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Social network analysis: Which contributions to the analysis of agricultural systems resilience?

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1 **Social network analysis: which contributions to the analysis of agricultural systems resilience ?**

2

3 **Highlights**

4 • Social relational networks are instrumental for the sustainability of social-ecological systems
5 and their resilience in the face of perturbations.

6 • Their role in the resilience of agricultural systems remains understudied.

7 • This special issue highlights the contributions of social network research to understand the
8 processes driving agricultural systems resilience.

9 • Contributions to this issue illustrate the diversity of social network analysis approaches that can
10 be applied to this research question.

11 • Research perspectives for this research field are presented.

1 Edito for the special issue “Social networks: insights for the transition towards resilient agriculture”

2

3 **Social network analysis: which contributions to the analysis of agricultural systems resilience ?**

4

5 **Abstract**

6 Agricultural systems around the world face the major challenge of the transition toward greater
7 resilience. Given this, there is a need for understanding the processes undermining the resilience of
8 agricultural systems, as social-ecological systems, i.e., driving their capacity to evolve, adapt, or
9 transform to cope with new constraints and opportunities. Social relational networks involving a
10 diversity of stakeholders play a key role in these processes as they drive the circulation of material and
11 non-physical resources in agrarian societies, but their role in the resilience of agricultural systems
12 remains understudied. This special issue features diverse contributions to understanding the role of
13 social networks in the resilience of agricultural systems, which covers their capacity to evolve, innovate,
14 adapt, and transform. These studies cover a wide range of agricultural systems in different geographic
15 areas and span over different space and time scales. They analyze networks with different kinds of
16 actors and relationships and illustrate the different methodological approaches that can be used for
17 collecting and analyzing network data. In this editorial, we summarize this diversity of approaches and
18 discuss their contribution to understanding the role of social networks in the resilience of agricultural
19 systems. Based on this synthesis, we draw research perspectives for this research field.

20

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3 Agricultural Systems journal

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5 **Social network analysis: which contributions to the analysis of agricultural systems resilience ?**

6

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17

18 **Abstract**

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32 systems. Based on this synthesis, we draw research perspectives for this research field.

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34 **Highlights**

- 35 • Social relational networks are instrumental for the sustainability of social-ecological systems
36 and their resilience in the face of perturbations.
- 37 • Their role in the resilience of agricultural systems remains understudied.

- 38 • This special issue highlights the contributions of social network research to understand the
39 processes driving agricultural systems resilience.
- 40 • Contributions to this issue illustrate the diversity of social network analysis approaches that can
41 be applied to this research question.
- 42 • Research perspectives for this research field are presented.

43

44 **1. Introduction**

45

46 Farming systems around the world face the major challenges of the transition toward more sustainability
47 and resilience while adapting to global change. In this perspective, there is a need for understanding the
48 processes undermining the resilience of agroecosystems, defined as social-ecological systems, i.e. their
49 capacity to adapt or transform to face perturbations. Environmental management literature indicates
50 that social relational networks involving a diversity of stakeholders play a major role in the
51 sustainability of social-ecological systems and their resilience in the face of perturbations (Barnes et al.
52 2017; 2020; Rockenbauch et Sakdapolrak 2017). The kind of actors involved and the way their
53 interactions are framed proved to affect the circulation and dynamics of material and immaterial
54 resources in a system, and are instrumental in actors' coordination and collective action for the
55 sustainable use of common natural resources (Bodin 2017) or landscape management (Guerrero et al.
56 2013).

57 Social network research expanded over the last decade on topics related to agriculture, and brought
58 valuable insights on different aspects of agroecosystems functioning. This literature particularly focused
59 on the social networks driving farmers' access to different resources, such as crop seed circulation
60 networks (Pautasso et al. 2013; Coomes et al. 2015; Ricciardi 2015) or advice networks (Conley et Udry
61 2001; Isaac 2012; Skaalsveen, Ingram, et Urquhart 2020). Some authors also explored the role of social
62 networks for dealing with management issues that go beyond the farm level (e.g. pests regulation, runoff
63 control), and in collective action (e.g. Pachoud, Labeyrie, et Polge 2019; Abizaid et al. 2018).

64 Social network is hence a flourishing research field in agricultural research, and brought significant
65 insights on the processes involved in agroecosystems functioning. However, this research rarely
66 discussed the implication social networks composition and structure have for the adaptation, transition,
67 or transformation of agroecosystems in the face of the new challenges raised by global change.

68 In this context, this special issue aims to highlight and illustrate the diversity of contributions brought
69 by social network research to the understanding of the processes driving the resilience of agricultural
70 systems, i.e. their capacity to adapt or transform. This special issue hence addresses the following
71 question: *What can be the contribution of social network analysis to understand the mechanisms that
72 determine the resilience of agricultural systems, and to identify what levers can be mobilized for their
73 transition, at different levels?*

74

75 **2. Networks and resilience**

76

77 Agricultural systems are increasingly subject to shocks of different kinds, climatic ones being
78 particularly preoccupying (Cottrell et al. 2019). In the face of an increase in the frequency and strength
79 of shocks, the concept of resilience has grown more interesting for research and development
80 stakeholders. The resilience of social-ecological systems covers both their capacity to adapt to
81 perturbations by absorbing them, or to transform by fundamentally reorganizing themselves (Walker et
82 al. 2006; Folke et al. 2010). Agricultural systems are social-ecological systems, in which people and
83 the different biological entities that compose cultivated ecosystems are linked through a variety of ties
84 (see Box.1). Social networks, which connect individuals or groups, are acknowledged to play a key role
85 in the resilience of social-ecological systems (Folke, Colding, et Berkes 2003; Armitage et al. 2009).
86 Indeed, social networks drive the circulation of material and immaterial resources, and they are key for
87 communities' cohesion and organization, which are crucial aspects for responding to perturbations.
88 Understanding the role of social networks in social-ecological system resilience is thus pivotal for
89 designing locally adapted development actions and decision-making that build on local resilience
90 mechanisms.

91 In their review, Rockenbauch and Sakdapolrak (2017) identified three main research areas that
92 bring insights on the resilience of rural communities in the Global South, and this typology applies also
93 for the resilience of agricultural systems. The main area of research dealing with the role of social
94 networks in agricultural systems is that of agricultural innovation, which rarely refers explicitly to
95 resilience while innovation mechanisms are instrumental for it (Rockenbauch et Sakdapolrak 2017).
96 This body of literature concentrates on advice or information diffusion and social learning (see for
97 instance Conley et Udry 2001; Matous 2015; Klerkx, Aarts, et Leeuwis 2010).

98 Then, another area of research that brings insights on the role of social networks in the resilience
99 of agricultural systems analyzes how networks drive farmers' access to different types of resources and
100 are part of household risk management practices (Rockenbauch et Sakdapolrak 2017). These studies
101 conceptualize social networks as part of households' social capital and analyze how they drive farmers'
102 access to financial and material resources but also to other immaterial resources.

103 A third area of research that brings insights on the resilience of agricultural systems is that of
104 natural resource management, which explicitly explored the role of social networks in social-ecological
105 systems resilience (Janssen et al. 2006; Bodin 2017; Barnes et al. 2017). Using structural approaches,
106 these studies analyze how the connectivity patterns between actors, but also between actors and
107 ecosystems, affect collective action and governance outcomes (see for instance Sayles et Baggio 2017).
108 Recently, Barnes et al. especially proposed a framework for analyzing how the nature of actors involved
109 and the way they are connected together and with ecosystems, i.e. social-ecological network structure,
110 drive the adaptation and transformation capacity of social-ecological systems (Barnes et al. 2017;

111 Felipe-Lucia et al. 2021). However, studies dealing with agricultural systems are rare in the latter
112 research area (Hauck, Schmidt, et Werner 2016; Leventon et al. 2017).

113 Last, some recent studies attempted to link the latter research area to agroecology issues,
114 analyzing biological flows in agricultural systems in relation with social connections, and discussing
115 how these social-ecological connectivity patterns affect agroecosystem resilience. This was especially
116 the case for seed circulation (see Labeyrie et al. 2021 for a synthesis), but frameworks were also
117 proposed for other types of ecological flows in agroecosystems (Bohan et al. 2013).

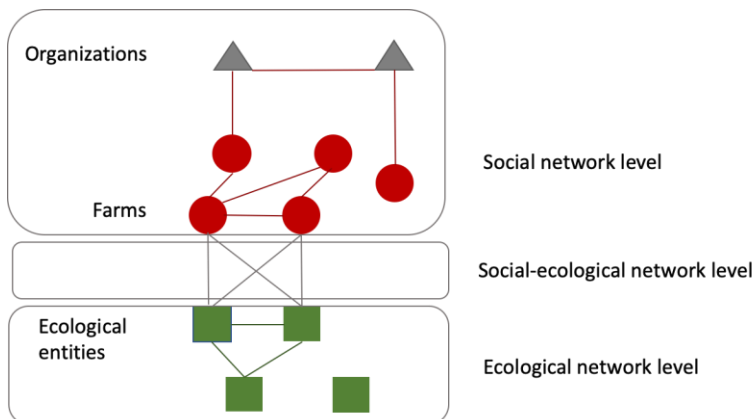
118

119 **Box 1 : social-ecological networks and resilience: some concepts and vocabulary**

120 Networks are a way to represent and analyze pairwise relationships or interactions, represented as ties,
121 between entities, represented as nodes. In social-ecological networks, nodes can be social actors
122 (individuals, households, groups or institutions) or biological ones (species, varieties, landscape units).
123 Ties can be: i. social interactions of different kinds, such as learning, exchange of information, or
124 transfers of material or financial resources; ii. ecological flows (e.g flows of organic matter, of
125 biological material), including ecological interactions (predation, pollination, etc.), iii. social-ecological
126 interactions, such as management actions from social actors on ecological units (planting, harvesting,
127 etc.). The structure of the network is the footprint of the social and ecological processes involved in the
128 system studied, and it has impacts on the circulation of resources of different kinds. By analyzing this
129 structure, it is possible to predict the behavior of the system, for instance its response to perturbations.

130

131 FIGURE 1: social-ecological network display (based on Barnes et al.2017)



132

133 **Network patterns and resilience** (based on Barnes et al 2017):

134 According to these authors, the way actors are linked together matters for their capacity to adapt or
135 transform. For instance, cohesion between actors, which can be gauged using network closure (Fig. A),

136 is expected to be key for the adaptation of social-ecological systems as it facilitates the negotiation of
137 new arrangements, collective organization, and social learning. Centralized networks, in which a few
138 actors act as “hubs” (Fig B), limit transaction costs and allow rapid decision-making and coordination.
139 Another key structural pattern for the transformation of social-ecological systems is the connectivity
140 between a diversity of actors (Fig C), which enhances the innovation and diffusion of new resources
141 and knowledge. Furthermore, the connectivity between institutional actors at different levels and
142 “ground actors” (Fig D) is also key for the transformation of SES, especially for rapidly responding to
143 local problems through measures adapted to the local contexts.

144 These authors also underline that not only the connectivity between social actors but also between these
145 actors and the ecological entities is key in the ability of social-ecological systems to adapt (Fig C). For
146 instance, socially connected actors managing ecologically connected units (e.g. landscape patches)
147 favors coordination for managing more efficiently environmental issues at the landscape level (Bodin,
148 Sandström, et Crona 2016).

149 **3. Contribution of this special issue**

150
151
152 This special issue consists of studies that cover a wide range of agricultural systems in different
153 geographic areas, from smallholder rainfed agriculture in Sahel, to input-intensive farming in Europe.
154 These studies analyze networks with different kinds of actors (nodes) and relationships (ties), e.g.
155 collaboration networks between individuals and organizations involved in agricultural research or
156 governance, or farmer-to-farmer resource-sharing networks. The networks studied span over different
157 geographical extents, from the very local scale at the village level, to the national scale. The studies
158 cover different time scales, most of them being snapshot studies or retrospective surveys, and only a
159 few analyze temporal series over several years. Last, this special issue is especially illustrative of the
160 different methodological approaches that can be used for collecting and analyzing network data.

161 162 **3.1. The diversity of relationships studied**

163 The theoretical literature on resilience puts emphasis on the importance of connectivity between social
164 and ecological entities, which covers different types of social, ecological and social-ecological
165 relationships. In their review on social networks and resilience in rural communities, Rockenbauch et
166 Sakdapolrak (2017) observed that a majority of studies deal with information diffusion, learning or
167 advice networks between social actors. This is also the case in this special issue, although the
168 relationship studied cover various domains: how to implement a set of agroecological innovative
169 practices in Mexico (Camacho-Villa et al.), how to prevent the damages of climate change in Peru
170 (Blasquez et al.), how to manage irrigation in Ethiopia (Mekonnen et al.), which improved maize variety
171 to grow in Kenya (Giroux et al.), or how to prevent banana disease in Rwanda (Kabirigi et al.). Another
172 approach is that of Slijpers et al., who analyzed the ties mobilized by Dutch farmers for learning in

173 general, without specifying a particular management domain. Beyond information and advice, other
174 immaterial resources are of interest for agricultural systems' resilience but were more rarely studied
175 through social network analysis. This is the case e.g. for access to resources such as administrative
176 support, technical skills or market opportunities, which were part of the pool of immaterial resources
177 studied by Polge et al. in their study on the resources mobilized by organic and conservation agriculture
178 farmers in the France Limagne region for adopting agroecological practices. Last, the study of Junquera
179 et al. considered the whole range of relationships mobilized by swiss farmers in their daily interactions
180 without specifying any particular domain or context.

181 Then, a pool of studies in this special issue focus on the circulation of biological entities, mainly
182 planting material and seeds. This is the case of Porcuna-Ferrer et al. and Labeyrie et al. in Senegal, and
183 Mariel et al. in Madagascar. This research theme has experienced a growing interest over the last
184 decades as it is a key aspect of smallholder farmers' resilience in the global south because crop diversity
185 is one of the main resources that farmers can mobilize as they have limited financial and material assets
186 (Pautasso et al. 2013, McGuire et Sperling 2016).

187 Last, Zimmerer et al., adopted an original approach by considering all the different types of
188 resources circulating between peri-urban and rural landscapes, ranging from water or other agricultural
189 inputs to workforce or financial resources.

190

191 **3.2. The diversity of methods applied**

192 The studies in this issue adopted different methods to document social and ecological ties. Part of the
193 studies based their analysis on surveys conducted through questionnaires with the objective to analyze
194 the connectivity of farms with different stakeholders. Some of these studies conducted large-scale
195 surveys over thousands of farms and covered a broad geographic area. For instance, Blasquez et al. used
196 data from the national institute of statistics covering four years and around 30 000 smallholders and
197 1500 large scale farmers in the 25 regions of Peru. Camacho-Villa used data collected through and
198 extensive subsidy program implemented by Mexican Government in around 30 000 farms. Other studies
199 were conducted on a smaller farms sample and within a smaller geographic area, such as Junquera et
200 al. who surveyed through e-mail around 100 farms within a UNESCO reserve area in Switzerland. This
201 type of data was analyzed through egocentric network data treatment, which encompasses the
202 computation of network metrics at the node level (e.g. farm level) and nodes clustering methods.
203 Examples of network metrics used in these studies are degree, i.e. the number of connections of a node,
204 and degree diversity indices such as the Shannon index which quantify the diversity of relationships
205 between actors, e.g. farmers and the different types of actors they are connected to (e.g., Camacho-Villa
206 et al., Junquera et al.). For instance, Junquera et al. computed indices of contacts' type diversity based
207 on Shannon index that accounts for the frequency of contacts with the different types of stakeholders
208 such as agricultural organizations, agrobusiness, colleagues, or family and friends. Some authors
209 conducted node clustering based on these data, such as Blasquez et al. who applied Latent Block

210 Modeling to identify different groups of farms depending on the type of information sources they used
211 to learn about climate change adaptation. Latent block models (LBM) consist in a probabilistic model-
212 based clustering of the nodes (e.g. farmers) in which the clusters gather nodes with similar patterns of
213 connectivity, for instance farms presenting similar connectivity patterns with the different information
214 sources in the case of Blasquez et al. study.

215 Then, a set of studies focused on one or a small number of social units (e.g. villages) and
216 adopted a closed complete network sampling approach by surveying all individuals within these units.
217 This is for instance the case of Mekonnen et al. who analyzed the exchange of information concerning
218 the duration of irrigation events among farmers in an irrigation scheme in Ethiopia, or Giroux et al. who
219 analyzed the exchanges of information concerning maize varieties in a water-management community
220 in Kenya. This type of data allows specific types of data treatment, especially the implementation of
221 exponential random graph model (ERGM). ERGMs are dedicated to analyze the factors structuring
222 networks. These models assume that the probability of ties presence is proportional to the exponential
223 of a linear combination of network statistics, such as the number of ties, the presence of specific
224 substructures (motifs), or the distribution of node characteristics. In Giroux et al., ERGMs were used to
225 understand what factors predict the formation of an advice-seeking relationship between farmers.
226 Exogenous factors are farmer household-level attributes like highest level of education achieved or
227 physical distance from other households. In Kabirigi et al., ERGMs were used to analyze how the
228 different types of proximities between farmers (geographical, cognitive and social) affect the circulation
229 of information concerning the management of a Banana disease in four villages in Rwanda.

230 Other studies at the community scale rather applied linear models because they analyzed open
231 networks, i.e., part of the ties analyzed ranged outside the communities studied and were established
232 with actors who were not surveyed (Porcuna-Ferrer et al., Mariel et al., Mekonnen et al.). Linear models
233 quantify the relationship (approximated by a linear equation) between a variable of interest and
234 explanatory variables. In this class of models we can cite generalized linear models - called «
235 generalized» when the variable of interest might take discrete values such as the presence/absence of a
236 tie or the number of ties (degree). For instance, Mekonnen et al. used a linear model for analyzing how
237 personal relationships between farmers (e.g., being relatives, neighbor or friends) affect their probability
238 to exchange information concerning innovations. Porcuna-Ferrer et al. implemented linear models to
239 test the link between households' centrality in the network, a metric that measures how central is a node
240 within a network, and crop diversity at the farm level.

241 Some studies adopted qualitative data collection approaches such as Polge et al. who mobilized
242 the relational chain and quantified narration method, which consists in conducting qualitative semi-
243 structured interviews on the changes farmers implemented in their farms and documenting
244 systematically the resources they mobilized for implementing these changes and from which
245 stakeholder they get it. In this method, farmers narratives are then coded to allow quantitative data
246 treatment. Another approach is that of Zimmerer et al., who conducted expert interviews for

247 documenting the connectivity between rural and peri-urban landscapes in Spain. Slijpers used a
248 combination of semi-structured interviews, e-mail surveys and focus groups, from which they
249 triangulated the results to identify the actors influencing Dutch farmers' daily decision-making. The
250 data collected through qualitative methods were treated in very different ways in these studies. For
251 instance, Polge computed descriptive statistics such as the frequency of ties with the different types of
252 stakeholders (e.g., peers, farmers groups and unions, upstream and downstream commercial actors),
253 while Zimmerer applied Block Modelling approaches to analyze how the flows between pairs of
254 landscapes related to the different categories of resources (e.g. inputs, workforce, markets).

255

256 **4. Discussion and conclusion**

257

258 The diversity of relationships covered in this special issue illustrate the different aspects of importance
259 from a resilience perspective. Social learning and innovation diffusion are key aspects that have been
260 broadly studied in relation with resilience and are also more represented in this special issue. This
261 imbalance in the types of relationships illustrates the need for broadening the types of resources
262 considered to include the different types of resources needed by farms for adapting or transforming their
263 system. As illustrated by some of the studies in this special issue, research on the social-ecological
264 interactions in agricultural systems also opens promising perspectives for understanding the resilience
265 mechanisms (Barnes et al. 2017), and it would deserve further developments for agricultural systems
266 study. Last, more research is also needed on multi-actor and multi-level networks, to understand how
267 the connectivity patterns between farmers and the range of actors of the agricultural sector at different
268 institutional levels and different spatial scales affect agricultural systems resilience. Such approaches
269 proved to be valuable for understanding social-ecological systems resilience processes (e.g., Sayles et
270 Baggio 2017; Guerrero et al. 2013), and were rarely implemented on agricultural systems.

271 This special issue also illustrates that different approaches can be adopted according to the
272 relationship studied. Focusing on a particular type of relationship presents the advantage of getting more
273 precise data on the practices that farmers actually implement, while asking for general patterns may
274 lead to broader answers, and interviewees are more susceptible to forget some of the ties they
275 established. However, the latter approach may be of particular interest from a resilience perspective, as
276 it is multifaceted and covers different activities and resources within a farm. Finding a way to cover the
277 diversity of ties mobilized by farmers to adapt or transform their system, while getting precise and
278 quality data hence remains a key challenge for resilience research.

279 The temporal dimension of studies is also a crucial aspect for resilience research. In this special
280 issue, most studies were snapshots or adopted retrospective approaches, and only few of them collected
281 panel data. Snapshot studies are more limited for analyzing resilience mechanisms, as they do not allow
282 to monitor how farmers cope with perturbations as compared to regular situations. Most studies
283 adopting this approach do not document the role of networks in the resilience process, but rather discuss

284 how the network configurations they observe are expected to enhance or limit agricultural systems
285 resilience based on existing theoretical frameworks. Retrospective studies allow to capture temporal
286 dynamics and they are especially relevant for documenting processes of changes, but they raise issues
287 concerning the quality of data, as interviewees are more susceptible to forgetting some ties. Panel data
288 collection is rarely implemented because it is costly and the short time span of projects makes the
289 implementation of such approaches difficult, but they are more insightful for resilience research as they
290 allow to document on-going processes of change. Developing such approaches is needed to get a better
291 understanding of the actual role of the different network configurations at the different stages of
292 resilience processes, but it also raises major analytical challenges.

293 Last, this special issue illustrates the broad range of network analysis methods that can be used
294 in resilience studies. Descriptive statistics are the most frequently used, but inferential models allow to
295 go further in the analysis of the processes involved in agricultural systems resilience. Some methods
296 allow us to uncover the social processes driving the circulation of resources within communities, such
297 as linear models and ERGMs, which is insightful for understanding the social processes involved in the
298 resilience of agricultural systems. Other methods cluster nodes according to their connectivity patterns
299 (e.g., LBM), which can then be related to indicators of resilience to understand which network
300 configuration confers more resilience to agricultural systems.

301 To conclude, this special issue illustrates the rich contribution of social network research to the
302 understanding of resilience processes in agricultural systems. We identified different challenges for this
303 research area that are listed above. A last challenge is the development of mixed approaches, combining
304 structural social network analysis with qualitative methods. Some approaches, such as quantified
305 narration and relational chains open promising perspectives in this direction and pave the way for
306 developments both on the quantitative and qualitative sides. Quantitative and qualitative approaches are
307 complementary, and combining both would contribute to building a better understanding of the complex
308 processes involved in agricultural systems resilience.

309

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