The role of institutional networks and their links with vulnerable spaces. The example of Honduras for the agriculture sector

State-of-art

Irma Ayes Rivera
Carlos Eduardo González

November 2021

1. Introduction

Major challenges for climate change adaptation, requires not only the understanding of the plausible future scenarios and threats, but also the knowledge on how to adapt to it. Moreover, as climate change is just one component of what is known as global environmental change (Vitousek, 1994; Schellnhuber et al 1997), we need to consider the interactions and feedbacks with the population growth and the socio-economic activities that change the land uses, increase the loss of biodiversity, and alter other biochemical cycles, besides the carbon one. Then, it is required a deep understanding on the vulnerability of the territories and communities' capacity to cope the impacts generated by these environmental changes.

The understanding of the socio-economic and political decisions in which the vulnerability and adaptative capacities have taken form in a certain territory is a must before attempting to do climate adaptations plans. A detailed and historically oriented analysis can help clarify how interactions of political, economic, and cultural variables, not only promotes, or obstructs social capital and networks, but also conditions local development (Trigilia, 2001). This includes a social network analysis over a territory, a snapshot of the current network characteristics, and a prospective assessment over different future scenarios. A major feature of a networks are the ties between the actors, in which the governance of a territory takes place. Without a proper understanding of the institutional and social network structure (i.e., how they are connected, which actors possess a larger influence, among other characteristics), any adaptation plan (national, or sectorial) even if the climate and socio-economic scenarios have a minimum uncertainty, will likely fail (Wilkin et al. 2019), more if it's a top-down policy.

For the Intergovernmental Panel on Climate Change (IPCC), adaptation capacity is "the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to cope with negative consequences" (from MEA 2005). Folke et al. (2005) and literature cited by them, referred as social-ecological system and to the adaptative management or governance, which creates the conditions for ordered rules and collective action or institution of social coordination. This last appreciation put in evidence the need to assess how the rules and interactions among institutions are related to the capacity to adapt to different changing situations in a holistic approach, considering their link to the territory. Social-ecological network (SEN) as referred by Folke et al. (2005) address the connections between human actors and environmental services or ecosystems. Though SEN is not the focus of this paper, they are important to understand the characteristics of a network, since they evolved out from sociology, political science, earth science, among others. Indeed, to be considered as a SEN, it must address both social and ecological phenomena, and their interaction, in a meaningful way (Sayles et al. 2019). Bodin and Tengö (2012) developed a SEN analysis through the integration of methodological and theoretical framework that, as the authors concluded in a case of study in Madagascar, it makes possible the exposure of important patterns of interdependencies that helped them to hypothesis on, why the social actors were able to preserve the integrity of their landscape through time. Conversely, social-institutional network as it is the focus of this review, aimed to assess the relationship among the actors within the territory.

MacGillivray (2018) suggest that for analyzing resilience to climatic hazards in a territory, the structure, geography, and content of social networks, offers a good path for understanding the vulnerability, effective actions been implemented to reduce vulnerability, and interventions that are required to fit environmental and social changes. Indeed, and over a context of climate change adaptation, Valente (2012), describes that network interventions are "purposeful efforts to use social networks or social network data

to generate social influence, accelerate behavior change, improve performance, and/or achieve desirable outcomes among individuals, communities, organizations, or populations".

Over the above framework and like adaptation capacity, the concept of social networks has been applied in a wide range of sciences and have been shown to foster the capacity to buffer, adapt to, and shape change (Moore and Westley, 2011). The social weave and the institutional relationships over a territory, is an example, in which nowadays network analysis is used to evaluate adaptations capacities over a multi-disciplines approach. For instance, over a global scale, the IPCC from the United Nations is a large network -if not the largest-, of scientific collaboration. While in Honduras within the Adaptation Fund Project from the UNDP (https://acchonduras.wordpress.com/) an institutional network over a context of climate change adaptation and the sectors prioritized by the National Climate Change Strategy (MiAmbiente, 2010) was formed at a national scale. At a regional and local scale, Rockenbauch and Sakdapolrak (2017) critically reviewed the social networks and the resilience of rural communities. This review noted that in terms of governance, the social networks are a form of coordination in the context of management system, though because of methodological constraints it tends to underestimate the role of the individuals and power asymmetries. A further review by Wilkin, et al. (2019) also found that without a bottom-up mapping of the social networks the implementation of top-down preparedness policy as what is intended with the Paris Agreement or climate change national strategies would fail. Finally, and need to be remarked, socio-environmental issues are not stable and will likely change over time. This implies that an effective network should also change over time (Bodin, 2017).

Because developing countries as Honduras are currently suffering different effects since extreme meteorological events, which impact the agriculture, this literature review aims to evaluate the role that institutional networks (i.e., public, privates, social, etc.) have on the developing of the territories and their capacity to cope the effects of present and future climate conditions. This will be assessed in terms of climate change adaptation for the agriculture sector and food security. A first section is destinated to a brief theoretical aspect of Network Analysis and how it is use and related to institutional governance and adaptative capacities of the territories. This includes a review of studies cases in Latin America countries, comparing how social networks, adaptation capacities, resilience, and fit interactions are conceptualized, operationalized and the metrics used to evaluate the institutional networks and their interventions. Though, some studies are not explicit and necessarily consider the role networks have to reduce vulnerability and increase the adaptative capacities, they are useful to assess how network analysis can be applied to evaluate future interventions and adaptative plans.

2. Methodology

A systematic literature research procedure was done to allow that different research designs studies to be compared. A stepwise research procedure was done, firstly it was search in Google academic and Science direct, using a combination of term listed in table 1. Based on these preliminary terms, it was added key terms related to: "bridging actors", "foresight strategy", and "Latin America". The scientific research was restricted to peer-reviewed articles published in English between 2000 and 2021. Books or book's chapters were considered before 2000. As in Rockenbauch and Sakdapolrak (2017) and Wilkin et al. (2019), greater importance was given to the spatial domain of rural development in the countries considered as "low-income" and "middle-income" in Latin America (World Bank, 2021). Finally, the study cases were analyzed following Rockenbauch and Sakdapolrak (2017) according to how they 1) conceptualize, 2) operationalize institutional networks and, 3) if they measure the institutional networks capacities, how do the studies assess it.

Table 1 Systematic terms searched in Google Academic

	AND	OR
Social network	Territorial development	Climate change
Social network analysis	Rural development	Adaptation capacities
Institutional governance	Rural community	Resilience
Institutional networks	Territory intervention	Agriculture
Agriculture governance	Technology transfer	Food security
Social-ecological network (alone)		

This literature methodology was considered since it gives the opportunity for research cross-comparability and to seek common objectives when relating network analysis within climate change, agriculture, and food security. Figure 1, summarize the categories used to assess the case of studies that analyzed institutional and social networks, while the description of each category is below the figure. Note that these categories are not exclusives and the conceptual framed of each article was evaluated according on how the adaptation capacities are address, if it is implicit or explicit in the results, and how social network is framed.

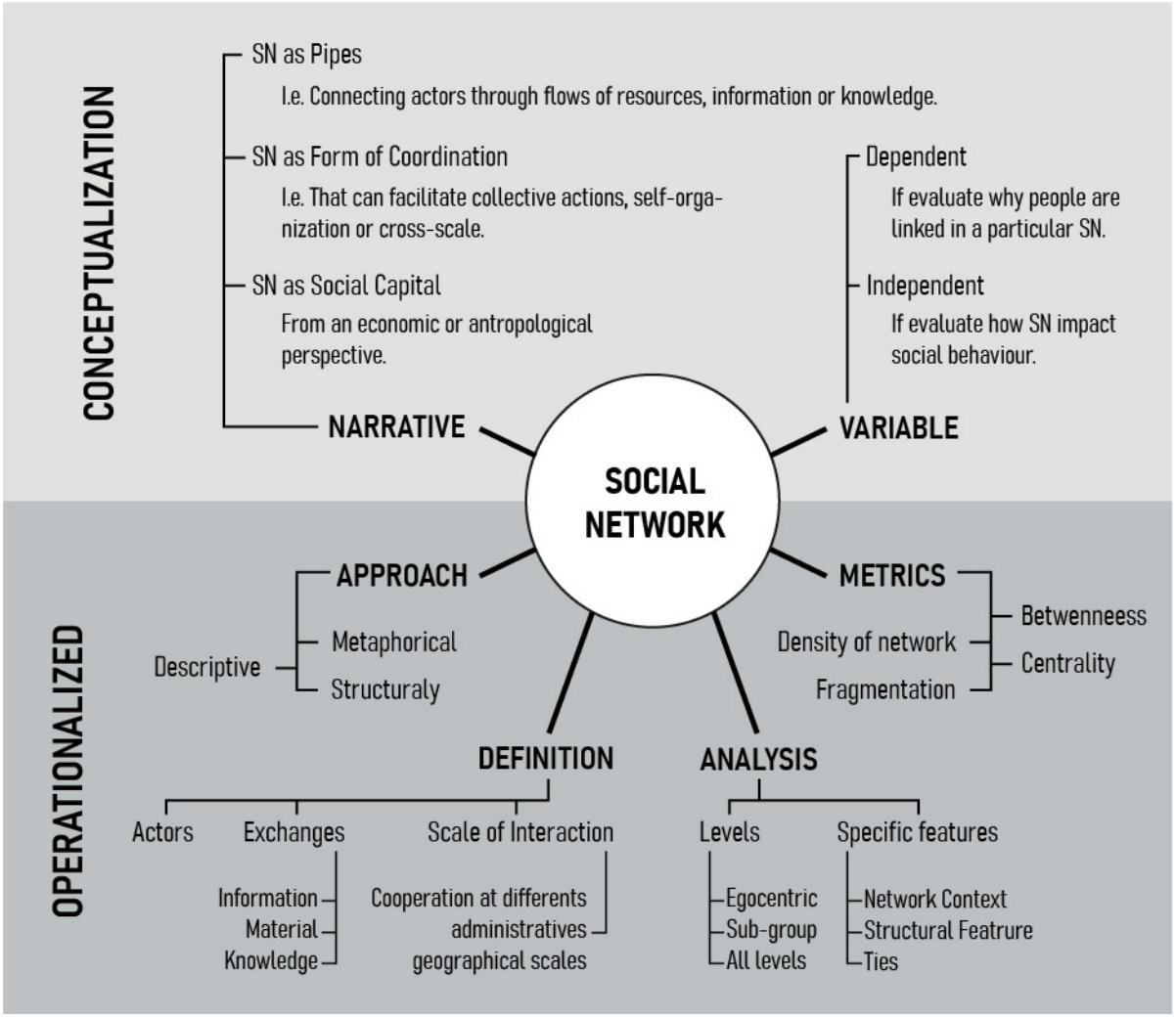


Figure 1 Categories applied for the case of studies literature research. SN stands for Social Network. Source: adapted from Rockenbauch and Sakdapolrak (2017)

2.1 Network conceptualization

These characteristics refer firstly to: ***how the researchers conceptualize their research?*** If the focus of the study is to assess how the structure of a network impacts on the actors, or if it is backward. Subsequently it was analyzed the narrative the authors decided to use. Then it was identified the following:

a) Network variable: Here the network is categorized as independent if its structure and relations impacts the individuals or institutions behavior or, as dependent if the focus is on why the individuals or institutions are linked in a particular way.

b) **Network narrative:** This address theoretical assumptions on how networks make a difference in a particular field, or in this case in climate change, agriculture, or food security. Networks can be seen as "pipes" when connecting actors through flows of resources, information or knowledge (Podolny, 2001; Borgatti et al. 2009). Networks can also help to assess the "social capital" (Putnam 1995 in Krishna and Shrader 1999), associated to the kind of relations which binds individuals and collective actors, and which

can promote cooperation and trust, but also generate obstacles to local development (Trigilia 2001). Do consider that social capital has different connotations depending on whether it is evaluated from an anthropological and sociology perspective (Welman, 2000) or economic perspective (Coleman, 1988). And finally, the conception of network as a form of coordination that can facilitate collective actions, self-organization or cross-scale coordination (Rockenbauch and Sakdapolrak 2017).

2.2 Network operationalized

In the literature reviewed the social network analysis per-se, can be done according to different approaches, evaluating different actors and interactions, and can be assess at different levels. While for some studies the aim is to evaluate the network analysis from an actor perspective, others can do the same for a sub-groups' perspective, or it can be evaluate the complete network.

a) **Network approach:** According to Bodin et al. (2011), there are three broad categories in which social networks can be evaluated: (1) In the binary metaphorical approach, actors of the network are closer to each other, or they exchange resources in an informal way within a common goal or objective. However, over this kind of studies there is not a well-defined internal structural analysis of the network. (2) The descriptive approach goes a step further than the metaphorical and evaluates different descriptors of the shape and form of a network through a qualitative analysis. For example, studies do refer to how horizontal or vertical a network is, how are the connections between actors, or how dense is the network. Yet, some of these studies within the descriptive approach lack a clear network methodological framework and reduce the ability to understand the social links and explain the network structure. (3) The structurally explicit approach refers to those studies in which a formal network analysis is done to quantify the structural networks features. Then, research following this last methodological approach follows the principles of network analysis (Barabási, 2015). Depending on the purpose of the analysis a good metaphorical approach can fulfilled the objective as well as the other two. And though the structurally approach could be better since its mathematical analysis, the understanding beyond the actors and their relationships sometimes cannot be quantify because of socio-cultural considerations.

b) **Network definition:** Refers to the clear definition of actors (i.e., farmers, public institutions, ONGs, etc.), the kind of exchange of resources (i.e., information, material, knowledge, technology) and the scale of interactions between different levels of administration (regional, national government, local, etc.) or geographical scale.

c) **Network analysis:** Refers on which network level the analysis is focused, as it can be at the individual or institutional level, subgroups or the complete network level. And which specific characteristics are highlighted (actors, links, clusters, or some other structural features).

d) **Network metrics:** In literature there are many metrics that can be used to evaluate the structure of the network, in case a structurally approach has been considered. Besides evaluating which metrics, the study cases used, it was also reviewed if other indicators as to assess effectiveness and sustainability are proposed.

3. Network analysis and governance

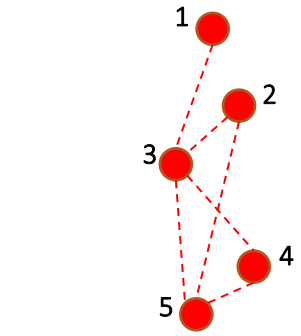
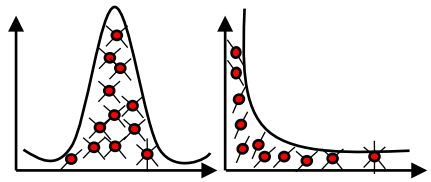
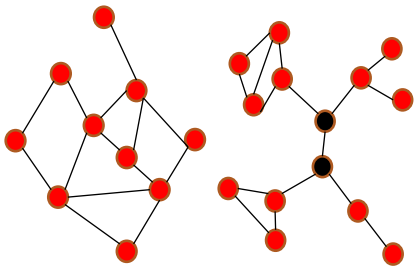
3.1. Basics of social network analysis

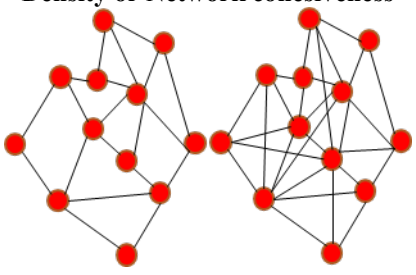
According to Barabási (2015), network science is a discipline that has emerged in the 21st century. Even though the graph theory -a subfield of mathematics- explored the graphs characteristics in a similar way as network analysis does nowadays yet, since 1735 with the puzzle of "The Bridges of Königsber", resolved by Leonhard Euler in 1736. The work of Paul Erdös and Alfred Rényi in 1959 marks the beginning of the study of random networks within the graph theory, while the paper "The strength of weak ties" in the

American Journal of Sociology of Mark Granovetter in 1973 is a milestone in social network analysis. As described by Granovetter (1973), "treating only the strength of ties ignores, for instance, all the important issues involving their content." He questions the relation between the strength and degree of ties, or between the strength and hierarchical structure. Moreover, the theoretically discusses a linkage paradox: weak ties, are seen as indispensable to actors' opportunities and to their integration; while strong ties, breeding local cohesion, can lead to overall fragmentation. The above is important to plan network interventions.

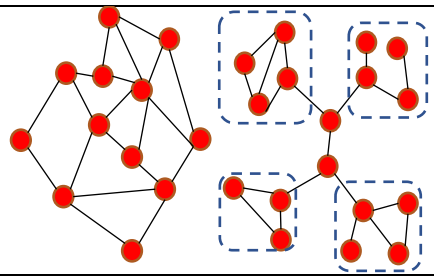
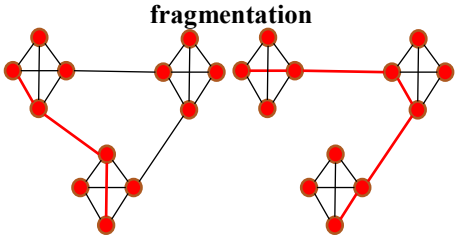
Bodin et al. (2011) describes the focus of network analysis in social science as the "relationships among entities, and on the patterns and implications of these relations." **Hence, it is intended to evaluate how resources, goods, and information flow from an actor to another in different configuration of social ties**." The latter evaluation makes a distinction between network analysis per-se and social network analysis. Though, both analyses can mathematically evaluate the network structure, the social network analysis requires a further analysis of whether the network is a source, form, or even is a consequence of the social capital (Wilkin et al. 2019). This is the socio-economic and even cultural aspects related to how humans relate. To reduce this limitation, Bodin et al. (2011), observed that the real strength of social network analysis comes when it is applied in combination with other theoretical frameworks. Ultimately, must be linked with other measures of norms, trust, and reciprocity to provide "local and contextual measurement" (Krishna and Shrader, 1999), to assess social capital. Table 2 shows some of several network characteristics and how the researchers quantify them. A deep description of the metrics and more metrics can be read on (Network Science by Albert-László Barabási (networksciencebook.com) and Networks: An Introduction by Mark Newman.

Table 2 Quantitative network measures and how they are related to network features. Adapted from Bodin et al. 2006. Here "nodes" as referred in Network Analysis is the same as "actors" or "institutions" in Social Network Analysis.

Feature	Measure
Degree heterogeneity  **(a)**  **(b)**	Measured in terms of the diversity of connection reflected through its node degree (Jacob et al. 2016)**.** Been the degree of a node, the total number of nodes adjacent to it. There can be an incoming degree that stands for the number of links pointing to a node, or outgoing degree, when the link is pointing from the node. We denote with k_i the degree of the i^{th} node in the network. For example, for the undirected network shown in figure **(a)**, k_1=1, k_2=2, k_3=4. In an undirected network the total number of links, L, can be expressed as the sum of the node degrees (Barabási): $$L = \frac{1}{2}\sum_{i=1}^{N} k_i$$ Here the ½ factor is needed to correct the fact that in the sum, each link is counted twice. An important property of a network is its *average degree*, which for an undirected network is: $$\langle k \rangle = \frac{1}{N}\sum_{i=1}^{N} k_i = \frac{2L}{N}$$ While, a node's total degree, k, is given as: $$k_i = k_i^{incoming} + k_i^{outgoing}$$ Finally, the degree distribution as observed in **(b)**, p_k, provides the probability that a randomly selected node in the network has degree k. Since p_k, is a probability, it must be normalized.
Centrality 	The degree of centrality indicates how many links a node has. This measure can be applied to individual nodes or the whole network (as in figures at the left). A high degree of centrality for an individual node indicates that it has many links compared to other nodes. Centrality for the whole network indicates the tendency in the network for a few actors to have many links, and a high influence. Here four measures of centrality are described: 1. ***Degree centrality*** as defined by Gómez (2019) is the simplest proposal of a centrality measure for the nodes in a network, then and relating with the previous metric is: $$C_i^{(\text{degree})} = k_i$$ Another approach is also to separate by in- and out- degree as: $$C_i^{(\text{degree})} = \frac{k_i^{in} + k_i^{out}}{2}$$ 2. ***Betweenness centrality*** is a way of detecting the amount of influence a node has over the flow of information in a graph. It is often used to find nodes that serve as a bridge from one part of a graph to another. This measure can be applied to individual nodes and can then be used to identify the actors that contribute most to linking the network **(c)**. The measure can also be applied to the

	network as a whole to quantify the degree of modularity, i.e., separation into smaller groups or modules. $$C_{(betweenness)} = \sum_{\{s,t\} \subseteq V} \frac{\sigma_{st}(V)}{\sigma_{st}}$$ Here, σ_st stands for the number of shorter paths between node *s* and node *t*, and $\sigma\_st\ (V)$ is the number of these paths that cross by node $v \neq s, t$ (Luke, 2015) 3. ***Closeness centrality*** considers the distances to the rest of the nodes, then central nodes would be close to all of them, giving a picture of the network centrality. This metric according to Gómez (2019) is based on this idea: "for each node, you calculate the distance to all the other vertices in the network, and define a centrality in which shorter distances imply higher closeness centrality and vice versa." The mathematically can be represented as: $$C_i^{(clos)} = \frac{1}{\sum_{j=1}^{N} d_{ij}}$$ Here d_{ij} is the distance between the nodes *i* and *j*. This is, the number of links needed to move from one node to another, or the shortest path between them. This metric can be normalized. 4. ***Eigenvector centrality*** is different as the three above. The previous measures take into account the position of nodes in the network but not the importance of the nodes themselves. Hence, this measure consists of defining the centrality of a node as proportional to the sum of the centrality of the neighbours, so as the larger the importance of the neighbours, the more central the node is (Goméz 2019). Mathematically is: $$\gamma C_i^{(eig)} = \sum_{j=1}^{N} a_{ij} C_j^{(eig)}$$ Here γ is the proportionality constant. The a_{ij} term emphasizes that node *i* receives the contribution to centrality from its neighbours through the incoming links.
Density or Network cohesiveness  **(a)** **(b)**	Number of links divided by the number of nodes in the network. Is defined as: $$\Delta = \frac{2l}{n(n-1)}$$ *l* stands for the number of links of the network and *n* is the number of nodes. Thus, it gives a first approximation of the articulation between the actors according to the homogeneity presented by the distribution of the links of the nodes of the network. **(b)** has a higher network cohesion than **(a)** since it has more links for the same number of nodes.
Clustering coefficient	For a node, clustering coefficient is the number of closed triplets[1] in the node's neighborhood over the total number of triplets in the neighborhood. While for the network structure (as in figures at the left), it refers to the number of subgroups or small networks within the network itself. $$C_i = \frac{2t_i}{k_i(k_i - 1)}$$

[1] A triplet is three nodes that are connected by either two (open triplet) or three (closed triplet) undirected ties.

	Here t_i is the number of triple connections of node i, and k_i the degree of node i. Therefore, the global value will be $\bar{C} = \frac{1}{n}\sum C_i$ and is used to evaluate the cohesion of the network in a global way, which results because of the density and asortativity.
Reachability or Degree of network fragmentation  **(a)** **(b)**	Diameter, i.e., the number of steps maximally needed to reach from one node to any other node in the network. In **(a)** it takes 3 steps to reach the nodes with red links, while in **(b)** it takes 5 steps. Number of components. A component is an independent network within the larger network in which all nodes are directly or indirectly in contact with each other. If a network consists of more than one component, it is considered fragmented; the degree of fragmentation is quantified by measuring the number of components.

So far, the features and measurements above merely describe the structure of a social (or institutional) network. Most of the time, however, is absent an evaluation of how networks are effective in delivering needed services (i.e., information, knowledge, financial resources, etc.; Provan, 2001) or developing trust and cohesion between the actors. Sampson (2011) argues, that while social networks foster the conditions under which collective efficacy may flourish, but they are not enough to develop social cohesion. Networks must be activated to be meaningful (Jorgensen et al. 2020). Of course, this depends on the form and objective a network was created, if it is a formal or informal network and the spatial influence, among others. While formal networks within top-down decisions can be the response of a law or national policy, as it will be seen in section 4.2 for Honduras, decisions within a smaller scale (community or municipality) can develop stronger ties among local actors. For example, the Denomination of Origin (DO) of Marcala's coffee in Honduras created and developed a network of coffee producers and buyers that in coordination support the rural development of Marcala Municipality and surrounded 18 municipalities since 2005. Though, its main purpose is "promoting the consolidation of an orderly offer with homogeneous quality and, on the other hand, it protects the knowledge, the know-how of the communities, the experience and local production techniques", the DO has been a "bridging actor" connecting the community to financial institutions as it is the case of the entrepreneurship project financed by the European Union (http://www.docafemarcala.org/Proyectos/proyecto-2/). Bowen (2010) evaluated two cases of geographical indication and concluded how these local networks can serve as a link between rural production systems and the national-global markets. Moreover, as she discusses, the opportunity to foster rural development and cultural resources in developing countries.

Network efficiency or "governance efficacy" as defined by Jorgensen et al. (2020), is especially important when formulating public policy to manage environmental resources at different spatial scales, so that interventions and scarce funding can be allocated where it is most needed. Yet is a challenge, it is critical to justify involvement by the different NGOs, for instance, but also to justify public support. By studying the management of plant and pest outbreaks in agriculture during 2010 in Australia, McAllister et al. (2017) showed that policy forums at national scales, where higher-level decisions are made, were associated with denser overlapping actors' interactions signifying collaboration, while at local scale, where plans are implemented, the requirement is to coordinate actions. Thus, "by properly identifying the mix of coordination and collaboration (see table 3 for differences) in networks for solving environmental problems,

capacity building can be more targeted, and rules-of-behavior can be developed that better fit the requirements of the diverse tasks involved" (McAllister et al. 2017).

As describe above, social networks can be evaluated from its mathematical structure, but also in terms of how effective they are to fulfill their goals. When evaluating over time, a network that has been planned in which the social weave and the networks are understood, can permit the sustainability of any plan or policy. Thus, sustainability can begin to be evidenced from the organizational relationships of communities and then be scaled and based on the understanding of the different relational dimensions (intergenerational, intragenerational and with nature). Sustainability can be understood in this line as the basis on which there can be an endogenous development of these communities, development that is "directly dependent on collective self-confidence in the ability to invent resources, mobilize existing ones and act in a cooperative and solidarity way, from the territory itself" (Boisier, w.d.). Measurement of trust as an important feature for adaptation (see table 2, Bodin et al. 2006) when analyzed over different periods can provide an income on how sustainable the networks has been.

Through both, the evaluation of effectiveness and sustainability, social network analysis can be a helpful tool in the comprehension of the social factors that define the success or failure in governing a common pool resource (Bodin et al. 2011), and in defining plans for possible future scenarios. Is at this point that social and institutional network analysis, as described in the introduction can help to increase the adaptative capacity of a territory (Tompkins and Adger, 2004), through a proper allocation of resources in a territory. Climate-smart agriculture (CSA; FAO, 2013) approach, is intended to help to reorient agricultural systems to support food security under conditions of climate variability and climate change (Martinez-Baron, et al. 2018). These authors reviewed the local social dynamics as a key factor in the widespread implementation of CSA, building resilience and strengthening development interventions related to climate change mitigation and adaptation through supporting technology adoption. A case of study in the innovation and technology transfer networks (ITTN) on Papaya production in Mexico using social network analysis, allowed the detection of central actors in the ITTN, standing out those that share information with the network and use best technology (Cano-Reyes et al., 2012). Highlighting these two lasts researches, that the diffusion and transfer of knowledge and technology are enhance by the interaction of the social actors.

Certainly, to address the possible impacts of climate change in the agriculture sector, it is imperative the understanding of how collaboration between the different actors can be improve and even barriers can be overcome. Bodin et al. (2006) and (2009), evaluated from a network analysis approach the role social networks has for the governance of natural resources. The features identified by these authors as important for the adaptative management and their relationships with social network analysis, can be read in table 3. Examples of literature in which this features and social network analysis is used, it is present below the table.

Table 3 Features identified as important for the adaptative management and their link to social network structure. Adapted from Bodin et al. 2006 and Hileman et al. 2018b.

Feature	Link to social network structure
Social memory Collective memory/experiences to be used when developing adaptation plans within an uncertainty frame.	***Reachability:*** access to many actors. ***Density:*** many links to others in the network.
Heterogeneity	***Betweenness:*** A certain degree of separation of groups in the network is needed to maintain heterogeneity.

The study of climate change and the possible impact over the territories requires the knowledge of different disciplines. A diversity of actors/institutions is necessary to increase the capacity for innovation.	***Density***: High density may have a negative effect on heterogeneity because it promotes homogeneity of experience and attitudes among actors and reduces the potential for innovation.
Redundancy In case one or more actors are removed, others can fill the position and the performance is not altered.	***Density***: Many links make the loss of single actors less disruptive, with a lesser effect on the average distance in the network. ***Betweenness***: A high degree of betweenness of single actors makes the network vulnerable to fragmentation should these actors disappear.
Learning Knowledge of how climate variability and climate change can alter a socio-economic sector? And thereby how to adapt to it? Can be continuously updated and adapted. Learning is conceived as a collective action where processes that involve sharing experiences and engaging in collective deliberation are in focus (Bodi 2017)	***Betweenness***: Maintenance of strong links within a group to some extent requires high modularity, and strong links are needed to transfer tacit knowledge and complex knowledge, i.e., knowledge that involves interpretation of a number of nonlinear and noncausal variables. ***Reachability***: access to many actors from whom knowledge and information can be amassed or to whom it can be distributed. Short paths can facilitate the transfer of knowledge throughout the network, but depends on the level of trust among actors (McAllister et al. 2017) ***Centrality***: A high degree of centrality may give rise to centralized management and thereby fewer experiments and experiential learning.
Adaptative capacity New knowledge and/or changing conditions require adaptative capacity and innovation to meet new needs.	***Reachability***: Collective action requires multiple actors to collaborate, but too much decentralization may have negative effects on the potential for collective action. ***Centrality***: Coordination ability, which is important in times of change and rapid response, increases with centrality. ***Density***: Too many links to others may lock an actor into a political position because of, e.g., peer-pressure, thereby limiting his/her ability to innovate and act. Dense networks may lead to homogenization and reduce adaptative capacity (Bodin and Crona 2009)
Trust Co-manegement of a territory can be facilitated by trust among actors/institutions.	***Density***: Many links foster feelings of belonging and group identity, and can facilitate cooperation. Trust may introduce a similarity effect to the extent that trustworthy actors tend to seek each other and avoid untrustworthy actors, hence creating clustered communities of high-trust cooperators and a excluded low-trust actors. (Berardo and Scholz 2010). ***Betweenness***: A high degree of separation among groups can undermine the development of trust.
Coordination or cooperation Many collective action problems can be divided in (1) coordination in which all or most actors agree on what they want to accomplish and separating the actor's activities in efficient way. (2) cooperation, is when actors display different opinions and interests, then by necessity involves negotiations and	***Centrality***: More centralized and sparse networks are better for low-risk coordination problems. ***Density***: Dense collaborative network structure is better at addressing high-risk cooperation problems. ***Degree***: incoming degree and outcoming degree can provide information on the influence the actors have.

deliberations to reach common agreements. Please note, that for some researchers there is not a distinction between these concepts. Also referred as bonding (coordination) versus bridging (cooperation) social capital.	

By analyzing organizations that design, fund, and implement water and sanitation programs in Central America, Hamilton et al. (2019), evaluated heterogeneous brokerage[2] to the multi-level network. For the researchers, "within the field of environmental governance, evaluation of heterogeneous brokerage activity and/or exclusivity can improve understanding of how different types of organizations acts as intermediaries between members of environmental science and policy communities". The study remarks, that linkages in this kind of governance network indicate only the possibility for influence or resources as information. Yet, a direct analysis, as proposed by the authors, of heterogeneous brokerage is possible in networks in which linkages represent financial transactions, dissemination of expertise, or other tangible resource or material. Evaluating the multi-level water governance network also in Central America, Hileman and Lubell (2018a) described a high homophily at the country-level which contributes to the local network's large clustering coefficient, along with the country-level subgroups. They also discussed opportunities and constraints within the regional Central America network. While they described that regional actors can help bridge between distant local-level actors, then fostering cooperation and knowledge across boundaries, the overarching importance of these actors also potentially makes the network vulnerable to the "exit problem" (i.e., when a project and its funding ends), putting in risk the network sustainability.

Matous and Todo (2015), highlighted the importance of social learning and the role of social networks in the adoption of conservation practices. The authors also appointed for the need to study the dynamic nature of socio-environmental systems, since most of the time, network analysis is done for data at one time point and methods that implicitly assume stationary conditions. Methodological constraints limit the network analysis evolution. This research gap has persisted in scientific literature, since the absence of social network data along a period, and the complexity of analytical tools for evaluating it. Though, it is important to evaluate future interventions along the network. The former authors developed a survey for a community of farmers in Ethiopia at two points in time, allowing the researchers to compare the network density, clustering and homophily, and the effect these network characteristics could have on social learning. They concluded that: "Extensions agents were able to directly raise individual farmers' awareness of composting faster than information diffusion through the cliquish farmer-to-farmer learning network; however, informal sharing among peers regarding experiences with the practice contributed to the actual change in farmers' habits." Similar to the previous study, at a Biosphere Reserve in Chiapas, Mexico, Garcia-Amado et al. (2012), evaluated the social capital network of a forest community at five points in time, reaching an analysis of 10 year of coffee producers' network. They observed a centralization of the network overtime, that even helped to organize productive activities, also was found to be a source of internal conflicts.

Isaac (2012) evaluated the relation of information exchange and organizational ties on managing agrodiversity in two farmers' networks in Ghana. He concluded that "the equity and advancement of information flow on agro-environmental practices, such as managing agrodiversity, within informal

[2] Brokerage in social network refers to the process by which one actor serves as an intermediary between two otherwise disconnected actors (Hamilton et al. 2019).

networks may be highly coupled with the presence of organizational ties. As within-community ties may be lost with an increase in ties to organizations, localized governance should focus on re-initiating such producer–producer ties. With regards to policy, efforts should be made to maintain personal network ties while simultaneously promoting efficient and effective exchange of information on agricultural innovation."

Bodin and Crona (2009) reviewed organizational and sociological studies and observed that the diversity of ideas that emerge with the presence of bridging ties enhance the capacity for innovations and for finding solutions to complex problems, and thus adaptative capacity. They comment for the study of Ramirez-Sanchez (2007) in Mexican fishing villages that, bridging ties, which from a hierarchical perspective of authority can be seen as horizontal, provided access to a resource which could buffer fluctuation in the local producers, but they also had a beneficial effect on social integration between interacting communities. Hence, it has a potential to increase adaptative capacity.

Within wildlife conservation in Bornean, Morgan et al. (2017) evaluated collaborative partnerships associated to trust. Qualitative surveying techniques were used to measure the perceptions of collaboration held by individual actors within the network and the impact of organizational attributes on network formation and perceptions. The study found that even there are collaborative actions, mostly related to innovation and knowledge sharing, efforts are still required to develop trust between the organizations. Concluding that, "increased operational transparency and improved performance evaluation will be critical for achieving improved collaborative efficiency." In indigenous communities of highland Peru, Lyle III and Smith (2014), observed that households heads with greater reputation (i.e., cooperative and work ethic) were considered more reliable, and because of this had more social support partners (measures as network indegree centrality).

3.2 Case of studies in Latin America

By using the methodology described in section 2, it was examined 33 peer reviewed articles for Latin America (collected 109 worldwide). Nearly 40% evaluated social networks within a rural development context, while climate change / water resources and social-ecological networks represented 27% each of them. Differences were observed when compare the articles collected by continent (Figure 2). Of course, this depends on the development of their nations and interests of research. Though it also depends on the sample used in this review. In Africa, most of the case of studies assessed the relationship between social and institutional networks in terms of climate change / water resources and rural development (86% of the articles), against 68% in Europe just for the rural development category. The count of articles in Asia as in Latin America describes equal percentage for climate change / water resources and social-ecological networks.

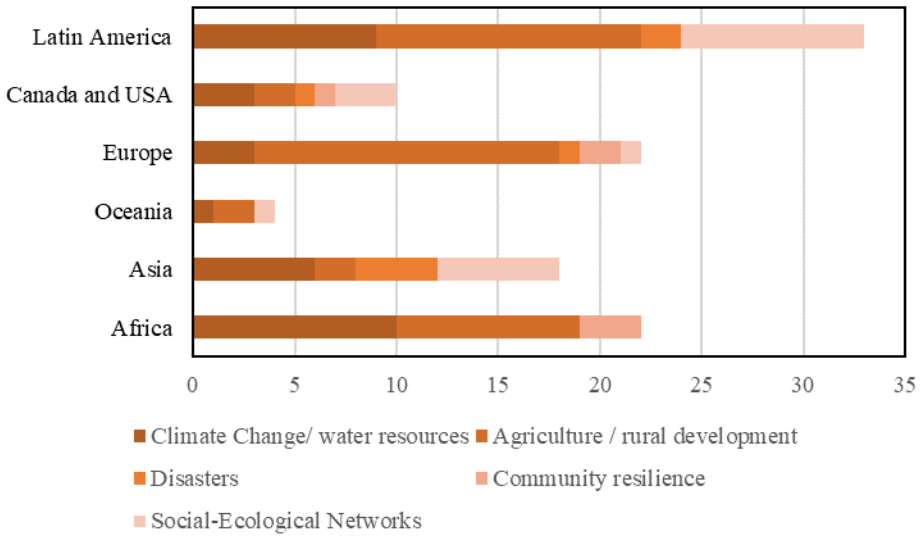


Figure 2 Articles collected by continent and categories related to social networks.

Figure 3 describes the concurrence of words in the abstracts from the 109 articles collected. It shows four defined subgroups, somehow connected between them, social network (which was the focus of this research), governance, rural and water, with climate change closing the unified four clusters. As mentioned in the previous paragraph there are differences among the continents articles which can be observed by separated in the Appendix 1. Note that there are studies that has a major attention on water resources management, which was taken here as related to climate change adaptation, while there are other studies that evaluates social networks within agriculture innovations focus or natural resources management. Because of this, in the following sub-sections it is present an overview of how these studies conceptualize, operationalize, and measure social networks in Latin America. General characteristics are described, highlighting study cases only where they are needed to illustrate differences in the conceptualization and operationalization of social networks. Detailed information on each case study is provided in Appendix 2.

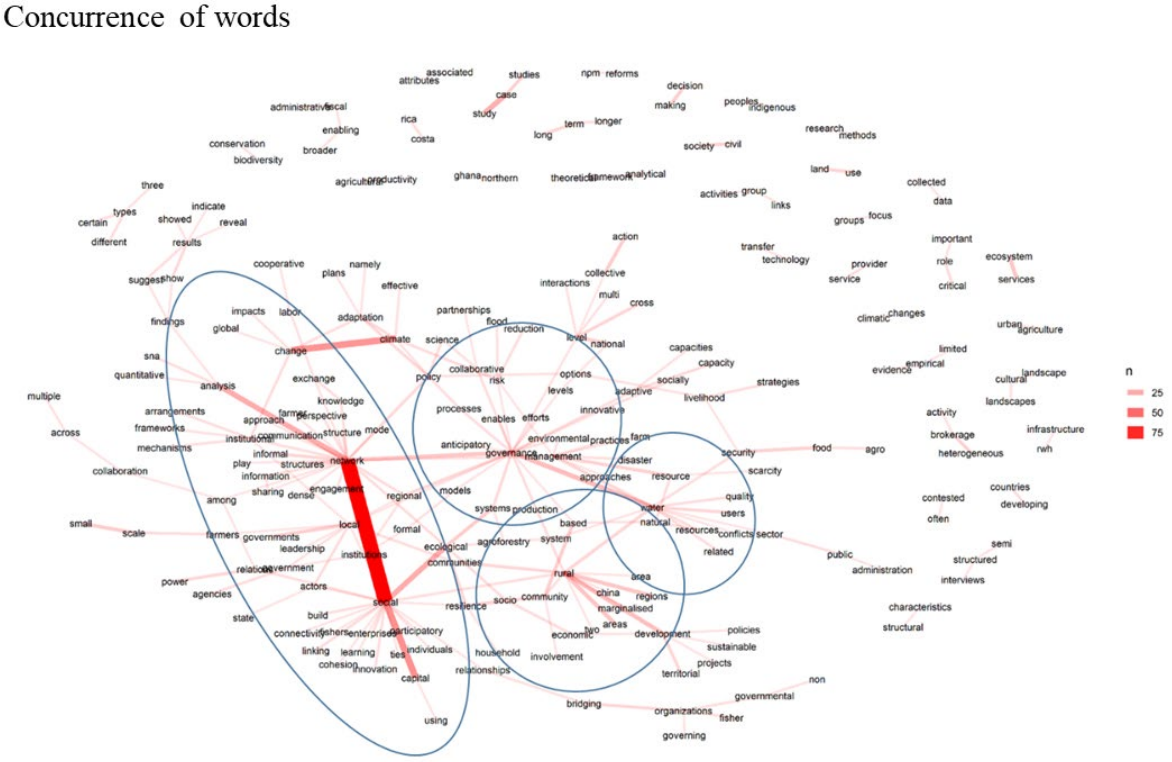


Figure 3 Concurrence of words in the abstract of the 109 articles collected. A ticker line among two words represents the number these two words are joint in the abstract. The combination of each pair of words allows to observed relationships between the articles objectives.

3.2.1 Social networks and water resources

Research in this area is concerned with diverse questions of how social and institutional networks affect the ability to adapt the necessities of current and future water users over a context of climate change, in which a redistribution of precipitation over time and space is expected. The case studies try to respond questions like how water governance networks may facilitate cooperation, social learning, and resource distribution (Hileman and Lubell, 2018a; Hileman et al. 2018b). How the governance can aggravate local water conflicts (Kuzdas et al 2015). And how do individual actors influence water governance? (Kuzdas et al. 2015), among others.

Network conceptualization

Three of the four articles, conceptualized adaptations capacity implicitly in terms of water resources governance and improving biophysical or sociopolitical outcomes at a national and regional level (Hileman et al. 2018b), or at local rural level in semi-arid developing region (Kuzdas et al. 2014, 2015). In the four cases, the social or institutional network is taken as independent in terms of how water governance may facilitate cooperation, social learning and resource distribution. The narrative of the studies focus on considering networks as form of coordination.

Network operationalization

The approach in this strand went from descriptive (Kuzdas et al 2015), to structurally approach for the Central America water management networks. Networks are defined by the collaboration and coordination

between actors. While in terms of boundaries, water resources networks are defined based on a local or national administrative border. The assessment is done for the complete structure, but also bridging actors related to the "exit problem" (Hileman et al. 2018b).

Metrics analyzed

The metrics that were used include the *density*, *centrality*, and *clustering coefficient*. In the case of Hileman and Lubel (2018) that assessed the multilevel water resources in Central America, they also used the weighted edgewise shared partners to capture the general tendency for closure among actors and the node match to capture the effects of geographic level.

3.2.2 Social networks and agriculture

Literature analyzed in this section is concerned with processes of social learning, networks of association that facilitate cooperation and how they are related to the territory development. The case studies reviewed for example, the creation and evaluation of a national network for rural development (Nuñez-Espinoza et al. 2013), a descriptive analysis of the causes and consequences of public institutions and local social sectors which can make a difference between the socioeconomic development of the territories (Manzanal, w.d.). Most of the studies reviewed for Mexico, evaluate networks for agriculture innovation (Muñoz et al. 2004; Zarazúa et al. 2012; Zambada-Martínez et al. 2013). While a study case in the north of the Brazilian Amazon (Maneschy and Klovdahl 2007), evaluated the external links between networks (NGOs, government institutions and social movements) within small-farmers (quilombolas in Portuguese) associations.

Network conceptualization

Studies related to social networks and agriculture do not address adaptation capacities explicitly. However, and as explained by Rockenbauch and Sakdapolrak (2017), "from a development economics' perspective, studies perceive of social network as factors shaping social learning and adaptative changes in the context of agrarian change, and hence implicitly address aspects relevant to resilience". Vignola et al. (2019) and Downey (2010) did make an explicit reference to climate change adaptation or environmental changes. In terms of variables, the majority of the studies treated social networks as independent variables in the way how the networks associations may facilitate cooperation and share information.

The narrative of most of the study cases, describe networks as pipes in which information and knowledge are transferred from bottom-up and circulate through the local actors. In some cases, the information that is transmitted is the seasonal forecast for the next three months (e.g., Guatemala' agroclimatic technical networks in 3.3), that it is used to define the best crop to cultivate in the near future. However, been able to transmit this information do not mean that farmers are familiar on how to interpret this information (Zoyla Moreno, DO-Marcala personal communication). In the other hand, there are studies that refers the transfer of innovative technology of institutional networks related to the production and distribution of a particular crop. The third narrative that was present in the study cases, conceptualized social networks as social capital, helping to understand the value of bridging links across different groups and communities (Maneschy and Klovdahl, 2007).

Network operationalization

Network approach in this strand went from metaphorical (Manzana, w.d.), to a descriptive approach (Maneschy and Klovdahl, 2007, Zambada-Martínez et al 2013). Studies in Mexico were most related to innovation networks for rural development within a structurally approach (Muñoz et al 2004, Zarazúa et al. 2012, Nuñez-Espinoza, et al. 2013). Abizaid et al. (2015), employed a structural analysis to study labor sharing among peasant households in the Peruvian Amazon and found that women's personal networks

play an important role in the mobilization of cooperation labor. Network is defined in most of the studies as social relations in which information and knowledge is exchange between farmers and external actors such as extension staff from central government and/or by NGOs.

Metrics analyzed

The most frequent metrics used were, as for water resources management, *density, centrality, degree* and *betweenness.* Particularly Abizaid et al. (2015) for Andean communities in Peru, evaluated household reciprocity through Dyadic regression analysis (DRA). As the authors said: ¨ We use DRA to identify the main factors that influence the formation of labor sharing networks and the intensity of labor flows. Dyadic multiple regressions adopt the dyad (or pair of farmers) instead of the farmer as the unit of analysis. Whereas a conventional regression framework could be used to identify the main factors that influence the amount of cooperative labor received by different households, it would fail to account for relational aspects that are crucial to understanding labor flows." Here a brief description of this analytic approach is given:

Thinking on cooperation and reciprocal labor-sharing arrangements, a farmer *i*'s decision to request help from *j* and *j*'s decision to participate are based on a comparison of benefits (i.e., for *i* the expected labor by farmer *j*; for *j* the direct benefits, reputation building and expected labor to be contributed by farmer *i* in the future) and costs (i.e., for *i* direct cost of preparing cooperation labor, plus reciprocation costs; for *j* opportunity cost of labor); reciprocation history between *i* and *j* matters. "As is common in social network analysis, data are organized into matrices that capture relationships among different actors, namely, the labor sharing network (i.e., dependent variable) and the relational factors that might influence labor sharing (i.e., explanatory variables). DRA account for the fact that the observations are interdependent and, as such, are suitable for relational data (Hubert and Schultz 1976)" in Abizaid et al. (2015). A dyadic regression model takes the following canonical form:

$$Y_{ij} = \propto + \beta X_{ij} + u_{ij}$$

Here *i* and *j* are farmers or actors; Y_{ij} is an N * (N-1) matrix that accounts for the dependent variable; X_{ij} is *K* sets of N * (N-1) matrices that account for the explanatory variables (*N* is the number of farmers and *K* is the number of explanatory variables); and u_{ij} is an error term that is interdependent because of the presence of farmer-specific factors common to all observations involving that farmer.

The models distinguish node-attribute (i.e., attributes z_i and z_j of the nodes *i* and *j*; e.g., farmer structure) and link-attribute data (i.e., attributes w_{ij} of the link between *i* and *j*; e.g., kin relations and group affiliation) as explanatory variables (X_{ij}; Fafchamps and Gubert, 2007 in Abizaid et al. 2015), a clear departure from most empirical applications of DRA, which treat node- and link attribute data. Identification requires that the effect of (z_i, z_j) on Y_{ij} is the same as the effect of (z_j, z_i) on Y_{ji} (i.e., $\beta X_{ij} = \beta X_{ji}$). Depending on whether or not analysts examine the direction of links, this symmetry can be preserved in the following specifications:

$$Y_{ij} = \propto + \beta_1 |z_i - z_j| + \beta_2 (z_i + z_j) + \gamma |w_{ij}| + u_{ij} \ (undirected\ model)$$

$$Y_{ij} = \propto + \beta_1 (z_i - z_j + \beta_2 (z_i + z_j) + \gamma w_{ij} + u_{ij} \ (directed\ model)$$

Link attributes can be directed or undirected, been the difference that in undirected model the direction (sign) of directional links attributes and the difference in node attributes are unimportant, here only their absolute magnitude values matter.

3.2.3 Social networks and natural resources management (adapted from Rockenbauch and Sakdapolrak, 2017)

Research in this category is concerned with the question of how social networks affect the ability to adaptively manage natural resources. The case studies deal with issues, ranging from coastal area management (Tompkins and Adger, 2002, Ramirez-Sanchez and Pinkerton 2009, Marín et al. 2012 and Cárcamo et al. 2014), migration-related livelihood groups, and how are their dynamic livelihoods propelled through global change? (Zimmerer, 2014), and what can be gained when adopting a cultural perspective to understand resilience and the associated social dynamics of social-ecological system (Apgar et al. 2015).

Network conceptualization

Social networks are conceptualized as key factor for understanding collective action. Some of the articles explicitly evaluate the influence of social networks to foster adaptative capacity (Apgar et al. 2015, Ramirez-Sanchez and Pinkerton 2009, García-Amado et al. 2012 and Zimmerer, 2014). While other do it implicitly by considering that social networks are key to understand a sustainable management of natural resources (Marín et al. 2012 and Cárcamo et al. 2014). Most of the studies reviewed focus on the structure of social relations and the impacts they have on management outcomes. Therefore, they treat social networks as independent variable, though there are also studies that considered external factors impacting the social network, such as economic variables (García-Amado et al. 2012).

Network as form of coordination, is the narrative that half of the studies used in this strand when evaluating social networks. Either focusing on the communication between resource users at the community level, or with an emphasis on formal organizational network (Cárcamo et al. 2014). The other half of the articles, refers to social network as a structural feature of social capital, either by evaluating the performance of particular organizations (Marín et al. 2012), individual actors (Ramirez-Sanchez and Pinkerton 2009).

Network operationalization

An example of each approach was observed in this strand. From metaphoric (Tompkins et al. 2002, Zimmerer, 2014), to descriptive (Nygren and Myatt-Hirvonen. 2009, Apgar et al. 2015), and structurally explicit approach (Marín et al. 2012 and Cárcamo et al. 2014). Networks are defined by the exchange of information, knowledge exchange and collaboration between actors. In terms of boundaries, networks are defined based on a clear ecological, geographical or administrative border. Whereas social ties in most cases were perceived as facilitating exchange and mutual understanding, few studies appointed to the restrictive potential of social ties (Marín et al. 2012). Scale of interaction in most of studies was address as cross-scale between political and administrative actors, or in other words as multilevel and multidimensional scales (Tompkins and Adger, 2002, Cárcamo et al. 2014). Formal network analysis comprises the complete network, subgroups, and the individual level. Structural features focused on network density, centrality, or fragmentation. Some studies distinguished between bonding, bridging and linking ties (Ramirez-Sanchez and Pinkerton 2009, Marín et al. 2012, Cárcamo et al. 2014 and Apgar et al. 2015).

Metrics analyzed

Besides density and centrality, in/out degree was used by Cárcamo et al. (2014). Moreover, Marín et al. (2012) described the use of two composed indices (please refers to the article for a complete explanation), ***linking social capital index (LSCI)***, which is based on relationships with actors at other scales and is expressed with three elements:

$$LSCI = \frac{(Fd - Hd) + (Td - Ud) + (Hf)}{3}$$

"(1) Net facilitating degree equals facilitating degree (Fd) minus hindering degree (Hd); (2) Net trustworthiness degree equals trustworthy degree (Td) minus untrustworthy degree (Ud); (3) Heterogeneity factor (Hf) or the variety of alters with respect to relevant dimensions (Borgatti et al. 1998), defined here as the proportion of functional groups, e.g., power-sharing and enforcement; monitoring, research and development; and marketing, identified by Marín and Berkes (2010) with which the organization has facilitating and trustworthy relationships."

And the ***bridging social capital index (BSCI)***, which "captures horizontal linkages between organizations at the same level, and is calculated as the simple mean of three elements: (1) and (2) as described above for the LSCI but with respect to horizontal relationships with other near and far fishing villages, presented as two distinct categories; and (3) a complementary factor (Cf) using other questionnaire items referring to specific inter-village positive linkages, also expressed as a proportion."

$$BSCI = \frac{(Fd - Hd) + (Td - Ud) + (Cf)}{3}$$

Finally, Ramirez-Sanchez and Pinkerton (2009) used the **Crowe´s framework** (Crowe 2007) to evaluate bonding and bridging social capital within each community. And used **Crona and Bodin's** (2006) approach, to assess linking social capital, which consist of finding the proportion of observed vs expected ties. The latter is done by using a relational contingency table analysis.

3.3 Endogenous and exogenous drivers of network change

Endogenous development has been promoted over the last few years as a mechanism to facilitate bottom-up development, by taking the potentiality of local actors and resources (Schucksmith 2010; Bosworth et al. 2020). Is according to the authors, a holistic approach to rural development that includes local empowerment, capacity building, overcoming exclusion, adding value to local resources, promoting innovation, and enhancing connectivity. In this regard, over the last years different institutions as the Inter-American for Cooperation on Agriculture (IICA) are working to put in evidence the need to considered local networks to design a proper territorial planification. An example of this is the technical support the IICA has been giving to the establishment of Territorial Action Groups (TAG) across the Central America countries, with the aim to do their own planification with a prioritization of interventions within the territory (IICA, 2013) according to their needs and why not, their preferences. This includes a binding participation of all actors, of different sectors and scales, that inhabit and intervene in the territories. The successful experiences of self-management and local development through the establishment of TAGs in Central America or territorial planification based on biophysical features (as the basin limits) and socio-cultural characteristics, can contribute to the sustainability and efficiency of the network.

In the dry corridor of Honduras two TAGs were supported by the IICA[3], ***Belén Gualcho*** in the department of Ocotepeque, which corresponds to a Lenca[4] identity municipality, and ***Valle de Sensenti*** which includes 8 municipalities also in Ocotepeque. Both are part of the implementation of the Central American Strategy for Rural Territorial Development (ECADERT in Spanish) and can be consider as local-

[3] http://repiica.iica.int/docs/b3238e/b3238e.pdf

[4] Los Lencas - Instituto Hondureño de Ciencia, Tecnología e Innovación (ihcieti.gob.hn)

network interventions (see section 3.4). In the first case the territorial plan had the support of two NGOs and lack of it from the national government. Then, an investment plan and projects profiles were developed locally in a way that actors' projects will not overlap and the necessities of all the community could be considered, or in words of a villager, "previously without this planification, NGOs came to Belén Gualcho and chose the territory and beneficiaries to implement a project. But now with a prioritization of territory and needs, we can work along with the NGOs in a way that overlapping interventions will not occur anymore" (personal communication, 2013). In the second case, the region is part of the Trifinio Plan[5] that includes communities from Guatemala, El Salvador and Honduras and, for the territorial development plan, included the coordination between local actors (local leaders and water managers -juntas de agua in Spanish), international NGOs, local governments, and the Ministry of Health of Honduras.

With a similar approach (i.e., external support and horizontal decision makers) and with the support of public and private actors as it is the National Institute of Seismology, Volcanology, Meteorology and Hydrology (Insivumeh in Spanish) in Guatemala, 19 "agroclimatic technical networks (mesas técnicas agroclimáticas in Spanish)" have been stablished over all the country territory. According to Insivumeh (https://insivumeh.gob.gt/mesas-agroclimaticas/) these networks are "a space for dialogue between a diversity of local actors including scientists, technicians, representatives of the public and private sector and farmers, which seeks to understand the possible behavior of the climate in a locality and generate recommendations to reduce the risks associated with the expected climate variability." These networks are a combination of top-down and bottom-up approaches, in which the communities become more empowered to make decisions within a supportive, but not over-bureaucratic, framework (Bosworth et al. 2020).

The choice to adopt an inclusive decision-making strategy as described above in Guatemala, is an example in which the goals of public institutions are compatible with the interests of the local executive and farmers. Anderson and Laerhoven (2007), evaluate how rural local government representatives in 390 municipal governments in Brazil, Chile, Mexico and Peru relate to both central government officials and small-farmers, and how these relationships affect the likelihood of involving farmer in the planning, implementation, and monitoring of public services in the agricultural sector. They found that with exception of Peru, local politicians are more interested in participatory governance. The authors explained that maybe this could be related by decentralization reforms that allow local politicians been more politically and financially empowered, but also to greater prevalence of poverty and socioeconomic inequalities in Peruvian rural societies, compared to Brazil, Chile and Mexico. Using social network terminology, this can be expressed by the degree of centrality and density, albeit the socioeconomic inequalities are beyond this kind of analysis.

The local/global dualism, as describe by Rubertis (2020) permitted that a new concept was adopted when referring to rural development -at least for European countries-, this is the *neo-endogenous development approach*, that goes beyond endogenous and exogenous modes.

> "The notion that rural development is best achieved through a combination of local resources and local action integrated within wider networks reflects the neo-endogenous development approach, which offers an alternative to dualistic 'top-down' or 'bottom-up' perspectives. Building on earlier

[5] The Trifinio Plan is a regional organization that is part of the Central American Integration System (SICA in Spanish), which seeks to develop a process for managing the environment and the territory, in order for it to become the possibility of improving conditions of border communities. In 1997, the Trinational Commission of the Trifinio Plan (CTPT) was established, with the signing of a Trinational Treaty, between the Republics of El Salvador, Guatemala and Honduras; which is led by the Vice Presidents of El Salvador and Guatemala and a Presidential Designee of Honduras, as the entity in charge of supervising the execution of the Trifinio Plan and its permanent updating (Art.5). In: https://www.plantrifinio.int/

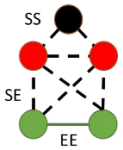
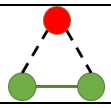
work on purely endogenous development (van der Ploeg and van Dyck, 1995), local control remains at the heart of neo-endogenous development but the need to embrace 'extra-local' factors is also emphasized (Ray 2001)" (Boscorth et al. 2016, p. 428 in Rubertis 2020).

The above demonstrate the intricate interconnections that occurs within the territory among the different actors. From decision-makers in a central government position, to local government, till the small-farmer in which the family depends on. Rather than separating between internal or external development, a hybrid approach is a necessity, as the territory is a *multidimensional mesh* (network of network) that is continually redesigned by the interaction between social and natural features (Rubertis 2020), analogous to climate change and global change[6]. Through this knowledge it is possible to investigate governance gaps within territory development and the possible interventions.

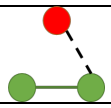
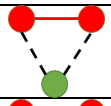
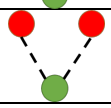
3.4 Governance gaps and interventions in terms of social-ecological networks

Develop adaptation capacities and environmental sustainability issues cannot be separated from their social and biophysical context, and the governance of interdependent issues. Bergsten et al. (2019), explained that governance gaps emerge when responsible actors fail to recognize how multiple issues and actors are interlinked. The authors focus their research on two types of governance gaps: (1**) integrative gaps** arising when **complex issues are managed in separation** meaning that interdependencies among issues are not managed, and (2) **collaborative gaps** arising when actors working on common issues are not collaborating with each other. Their study in Ethiopia found for example, a collaboration gap around forest and wildlife conservation, but dense collaboration around issues relating to agricultural production, despite forest and wildlife are highly interdependent. The response to climate change in the agricultural sector will indeed require close coordination with policies to reduce deforestation, protect biodiversity and manage water resources (Lennox, 2012). Hence, the authors define ***integrative misfit*** when a governance actor manages a sustainability issue that is directly linked to other issue, as the previous example, without engaging with the linked issue (see table 4). Among the causes, it can be included the bureaucratically assigned responsibilities which do not reflect the interdependencies among issues and may result in inappropriate management responses. Though these gaps are explained within a social-ecological network it is also applicable for bipartite social networks.

*Table 4 Actor-issue configuration and their theoretical implications on **institutional fit**. With higher institutional fit implying better conditions for effective governance of sustainability issues. Red nodes denote governance actors who may be collaborating (red link) and who have influence links (black dash line) to sustainability issues (green nodes) that may be interdependent (green link). Source: adapted from Bodin and Tengö (2012), Kininmonth et al. (2015) and Bergsten et al. (2019).*

	As proposed by Kininmonth et al. (2015), the fully connected five-node governance is depicted by this figure. Assuming the existence of a coordinating actor (black circle) and is not directly connected to the ecological resources. While the interdependencies between nodes are social-to-social (SS), ecological-to-ecological (EE) or social-to-ecological (SE).
Integrative fit	
	Integrative fit occurs for an issue and for an influencing actor if the actor also engages with the interdependent issue.

[6] Global change refers to all human-caused environmental changes, which includes climate change per-se, land use changes, loss of biological diversity among other modifications attributed to the human in the Earth System, and the feedback among these changes. More information can be read in Vitousek 1994 and Schellnhuber et al. 1997.

	Integrative misfit occurs when the interdependent issue is not managed
Collaborative fit	
	Collaborative fit occurs for an issue and for two influencing actors collaborate with each other.
	Collaborative misfit occurs when the actors work in isolation

As the previous study, Angst et al. (2018) define *fragmentation* as "a setting where actors have overlapping responsibilities for issues than span across multiple levels of a relevant scale of governance or work independently on interconnected issues." Which is related to low-effective governance, especially because of competing responsibilities between the actors. Then, an institutional adjustment or network intervention can be suggested to reduce fragmentation and mis-fit configurations. In this manner, Bodin and Tengö (2012), and Kininmonth et al. (2015), developed a conceptual model for the systematic linkage of key socio-ecological governance links. Figure 4 is a simple model which relates the relation between governance complexity and governance effectiveness. The four combinations (a-d) just describe the situation when two resource managers share one ecological resource. (a) is the simplest, when two actors jointly manage a resource without any social-to-social interaction, hence it is the least effective configuration; (c) is when the actors do coordinate and has a social link. Higher effectiveness can also be reach when a coordinating actor is involved, though it can also increase the complexity.

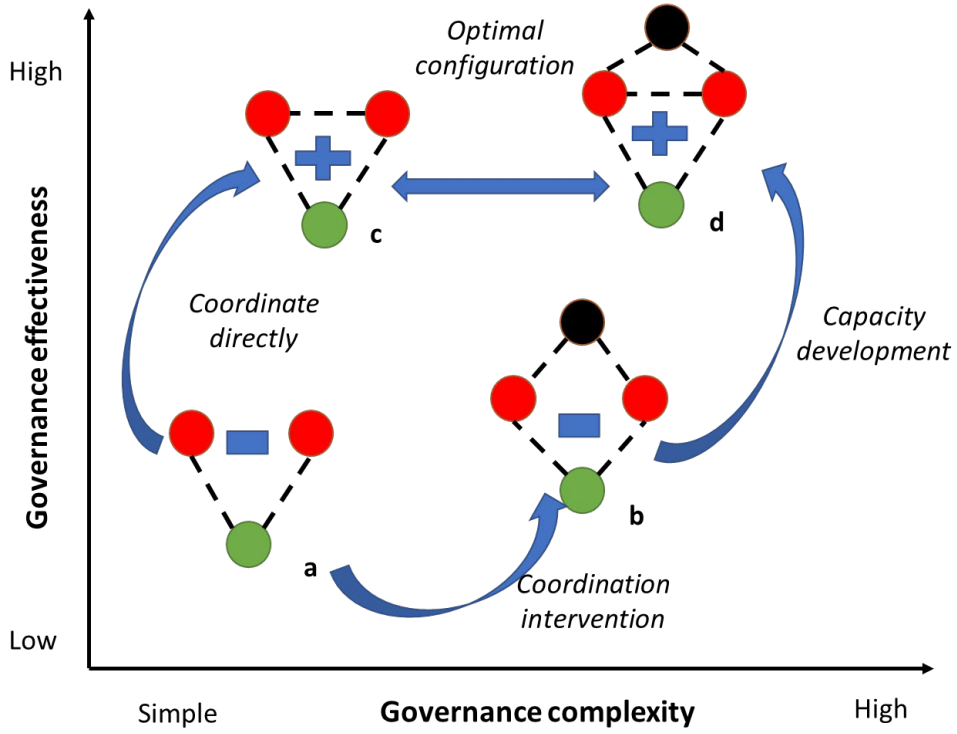


Figure 4 The common resource pool subsets (a-d) display across effective complexity space. Adapted from Kininmonth et al. 2015.

Considering the complete network, Angst et al. (2018) proposed to reduce fragmentation, to distinguish between two bridging positions, periphery connectors and central coordinators, and enhance their roles in the network. The key role of periphery connectors, as described by the authors, is that they can integrate otherwise unconnected actors to the core of the network. Moreover, they are often sources of information heterogeneity in a network because they are likely to be less prone to homophilous processes (i.e., when actors who interact often become more similar over time). Furthermore, this heterogeneity has been associated with effectiveness and adaptability in natural resources governance networks (Carlsson and Sandstrom 2008 in Angst et al. 2018). Central coordination, in the other hand, plays a different bridging role, by connecting a greater number of other actors and allowing the shortest network paths between many other actors.

To overcome fragmentation and actor-issues misfits, interventions can be done. Yet, choosing the right type of network intervention depends on the context and purpose. Valente (2012) listed four types of interventions. Here a brief description is done and are listed in order of increasing complexity: (1) *Individuals*, been the most frequent of this type, the use of opinion leaders. Even though, leaders may not always be the best change agents, since they could be interested in the status-quo, whereas bridging actors may be more amenable to change. Moreover, people on the margins of the network may also be identified by the intervention, because they are potentially excluded but it doesn't mean that they do not have the abilities to innovate, as they are free from social pressure to conform. (2) *Segmentation*, is related not to an specific actor but to identify groups of actors to change at the same time. This is done, through a core-peripheral structure (i.e., a group in the periphery of the network with core members within the group). For example, at the municipality level, local networks are often composed by several organizations and/or communities leaders which can have the potential to change from inside the group. (3) *Induction*, or also referred to as "going viral", is a intervention that do not necessarily use network data, but they depend on the network for their effects. It is also known by using a "snowball method", because create cascades in information or behavioral diffusion. (4) *Alteration* is a strategy in which the network suffers many interventions deliberately. According to the authors there can be three different tactics: (1) adding/deleting nodes, (2) adding/deleting links, or (3) rewiring existing links. Finally, selecting the best fit intervention depends on many factors, as the type and character of available network data, the type of change wanted, and the environmental or situational context.

There are many reasons **why a network intervention is needed.** In terms of territorial development within a climate change context, this means that institutional networks will require to have a long-term vision. As it was exposed before, the challenges to manage natural resources in a sustainable manner and intergenerational fairness are enormous. Balancing between short-term and long-term planning is a requirement to do a proper adaptation plan in the agricultural sector. Bleischwitz et al. (2014), linked future food and water stress with global supply vulnerabilities for foresight analysis and conclude -among others-, that the challenge of balancing short- and long-term planning is indeed a challenge across temporal and spatial scale:

> "-Transparency and accountability, usually seen as clear-cut correlations, will have to accept indirect dynamics where demand from end-users far away triggers unwanted effects in remote areas. Thus, the polluter-pays-principle from environmental policy and international law needs to be converted into a more general and binding responsibility for materials along their value chains and within regional environmental boundaries. Actors to be involved comprise regional and national authorities with assessment capacities, key industries, and concerned stakeholders.
>
> -The cumulative causation of decisions and their impacts go beyond the traditional risk criteria of availability of resources and access. It would be far too simple to conclude from geological surveys

that if the availability is for more than one generation and if the access can be safeguarded by a legal order future generations wouldn't have to suffer. The precautionary principle needs to be translated into principles for sustainable resource management at the level of countries that help to maintain the most relevant resource functions over time."

Though it is not an explicit analysis for climate change adaptation, Vargas-Lama and Osorio-Vera (2020), evaluated the role of territorial foresight to promote a sustainable development of a territory, analyzing its potential and some identified problems in Latin America governance. They identified three premises that could help to understand the origin of the nowadays short-term views from the public policies and the absence of collective and integrative projects: "(1) There is a gap between the increase in environmental challenges in recent years and the speed of response. The symptoms are chance, instability, and a specific general setback in social indicators. But in the end, there is a capacity gap between decision-makers and operational managers of the Public Administration, produced by the rise of international standards and the slow and poorly response capacity; (2) A little manifestation of the capacity for innovation of new decision-making models and organizational practices that strengthen institutions; and (3) The empirical situation manifest many dangerous mistake elements in itself because of decision-making process that relies on institutional and cultural aspects linked to how power is conceived and operated in the Public Administration". Then, as the authors proposed, foresight and future studies are a good alternative to support the generation of future regional visions. And recognized through a territorial foresight strategy the importance of the participation of the critical change actors on a territorial governance perspective.

4. Institutional networks in Honduras over a climate change adaptation context

4.1 Climate change vulnerability assessment in the Honduran Dry Corridor

Central America's dry corridor by its own natural climate variability receives approximately 1500 mm of rainfall per year, this is the case of the five Honduran's river basins that drain to the Fonseca Gulf (Depsky and Pons, 2021; IHCIT, 2014). The dry season can last six months, from November to April, while the rainy season goes from May to October, with a decreased of rainfall between July to August known as the mid-summer drought (MSD) or commonly canícula or veranillo. These natural climatic features have an interannual variability mostly related to the El Niño South Oscillation (ENSO), which can delate the starts of the rainfall, increase the duration and intensity of the MSD, or even generate droughts and floods related to the intensity of ENSO events. Since 2015 until 2019, the Central America's dry corridor suffered consecutive droughts with 2.2 million people having suffered severed crop losses and 1.4 million in urgent need of food aid (FAO 2018). Honduras for instance, declared a state of emergency and called for international assistance, since more than 1.3 million of inhabitants (mostly in the dry corridor) suffered from moderate to severe food insecurity (SRE, 2015).

Even there is not a significative rainfall tendency at interannual variability, the increase of temperature it is significant for observed dataset, satellite-based estimation products and models at different temporal scales (Durán-Quesada et al. 2020; Stewart et al. 2021). Added to the temperature raise, deforestation and soil degradation can increase evapotranspiration and aridity (Álfaro-Córdoba et al 2020), hence reducing water availability. And given the diverse economic activities in the region, such as agriculture and hydroelectric generation, are climate dependent, it is evident that climate change could impact the development economies. Projections for the future in Honduras suggest an increasing of the

MSD and a reduction of the rainy season magnitude (Navarro-Racines et al. 2018) regardless the representative concentration pathway (RCP[7]) from the IPCC.

Rural, small-farming communities dependent on timely and sufficient rainfall from May to October to produce both staple and cash crops, then a reduction of rainfall have impacted the communities' crop yields, income and food security and have been linked to internal displacement and migration in the region (IDB, 2017). In severe water-limited regions as the Central America Dry Corridor, changes in drought and aridity are effects that are expected from climate change, and thus will impact on the hydrological cycle. In fact, by the end of the century, runoff across Central America is projected to decrease substantially due to rising temperatures (Imbach et al. 2017). In Honduras vulnerability to the natural climate variability and climate change is especially severe because it has one of the highest inequality indexes in Latin America, a rural poverty rate of 90% and perhaps more than 50% of the rural population is dedicated exclusively to the production of basin grains (FAO-RUTA, 2010 and CEPAL, 2012 in Müller et al. 2018).

In Honduras as in the rest of Central America, over the last few years it become clear that climate change affects multiple sectors, so it is not longer an environmental issue to be manage by the Minister of the Environment, but a major economic and social treat, so necessarily involving Ministries of Agriculture, Forest conservation, Health, Education, among others. Without letting outside the universities, NGOs, chambers of industry and civil society. Thus, since the National Climate Change Strategy published in 2010 by the Minister of the Environment, the country has intended to unify efforts among public, private, and social actors to the development of *Territory Plans* and *Adaptation Plans* at different spatial scales and sectors. Though, the challenge as in all Latin America is to operationalize these politics and plans in an effective and sustainable manner.

4.2 Institutional networks related to the National Adaptation Plan and the Agriculture Adaptation Plan

From a territory development planification, the state of Honduras approved (No. 286-2009) the Nation Plan (2010-2022) and National Vision (2010-2038) as a guiding framework for the long-term development planning process. For mitigation and adaptation to climate change, the plan was to: "By 2022, Honduras will have consolidated an institutional framework to promote and keep the issues of adaptation and mitigation to climate change in force." And the vision to: "By 2038, Honduras will have transversally inserted the issue of climate change in sectorial planning and all public and private investments will be carried out under a vision of mitigation and adaptation." A formal network institution has been indeed promoted as it is described below, yet it is not considered to be consolidated.

Honduras possesses by Law (No. 1203-2013), two national committee in terms of climate change, an institutional committee in which the executive branch leads it and, a technical committee in which the Ministry of Environment is the head. The last committee possess three branches of work: mitigation, adaptation, and environmental and social safeguarding. Over these three sub-groups not only the government institutions interact but also the private sector, academia, NGOs, and civil society can take part. Additionally, to the National Adaptation Plan, the country possesses the National Strategy for Adaptation to Climate Change for the Agri-Food Sector of Honduras (2014-2024) which is led by the Ministry of Agriculture (SAG in Spanish) as part of the agriculture technical subcommittee. Related to this sector and food security, the country possesses different national plans and strategies to reduce the drought risk and to reduce the risk of malnutrition and food insecurity. Giving in each of them a formal institutional framework in which each plan or strategy will be operated.

[7] van Vuuren et al. (2011). *The representative concentration pathways: an overview* in: rcp.pdf (noaa.gov)

For Honduras a power mapping of social actors related to climate change and agriculture (Castro et al. 2014), summarized the large influence the SAG and the Ministry of the Environment possess to implement the national climate change politics in the agricultural sector. Though the Forest Conservation Institute (ICF in Spanish) has a low influence, this is a key institution in terms of natural resources management. As commented by the Climate Change Director from the Ministry of Environment: "The actualization of the National Adaptation Plan to submit to the COP26 in 2021 will include a coordination between the SAG and ICF, to link both sectors in 2 specific objectives to reduce overlapping responsibilities. The first objective is the Reducing Emissions from Deforestation and Forest Degradation (REDD+) actions related to mitigation measurements, and the second one, the Rural Development as an adaptation measurement to overcome the recurrent droughts and floods. It also seeks to take advantage of the regional institutions located unequally throughout the country. This is because in some regions of the country there is only one of the two institutions." (Sergio Palacios, personal communication).

Interestingly, the power mapping also described a larger influence of international cooperation, as USAID and FAO, when compared to the universities and even to NGOs, private sector, or civil society. Describing then huge gaps in how adaptation plans are formulated and implemented. Universities for instance, should have an important role in climate scenarios research, possible impacts of climate change and the development of adaptation measures. Yet, research is limited to specific works or initiatives of faculties, without having in the same university a defined plan. The private sector does not have a large influence as well, at least when evaluated for the implementation of public politics. But, as it was described in previous sections with the example of the Marcala's coffee Denomination of Origin, it actually has a large impact as a bridging actor and as a local development driver at a specific agricultural product. This product (coffee) is coordinated from private institutions as the Honduras Coffee Institute (IHCAFE) and coffee cooperatives or associations, with low influence from the SAG.

Civil society, as exposed in the previous sections possess an important role at their local development, but as observed by Castro et al. (2014) in Honduras' agriculture-climate change sector, the influence is low or is not even considered by some actors. Over a general global context and related to mitigation measurements -which is analogous to adaptation-, Wynes and Nicholas (2017) observed that in general, individual and collective level actions at shorter spatial scales are ignored or neglected, doing very difficult the implementation of any adaptation plan. In Honduras, a mechanism in which civil society interact in a specific socio-economic or interest sector, as agriculture, climate change, risk reduction and food security is through the "Mesas Regionales" that each of the sixteen regions has, defined by the National Vision (2010-2038) and Nation Plan (2010-2022). Art. 27 of No. 286-2009 says: "The Regional Development Councils may be integrated by subject and may also be constituted with different representatives for each subject, according to the parties interested in it. To this end, each Regional Board will issue regulations for its operation, which must be made known to the Technical Secretariat for Planning and External Cooperation." The question is the influence and effectiveness the "Mesas Regionales" possess to be considered when planning, coordinate and implement actions. Moreover, the existence of trust from the Mesas Regionales to the decisions that comes from the national government institutions.

References

1. Abizaid, C., Coomes, O. T., Takasaki, Y., Brisson, S. (2015). Social network analysis of peasant agriculture: cooperative labor as gendered relational networks, 67:3, 447-463, doi: 10.1080/00330124.2015.1006562
2. Akhtar, N. (2014). Social network analysis tools. 2014 Fourth International Conference on Communication Systems and Network Technologies, 388–392.
3. Alfaro-Córdoba, M., Hidalgo, H. G. and Alfaro, E. J. (2020) Aridity trends in Central America: A spatial correlation analysis. Atmosphere, 2020, 11(427), doi: 0.3390/atmos11040427
4. Anderson, K. and van Laerhoven, F. (2007). Institutional incentives for participatory municipal governance in Latin America, *Comparative political studies*, 40(9), pp. 1085-1111, doi: 10.1177/0010414006288977
5. Angst, M., Widmer, A., Fischer, M., Ingold, K. (2018). Connectors and coordinators in natural resources governance: insights from Swiss water supply. *Ecology and Society*, 23(2):1, doi: 10.5751/ES-10030-230201
6. Apgar, M. J., Allen, W., Moore, K., Ataria, J. (2015). Understanding adaptation and transformation through indigenous practice: the case of the Guna of Panama, *Ecology and Society*, 20(1):45, doi: 10.5751/ES-07314-200145
7. Barabási, A. L. (2015). Network Science in http://networksciencebook.com/
8. Berardo, R. and Scholz, J.T. (2010). Self-organizing policy networks: risk, partner selection, and cooperation in estuaries. *American J. of Political Sci.*, 54(3), pp. 632-649, doi: 10.1111/j.1540-5907.2010.00451.x
9. Bergsten, A., Jiren, T. S., Leventon, J., Dorresteijn, I., Schultner, J., Fischer, J. (2019). Identifying governance gaps among interlinked sustainability challenges, *Env. Sci. and Policy*, 91, pp. 27-38, doi: 10.1016/j.envsci.2018.10.007
10. Bleischwitz, R., Johnson, C.M., Dozler, M. G. (2014). Re-assessing resource dependency and critically. Linking future food and water stress with global resource supply vulnerabilities for foresight analysis, *Eur. J. Future Res.*, pp.15:34, doi: 10.1007/s40309-013-0034-1
11. Bodin, O., Crona, B., Ernstson, H. (2006). Social Networks in natural resources management: what is there to learn from a structural perspective? *Ecology and Society*, 11(2), doi: 10.5751/ES-01808-1102r02
12. Bodin, O. and Crona, B. (2009). The role of social networks in natural resources governance: what relational patterns make a difference? *Global Envi. Change*, 19, 366-374, doi:10.1016/gloenvcha.2009.05.002
13. Bodin, O., Ramirez-Sanchez, S., Ernstson, H., Prell, C. (2011). A social relational approach to natural resource governance. In Social Networks and Natural Resources Management, edited by Örjan Bodin, Stockholms Universitet, Christina Prell, University of Maryland, College Park Publisher: Cambridge University Press doi: 10.1017/CBO9780511894985.002
14. Bodin, O. and Tengö, M. (2012). Disentangling intangible social-ecological systems. *Global Envi. Change*, 22, 430-439, doi: 10.1016/j.gloenvcha2012.01.005
15. Bodin, O. (2017). Collaborative environmental governance: achieving collective action in social-ecological systems, *Science*, 357, eaan1114, doi: 10.1126/science.aan1114
16. Boisier, S. (w.d.). Desarrollo endógeno: ¿para qué?, ¿para quién? 375 - 392. In: https://www.researchgate.net/publication/242755471_DESARROLLO_ENDOGENO_PARA_QUE_PARA_QUIEN_EL_HUMANISMO_EN_UNA_INTERPRETACION_CONTEMPORANEA_DEL_DESARROLLO accessed in July 23, 2021.

17. Borgatti, S. P., A. Mehra, D. J. Brass, and G. Labianca. (2009). Network analysis in the social sciences. *Science*, 323, pp. 892-895, doi:10.1126/science.1165821
18. Bosworth, G.; Price, L.; Hakulinen, V. and Marango, S. (2020) Rural social innovation and neo-endogenous rural development in Neoendogenous development in European rural areas; results and lessons. Springer.
19. Bouroncle, C.; Imbach, P.; Rodríguez-Sánchez, B.; Medellín, C.; Martinez-Valle, A.; Läderach, P. (2017). Mappint climate change adaptative capacity and vulnerability of smallholder agricultural livelihoods in Central America: ranking and descriptive approaches to support adaptation strategies. *Climatic Change*, 141:123-137, doi:10.1007/s10584-016-1792-0
20. Bowen, S. (2010). Embedding local places in global spaces: Geographical Indications as a territorial development strategy. *Rural Sociology*, 75(2), pp. 209-243, doi: 10.1111/j.1549-0831.2009.00007.x
21. Cano-Reyes, O., Villanueva-Jiménez, J.A., Reta-Mendiola, J.L., Huerta-de-la-Peña, A. Technology transfer networks on Papaya production with transitional growers. *Tropical and subtropical Agroecosystems*, 15, SUP2: S12-S20
22. Cárcamo, F.P., Garay-Flühmann, R., Gaymer, C.F. (2014). Collaboration and knowledge networks in coastal resources management: How critical stakeholders interact for multiple-use marine protected area implementation, *Ocean and Coastal Management*, 91, pp. 5-16, doi: 10.1016/j.ocecoaman.2014.01.007
23. Castro, L., Sova, C., Martínez Barón, D., & Saravia, D. (2014). Influencia de los actores sociales paraHonduras: Cambio climático y agricultura. In www.ccafs.cgiar.org
24. Coleman, J.S. (1988). Social Capital in the creation on human capital. *The American Journal of Sociology*, 94, pp.S95-S120, URL: http://www.jstor.org/stable/2780243
25. Crona, B., and Ö. Bodin. (2006). What you know is who you know? Communication patterns among resource users as a prerequisite for co-management. *Ecology and Society*, 11(2): 7. URL: http://www.ecologyandsociety.org/vol11/iss2/art7/.
26. Crowe, J. A. (2007). In search of a happy medium: How the structure of interorganizational networks influence community economic development strategies. *Social Networks*, 29, 469-488, doi: 10.1016/j.socnet.2007.02.002
27. Depsky, N. And Pons D. (2021). Meteorological droughts and projected to worsen in Central America's dry corridor throughout the 21st century. Environ. Res. Lett., 16, 014001, doi: 101088/1748-9326/abc5e2
28. Downey, S. S. (2010). Can properties of labor-exchange networks explain the resilience of Swidden agriculture? *Ecology and Society*, 15(4):15, URL: http://www.ecologyandsociety.org/vol15/iss4/art15/
29. Durán-Quesada, A. M., Sorí, R., Ordoñez, P., & Gimeno, L. (2020). Climate Perspectives in the Intra-Americas Seas. Atmosphere, 11, 959. doi:10.3390/atmos11090959
30. Eakin, H., Eriksen, S., Eikeland, P-O., Oyen, C. (2011). Public sector reform and governance for adaptation: implications of new public management for adaptative capacity in Mexico and Norway. *Environ. Management*, 47, pp. 338-351, doi: 10.1007/s00267-010-9605-0
31. Food and Agriculture Organization of the United Nations (FAO) 2013. Climate-Smart Agriculture Sourcebook.
32. Food and Agriculture Organization of the United Nations (FAO) 2018 FAO and WFP concerned about the impact of drought on the most vulnerable in Central America FAO (Article)
33. Folke, C.; Hahn, T.; Olsson, P.; Norberg, J. (2005). Adaptative governance of socio-ecological systems. *Ann. Rev. Environ. Resour.*, 30:441-73, doi: 10.1146/annuarev.energy.30.050504.144511
34. Garcia-Amado, L. R., Pérez, M. R., Iniesta-Arandia, I., Dahringer, G., Reyes, F., Barrasa, S. (2012) Building ties: social capital network analysis of a forest community in a biosphere reserve in Chiapas, Mexico, *Ecology and Society*, 17(3):3, doi: 10.5751/ES-04855-170303

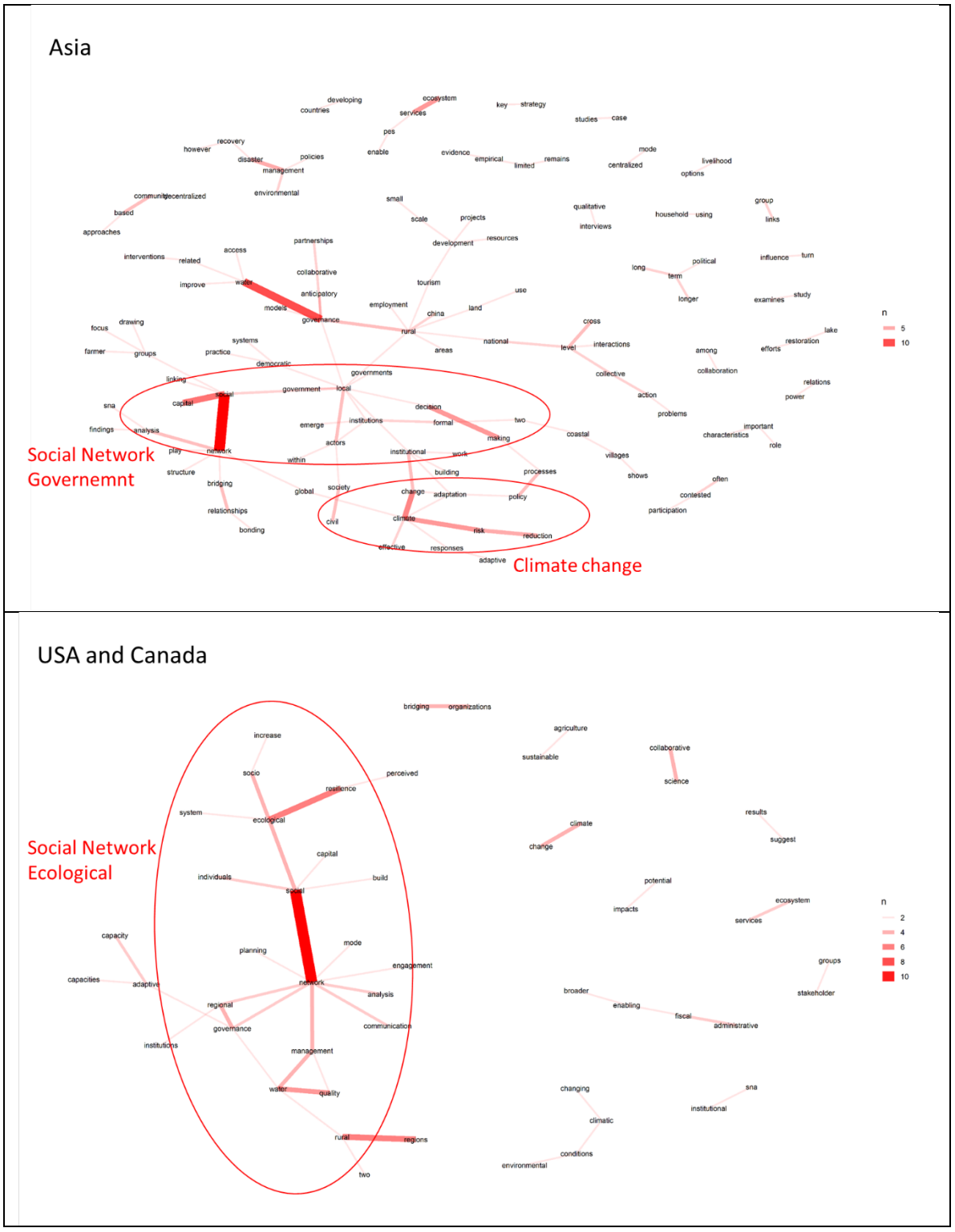
35. Gómez, S. (2019). Centrality in networks: Finding the most important nodes. En Business and Consumer Analytics: New Ideas (pp. 401–433). Springer.
36. Granovetter, M. (1973). The strength of weak ties. *America Journal of Sociology*, 78(6), pp. 1360-1380, https://www.jstor.org/stable/2776392
37. Hamilton, M., Hileman, J., Bodin, O. (2019). Evaluating heterogeneous brokerage: New conceptual and methodological approaches and their application to multi-level environmental governance networks. *Social Networks*, doi:10.1016/j.socnet.2019.08.002
38. Hileman, J. and Lubell, M. (2018a). The network structure of multilevel water resources governance in Central America. *Ecology and Society*, 23(2):48, doi: 10.575/ES-10282-230248
39. Hileman, J., Bastos, M. T.A., Lubell, M. (2018b). Robustness and the paradox of bridging organizations: the exit problem in regional water governance networks in Central America. *Society and Natural Resources*, 31:6, 683-697, doi: 10.1080/08941920.2017.1423436
40. Inter-AmericanDevelopmentBank(IDB)2017FoodSecurityandEmigration - Why People Flee and the impact n familymembers left behind in El Salvador, Guatemala andHonduras.IDB (Report)
41. Imbach, P., Beardsley, M., Bouroncle, C., Medellin, C., Läderach, P., Hidalgo, H., Alfaro, E., Van Etten, J., Allan, R., Hemming, D., Stone, R., Hannah, L. and Donatti, C.I. (2017). Climate change, ecosystems and smallholder agriculture in Central America: an introduction to the special issue. *Climatic Change*, 141, 1–12, doi:10.1007/s10584-017-1920-5.
42. IICA (2013) Sistematización de experiencias de Desarrollo Rural Territorial en Centro América. In: http://repiica.iica.int/docs/b3238e/b3238e.pdf%20%20, 2021.
43. Issac, M. E. (2012). Agricultural information exchange and organizational ties: The effect of network topology on managing agrodiversity. *Agricultural Systems*, 109, 9-15, doi:10.1016/j.agsy.2012.01.011
44. Jacob, R., Harikrishnan, K.P., Misra, R., Ambika, G. (2017). Measure for degree heterogeneity in complex networks and its application to recurrence network analysis. *R. Sco. Open sci.*, 4:160757, doi: 10.1098/rsos.160757
45. Jorgensen, A., Fallow, M. A., Nielsen, R. S. (2020). "Just ask Eric": on the importance of governance efficacy, territorial ties and heterogeneous networks for rural development, doi: 10.1111/SORU.12328
46. Kininmonth, S., Bergsten, A., Bodin, O. (2015). Closing the collaborative gap: Aligning social and ecological connectivity for better management of interconnected wetlands. *AMBIO*, 44, doi: 10.1007/s13280-014-0605-9
47. Krishna, A., Shrader, E. (1999). Social Capital Assessment Tool. In Proceedings of the Conference on Social Capital and Poverty Reduction, Washington, DC, USA, 22–24 June 1999.
48. Kuzdas, C., Warner, B., Wiek, A., Yglesias, M., Vignola, R. and Ramírez-Cover, A. (2015). Identifying the potential of governance regimes to aggravate or mitigate local water conflicts in regions threatened by climate change. *Local Environment*, doi: 10.1080/13549839.2015.1129604
49. Kuzdas, C., Wiek, A., Warner, B., Vignola, R. and Morataya, R. (2014). Integrated and participatory analysis of water governance regimes: the case of the Costa Rican dry tropics. *World Development*, 66, pp. 254-266, doi: 10.1016/j.worlddev.2014.08.018
50. Lennox, J. G., (2012). Sustainable and inclusive adaptation to climate change and public policy challenges in Central America In: ECLAC et al. (2012f) published by the Economic Commission for Latin America and the Caribbean(ECLAC), the Ministries of Treasury/Finance and Environment of the seven CentralAmerican countries, through their Council of Finance or Treasury Ministers(COSEFIN) and their Commission for Environment and Development (CCAD) of theCentral American Integration System (SICA) and the Secretariat for Central AmericanEconomic Integration (SIECA), with funding from UKAID/DFID of the Governmentof the United Kingdom and the Government of Denmark´s development cooperationprogramme, DANIDA. URL: https://www.jstor.org/stable/pdf/j.ctv941vsk.25.pdf

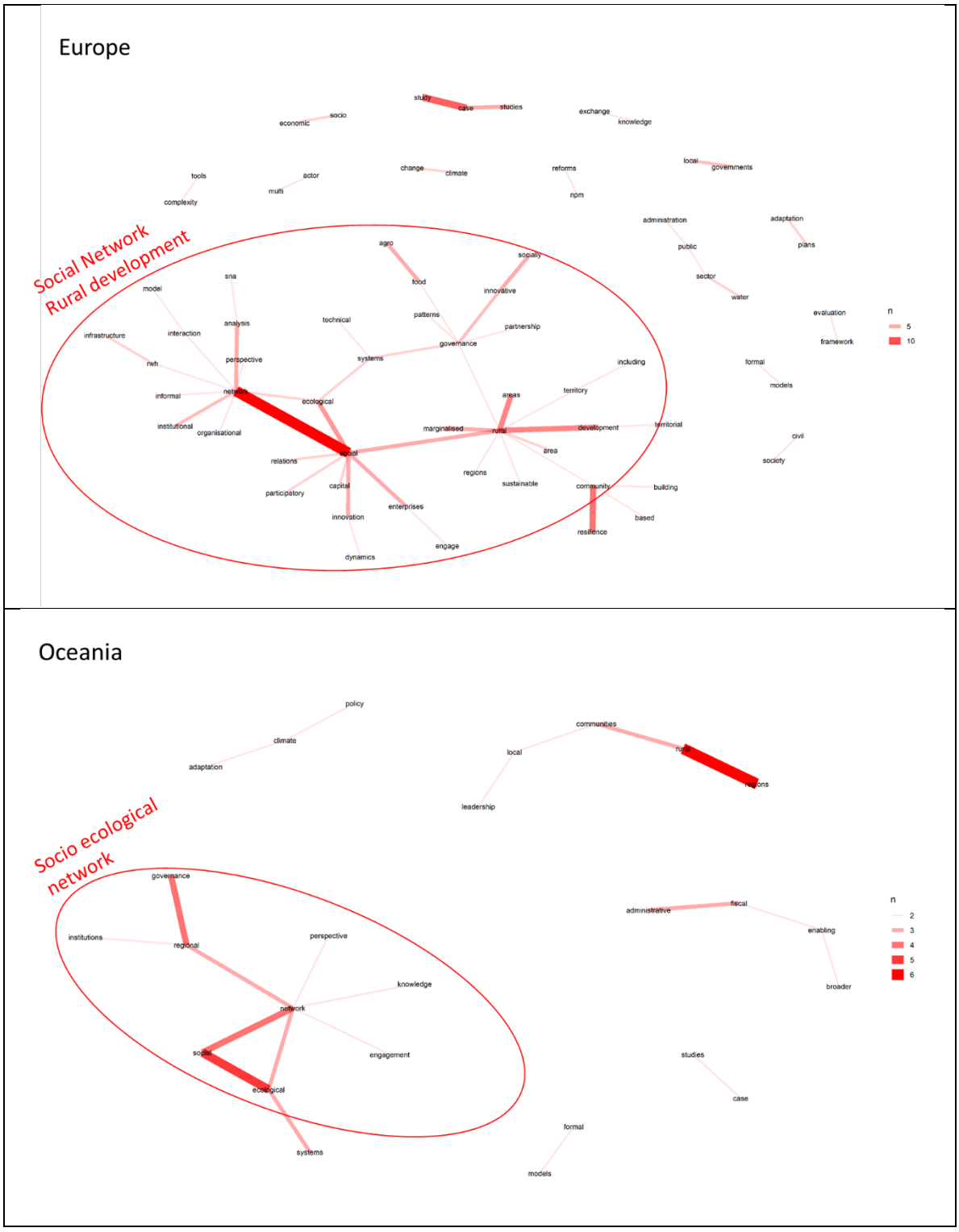
51. Lyle III, H. F. and Smith, E. A. (2014). The reputational and social networks benefits of prosociality in an Andean community. *PNAS*, 11(3), doi: 10.1073/pnas.1318372111
52. Luke, D. A. (2015). A user's guide to network analysis in R. Springer.
53. McAllister, R.R.J., Robinson, C.J., Brown, A., Maclean, K., Perry, S., Liu, S. (2017). Balancinc collaboration with coordination: Contesting eradication in the Australian plant pest and disease biosecurity system. *Int. J. of the Commons*, 11, pp. 330-354, doi: 10.18352/ijc.701
54. MacGillivray, B.H. (2018). Beyond social capital: The norms, belief systems, and agency embedded in social networks shape resilience to climatic and geophysical hazards. *Environ. Sci. and Policy*, 89(116-125), doi:10.1016/j.envsci.2018.07.014
55. Maneschy, M.C. and Klovdahl, A. (2007). Redes de associações de grupos camponeses na Amazônia Oriental (Brasil): fontes de capital social?, *REDES*, 12(4), pp. 1-19, E-ISSN: 1579-0185
56. Manzanal, M. (w.d.). Instituciones, territorio y gestión del desarrollo rural-local (teoría y praxis desde la realidad del norte argentino). URL: http://web.uaemex.mx/pwww/rii/docs/ponencias/VIII_Seminario_RII_Ponencias/Institucion_y_participacion_en_gestion/Mabel_Manzanal.pdf
57. Marín, A., Gelcich, S., Castilla, J.C., Berkes, F. (2012). Exploring social capital in Chile´s coastal benthic comanagement system using a network approach, *Ecology and Society*, 17(1):13, doi: 10.5751/ES-04562-170113
58. Martinez-Baron, D., Orjuela, G., Renzoni, G., Loboguerrero Rodríguez, A.M., Prager, S.D. (2018). Small-scale farmers in a 1.5 °C future: The importance of local social dynamics as an enabling factor for implementation and scaling of climate-smart agriculture. *Current Opinion in Env. Sustainability*, 31: 112-119, doi: 10.1016/j.cosust.2018.02.013
59. Matous, P. and Todo, Y. (2015). Exploring dynamic mechanisms of learning network for resources conservation. *Ecology and Society*, 20(2):36, doi: 10.5751/ES-07602-200236
60. MEA, (2005). Appendix D: Glossary. In: Ecosystems and Human Well-being: Current States and Trends. Findings of the Condition and Trends Working Group, Vol. 1 [Hassan, R., R. Scholes, and N.Ash (eds.)]. Millennium EcosystemAssessment (MEA), Island Press,Washington, DC, USA, pp. 893-900.
61. MiAmbiente, (2010). Estrategia Nacional de Cambio Climático de la República de Honduras.
62. Moore, M.-L. and Westley, F. (2011) Surmountable Chasms: Networks and Social Innovation for Resilient Systems. *Ecology and Society*, 16(1):5, URL: http://www.ecologyandsociety.org/vol16/iss1/art5/
63. Morgan, C.L., Guerrero, A. M., Ancrenaz, M., Meijaard, E., Wilson, K.A. (2017). Not more, but strategic collaboration needed to conserve Borneo's orangutan. *Global Ecology and Conservation*, 11, pp. 236-246, doi: 10.1016/j.gecco.2017.07.004
64. Müller, C., Salgado, R., Duron, M., Le Coq, J-L., de Varax, M., Gamba-Trimiño, C., Howland, F., Chia, E., Gallardo, O., Andrieu, N. (2018). Innovation platforms for climate Smart agriculture in Honduras, CCAFS Program for Latin America, CIAT.
65. Muñoz, M., Medel, R.R., Ávila, J. A., Muníz, J. G. G and Cárdenas, J.R.A. (2004). Redes de innovación. Un acercamiento a su identificación, análisis y gestión para el desarrollo rural. Fundación PRODUCE Michoacan y Universidad Autónoma Chapingo, URL: http://repositorio.chapingo.edu.mx:8080/handle/20.500.12098/321
66. Navarro-Racines, C., Monserrate, F., Llanos-Herrera, L, Obando, D. Córdoba, J. (2018). Desarrollo de los Escenarios Climáticos de Honduras y Módulo Académico de Capacitación. Centro Internacional de Agricultura Tropical (CIAT); Programa de las Naciones Unidas para el Desarrollo (PNUD); Dirección Nacional de Cambio Climático de MiAmbiente. 140p.

67. Noldus, R., & Van Mieghem, P. (2015). Assortativity in complex networks. Journal of Complex Networks, 3(4), 507–542. https://doi.org/10.1093/comnet/cnv005
68. Nuñez-Espinoza, J. F., Rodriguez, O. L. F. and Jiménez-Sánchez, L. (2013). Elementos para analizar redes sociales para el desarrollo rural en México. El caso RENDRUS. *Agricultura, Sociedad y desarrollo*, 11: 1-24, URL: http://www.scielo.org.mx/pdf/asd/v11n1/v11n1a1.pdf
69. Nygren, A. and Myatt-Hirvonen, O. (2009). "Life here is just scraping by": livelihood strategies and social networks among peasant households in Honduras, *The Journal of Peasant Studies*, 36:4, pp. 827-854, doi: 10.1080/03066150903354023
70. Podolny, J. M. (2001). Networks as the pipes and prisms of the market. *American Journal of Sociology*, 107, pp. 33-60, doi: 10.1086/323038
71. Provan, K. G. and Milward, H.B. (2001). Do network really work? A framework for evaluating public-sector organizational networks. *Public Administration Review*, 61(4), doi: 10.1111/0033-3352.00045
72. Ramirez-Sanchez, S. and Pinkerton, E. (2009). The impact of resource scarcity on bonding and bridging social capital: the case of fishers' information-sharing networks in Loreto, BCS, Mexico. *Ecology and Society*, 14(1):22, URL: http://www.ecologyandsociety.org/vol14/iss1/art22/
73. Rockenbauch, T. and Sakdapolrak, P. (2017) Social networks and the resilience of rural communities in the Global South: a critical review and conceptual reflections. *Ecology and Society*, 22(1):10, doi 10.5751/ES-09009-220110
74. Rubertis, S. Forewood from Neoendogenous development in European rural areas. Results and lessons, edited by Cejudo, E., and Navarro, F. *Springer Geography*, doi: 10.1007/978-3-030-33463-5
75. Sampson, R. J. (2011). Neighborhood effects, causal mechanisms and the social structure of the city in Pierre Demeulenaere 2011. Analytical Sociology and Social Mechanisms. New York: Cambridge University Press.
76. Sayles, J.S., Garcia, M.M., Hamilton, M., Alexander, S.M., Baggio, J.A., Fischer, A.P., Ingold, K., Meredith, G.R., Pittman, J. (2019). Social-ecological network analysis for sustainability science: a systematic review and innovative research agenda for the future. *Envi. Res. Lett.*, 14, 093003, doi: 10.1088/1748-9326/ab2619
77. Schellnhuber, H.-J.: Block, A.; Cassel-Gintz, M.: Kropp, J.; Lammel, G.; Lass, W.; Lienenkamp, R.; Loose, C.; Lüdeke, M.K.B.; Moldenhauer, O.; Petschel-Held, G.; Plöchl, M.; Reusswig, F. (1997) Syndromes of global change. GAIA 6 pp. 19-34, doi:10.14512/gaia.6.1.4
78. Shucksmith, M. (2010). Disintegrated rural development? Neo-endogenous rural development, planning and place-shaping in diffused power context. *European Society for Rural Sociology*, 50(1), doi: 10.1111/j.1467-9523.2009.00497.x
79. SRE (Secretariat of Foreign Affairs and International Cooperation-Honduras). 2015. Gobierno de Honduras realiza llamamiento internacional por emergencia de sequía. [press release]. Tegucigalpa: Dirección General de Comunicación Estratégica Tegucigalpa, M.D.C. 10 September 2015. 2 p.
80. Stewart, I.T., Maurer, E.P., Stahl, K., Joseph, K. (2021). Recent evidence for warmer and drier growing seasons in climate sensitive regions of Central America from multiple global datasets. *Int. J. Climatol.*, 1-19, doi: 10.1002/joc.7310
81. Trigilia, C. (2001). Social capital and local development. *European J. Social Theory*, 4:427, doi: 10.1177/13684310122225244
82. Tompkins, E. L. and Adger, W. N. (2002). Institutional network for inclusive coastal management in Trinidad and Tobago, *Envi. and Planning*, 34, pp. 1095-1111, doi: 10.1068/a34213
83. Tompkins, E. L. and Adger, W. N. (2004) Does adaptative management of natural resources enhance resilience to climate change? *Ecology and Society*, 9(2), URL: http://www.ecologyandsociety.org/vol9/iss2/art10/
84. Valente, T. W. (2012). Network interventions. *Science*, 337, 49, doi:10.1126/science.1217330

85. Vargas-Lama, F. and Osorio-Vera, F. J. (2020). The territorial foresight for the construction of shared visions and mechanisms to minimize social conflicts: the case of Latin America, *Futures*, 123, 02625, doi: 10.1016/j.futures.2020.102625
86. Vitousek, P.M. (1994) Beyond Global Warming: Ecology and global Change. Ecology 75(7) pp. 1861-1876, doi: 10.2307/1941591
87. Vignola, R., Otarola, M., Alpizar, F., Rivera, P. (2019). Gobernanza para la adaptación basada en ecosistemas (AbE) para pequeños caficultores de América Central. *Agrom. Mesoam.*, 30(1): 19-32, ISSN 2215-3608, doi:10.15517/am.v30i1.32596
88. Welman, B. (2000). El análisis estructural: del método y la metáfora a la teoría y la sustancia. *Política y Sociedad*, 33, pp. 11-40, URL: https://webs.ucm.es/info/pecar/Articulos/Wellman2806.pdf
89. Wilkin, J.; Biggs, E.; Tatem, A.J. (2019) Measurement of Social Networks for Innovation within Community Disaster Resilience. Sustainability. 11(7) 1943, doi 10.3390/su11071943
90. Wynes, S. and Nicholas, K.A. (2017) The climate mitigation gap: education and government recommendations miss the most effective individual actions. *Environ. Res. Lett.* 12 074024, doi 10.1088/1748-9326/aa7541
91. Zambada-Martínez, A., Cadena-Iniguez, P., Ayala-Sánchez, A., Sedas-Larios, L.E.I., Pérez-Guel, R.O., Francisco-Nicolás, N., Meneses-Márquez, I., Jacomé-Maldonado, S.M., Berdugo-Rejón, J.G., Morales-Guerra, M., Rodríguez-Hernández, F.R. and Rendón-Medel, R. (2013). Red de articulación institucional y organizacional para gestionar innovaciones en la región de Los Tuxtlas, Veracruz, México.
92. Zarazúa, J. A., Almaguer-Vargas, G., & Rendón-Medel, R. (2012). Capital social. Caso red de innovación de maíz en Zamora, Michoacán, México. Cuadernos de desarrollo rural, 9 (68), 105-124
93. Zimmerer, K. S. (2014). Conserving agrobiodiversity amid global change, migration, and nontraditional livelihood networks: the dynamic uses of cultural landscape knowledge. *Ecology and Society*, 19(2):1, doi: 10.5751/ES-06316-190201
94. Zoyla Moreno, CEO of Denomination of Origin Marcalas´ coffee, Marcala, Honduras.

Appendix 1 Concurrence of words in the abstract of the 109 articles collected per continent. A ticker line among two words represents the number these two words are joint in the abstract. The combination of each pair of words allows to observed relationships between the article's objectives. The red circle stands for the main word's groups.


Asia
developing
countries
ecosystem
services
key
strategy
studies
case
pes
however
recovery
disaster
policies
management
enable
evidence
empirical
limited
remains
mode
centralized
livelihood
options
environmental
community
decentralized
based
approaches
small
scale
projects
development
resources
qualitative
interviews
household
using
group
links
partnerships
access
interventions
related
collaborative
improve
water
anticipatory
models
governance
employment
tourism
china
land
use
rural
long
term
political
influence
turn
longer
examines
study
focus
drawing
farmer
groups
systems
practice
democratic
areas
national
cross
level
interactions
among
efforts
lake
restoration
linking
governments
government
local
collective
collaboration
relations
power
sna
capital
social
decision
action
problems
findings
analysis
emerge
institutions
formal
two
making
coastal
important
characteristics
role
play
network
actors
institutional
work
villages
structure
within
building
processes
shows
often
bridging
global
society
change
adaptation
policy
contested
participation
relationships
civil
climate
risk
reduction
bonding
effective
responses
adaptive
Social Network
Governemnt
Climate change
n
5
10
USA and Canada
bridging
organizations
agriculture
sustainable
collaborative
science
increase
socio
perceived
resilience
system
ecological
climate
change
results
suggest
capital
individuals
build
social
potential
impacts
ecosystem
services
capacity
mode
planning
engagement
capacities
adaptive
network
analysis
groups
stakeholder
broader
enabling
fiscal
administrative
regional
governance
communication
institutions
management
water
quality
changing
sna
institutional
climatic
rural
regions
conditions
environmental
two
Social Network
Ecological
n
2
4
6
8
10


Europe
Social Network
Rural development
study
case
studies
socio
economic
exchange
knowledge
local
governments
tools
actor
change
climate
reforms
multi
complexity
npm
administration
adaptation
public
plans
agro
socially
sna
food
innovative
sector
model
water
patterns
evaluation
technical
analysis
partnership
interaction
infrastructure
governance
framework
n
5
10
perspective
systems
including
formal
rwh
models
informal
network
ecological
territory
areas
institutional
organisational
marginalised
rural
development
territorial
civil
social
area
relations
society
regions
capital
sustainable
community
building
participatory
enterprises
based
innovation
resilience
engage
dynamics
Oceania
Socio ecological
network
policy
climate
communities
adaptation
local
rural
regions
leadership
governance
administrative
fiscal
n
2
3
4
5
6
institutions
regional
perspective
enabling
knowledge
broader
network
engagement
studies
social
case
ecological
formal
systems
models

Appendix 2

Authors	Research interest	Conceptual framing	Key findings	Metrics
Water Resources				
Hileman and Lubell, 2018	Network structure of multilevel water resources in Central America	Explicit reference to adaptation: The connection between the structure of governance netwoks and polycentric institutions to environmental outcomes and institutional adaptation in the face of change.	Highlights the utility of applying the idea of small- world networks to analyze the structure of a multilevel water governance network. Small-world networks are consistent with the requirement of polycentric governance systems to facilitate cooperation, social learning, and resource distribution. This suggests that the evolution of regional water governance in Central America may be a positive response to emerging interdependencies from global processes. The **small-world quotient** is a baseline comparison of observed network structure against the structure of a generalized random network with the same number of nodes and density, and provides a measure of the degree to which a network possesses small-world properties. The quotient represents a ratio of ratios—specifically, the ratio of observed and expected average local clustering coefficient divided by the ratio of observed and expected average path length—and the higher the value is above 1.0, the more small-world the network. For a full explanation of the theoretical and mathematical formulation, see Watts (1999) and Davis et al. (2003).	(1) **Weighted edgewise shared partners (gwesp)** to capture the general tendency for closure. (2) **Geometrically weighted degree distribution (gwdegree)** to capture the propensity for more open, centralized network structures. (3) **dichotomous indicator variable using nodefactor** to capture organizations that list partners on their websites, which is substantively important because they are more likely to be high-degree nodes that serve as hubs in centralized networks. (4) **nodematch** to capture the effects of geographic level, including within-country homophily (i.e., ties among actors whose offices are in the same country) and within-level homophily (i.e., ties among actors operating at the same level in the multilevel network). (5) **edges** to control for density, and a parameter for predicting isolates in the local and regional networks (the removal of pendant nodes precluded isolates in the multilevel network).

Hileman et al. 2018	Robustness and bridging organizations, a regional governance network analysis in Central America	Implicit reference to adaptation: In term of governance of water resources and improving biophysical or sociopolitical outcomes.	The results indicate removing bridging organizations has a greater impact on the network than any other type of actor, suggesting bridging organizations are critical to the robustness of the governance system. Furthermore, network structures supporting cooperation may be less robust than structures facilitating social learning.	(1) **Density**, as the overall connectivity of a network; measured as the ratio of the observed ties to the maximum number of possible ties; (2) **Average local clustering coefficient,** as the extent to which a network is comprised of dense subgroups; measured as the mean density of ties among all the partners of each node. (3) **Average path leght,** refers to the reachability within a network; measured as the mean number of ties separating any two nodes in a network. And (4) **Articulation points**, measured the cohesion of a network, as the number of nodes with ties to otherwise unconnected nodes or subgroups.
Kuzdas et al. 2015	Potential of governance to aggravate or mitigate local water conflics in regions threatened by climate change in Costa Rica	Implicit reference to climate change adaptation, through water scarcity conflicts.	Fragmented governance made it difficult for people to anticipate water-related problems and to coordinate their actions to address problems. Moreover, the local study cases in Guanacaste, Costa Rica, demostrated the importance of considering the local nature of water conflicts and accounting for multiple groups of people and their actions. Differences were found when compare formal and centralised water agencies, since in some cases they do not recognise the different stakeholders groups in decision processes.	N.A.
Kuzdas et al 2014	Participatory analysis of water governance in Costa Rica	Implicit reference to water management over a rural and semi-arid developing region.	Local and effective leaders in a community is a key driver to formulating a governing water system. The results suggest that an understanding of the current institutional schemes - when combined with understanding people's actions and the physical water system that people depend on – offers a more nuanced and systematic understanding of water governance, its outcomes, and its problems.	(1) **Number of organizations**, involved in the network and each domain. (2) **number of ties**, that is viewed as an indicator of the activeness of the governance regime. (3) **density**, to evaluate the proportion of all possible ties between actors with ties actually present in the network. (4) **centralization**, and (5) **cohesion**, refers to the extent to which the network functions as a single unit or not.

Agriculture				
Vignola et al. 2019	Gobernanza para la adaptación basada en Ecosistemas en caficultores de Centro América	Explicit reference to climate change adaptation.	It was compared three communities in Guatemala, Honduras and Costa Rica in terms of "information exchange networks" to promote ecosystem-bases adaptation. While in Costa Rica there was a nearly equilibrium between the kind of organization (private, public and civil society) and for the three scales (local, regional and national), in Guatemala most of the institutions that has a larger influece has national scale. This contrast with the community in Yoro, Honduras, in which most of the institutions work at a local scale, been most of them private organizations.	(1) **Density**, to estimate the cohesion of a group or network, (2) **Centrality (intermediation centrality)** to identify the capacity of an actor to be a bridgin actor.
Maneschy and Klovdahl 2007	Social networks in the Oriental Amazon (Brazil), as sources of social capital.	Implicit reference to adaptation	The extent to which these local organizations represented in the community are able to produce and to provide access to valued resources. Was observed that the network tend to reproduce the vulnerability of the members. Though the actors could have several contacts, this was not translated to an effective or uniform access.	N.A.
López-Torres and Ibarra 2021	Institutional collaboration for the development in the state of Zacatecas, Mexico	Implicit reference to adaptation	Collaboration network in Science and Technoloy to support sustainable rural development, can be funtional only if the key actors intervene as systemic managers in order to promote institutional commitments and do actually generates impacts.	The indicators of the *Social Network Analysis* used were density, *eigenvector* and centralization index by Borgatti, Everett, and Johnson (2013).

Zambada-Martínez et al 2013	A network for institutional and organizational articulation was formed to improve the relationships between institutions and organizations involved in a proposal of institutional intervention for the development of small-scale hillside farmers in Los Tuxtlas, Mexico	Implicit reference to adaptation: Through the development of innovations.	The relationships between actors “before the proposal of innovation management" allowed reflecting aware to improve the levels of the collaborate, cooperate and the levels of recognizes and knows.	Number of nodes, number of links, centralization and density.
Zarazúa, Almaguer-Vargas and Rendón-Medel 2012	Innovation network for the corn in Zamora, Mexico	Implicit reference to adaptation: Through the development of innovations.	Comparing between midsize and small farmers, it was shown that the midsize farmers' network is more comprehensive because it has higher density, size number of links and their centralization index is lower than in the small farmers' network. A fact related with unequal access to information and knowledge.	Number of ties or links, centralization index, density and normalized in-degree.
Muñoz et al 2004	Identification of innovation network, analysis and management for rural development. The case of cirtrus growers in Valle de Apatzingán, Mexico	Implicit reference to adaptation: Through the development of innovations.	Describes an intervention strategy under a network context.	Network centrality, degree and density.
Manzanal	Institutions, territory and rural-local development analysis in the North of Argentina	Implicit reference to adaptation:	Investigate the causes and consequences of public action and local social sectors that lead to territorial particularities that differentially define one place with respect to another in its potential for socioeconomic development.	N.A.

Nuñez-Espinoza, Rodríguez and Jiménez-Sánchez, 2013	Elements available to analyze social networks for rural development in Mexico: the case of the National Network for Sustainable Rural Development	Implicit reference to adaptation:		**Degree** (nodal degree) ans **betweennes** (degree of intermediation).
Downey 2010	Examine the influence of labor exchange networks on the socio-ecological resilience of rural Mayan communities in Belize and identify relevant network properties.	Explicit reference to adaptation: Labor exchange networks contribute to village cohesion and adaptive management, and therefore to community resilience in the context of socio-economic and environmental changes.	Labor networks not only increase a farmer's ability to coordinate large labor groups, they also enhance learning and adaptation. Increasing reciprocity rates can increase production, whereas decreasing reciprocity can help protecting shared resources from overuse. Resilience is not increased by developing fragile institutional hierarchies to protect common resources, but by the connective properties of networks.	**Network reciprocity and hierarchy statistics** because they form a quantitative continuum for measuring social organization.
Abizaid set al. 2015	Employ an analytic approach for the study of labor sharing networks among peasant households in the Peruvian Amazon.	Implicit reference to adaptation capacities: Social relations shape peasant resource use and livelihood security in rural areas. Labor exchange as a strategy to cope with seasonal labor shortage and cash limitations.	Structure and flows of labor within the network are shaped by how households are connected through relational networks at personal and group level. Participation in and access to cooperative labor is markedly unequal. Women's personal networks play an important role in the mobilization of cooperative labor. Cooperative labor is not always reciprocal in the short term.	**Dyadic regression analysis**, a regression method for network data, to examine the factors that shape the formation, structure, and operation of local cooperative labor networks.

Natural Resources (adapted from Rockenbauch and Sakdapolrak, 2017)				
Apgar et al. 2015	Understand underlying social dynamics at play in socialecological systems in indigenous territories of Panama.	Explicit reference to adaptation: Social networks as dynamic and informal web of interactions which foster adaptation and transformation of socialecological systems.	Changing roles of leaders prevent the network from becoming vulnerable to the loss of hubs and bridging links. Cultural practices facilitating leadership development and social networking are critical for enabling both adaptation and transformation.	N.A.
Cárcamo et al. 2014	Investigate the structure and properties of inter-organizational social networks involved in the use and management of natural resources in a coastal marine ecosystem in Chile.	Implicit reference to resilience: Structural properties of social networks influence comanagement arrangements which foster adaptive capacity and resilience of social-ecological systems.	Missing cross-scale interaction in comanagement networks potentially hampers adaptive capacity and resilience of social-ecological systems. Centrally positioned actors could act as bridging stakeholders.	(1) **Density**, as the proportion of all possible links present in a network, (2) **diameter**, to measure the longest number of steps between any two actors, (3) **average path length**, is the average number of steps between any two actors, (4) **in/out degree centralization**, measures the extent to which one actor is holding all the links in the network, and (5) **betweenness centralization**, for the variation in the number of times that actors in the network lie on paths between other actors.

Marín et al. 2012	Assess the multifunctional relationships of small-scale artisanal fisher associations and explore the role of bridging and linking social capital for comanagement of coastal benthic resource systems in Chile.	Implicit reference to resilience: Social networks linking actors at different levels promote performance of natural resource management and well-being.	Best performing fisher associations are those with higher levels of linking and bridging social capital. Policy regulations and instruments should promote vertical and horizontal relationships.	(1) **Linking Social Capital Index (LSCI)** captures the set of connections of each organization with actors at other scales, specifically actors in the second mode, and is composed of three elements (see equation in article): (1) Net facilitating degree equals facilitating degree (Fd) minus hindering degree (Hd); (2) Net trustworthiness degree equals trustworthy degree (Td) minus untrustworthy degree (Ud); (3) Heterogeneity factor (Hf) or the variety of alters with respect to relevant dimensions (Borgatti et al. 1998), defined here as the proportion of functional groups, e.g., power-sharing and enforcement; monitoring, research and development; and marketing, identified by Marín and Berkes (2010) with which the organization has facilitating and trustworthy relationships. (2) **Bridging Social Capital Index (BSCI)** captures horizontal linkages between fisher organizations at the same level, and is calculated as the simple mean of three elements (see equation in article): (1) and (2) as described above for the LSCI but with respect to horizontal relationships with other near and far caletas, presented as two distinct categories; and (3) a complementary factor (Cf) using other questionnaire items referring to specific inter-caleta positive linkages, also expressed as a proportion.

Ramirez-Sanchez and Pinkerton 2009	Examine the effect of resource scarcity on the bonding, bridging, and linking socialcapital patterns of fishers' informationsharing networks in coastal communities in Chile.	Explicit reference to resilience: Social capital patterned by social networks of trust can enable or constrain collaborative arrangements and collective action and therefore impact the resilience of socialecological systems governance.	Social networks are activated and deactivated during transitions in fish abundance. Presence of linking ties as indicator of the extent to which fishers adopt geographic mobility as a coping strategy to deal with resource scarcity. Although fishers have adaptive capacity for dealing with fish fluctuations, they have little or no proactive resilience to address the decline of resources.	**Crowe's framework** to evaluate bonding and bridging social capital within each of our study communities. To assess linking social capital we adopt Crona and Bodin's (2006) approach, which consists of finding the proportion of observed vs. expected ties. **k-cores** and **cut-points** network metrics (Crowe 2007) to determine the extent to which each community network resembles a complete, coalitional, or bridging structure. Linking social capital among communities, after Crona and Bodin's (2006) approach, which consists of calculating the ratio of measured vs. expected relations within and between communities using a **relational contingency table analysis** (Borgatti et al. 2002).
García-Amado et al. 2012	Understand social capital, decisionmaking, and collective action in forest-based common pool resource management in Chiapas, Mexico.	Explicit reference to resilience Social networks of trust, reciprocal exchanges, norms, and sanctions are positively related to collective action required for resilient common pool governance.	Market requirements shape networks Organic coffee commercialization is the main source of bridging ties that have resulted in more connectivity and resilience. Despite power asymmetries and internal conflicts, the local network facilitates an effective management of common pool resources. Institution-building is required, because highly centralized networks may not be appropriate for governing socialecological systems in the long term.	Active nodes, ties, transitivity, network central indedree, network central outdegree.

Tompkins et al 2002	Investigate the role of institutional networks for integrated and inclusive coastal-zone management in Trinidad and Tobago.	Implicit reference to resilience: Social networks and the ability of its social actors to combine information and resources outside the local sphere of institutions are important means by which integrated and inclusive management are maintained.	Cross-scale networks may permit an institutional shift towards more integrated and inclusive approaches. There are winners and losers in any strengthening of networks for the comanagement of resources. Thus there is a need to understand the institutional form of networks facilitating inclusive decision making at various scales.	N.A.
Nygren and Myatt-Hirvonen. 2009	Analyze the diverse ways in which peasant households in Honduras struggle to earn their living and cope with distress amid globalization.	Implicit reference to resilience: Social networks play an ambiguous role in shaping the opportunities and constraints of poor households to cope with poverty.	Social networks are not a "capital" or "asset" that poor always can draw from. Rather networks are based on dynamic and negotiated transactions that cannot be mechanically stored or accumulated. Networks are not necessarily available and free of charge but are based upon complex norms of reciprocity. Cultivation of networks requires time, effort and money which the poor peasants lack. Instead, social networks tend to reinforce the existing differences.	N.A.
Zimmerer 2014	Examine agrobiodiversity in smallholder cultural landscapes with the goal of offering new insights into management and policy options for the resilience-based insitu conservation in Bolivia.	Explicit reference to resilience: Migration alters social networks central to insitu conservation of agro-diversity and hence impacts social ecological resilience.	Social networks of migration related livelihood groups are powerfully shaped through international and national migration, while at the same time supporting agrobiodiversity use and in-situ conservation.Context: migration.	N.A.