Supplementary Information

1 List of actors selected for the analysis

Table 1: Description and characteristics of the actors selected for the analysis. Num. Inter.: Number of interviews. (*) indicates the interviews that were conducted with multiple participants.

Actor name	Scale	Sector	Description	Num. Inter.
Fish farmers	Local	Businesses	Small-scale and familiar fish farmers	1
Water-related businesses	Local	Businesses	Companies using water for their activities (distillers, slaughterhouse, car wash, public swimming pools)	2
Emolienteros	Local	Businesses	Vendors selling herbal beverages with medicinal properties	1
Plant traders	Local	Businesses	People harvesting and selling medicinal plants in local markets	1*
Transport companies	Local	Businesses	Companies proving transportation services (taxis, bus, freight carrier)	1*
Hotels and Restaurants	Local	Businesses	Hotels and restaurant	1
Ecotourism businesses	Local	Businesses	Businesses providing services related to ecotourism (travel agencies, guides, muleteers, rentals for extreme sports such as paraglider)	2
Natural resources based businesses	Local	Businesses	Businesses using natural resources for economic activities (such as craftsmen or brickmakers)	1
Agroindustrial companies	Local	Businesses	Food industries (dairy products, honey, traditional, noodles)	1*
Urban population	Local	Civil Society	Population that lives in urban areas of Abancay and Tamburco	2
Rural population	Local	Civil Society	Population living in rural settlements	3
Communities	Local	Civil Society	Rural organizations: communities (formally recognized legal personality with communal property rights) and sectors (group of people with individual rights)	2
JASS	Local	Civil Society	Community-managed organizations that provide sanitation and drinking water services in rural areas	1
JUDRAB	Local	Civil Society	Water user associations managed by communities and that provide irrigation water service	1
Ecotourism associations	Local	Civil Society	Associations of hikers or bikers	1
Abancay Municipality	Local	Public sector	Municipality of Abancay	2*
Tamburco Municipality	Local	Public sector	Municipality of Tamburco	1
EMUSAP	Local	Public sector	Water utility (public company) responsible for providing drinking water and sanitation services in urban areas of Abancay and Tamburco	1
Electro Sur Este	Sub-national	Businesses	Electricity utility (private company) responsible for the production and distribution of electric power in various regions of southern Peru	1
CEDES	Sub-national	NGO	Center for studies and social development	1
IIDA	Sub-national	NGO	Institute for research and Andean development	1
CICCA	Sub-national	NGO	Centre for research and rural training	1
RGA - Civil defense	Sub-national	Public sector	Regional office for civil defense (Regional Government)	1

Mariño micro-catchment Project	Sub-national	Public sector	Project aiming at improving agricultural production in the Mariño watershed through the integrated management of water resources	1
RGA - Economic Development	Sub-national	Public sector	Regional office for economic development (Regional Government)	4
RGA - Infrastructure	Sub-national	Public sector	Regional office for infrastructures (Regional Government)	3
RGA - Planning and Budget	Sub-national	Public sector	Regional office for planning and budget (Regional Government)	1
RGA - Natural resources	Sub-national	Public sector	Regional office for environment and natural resources (Regional Government)	1
RGA - Social Development	Sub-national	Public sector	Regional office for social development (Regional Government)	1
Tourists	National and International	Civil Society	National or international tourists	1*
PREDES	National and International	NGO	Centre for Disaster Prevention and Studies	1
Andean Forests program	National and International	NGO	Initiative from the Swiss Agency for Development and Cooperation aiming at promoting sustainable management of Andean forests	1
CESAL	National and International	NGO	Organization promoting integrated development models	1*
CARITAS	National and International	NGO	Catholic organization aiming at improving human development and responding to humanitarian emergencies	1
IDMA	National and International	NGO	Institute for Development and Environment	1
INDECI	National and International	Public sector	National Institute for Civil Defense	1
INGEMMET	National and International	Public sector	Geological Mining and Metallurgical Institute	1
CENEPRED	National and International	Public sector	National Centre for the Estimation, Prevention and Reduction of Disaster Risk	1
ANA	National and International	Public sector	National Water Authority	2*
SENAMHI	National and International	Public sector	National Service for Meteorology and Hydrology	1
Provias	National and International	Public sector	National road authority	1
PRODERN	National and International	Public sector	Program for Sustainable Economic Development and Strategic Management of Natural Resources	1
OEFA	National and International	Public sector	Agency for Environmental Assessment and Enforcement	1
Public prosecutor	National and International	Public sector	Public prosecutor specialized in environmental matters	1
SERNANP	National and International	Public sector	National Service of Natural Protected Areas	1
Peruvian ombudsman	National and International	Public sector	Office of Public Defender	1*
SERFOR	National and International	Public sector	National Forest Service	1
Police	National and International	Public sector	Police specialized in environmental matters	1
FONCODES	National and International	Public sector	Social Development and Compensation Fund Project	1*
AgroRural	National and International	Public sector	National program promoting rural agrarian development	1
SENASA	National and International	Public sector	National Agricultural Health Service	1

| Sierra Exportadora | National and International | Public sector | National program that promote the exportation of economic activities from Peruvian Andes | 1* |

2   Analysis of "primary relationships"

2.1   Construction of the primary relationships matrices and networks

Table 2 : Primary relationships structure and transformation.* When equal to one, these 11 matrices informed on the existence of a directed tie from "ego" (i.e. the interviewee) to "alter" (i.e. one of the 52 actors from the list) [12].

Type of interactions	Original matrices*: Information given by the cell (A,B)	Reciprocity calculation	Matrix transformations	Resulting matrices	Resulting networks
Influence	A said: "I share information with B" A said: "I advise B or I am advised by B"	Comparison of the matrix and its transposed	Adding the Boolean matrix and its transposed (i.e. A and B influence each other if either A reports an influence relationship with B or B reports a relationship with A)	2 symmetrical matrices	2 undirected networks of influence (information sharing and advice)
Domination	A said: "I restrict B's activities" (active matrix). A said: "I am restricted by B" (passive matrix) A said: "I supervise B" (active matrix). A said: "I am supervised by B" (passive matrix)	Comparison of the active matrix and the transposed of the passive matrix	Adding the Boolean active matrix to the transposed Boolean passive matrix (e.g. A dominates B if A reports dominating B or B reports being dominated by A)	2 asymmetrical matrices	2 directed networks of domination (restriction and supervision)
Cooperation	A said: "I have a common project with B" A said: "I regularly meet with B" A said: "I irregularly meet with B" A said: "I do business with B"	Comparison of the matrix and its transposed	Adding the Boolean matrix and its transposed (i.e. A and B cooperate with each other if either A reports cooperating with B or B reports cooperating with A)	4 symmetrical matrices	4 undirected networks of cooperation (common project, regular meetings, irregular meetings, business)
Conflict	A: "I am in conflict with B"		Adding the Boolean matrix and its transpose	1 symmetrical matrix	1 undirected network of conflicts

2.2 Characteristics of the primary relationships

Table 3: Undirected primary relationships networks. Recip: Reciprocity of ties in the networks; Num: number of ties; Dens: Density of the network (number of actual ties divided by total number of potential ties); Diam: Unweighted diameter of the network (the longest of all the shortest paths in the network); Trans: Transitivity of the network (number of actual triangles in the graph, divided by total number of connected triples of nodes. It is closely related to the presence of clustering).

	INFLUENCE			COOPERATION			CONFLICT
	Information sharing	Advice	Common project	Regular prof. meetings	Irregular prof. meetings	Business	
TRUE	2088	2448	2284	2256	2038	2620	2468
FALSE	616	256	420	448	666	84	236
Recip (%)	77.22	90.53	84.47	83.43	75.37	96.89	91.27
Num	570	163	351	347	600	55	135
Dens	0.43	0.12	0.26	0.26	0.45	0.04	0.10
Diam	3	4	3	3	3	4	6
Trans	0.64	0.25	0.46	0.54	0.66	0.30	0.24

Table 4: Directed primary relationships network. Recip: Reciprocity of ties in the networks; Num: number of ties; Dens: Density of the network (number of actual ties divided by total number of potential ties); Diam: Unweighted diameter of the network (the longest of all the shortest paths in the network); Trans: Transitivity of the network (number of actual triangles in the graph, divided by total number of connected triples of nodes. It is closely related to the presence of clustering).

	DOMINATION	
	Restriction	Supervision
TRUE	2621	2566
FALSE	83	138
Recip (%)	96.93	94.9
Num	110	178
Dens	0.04	0.07
Diam	5	8
Trans	0.13	0.28

3 Cooperation and conflicts networks

Figure 1: Network of cooperation. The size of nodes is proportional to the number of actors with whom each actor is cooperating (i.e. node degree).
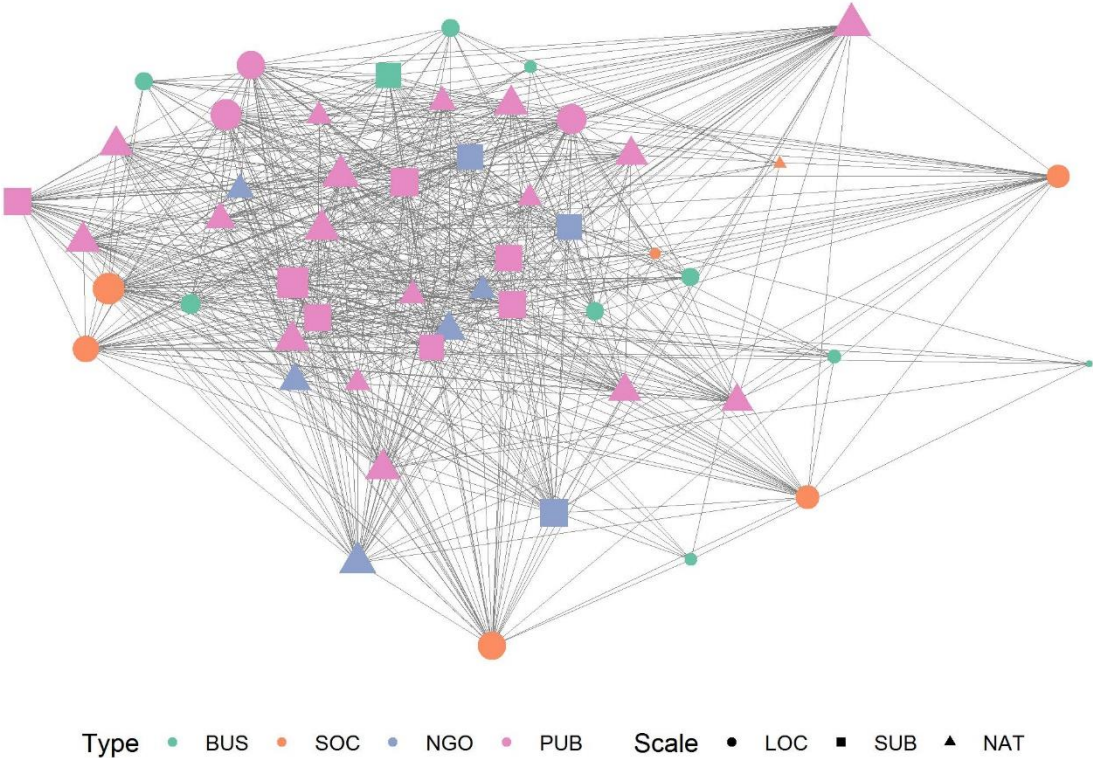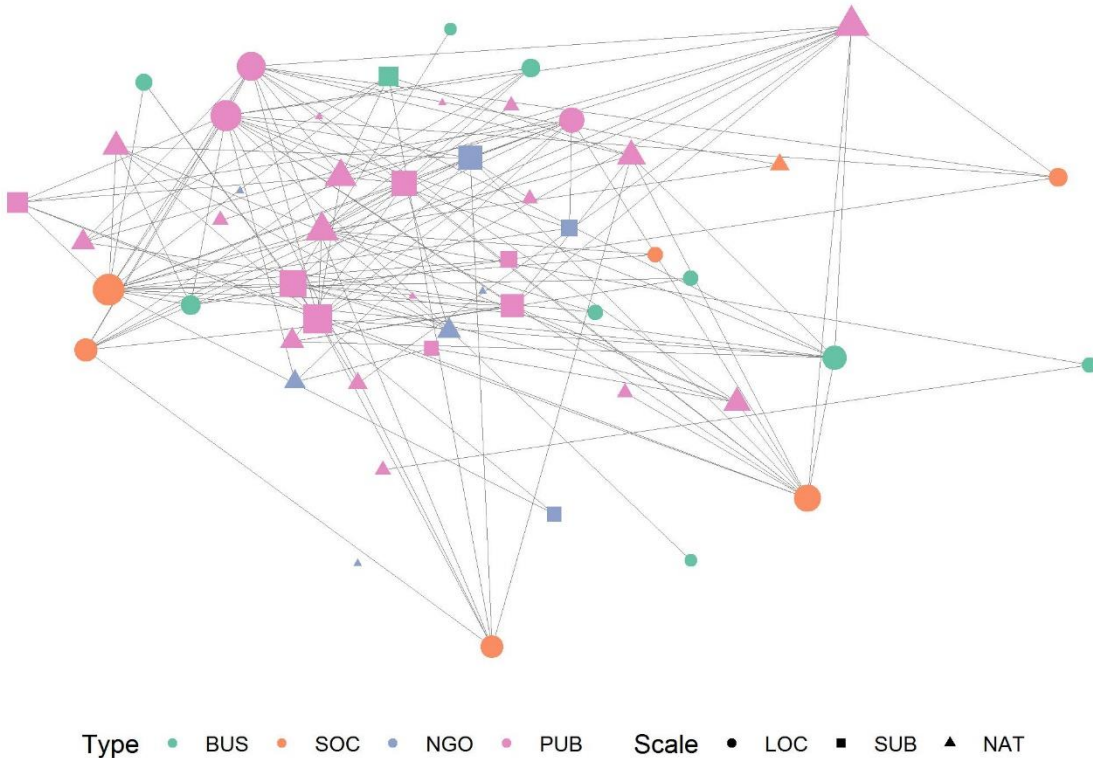

Figure 2: Network of conflicts. The size of nodes is proportional to the number of conflict in which each actor is involved (i.e. node degree).

4   Analysis of the core / periphery structure

4.1   Methods

The Core/periphery structure of influence and domination networks was analyzed using UCINET categorical partitioning algorithm, with 100 random starts and 5000 maximum iterations [1]. The effect of sector and level of intervention on the position in the network was tested using Clopper-Pearson exact Confidence intervals (CPCI) [2] and chi-squared test with standardized residual (SR) analysis [3].

Contingency tables and SR were represented as mosaic graphs [4]. Blue and red gradients indicate SR with absolute values exceeding critical values (i.e. significant differences at the 99%, 95% and 90% percentiles in the distribution of SR), and highlight a lack of independence between the two variables. Blue boxes indicate positive residuals (i.e. it is more likely to find actors in this category than expected if the variables were independent) and red boxes indicate negative residuals. Boxes with absolute residuals below the critical value of 90% are white if the Chi-squared test based on Pearson statistic is significant, and grey otherwise. The plots were drawn with the vcd package and R software [5–8]. We used PropCIs package to compute CPCI [9].

4.2   Confidence intervals

Table 5: Confidence intervals of the proportion of actors found in the core and periphery of influence and domination networks at a confidence level of 95 % (α=0.05), according to sectors (BUS=Business, SOC=Civil Society, NGO=Nongovernmental Organizations, PUB=Public Sector).

Sec.	N	Influence				Domination			
		Core		Periphery		Core		Periphery	
BUS	10	0.00 (0.00, 0.07)	a	1.00 (0.93, 1.00)	a	0.20 (0.16, 0.27)	a	0.80 (0.73, 0.84)	a
SOC	7	0.43 (0.35, 0.51)	b	0.57 (0.49, 0.65)	b	0.29 (0.22, 0.38)	ac	0.71 (0.62, 0.78)	ac
NGO	8	0.25 (0.19, 0.33)	c	0.75 (0.67, 0.81)	c	0.00 (0.00, 0.09)	b	1.00 (0.91, 1.00)	b
PUB	27	0.44 (0.42, 0.47)	b	0.56 (0.53, 0.58)	b	0.33 (0.31, 0.36)	c	0.67 (0.64, 0.69)	c

Table 6: Confidence intervals of the proportion of actors found in the core and periphery of influence and domination networks at a confidence level of 95 % (α=0.05), according to levels of intervention (LOC=Local, SUB=Subnational, NAT=National and International).

Lev.	N	Influence				Domination			
		Core		Periphery		Core		Periphery	
LOC	18	0.28 (0.25, 0.32)	a	0.72 (0.68, 0.75)	a	0.33 (0.30, 0.37)	a	0.67 (0.63, 0.70)	a
SUB	11	0.45 (0.40, 0.51)	b	0.55 (0.49, 0.60)	b	0.27 (0.23, 0.33)	a	0.73 (0.67, 0.77)	a
NAT	23	0.30 (0.28, 0.33)	a	0.70 (0.67, 0.72)	a	0.17 (0.15, 0.21)	b	0.83 (0.79, 0.85)	b

At confidence level of 95% (α =0.05), the CPCI indicated that actors from the business sector were significantly less in the core of the influence network than NGOs, and much less than public sector and civil society. The opposite pattern was logically observed in the periphery of the influence network, with significantly less actors from public sector and civil society than NGOs, and business sector. Actors with regional level of intervention were significantly more in the core, and less in the periphery of the influence network. NGOs were significantly less in the core of the domination network than business sector and civil society, the latter being with public sector significantly more in the core than all actors. The opposite trend was observed in the periphery of the domination network. National actors were significantly less in the core of the domination network, and more in the periphery.

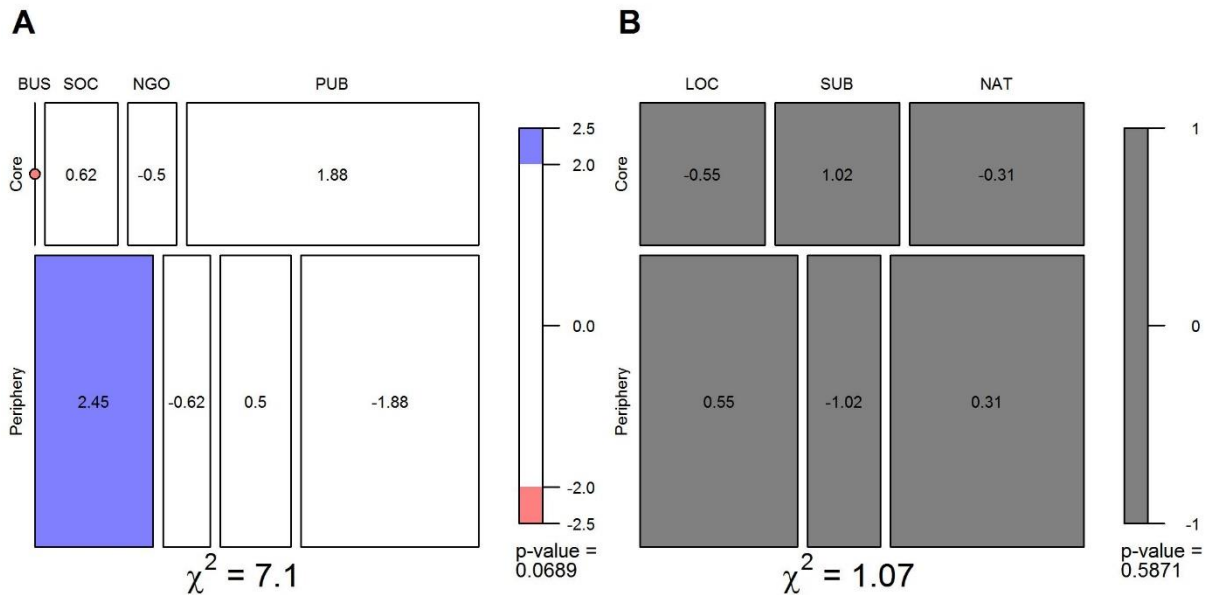## 4.3 Chi-squared tests and standardized residual analyses

Figure 3: Mosaic plots of the frequency distribution of the influence network position (core / periphery) for different groups of actors. The height of the box is proportional to the number of actors in the core and periphery of the network; and its width to the number of actors in each group: sector in Panel A (BUS=Business, SOC=Civil Society, NGO=Non-Governmental Organizations, PUB=Public Sector) and level of intervention in Panel B (LOC=Local, SUB=Sub-national, NAT=National and International). The value of Pearson chi-squared statistic (X^2) is indicated below each figure. SR are labeled in each mosaic cell.

Figure 4: Mosaic plots of the frequency distribution of the domination network position (core / periphery) for different groups of actors. The height of the box is proportional to the number of actors in the core and periphery of the network; and its width to the number of actors in each group: sector in Panel A (BUS=Business, SOC=Civil Society, NGO=Non-Governmental Organizations, PUB=Public Sector) and level of intervention in Panel B (LOC=Local, SUB=Sub-national, NAT=National and International). The values of Pearson chi-squared statistic (X^2) is indicated below each figure. SR are labeled in each mosaic cell.
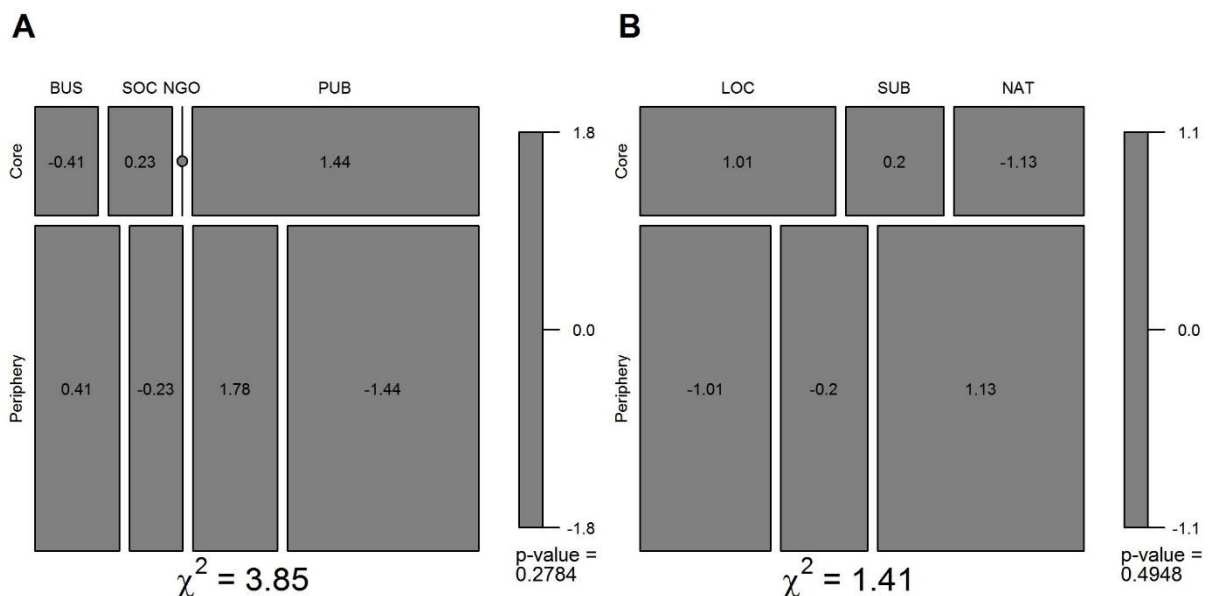
The Chi-squared test indicated that sector had a significant effect on the position in the influence network at confidence level of 90% (α =0.10), but not level of intervention. SR analysis indicated that actors from the business sector were significantly less in the core, and more in the periphery. It is

worth noting that the effect of sector was not significant at higher confidence level. Neither sector nor level of intervention had a significant effect on the position in the domination network.

5 QAP detailed results and diagnostics

We applied the quadratic assignment procedure (QAP) to model the existence of influence and domination relationships. Weighted influence and domination network were converted into two binary networks beforehand. The QAP models were fitted using the netlogit function included in the sna package [10], with 200 iterations for quantile estimation. Several explanatory variables were selected following different theoretical mechanisms and variable types (Table 4). Model goodness-of-fit was assessed before analyzing model terms significance and effect. The distribution of four characteristics of the modeled networks were plotted against those of observed networks: number of shared partners per edges, path distances, actors' degree centrality (in and out degrees were differentiated for domination since the network is directed) and k-star (tendency for actors to have multiple partners, as a sender or as a receiver in the case of directed networks). Goodness-of-fit analysis was conducted using btergm package [11].

QAP model fit was good for the two networks (Figure 5 and 6), although the Incoming k–star were slightly underestimated by the QAP model in the domination network.

Table 7: Results of the QAP models. Symbols display each variable significance level: . for p<0.10; * for p<0.05; ** for p<0.01 and *** for p<0.001.

Networks		Influence		Domination	
Baseline	Intercept	-2.33	***	-9.11	***
Actors' attributes	One of the actor is from BUS	-0.97	***		
	One of the actor is from SOC				
	One of the actor is from PUB	0.55			
	One of the actor acts at LOC				
	One of the actor acts at SUB				
	Receiver is from SOC sector			0.51	
	Receiver is from BUS sector			1.02	*
	Sender is from PUB			1.62	***
Paired actors' attributes	Same actor level of intervention	-0.33	.		
	Same actor type			0.77	*
	Difference in the level of intervention (coded as discrete variable)			0.85	***
Covariate network	Cooperation network	9.38	***	2.51	***
	Sender is central in the cooperation network (assessed with degree)			0.11	***
Pseudo adjusted R2		0.44		0.50	
BIC		823		1127	
AIC		797		1080	

Figure 5: Goodness-of-fit assessment of the QAP model for the influence network (undirected).
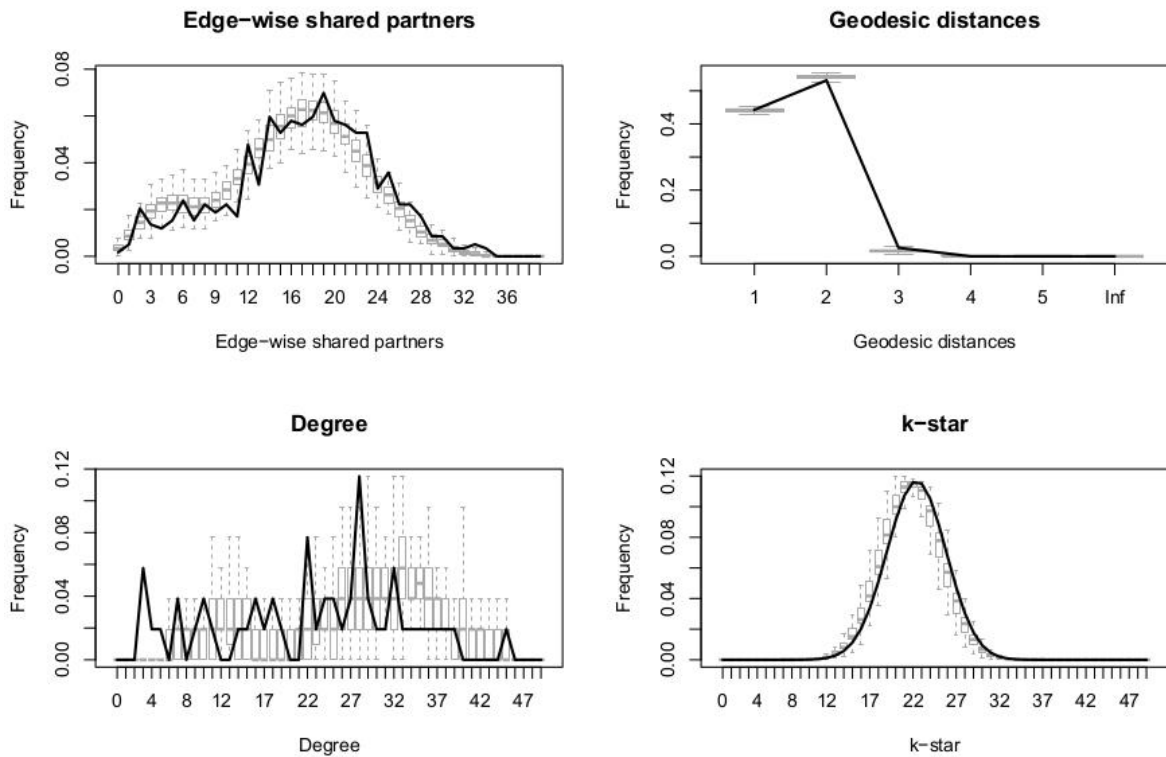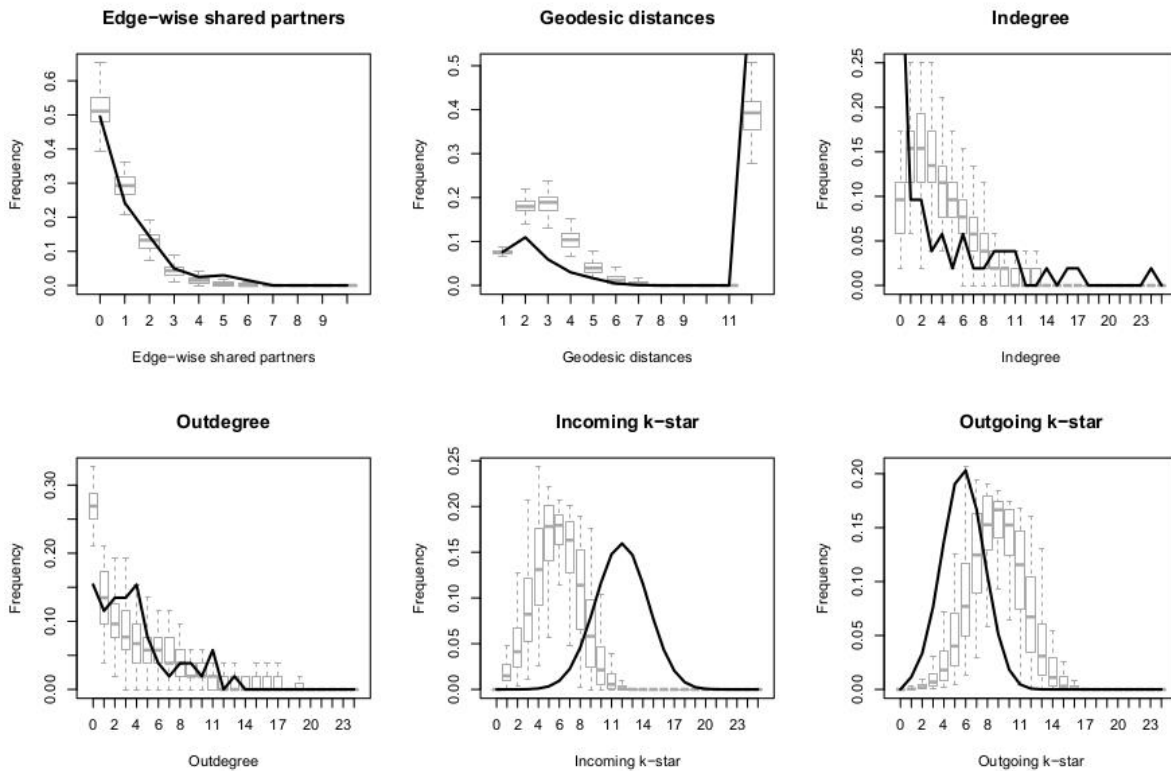

Figure 6: Goodness-of-fit assessment of the QAP model for the domination network (directed).

6   Forms of power and actors' characteristics

6.1   Methods

The effect of sector and level of intervention on the forms of power handled by actors was tested using Clopper-Pearson exact Confidence intervals (CPCI) [2] and chi-squared test with standardized residual analysis [3].

Contingency tables and SR were represented as mosaic graphs [4]. Blue and red gradients indicate SR with absolute values exceeding critical values (i.e. significant differences at the 99%, 95% and 90% percentiles in the distribution of SR), and highlight a lack of independence between the two variables. Blue boxes indicate positive residuals (i.e. it is more likely to find actors in this category than expected if the variables were independent) and red boxes indicate negative residuals. Boxes with absolute residuals below the critical value of 90% are white if the Chi-squared test based on Pearson statistics is significant, and grey otherwise. The plots were drawn with the vcd package and R software [5–8]. We used PropCIs package to compute CPCI [9].

6.2   Confidence intervals

Table 8: Confidence intervals of the proportion of actors found in Knoke's power categories at a confidence level of 95 % (α=0.05), according to sectors (BUS=Business, SOC=Civil Society, NGO=Nongovernmental Organizations, PUB=Public Sector).

Sec.	N	Authoritative power		Coercive power		Persuasive power		Weak power	
BUS	10	0.00 (0.00, 0.07)	a	0.00 (0.00, 0.07)	a	0.00 (0.00, 0.07)	a	1.00 (0.93, 1.00)	a
SOC	7	0.00 (0.00, 0.10)	a	0.29 (0.22, 0.38)	b	0.43 (0.35, 0.51)	b	0.29 (0.22, 0.38)	b
NGO	8	0.00 (0.00, 0.09)	a	0.25 (0.19, 0.33)	bc	0.50 (0.43, 0.57)	b	0.25 (0.19, 0.33)	b
PUB	27	0.59 (0.57, 0.62)	b	0.19 (0.17, 0.21)	c	0.11 (0.09, 0.14)	c	0.11 (0.09, 0.14)	c

Table 9: Confidence intervals of the proportion of actors found in Knoke's power categories at a confidence level of 95 % (α=0.05), according to levels of intervention (LOC=Local, SUB=Subnational, NAT=National and International).

Sec.	N	Authoritative power		Coercive power		Persuasive power		Weak power	
LOC	18	0.11 (0.09, 0.15)	a	0.06 (0.04, 0.10)	a	0.17 (0.14, 0.21)	a	0.67 (0.63, 0.70)	a
SUB	11	0.36 (0.32, 0.42)	b	0.09 (0.06, 0.15)	a	0.36 (0.32, 0.42)	b	0.18 (0.14, 0.24)	b
NAT	23	0.43 (0.41, 0.46)	b	0.30 (0.28, 0.33)	b	0.13 (0.11, 0.16)	a	0.13 (0.11, 0.16)	b

At confidence level of 95% (α =0.05), the CPCI indicated that actors from the public sector were significantly more in the authoritative power group, and that actors from the local scale were significantly less. Actors in the coercive power group were significantly less from the business sector. National and international actors were significantly more in the coercive power group. NGO and civil society were significantly more in the persuasive power group than public sector and business sector, the former being significantly more frequent than the latter. Actors from the regional level were significantly more in the persuasive power group. And finally, business sector was significantly more in the weak power group, as well as local actors.

6.3 Chi-squared tests and standardized residual analyses

Figure 7: Mosaic plots of the frequency distribution of the forms of power handled by different groups of actors. The height of the box is proportional to the number of actors in the different categories of power; and its width to the number of actors in each group: sector in Panel A (BUS=Business, SOC=Civil Society, NGO=Non-Governmental Organizations, PUB=Public Sector) and level of intervention in Panel B (LOC=Local, SUB=Sub-national, NAT=National and International). The values of Pearson chi-squared statistic (X^2) is indicated below each figure. SR are labeled in each mosaic cell.
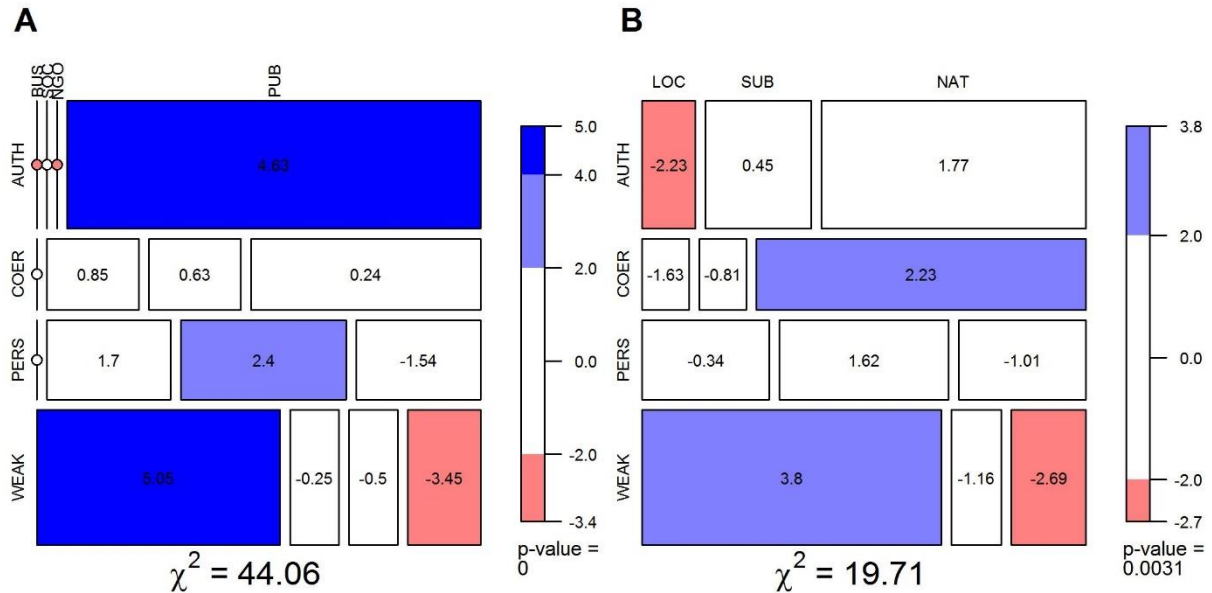
The Chi-squared test indicated that both sector and level of intervention had a significant effect on the forms of power handled by actors at confidence level of 99% (α =0.01). SR analysis indicated that actors in the authoritative power group (high levels of both influence and domination) were significantly less from the business sector, from the NGOs sector and from the local scale, but significantly more from the public sector. National and international actors were significantly more in the coercive power group (high domination and low influence). NGOs were significantly more in the persuasive power group (high influence and low domination). And finally, actors in the weak power group (low influence and low domination) were significantly more from the business sector and the local scale, and significantly less from the public sector as well as national and international scale.

7   QAP diagnostic for conflict network

We applied the quadratic assignment procedure (QAP) to model the existence of conflicts between actors. The QAP models were fitted using the netlogit function included in the sna package [10], with 200 iterations for quantile estimation. Model goodness-of-fit was assessed before analyzing model terms significance and effect. The distribution of four characteristics of the modeled networks were plotted against those of observed networks: number of shared partners per edges, path distances, actors' degree centrality (in and out degrees were differentiated for domination since the network is directed) and k-star (tendency for actors to have multiple partners, as a sender or as a receiver in the case of directed networks). Goodness-of-fit analysis was conducted using btergm package [11].

We fitted two models: one including only domination network as a covariate (Model 1), and a second including domination and influence networks (Model 2). Model fit was better for Model 1 than for Model 2 (Figure 8 and 9).

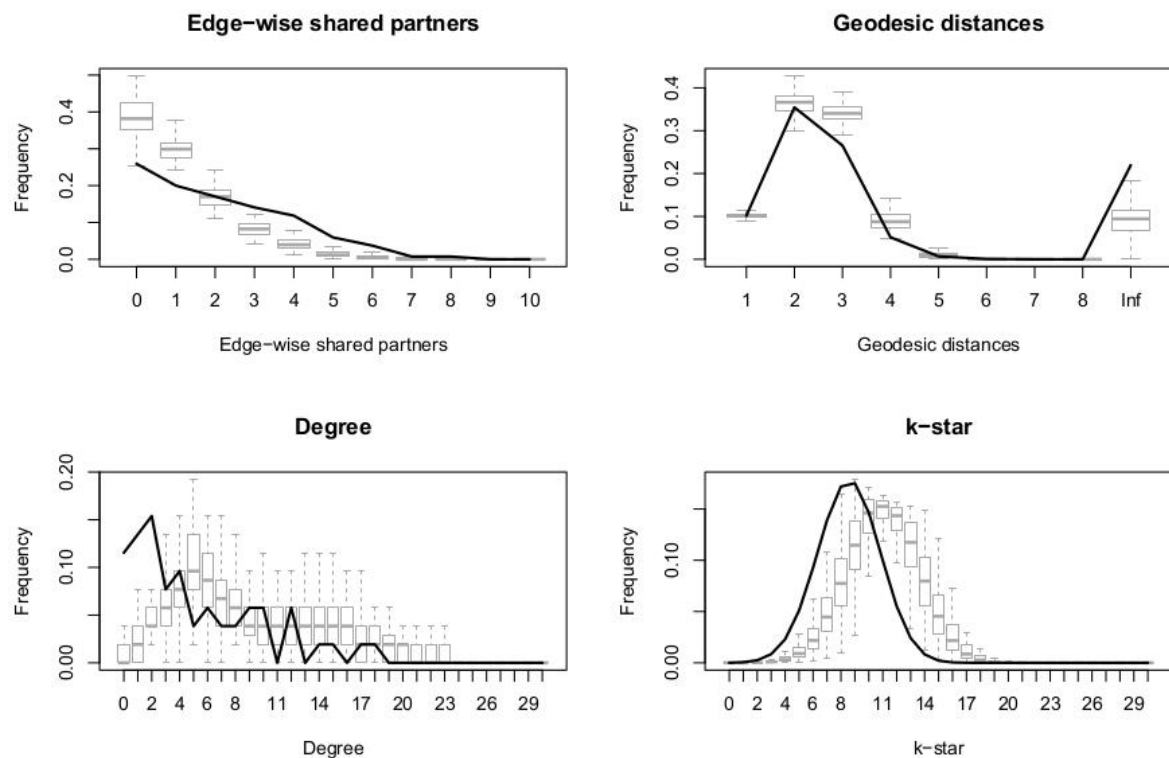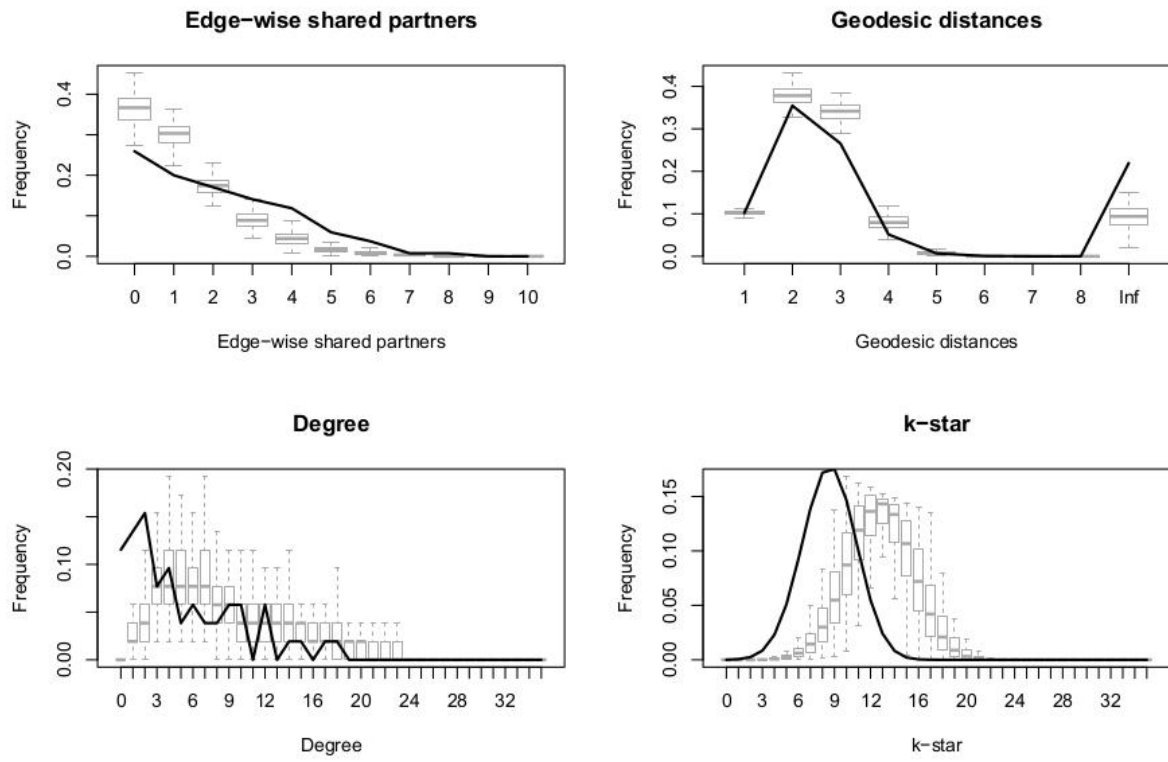*Figure 8: Goodness-of-fit assessment of the QAP Model 1.*

Figure 9: Goodness-of-fit assessment of the QAP Model 2.

8   Interview guide

8.1   Description of the actor or institution activities

What are the activities that you (or your institution) carry out and that are linked to the environment or the natural resources of the Mariño watershed?

Are you taking part in the management of ecosystems in the watershed? If yes, how do you contribute to their management (monitoring, legislation, inspection, access control, technical assistance)?

Do you participate in any platform about the environment or natural resources of the watershed? Could you list the actors and institutions you interact with through this platform?

8.2   ES Benefits

This is a list of 8 ecosystem services (i.e. benefits from nature). Could you identify the ones that provide benefits (material or not) to you?

- Agricultural production
- Medicinal plants
- Water purification
- Regulation of water quantity
- Buffering and attenuation of mass movement
- Control of soil sheet erosion rates
- Global climate regulation by reduction of greenhouse gas concentrations
- Ecotourism

For each of the ES indicated, please answer the following questions[1]:

- What kind of benefits does this ES bring?
- Is there any institution that regulates negatively (e.g. restricts, limits) or positively (e.g. favors, facilitates) the way you benefit from this ES? How?

8.3   ES management

In the same list of ecosystem services, could you identify the ones that you manage?

For each of the ES indicated, please answer the following questions[2]:

- How do you manage this ES? Through what direct activities? Through what indirect actions (monitoring, inspection, technical assistance, legislation such as agricultural quota or order or other)?
- Do you have a problem with other institutions or actors with regards to the management of this ES? For example, in the last year, with which institutions or social groups have you had problems or conflicts?
- Do you participate in any work platform with other institutions about this ES and its management?

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[1] The questions were adapted to each ES and examples were provided if the interviewee had trouble understanding them.

[2] The questions were adapted to each ES and examples were provided if the interviewee had trouble understanding them.

9   Correlation matrices of networks centralities

Figure 10: Correlations between influence network centralities. The distribution of each centrality is plotted on the diagonal. The lower diagonal displays a bivariate scatterplot for each pair of network centrality. Pearson correlation coefficients are on the upper diagonal. Names of the centralities are indicated on the top, and on the right: deg (degree centrality, which is also the proxy for influence score), bet (betweenness centrality), clo (closeness centrality) and eig (eigenvalue centrality).
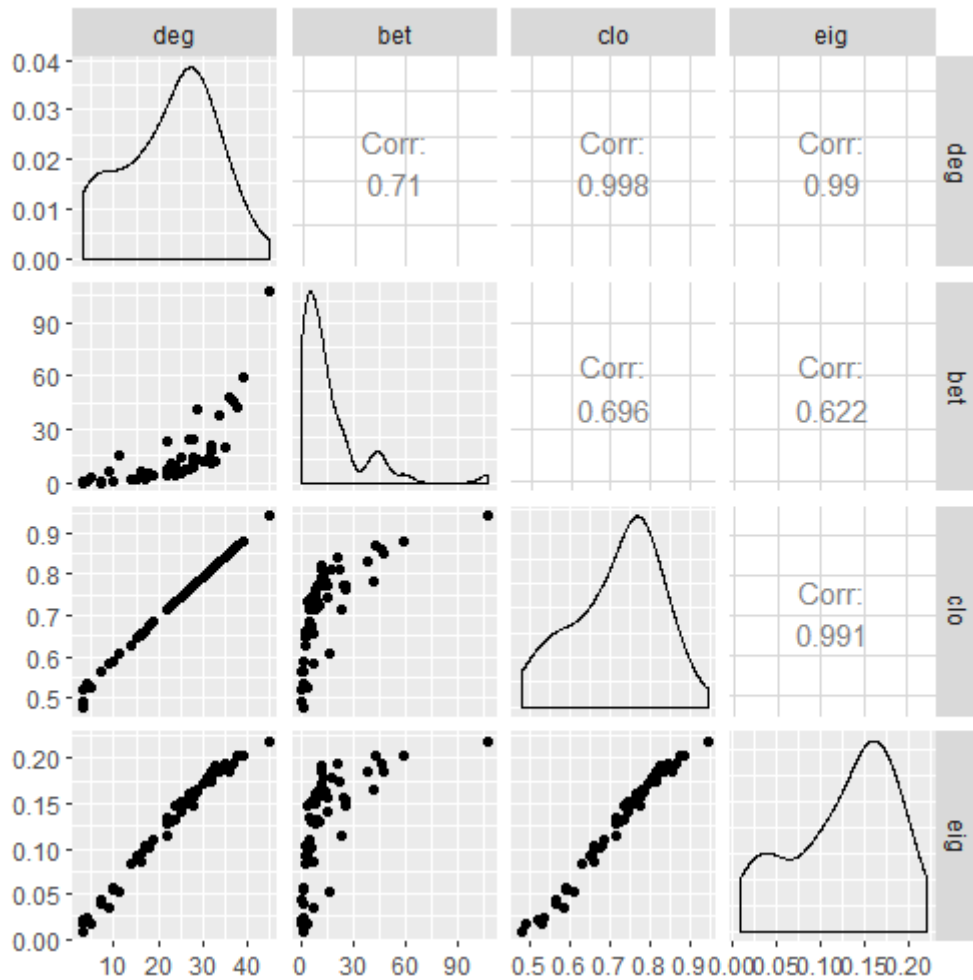
Figure 11: Correlations between domination network centralities. The distribution of each centrality is plotted on the diagonal. The lower diagonal displays a bivariate scatterplot for each pair of network centrality. Pearson correlation coefficients are on the upper diagonal. Names of the centralities are indicated on the top, and on the right: outdeg (outdegree centrality), indeg (indegree centrality), bet (betweenness centrality), clo (closeness centrality) and eig (eigenvalue centrality), ind (the proxy for domination score, which equals outdegree - indegree).
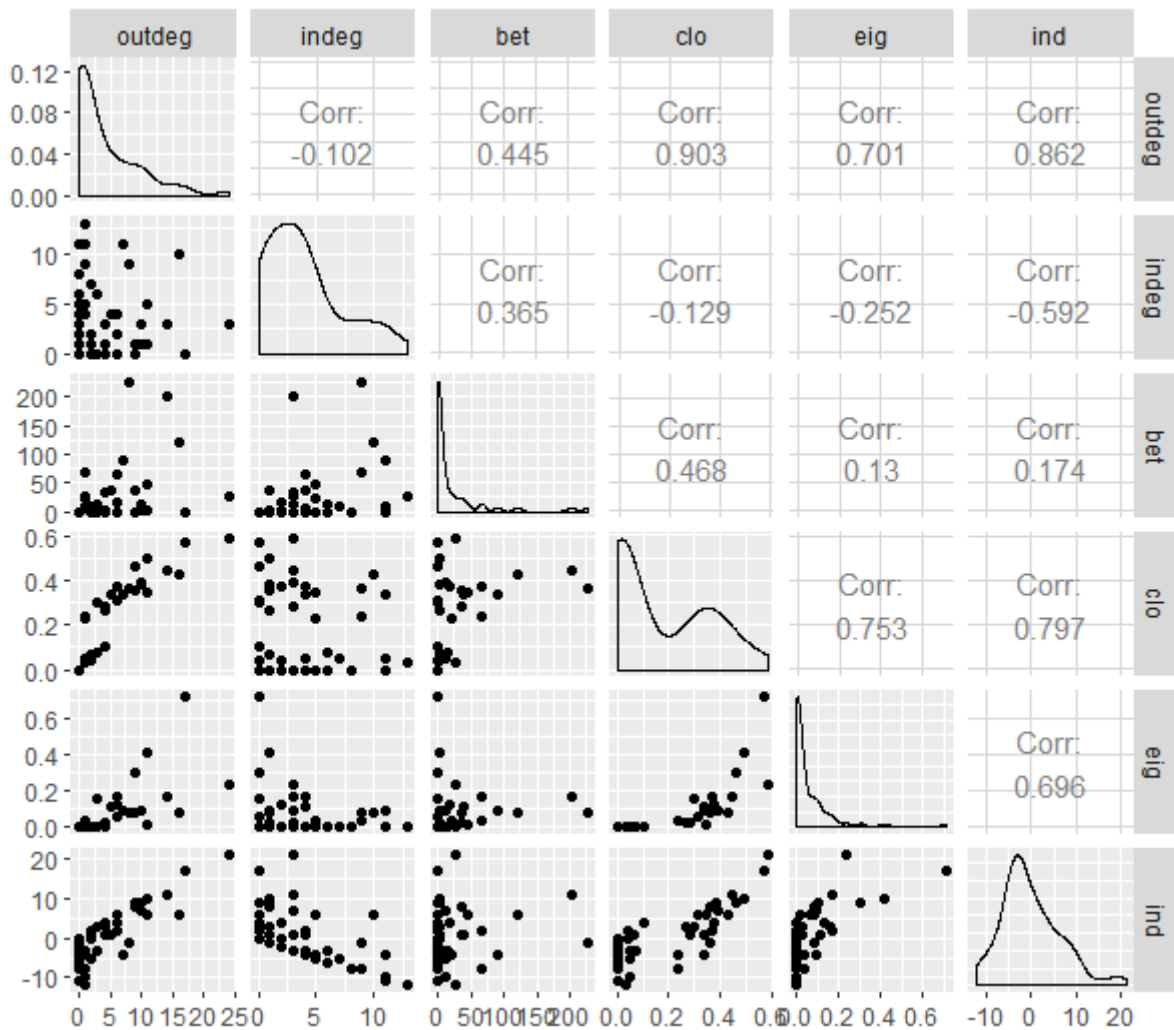
10 Supplementary Information references

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