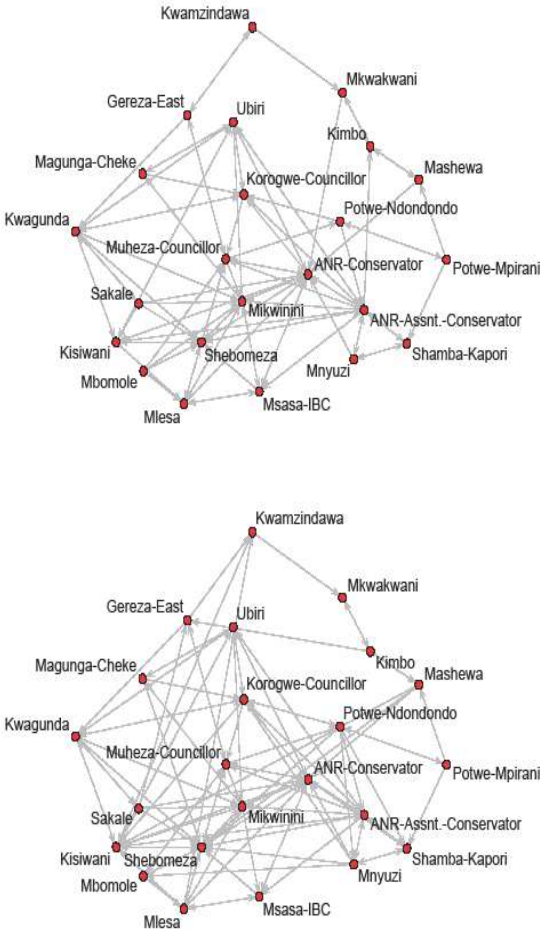

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Figure 1: *Trust Network structure of VCDC actors. Graph on the left shows the first wave and the graph on the right depicts the second wave. Actors are labelled on basis of the villages they represent or the positions they occupy.*

Parameter Estimates

To test our hypothesis by exploring whether actors with similar attributes tend to trust similar influential actors on the decisions about issues related to collaborative practices of NRM, this paper presents results of the two models (summarised in Table 1). The first model includes out-degree density, reciprocity, homophily effects for actor attributes and the behaviour similarity effect on trust network. All these aspects are for the network dynamic (social selection) part of the model whereas for behaviour dynamics (social influence part of the model) the first model includes the two effects that have to do only with the behavioural variable itself (linear and quadratic shape effects). The second model includes all the effects the stated effects included in the first model together with the transitive triplets (for social selection) and average similarity (for social influence).

Table 1: *SIENA Estimation Results for VCDC Trust Network Models*

VCDC Trust Models	**Model 1**			**Model 2**		
Effect	**par.**	**(s.e.)**	***T***	**par.**	**(s.e.)**	***t***
Network Dynamics						
Constant network rate t_1-t_2	1.52	0.31	4.90	1.52	0.29	5.24
Out-degree (density)	-0.45	0.28	-1.61	-0.93	0.33	-2.82
Reciprocity	0.14	0.47	0.30	-0.03	0.51	-0.06
Transitive triplets				0.23	0.09	2.56
Gender similarity	0.43	0.44	0.98	0.51	0.45	1.13
Age similarity	-0.19	0.78	-0.24	-0.05	0.75	-0.07
VCDC influence similarity	-0.70	1.86	-0.38	-1.42	1.78	-0.80
Behavioural Dynamics						
VCDC influence rate t_1-t_2	3.26	1.50	2.17	3.31	1.77	1.87
VCDC influence linear shape	0.06	0.26	0.23	0.06	0.30	0.20
VCDC influence quadratic shape	-0.25	0.22	-1.14	-0.27	0.48	-0.56
VCDC influence average similarity				-0.13	3.31	-0.04

Note. The weights in the evaluation function can be tested by *t*-statistics, defined as parameter (par.) estimate divided by its standard error (s.e.). They are significant if they are larger than +2 or less than -2. (The *t*-test should not be confused with the *t*-ratio for checking convergence).

For the social selection part of the model, both trust models offer one opportunity for change per actor between the first and second observation. This guarantees VCDC actors at least one opportunity for the selection or dissolution of trust network ties. Negative parameter values for out-degree density effects in both models signify that VCDC actors have a tendency of not establishing trust ties with just anyone as the cost of trust ties seems to be higher than their benefits. This is well-demonstrated in Figure 1 above whereby the topological structure of trust network in both waves seem to accord centrality to some particular actors because of their salient attributes that are controlled in the models, therefore, providing evidence to confirm our hypothesis.

The reciprocity effect is positive and significant in Model 1 but negative and insignificant in Model 2. This implies the tendency of VCDC actors to establish or maintain trust ties to those who themselves establish trust ties to them but when triadic level and behavioural similarity effects are not considered. The *t*-statistic for transitive triplets which is only included in Model 2 is positive and significant and can be regarded as the tendency of some VCDC actors (egos i) to select or keep alters j's trustworthy partners h (in similar sense of friend of a friend).

With regard to the homophily effects for actor attributes, both models show evidence of homophily on age but not on gender. This demonstrates the tendency of VCDC actors to choose or keep other actors of similar age for trust, or in other words, VCDC actors are more free to report on any matter pertaining to NRM to other actors of a similar age and but not necessarily of similar gender.

According to the homophily hypothesis (which one of the oldest network mechanisms used to explain interpersonal close ties, van de Bunt *et al.* (2005: 342), citing Festinger *et al.* (1950); Lazarsfeld & Merton (1954); Blau (1977), "the more characteristics ego and alter have in common (in the case of this paper they are named attributes), the more likely they will develop a close relationship…"

Results on the significance of age similarity among VCDC actors suggest that trust is a readily available aspect of similarity-attraction given the interactions of actors with different age categories during and after VCDC meetings. Moreover, both models provide evidence of the preference for alters who have values that are similar to the ego's values on behavioural attribute (influence on decisions about issues related to local collaborative practices of NRM). This follows a significant *t*-statistic for VCDC influence similarity effect.

For the social influence part of the model, both models exhibit at least three opportunities for change of behaviour (VCDC influence) per actor between the first and second observation. Shoham *et al.* (2012: 7) state that the behaviour objective function is gentler than the network function since it allows an actor to make only three choices: Stay the same; move up one unit; or move down one unit. Based on this observation, the behavioural dynamics of VCDC trust models signal the probability of egos staying the same or changing the current behaviour up to one unit (given the positive linear shape parameter value) but also the probability for changing future behaviour down one unit (given the negative quadratic shape

parameter value). However, such probabilities depend also on the behaviour (VCDC influence) average similarity, which is included only in Model 2. Looking at the significant *t*-statistic on the behaviour average similarity, one can note at least the tendency of some VCDC actors (egos) whose levels of influence differ from that of their alters to integrate their alters with similar attributes by trying to increase their influence on decisions pertaining to issues related to local collaborative practices. This partly resonates with the findings by McAllister *et al.* (2005: 2337), who at some point, found that individuals with increasing amount of trust in others tend to achieve better outcomes from agistment.

Overall, examining these two VCDC trust network models reveals that transitivity prevails among VCDC actors when it is included in the model alongside two other structural effects (out-degree and reciprocity), the homophily effects for actor attributes (gender and age), the behaviour similarity effect on network (VCDC influence similarity) but more importantly with the behaviour average similarity. Moreover, age similarity and not gender similarity triumphs in the VCDC trust network whether with the exclusion or the inclusion of transitive triplets and VCDC influence average similarity. This confirms our hypothesis that VCDC actors with similar attribute(s) (in this case age) tend to trust similarly influential actors when it comes to decisions on issues related to local collaborative practices of NRM.

Conclusion

Although the two trust models presented in this paper are simple, they allow one to consider the importance of examining the co-evolution of network (social selection) and behaviour (social influence). This paper employed three structural effects, two homophily effects for actor attributes, one behavioural similarity on the part of social selection and two effects of the behavioural variable itself and one effect for behaviour average similarity on the part of social influence. This approach has helped to explain the role of homophily and the influence of actors in choosing or maintaining trust ties in the context of collaborative practices of NRM.

Irrespective of the small dataset of only 23 actors forming the VCDC vertical network, the VCDC actors partly exhibit positive features of reciprocity with regard to trust when transitive triplets and behaviour average similarity are not considered but also allow for the presence of transitivity when behaviour average similarity is considered. This scenario easily facilitates the selection, maintenance or dissolution of trust ties among actors in addition to shaping the probability of these actors to stay the same or change their influence behaviour on decisions pertaining to NRM issues. Eventually, this situation may have some implications for improving the decision outcomes for successful collaborative practices of NRM in ANR.

This paper admits some data limitations because the collection of trust information appears to be an intricate process due to the complexity of the trust concept itself. A simple question in the social network questionnaires of *"Who do you trust or feel free to report to for any matter related to natural resources?"* might imply different interpretation to different actors and, probably, it would always be prone to further clarification. Inclusion of more questions resulting from measuring

the levels and types of trust that would help to differentiate between expressive and instrumental trust would have helped to overcome this data limitation. In this regard, Putnam (1995) notes, "since trust is so central to the theory of social capital, it would be desirable to have strong behavioural indicators of trends in social trust or misanthropy". However, as the primary purpose of this paper was to develop and provide two simple models using the stochastic actor-oriented modelling (SAOM) approach for dynamics of trust relationships, the models' results and the theoretical discussions may still help to demonstrate the context of a small vertical network of actors involved in the local collaborative practices of NRM in ANR for a successful collective action.

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