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Social Networks Analysis of the Ivorian Agricultural Sector Regarding Adaptation to Climate Change

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Abstract

In the context of climate change in developing countries, smallholder farmers need strategies and institutional support in order to adapt. The goal of this paper is to identify and analyze stakeholder networks in the agricultural sector of Côte d'Ivoire to evaluate the institutional support surrounding farmers. A research study was undertaken to derive an empirical diagnosis of strengths and weaknesses in the social networks in two regions, Toumodi and Korhogo, in order to facilitate the future implementation of adaptation strategies. We identified central actors and evaluated networks with criteria such as cohesion and centrality. The network structure appeared to be highly dependent on one major actor in the Toumodi region, while the regional network relied more on a group of diverse actors in the Korhogo region. Therefore, in Toumodi, we suggest encouraging actors to form cooperatives to reduce centralization and increase network cohesion and integration, which is the favorable network configuration for policy implementation. As such, sharing experiences and knowledge could enhance the ability of smallholder farmers to adapt to climate change.

Keywords: Social Networks, Adaptation, Climate Change, Agriculture

JEL classification: Q15, Q54

1. Introduction

Subsistence farmers in Sub-Saharan Africa are especially vulnerable to global warming as they rely on traditional farming and cultural calendars inherited from their ancestors. They are currently disoriented because of the discrepancy between their cultural calendars and climate conditions (Brou and Chaléard 2007). As such, adaptation strategies are essential to help these communities cope with environmental changes (IPCC 2007). Rosenzweig and Parry (1994) showed that it is only with institutional support for adaptation strategies that the effects of climate change on food security can be offset; that is, a fruitful farming season that produces all of the necessary crops for survival. In Sub-Saharan Africa, institutional capacities need to be significantly consolidated to respond to this challenge. The main goal of our research is to evaluate the ability of stakeholder networks to support farmers' capacity for climate change adaptation in two counties of Côte d'Ivoire. Specifically, local stakeholders are identified, and a diagnosis of the actual networks is made in order to help actors undertaking the future implementation of climate change adaptation strategies. Thus, in-depth knowledge about stakeholders will be acquired in both study regions, and three types of relations will be studied in detail: information exchanges, collaboration, and financial transfers. We will address the following questions: (i) What are the relationships between stakeholders and the grouping effects between them? (ii) Which stakeholders are taking a central position and facilitating the most support for farmers? and (iii) How is the information about climate change diffused in the networks, as well as (iv) What are the strengths and weaknesses of the networks with regard to climate change? In addition, these questions are explored and compared between the two study regions.

Many authors have worked on either case studies or models to assess the sustainability, robustness, or resilience of social-ecological systems and outlined some useful characteristics to analyze the actors' networks in Côte d'Ivoire, while revealing the need for more empirical observations (Bodin and Norberg 2005; Bodin and Crona 2009; Bodin and Prell 2011).

2. Theoretical Background

Social networks analysis (SNA) offers a guided way to identify actors (i.e. individuals, groups, or organizations) and to analyze the relationships between them (Scott 2004). This method can help to analyze social capital and relationships in a quantitative way and allows for the building up of figures to determine strengths and weaknesses in structures that can sometimes be very complex (Bodin and Prell 2011; Ziervogel and Downing 2004). Thus, regular patterns of information exchange may be considered as «social networks», with actors as «nodes» in the network and relationships between the actors as «links» between these «nodes». There are different types of resources being shared between the actors: tangibles such as goods, services, or money, and intangibles such as information, social support, or influence (Haythornthwaite 1996). The interacting links between actors are also called «ties» (Scott 2004). The SNA examines both the content and the pattern of relationships in order to determine how and what resources flow from one actor to another. Two principles that network analysts often use to examine actor networks are as follows:

- Cohesion is measured by the concepts of density and centralization:
 - The density of a network indicates the degree to which members are connected to all other members. It is calculated as the ratio of the number of actual links in a population to the number of possible links in the population.
 - Centralization measures the extent to which a set of actors is organized around a central point; thus, a high centralization is when one central actor is connected to everyone else and all others have few connections (Hanneman and Riddle 2005).
- Centrality scores indicate which actors have influence or power in a social network. The centrality of an actor is measured most simply by counting the number of relationships maintained by the actor in a social network. The occupant of the central position is known as the «network star». This position gives the «star» a great deal of access to information from others in their network (Scott 2004). By facilitating, controlling, or inhibiting the flow of information from one site to another in the network, central actors can maintain, create, or prevent the creation of information pathways. A

useful way of measuring this idea is the betweenness centrality, which translates the extent to which an actor sits between others in the network. As an intermediary, actors with high betweenness centrality can fill an important information role as a broker or gatekeeper, filtering and importing information into the network (Burt 1992b; Nohria 1992; Haythornthwaite 1996; Hanneman and Riddle 2005; Bodin and Crona 2009). Actors with high centrality scores are at the core of networks and are the most important for the coordination and prioritization of joint actions (Bodin and Crona 2009). Their role as bridging elements means that they provide access to external resources and knowledge to support actors initiating action. The centrality scores of actors can be used similarly as dependent variables in t-tests to verify the influence of actors' characteristics on their potential to create relations. The difference in the centrality scores is considered significant when the same difference occurs in less than 5% of random cases.

A well-structured network provides information benefits in terms of access to information, timing, and referrals. Access involves not just receiving valuable information, but also having those who can use it in the network. A well-structured network can act as a screening device in the face of information overload, provide opportunities to others, and deliver information (Burt 1992a). Ingold et al. (2010) and Isaac and Dawoe (2011) further argue that a high local adaptive capacity is dependent on high vertical and horizontal integration, which means that several sectors and political levels should be represented in the center of networks to show a good supporting capacity from the networks to the farmers.

All network measures can be obtained after entering the relational data into the software package UCInet (Borgatti et al. 2002), which includes Netdraw, a tool to visualize the networks and produce figures.

3. Method

3.1 Description of the study areas

The study took place within a larger project on climate change adaptation strategies in Côte d'Ivoire (Comoé et al. 2012; Schmitt 2012). In accordance with this project, two administrative departments of Côte d'Ivoire were chosen as case studies: Toumodi in the center of the country, 230 km north of Abidjan, and Korhogo in the north, at the Malian border. They allow comparisons to be drawn from different socio-political and climatic contexts and thus the analysis of their possible consequences on the adaptive capacity of actors' networks. Toumodi covers an area of 2,780 km² and counted 147,105 inhabitants in 2009, of which 65% are active in agriculture (CountrySTAT 2012). Toumodi has two rainy seasons and has a landscape of transition between dense forest and savanna. The region of Korhogo is bigger, at 12,500 km², and it had a population of 630,725 inhabitants in 2009, of which 80% are active in agriculture (CountrySTAT 2012). There is only one rainy season in Korhogo and the ecosystem is a typical savanna. Due to the climate differences between the two regions, agricultural systems vary from agro-forest cultures (mainly cocoa) in central Côte d'Ivoire, to cotton and livestock in the north, as well as mango and cashew trees.

Politically, the northern half of the country, including the department of Korhogo, was under the control of a rebel group from 2002 to 2007. During this time, the governmental agencies had to leave the northern region and the existing actors were subject to many perturbations. Major international organizations such as the United Nations Food and Agriculture Organization (FAO) and the United Nations Development Program (UNDP) installed a management base in the region for humanitarian work. The political crisis continued until 2011, three months after the new presidential election, a period in which tensions and conflicts occurred in many parts of the country. Since then, there have been efforts to reunify the country and important reforms are under way, especially concerning agricultural institutions organized around crop sectors. The cocoa sector is being sanitized of corruption and new institutions are being created. The cotton and cashew sectors are also undergoing reforms, especially to sort out viable and legal organizations from the cooperatives that proliferated during the crisis.

3.2 Survey design and data gathering

The SNA starts with the elaboration of a list of actors, which are, in this study, formal entities such as farmers' associations (named cooperatives), governmental and non-governmental organizations (NGOs), companies, and agronomic research institutions. The criterion by which actors are selected for the purpose of this research is that they had to conduct agricultural or rural development activities in the two case study areas. Some actors are based in Abidjan but conduct important activities in the two regions and are also considered to belong to the regional networks.

The precise list was first completed by desk research, followed by seven preliminary interviews with major and available organizations in the field. In the following text, the terms «actor» and «organization» will be used synonymously. In Toumodi, 47 actors were identified in total, including those based in Abidjan, and comprised the different kinds of organizations as described in Table 1. In Korhogo, 53 organizations were identified and are also detailed in Table 1. There are more actors in Korhogo because of its higher administrative level and as a result of the international organizations that were implemented during the crisis.

Table 1: Summary of the type of actors found in the two regions

Type of organization	Toumodi	Korhogo
Governmental offices	8	10
Ministries sub-divisions	5	7
Local authorities	3	3
Research and development structures	9	12
Local NGOs	1	3
Extension services	1	3
Research centers	3	2
Development agencies and projects committees	4	4
Cooperatives and farmers' associations, IPAs	17	18
In cash crops	11	14
In food crops or breeding only	6	4
Retailing companies	8 (7 in cocoa)	5 (only cotton)
Locally founded	3	3
International	5	2
International organizations	5	8
Foundations or international banks	2	3
Divisions of the United Nations (UN)	2	2
Bilateral collaboration, international NGOs	1	3
TOTAL	47	53

The data was collected through face-to-face structured interviews conducted between February and April 2012 with the local directors of offices or an available member of the directing committee of the organizations. With generalist organizations such as the local authority or the UN Development Program, the person responsible for the agricultural department was contacted. Thirty interviews were conducted in Toumodi, 38 in Korhogo, and five more with actors in Abidjan, thus covering 73% of the actors initially identified. The questions prepared for the interviews involved several types of relations as described in Table 2: (i) information exchanges about climate change or about adaptation techniques; (ii) collaboration, whether technical or strategic or both; and (iii) financial exchanges, such as payment for services or direct trade of commodities or donations. The questions related to information exchange reveal which actors generate, block, diffuse, or receive information about climate change, and most importantly, which actors do not receive information. The network

on strategic collaboration helps the understanding of which actors create projects and design policies in the sector, while that of technical collaboration shows who is responsible for the implementation of adaptation strategies in the field. The financial exchanges reveal which actors have the ability to invest in programs and who receives the most funding. These elements help diagnose their ability to support farmers to cope with environmental changes.

Table 2: Types of relations studied and operationalization

Type of links	Question in interview	Type of Data *
Exchange of information About climate change About adaptation techniques	With whom do you exchange relevant information?	Relational data: Binary and directed (receive from/give to)
Collaboration Strategic Technical	With whom do you have joint activities in projects, strategic planning, or other?	Relational data: binary, undirected (symmetrization of data as collaboration must involve the two actors of the relation).
Financial flows Services and mandates Commercial Donations	With whom do you have financial links?	Relational data: binary and directed (receive from/give to)
Quality of relations	What is the quality of the relations you have? (good/conflict)	Relational data: valued and directed
Influence reputation Present In the future	Which are the most influential actors (between 5 and 10) concerning agricultural development in your region?	Influence score (average of number of times cited by others)

* *binary means that the value of the link is either «present' or «absent». A valued link can have different values such as: «positive», «absent» and «negative».*

Questions also addressed the quality of links between actors in order to determine whether organizations experienced tension or good relations with each other. Organizations were also asked to cite the most influential actors concerning climate change adaptation in their region. We collected information on the identity of the organization (activity, age, type of crop), their vision of climate change and agriculture, strategies they wish to implement, their priorities, and finally, their difficulties with strategy implementation.

4. Results

4.1 Stakeholders' relationships pattern

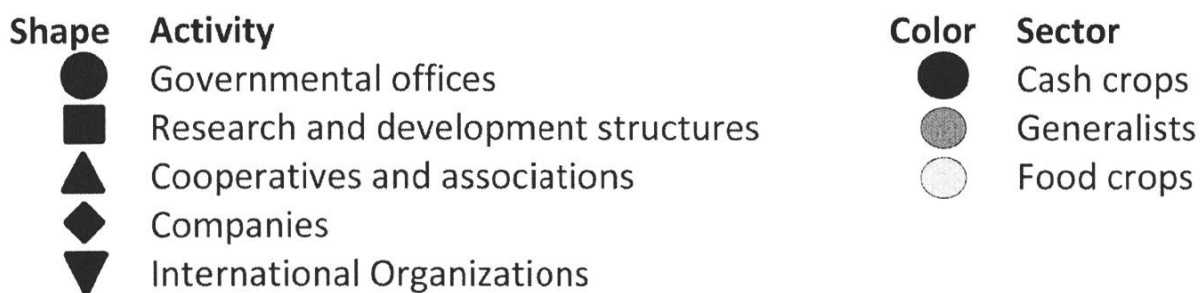
The relational measures in networks are summarized in Table 3, according to the types of relationships analyzed that were presented in Table 2. Generally, densities were below 20%, which can be considered a low density for networks (Scott 2004). Networks in Korhogo have a slightly higher density, especially in the **information networks**, except for *information exchanges concerning adaptation techniques*. This should be put in perspective with the fact that, in both regions, the density of specific information networks is very low (1.6–3.9%). The **collaboration networks** have even lower densities than information networks (7.2–9.2%), and specific collaboration networks ranged around the very low level of 3–4% density. The **economic networks** had the lowest densities as they involve only a small number of actors. Measures of centralization were spread across a large range, from 3.5–65.6%, with the *general information exchanges* network in Toumodi being the most centralized. **Information networks** are more centralized in Toumodi, and **collaboration networks** are more centralized in Korhogo, except for the *technical collaboration* network.

Table 3: Network densities and centralizations

	Density		Centralization	
	Toumodi	Korhogo	Toumodi	Korhogo
Information exchanges	11.5	17.8	65.56	37.82
Climate change	2.3	3.6	22.46	15.91
Techniques	3.9	1.6	40.39	11.8
Collaboration	7.2	9.2	26.7	42.38
Strategic	3.0	3.0	17.34	22.81
Technical	3.7	4.4	39.28	23.38
Economic networks				
Mandates	1.8	2.4	32.66	23.15
Trade	1.2	0.5	13.48	7.01
Donations	0.2	0.2	4.15	3.54

Figure 1 presents the networks of information exchanges in Toumodi and Korhogo. The core «nodes» are clearly dominated by research and development «(R&D) structures» and «decentralized governmental offices».

Figure 1: Networks of information exchanges in Toumodi (a) and Korhogo (b)



Actors active in the food crops and livestock groups are generally less represented than those active in producing the dominant cash crop, as reflected by the high number of cooperatives in the cocoa sector for Toumodi (and cotton for Korhogo). Farmers also regroup in associations by sectors, such as the ANARIZ-CI for rice. There is an important national federation of all sectors, the ANOPACI¹. In addition, companies and farmers sometimes regroup in a common federation designated as an «inter-professional association» (IPA), which is an association of interest groups related to a particular commodity in a particular country (Shepherd et al. 2009).

In Toumodi, the density of links is generally higher for research and development organizations (R&D structures) and for «decentralized offices of national organizations», such as the local offices of the national extension services (ANADER) or the local representation of the Ministry of Agriculture (MINAGRI). This means that all other types of actors tend to communicate more with this particular type of actors. In the *strategic collaboration* network, however, the density of ties is higher within «local» and «governmental agencies».

By regrouping actors according to their type of main crop, the only grouping effect can be observed in the *general information* network, especially among cooperatives for cocoa, and in the *strategic collaboration* network. In the *trade network*, the densities are logically revealed to be higher between cooperatives and companies, than between the other actors.

Similar patterns exist in Korhogo, but grouping effects were the most visible in the *general information* network. Actors communicate more in the same crop sectors, except for cooperatives, which have the most relationships with companies. Governmental agencies tend to turn more to international organizations concerning *information about climate change or adaptation techniques* and for *strategic collaboration*. International organizations are also tightly linked to «R&D structures» in the specific information exchanges. Interestingly, in the *strategic collaboration* network in Toumodi, the density of ties of all groups is higher with national organizations.

¹ The list of all organizations and their complete names, as well as their main characteristics, can be consulted in Appendix 1.

Figure 1 shows an area of higher density at the center of the networks, also known as the core. This core is generally composed of actors with the highest degrees of centrality and the most links to others. In Korhogo, there is a higher diversity of organizations at the core of networks, with the presence of more NGOs, IPAs, companies, and international organizations, while these actors are rather in the periphery of Toumodi's networks. This presence of a high diversity of actors in the center of networks translates to a higher horizontal integration in Korhogo. Concerning vertical integration, all hierarchical levels are present with local offices of local, national, and international organizations in both regions, except for international organizations which are absent in Toumodi. They were all based in either Abidjan or Bouaké and have only sporadic activities in the region of Toumodi.

4.2 Central actors

In Toumodi, we found that the high centralization is linked to the presence of actors who tend to be recurrently central in most networks. The ANADER is unequivocally the most central actor, with the highest centrality scores in almost every network. The MINAGRI is also very central, especially in the *strategic collaboration* network. The National Centre for Agronomic Research (CNRA) is central too, although they do not have a local office in Toumodi. The local offices for cocoa (FDPCC) and for rice development (ONDR), in addition to some cooperatives from different sectors, complete the list of central actors (Appendix 1).

In Korhogo, the diversity of central actors is higher in the different networks. The Inter-Professional Fund for Research and Agricultural Support (FIRCA) is the most central in the *general information* network. The local authority, the *Préfecture*, was also mentioned as an important actor, particularly in the *collaboration* network. The United Nations Organizations created the Food Security and Nutrition Group (GSAN), which brings together local stakeholders in a formal, regular coordination group under the supervision of the FAO. It includes the influential local NGO Animation Rurale de Korhogo (ARK), the local rural engineers' bureau BFCD, the CNRA, the German bilateral cooperation (GIZ), the MINAGRI and related offices, as well as the ANADER and others.

4.3 Climate change information

The SNA shows that information concerning climate change and adaptation techniques follows different patterns in both study areas. In Toumodi, the extension services ANADER is one of the few partners providing information about climate change to cooperatives; the others include one cocoa company and the Inter-Professional Fund FIRCA. Scientific research organizations do not communicate directly with the cooperatives in the network, but instead only with each other. The meteorological institution is at the very periphery of the network and thus does not communicate sufficient information. The *information network relating to adaptation techniques* in Toumodi has more links than in Korhogo, indicating that actors communicate more directly on techniques such as on how to prepare the fields, irrigation, and treatments than on climate change (causes, effects, etc.).

In addition, there is a core of «R&D structures» exchanging information about adaptation, but their links to the farmers are almost exclusively through the ANADER.

The structure in Korhogo is quite different. A substantial number of farmers' organizations are also excluded from any information about climate change. The most central actor is the National Center for Agronomic Research (CNRA), who has a regional office in Korhogo. Moreover, actors in the cotton sector are also rather central and form a sub-part in the *information network about climate change and relating to adaptation techniques*. However, it is primarily the large companies and associations that share information with others. Despite the fact that the meteorological service has a regional office in Korhogo, they are also outside the network. In the *information network about adaptation techniques*, ANADER occupies a more central position, mainly linking with other «R&D structures». The CNRA and a cotton company, IvoireCoton, also provide many actors with information.

T-tests were conducted to evaluate the influence of actors' characteristics on their probability to share links in the *climate change information networks*. In Toumodi, the only actors with a significantly higher chance of having access to climate change information are government-related actors, which include ANADER and CNRA. It is also clear that companies do not share many links in the *information about climate change network*. During the interviews, however, certification programs were mentioned, and these could have direct or indirect

beneficial effects for the farmers' adaptation to climate change as they provide the farmers with technical support.

The same t-tests in Korhogo show that belonging to an association related to a crop or working at the national, regional, or local level does not have a significant influence. Companies are much more present in the *information about climate change* network, but only in the cotton sector.

5. Discussion

5.1 Strengths and weaknesses for climate change adaptation in Toumodi

In Toumodi, the low density of networks limits the potential for collective action between actors (Bodin and Crona 2009). A higher density coupled with a low centralization indicates network cohesion (Bodin and Prell 2011), which is a positive sign for coordinated actions in a network, however this is not present in Toumodi. The high centralization also demonstrates that the network in Toumodi is not cohesive, but instead a type of network centralized around one major actor, which is more efficient for the resolution of simple problems as the central actor can «prioritize and coordinate activities» (Bodin and Crona 2009, p.371) and also diffuse information faster. The coordination ability of the most central actor is exceptionally important in times of change and is determined by their access to knowledge and experiences (Bodin et al. 2006), although these networks are very vulnerable to attacks on or the removal of the central nodes (Janssen et al. 2006). However, the high centralization in the network *information about adaptation techniques* in Toumodi is strong as it is accompanied by a higher density of the network. This might be due to the ANADER taking advantage of its central position to diffuse more information to all actors. In addition to its formal mission, ANADER also exerts a high influence on the field (93.1% of reputational score), and this can facilitate implementation and legitimacy (Bodin and Crona 2009). The network is, however, completely dependent on the capacities of ANADER and on the resources it receives.

A weakness of this network is that cooperatives, particularly in the food crop sector, are always at the periphery of the network, and bonds between cooperatives and farmers' associations are weak and can prejudice the building of trust and consensus, in addition to maintaining low density. A higher cooperation with companies could also be a factor in resolving conflicts, and structures such as IPAs are a good mediation channel along the food value-chains, as is the case in Korhogo.

The level of vertical and horizontal integration in Toumodi is thus penalized by the lack of diversity in central actors. However, as the most central organizations are «R&D structures» which are active at a decentralized level, such as the ANADER, MINAGRI or CNRA, they should be able to bridge links and transmit research results and technologies in the domain of agricultural development and adaptation, as long as the existing diffusion channels are used efficiently. Nevertheless, the *information network related to climate change* in Toumodi does not include many farmers' organizations, as well as international organizations and research institutes. As such, the regional network is not efficient at establishing the bridging link between knowledge at the international level and farmers in the field. Financial support, however, would be necessary to improve the diffusion of this information and elicit active support from ANADER, which is currently overseeing this knowledge distribution. As some companies are setting up diverse certification programs in the context of sustainable development and supporting farmers in different ways, coordination with and between companies should be increased to make this support more efficient and organized.

5.2 Strengths and weaknesses for climate change adaptation in Korhogo

In Korhogo, the network is less vulnerable to changes as it has higher densities and lower centralization, particularly in the information networks, and as the Food Security and Nutrition Group (GSAN) fosters multiple central links on a group rather than on a single actor. The GSAN is a very positive structure for the sharing of experiments in the field and of new techniques. It is also a good way to collect feedback from experiences and to learn from previous mistakes. It is possible that this situation is the result of the past decade's crisis and the weakening of governmental offices and ANADER, which incited other actors such as NGOs or the FAO to take action and become more central. Bodin et al.

(2006) demonstrated that networks with low centralization, including diverse structures, have a higher ability to solve complex problems, which is a clear advantage for the coordination of support for farmers in terms of climate change adaptation.

The risk, however, is that after the end of the crisis, international organizations will decide to leave the region and the network will instead centralize more around national organizations. Still, Korhogo exhibits more diversity in local organizations at its core, and this is a strength (Ingold et al. 2010). The implication of companies and IPAs in the center of networks, in projects, and in the diffusion of information regarding climate change in Korhogo is also a valuable strength and offers farmers more diverse support for the adaptation to new climatic and environmental conditions.

5.3 Comparison of the two regions and recommendations

The low network density in both regions is an obstacle to collective action, and an increase in links would be necessary to improve the capacity of farmers to receive useful information, to be more aware about climate change, to know more about possible adaptation strategies, and finally, to adopt new techniques to cope with the consequences of climate change. However, we posit that the density of real-world networks is naturally much lower than in theoretical models, especially in developing countries where exchanges and access to social gatherings are more difficult and costly. Luzi et al. (2008) conducted a comparison between water policy networks in Egypt and Ethiopia, and obtained similarly low densities for information exchange networks (15% and 16% respectively) with similar actors and centralities. Successive reforms and tensions, as in Korhogo, were also given as a reason for weaker cohesion and the presence of more diverse actors.

Development strategies in countries such as Côte d'Ivoire, which is nationally centralized, are primarily decided by the national offices or even by international level organizations. This can be spotted in the networks, as in both Toumodi and Korhogo, where the *strategic collaboration* network has a lower density than the *technical collaboration* network. In addition, the local *strategic collaboration* network is more oriented towards local cooperatives for their own economic and strategic development, but does not really include the local representation of governmental and non-governmental agencies. A reinforcement

of local decision and policy-making power could encourage bottom-up rather than top-down steering if local cross-sectoral actors were more involved in the *strategic network*. Such approaches involve a more successful and sustainable use of resources (Bodin and Norberg 2005). The implication of regional boards in national committees, such as the Food Security Cluster already in place in Abidjan, could foster exchanges and the integration of the regional diversity. The presence of supporting international organizations in Korhogo, in contrast to Toumodi, might be an asset in the planning of measures for climate change adaptation, as their influence and links with governmental agencies can be exploited for the purposes of diffusion and dissemination of their knowledge. The transfer of information concerning climate change to farmers is essential in the initial steps of adaptation, as it raises awareness. Comoé et al. (2012) show that farmers in these two regions perceive changes in their environment, especially changes in the seasonality of rains, and attribute these to deforestation or changes in their practices. They are searching for new techniques of adaptation of the cultural cycles. Farmers in both study areas also expressed the specific need to access information on weather forecasts (Schmitt 2012). A more central position of the meteorological services within the network would facilitate the supply diffusion of forecast information to farmers. As recommended by Ziervogel and Downing (2004) in their study on weather information diffusion in Lesotho, the involvement of NGOs will be more efficient and equitable to reach farmers at the local level. In addition, the strategy used by an NGO in Korhogo, which involved setting up an information system about cashew prices through the short messages system (SMS), could be capitalized on and used by more NGOs. This sort of strategy deserves consideration, as it was also a necessity expressed by local actors in Côte d'Ivoire, and better coordination between actors allows the sharing of adapted innovation.

6. Conclusion and policy implications

This study presents empirical evidence of the strengths and weaknesses of social network configurations in the context of climate changes in Côte d'Ivoire. The two study regions present rather different patterns linked to their regional contexts. We suggest encouraging actors to increase network density for joint action through working groups such as the GSAN to reduce centralization and thus increase the networks' cohesion and integration.

It was found that the network cores in both regions are primarily comprised of «R&D structures», which should utilize this position to diffuse information widely.

In Toumodi, the diffusion of information relies on one actor (ANADER), a situation which renders the network more vulnerable. If the ANADER is removed from Toumodi for political, financial, or other reasons, as much as 25% of the network links would be removed and more actors would be isolated from information. The future implementation of more local offices of international organizations and national NGOs in Toumodi would alleviate this risk and make this network more resistant. In addition, the bonds between farmers' cooperatives and other actor groups were found to be weak in both regions – reinforcing these links could have several positive effects. Firstly, it would create trust and solidarity between farmers' interest groups. Secondly, it could reinforce the centrality of these groups in the networks and increase horizontal integration, which would help them to defend their interests and increase global cohesion. In Korhogo, the Cotton Inter-Professional Association (Intercoton) is already mediating between cotton producers and retailers. Its central position makes it an important actor, and it should be a model for other sectors, particularly because it also increases cohesion within the network. The food crop sector was found to be especially weakly represented and to have very few dedicated organizations, which might be prejudicial towards food security policy making. In order to support farmers and communities in adapting to environmental changes, a larger integration of food crop associations and institutional support for their maintenance are necessary. However, the integration of new and more actors might not be an easy task due to local constraints. Political instability strongly impacted the actors and changed the institutional landscape, which revealed the need for stable governmental services and budgets.

In both regions, regional boards could be created in collaboration with the local authorities. These new boards should increase direct interaction between the «R&D structures», the cooperatives, the meteorological services, and the major companies. MINAGRI could take the lead in inviting all organizations to do so, as it seems to be the most legitimate coordinator. Policy-makers should thus promote the integration of key stakeholders in order to diffuse information on climate change and possible adaptation strategies to the farmers, with the support of the major organizations. The meteorological services should have more resources to diffuse information to the farmers; the participation of local farmers' associations should be promoted; and the federation of inter-professional associations should be reinforced at the national level. Cooperatives play an important role and cooperation with a strong extension service and NGOs could generate the sharing of experiment results and knowledge among key knowledge providers.

Finally, SNA is an appropriate method for analyzing and diagnosing social and institutional networks. After presenting recommendations based on empirical evidence, it would be most interesting to study networks such as those in Toumodi and Korhogo on a long-term basis and explore their changes in response to external constraints. This could also lead to the development of more reliable indicators and criteria for the assessment of sustainable networks.

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Appendix

Appendix 1: Table of actors' names and centrality scores

Note: The two tables provide information on the actors' names and types and their centrality scores for a) Toumodi, and b) Korhogo. The first column gives the full name of all actors translated from French to English. The second column presents their abbreviation used in the networks listed in Figure 1. Appendices _T and _K indicate the locations of organizations in the regions of Toumodi and Korhogo, respectively, for those with offices in these regions. The next two columns provide more details on the type of actor; first their role, and next, the agricultural sector in which they are active. The influence score (fifth column) is calculated by the number of times an actor was mentioned as being influential divided by the number of actors interviewed. The last two columns provide the in-degrees and out-degrees of actors in the network of information exchanges and in the network of information exchanges about climate change. The in-degree is the number of links arriving at the node (e.g. the number of actors a node is receiving information from) and the out-degrees is the number of links leaving the node (e.g. the number of actors a node is supplying information to). The actors have been classified according to their centrality (from the most to the least).

a) Toumodi

Complete name (translation)	Abbreviation	Role ¹	Sector ²	Influence score	Degree info in/out	Degree cc in/out
The National Agency for Rural Development Support	ANADER_T	Extension	All	93.1	30/33	10/11
Ministry of Agriculture	MINAGRI_T	Gov.	All	75.9	21/20	3/3
Fund for Development and Promotion of Activities from the Producers of Coffee and Cocoa	FDPCC_T	R&D	Cocoa	24.1	14/14	1/1
National Centre for Agronomic Research Cooperative "Ebo yokun"	CNRA_T	Research	All	24.1	9/13	5/5
Enterprise Agricultural Cooperative of Kpouébo Prefecture (local authority)	Ebo yokun ECOOPAK	Coop.	Cocoa	41.4	11/10	1/1
AgriHall	Prefecture_T AgriHall	Gov.	All	3.4	8/10	2/2
National Office for Rice Development Cooperative "Cacoci"	ONDRI CACOCI	Comp.	All	41.4	10/6	1/1
Under-prefectures (subdivisions)	Sous-prefectures_T	R&D	Food	3.4	4/10	3/3
Interprofessional Fund for Agricultural Research and Advice	FIRCA	Coop.	Cocoa	17.2	9/9	3/3
Cargill Inc.	Cargill	Gov.	All	37.9	9/7	1/1
Barry Callebaut – African Cocoa Society Cooperative Association of Women from Djékanou	ASCAFED	Coop.	All	31.0	9/6	0/0
OLAM – Outspan	OLAM	R&D	All	17.2	8/7	2/2
Swiss Centre for Scientific Research in Côte d'Ivoire	CSRS_T	Comp.	Cocoa	6.9	8/5	1/1
General Council of Toumodi	CGToumodi	Comp.	Cocoa	10.3	8/4	2/2
Cooperative of Agricultural Producers of Kimoukro	COOPAK	Coop.	Cashew	3.4	6/7	3/3
National Association of Rice Producers in Côte d'Ivoire	ANARIZ-CI	Comp.	Cash	13.8	6/7	1/1
Management Committee for the Coffee-Cocoa Sector	CGFCC	Research	Food & Breed.	10.3	4/7	1/1
Biopartenaire Cooperative Dialogue of Djékanou Development Project of the Region "Lacs"	Biopartenaire CDD PADER	Gov.	Food	27.6	7/2	1/0
		Assoc.	Cocoa	17.2	6/6	0/0
		Gov.	Food	13.8	6/6	3/3
		Comp.	Cocoa	13.8	4/6	1/0
		Comp.	Cocoa	6.9	5/5	1/1
		Coop.	Cash	20.7	5/5	0/0
		Project	Food &	3.4	5/4	1/1

Cooperative "Ekloiyo"	Ekloiyo	Coop.	Breed.	6.9	5/4	0/0
Ministry of Animal and Fish Resources	MIRAH_T	Gov.	Cashew Breed.	31.0	2/5	1/1
National Association of Producers of Coffee and Cocoa	ANAPROCI	Assoc.	Cocoa	6.9	1/5	0/0
Cooperative "Trofé"	Trofé	Coop.	Cocoa	20.7	4/4	1/1
United Nations Development Program	PNUD_T	Interna.	All	0	4/4	0/1
Cooperative for Production and Commercialization of Food Crops	CPCPV	Coop.	Food	10.3	4/4	0/0
Agricultural Cooperative of Toumodi	COOPAT	Coop.	Cocoa	17.2	3/2	0/0
Departmental Cooperative of Rice Producers	CODERIZ	Coop.	Food	6.9	2/1	0/0
SNADCI Ltd.	SNADCI	Comp.	Cocoa	6.9	2/1	0/0
Nestlé	Nestlé	Comp.	Cocoa	0	2/1	0/0
Archer Daniels Midland Co.	ADM	Comp.	Cocoa	3.4	1/2	0/0
Society for Management and Development of Airports, Aviation and Meteorology	SODEXAM	Gov.	All	3.4	1/1	1/1
Cooperative "Entente"	Entente	Coop.	Cocoa	6.9	1/1	0/0
National Laboratory for Agricultural Development	LANADA	R&D	All	10.3	1/1	0/0
International Institute of Tropical Agriculture	IITA	Interna.	All	0	1/1	0/0
Union of Farmers from Toumodi	UAT	Coop.	Food & Breed.	0	1/1	0/0
National Association of Food Crops Producers in Côte d'Ivoire	ANAPROVICI	Assoc.	Food	0	1/1	0/0
National Federation of Food Crops Cooperatives in Côte d'Ivoire	FENACOVICI	Coop.	Food	0	1/1	0/0
State of Côte d'Ivoire	CI	Gov.	All	6.9	0/0	0/0
International Fund for Agricultural Development	FIDA	Interna.	All	3.4	0/0	0/0
World Bank	BM	Interna.	All	0	0/0	0/0
Food and Agriculture Organisation	FAO	Interna.	All	0	0/0	0/0
Sinzoundjanfoué	SNDF	NGO	Unknown	0	0/0	0/0
MEAN				14.9	5.3/5.3	1/1

b) Korhogo

Complete name (translation)	Actor	Role ¹	Sector ²	Influence score	Degree info in/out	Degree info cc in/out
Interprofessional Fund for Agricultural Research and Advice	FIRCA	R&D	All	26.3	29/28	5/5
Ministry of Agriculture	MINAGRI_K	Gov.	All	63.2	26/22	4/4
National Centre for Agronomic Research	CNRA_K	Research	All	55.3	22/24	9/9
The National Agency for Rural Development Support	ANADER_K	Extension	All	68.4	20/21	5/3
Project to Support Small Horticulture of the "Region Savanes"	PPMS	Project	Food	34.2	20/20	0/0
Umbrella Organization from the Cooperatives of the Cotton Sector	AFFICOT-CI	Assoc.	Cotton	23.7	19/20	8/8
Cotton Inter-Professional Association	Intercoton	IPA	Cotton	28.9	20/19	6/6
Food and Agriculture Organization	FAO_K	Interna.	Food & Breed.	28.9	19/20	4/8
Ivorian Cotton Company Ltd.	COIC	Comp.	Cotton	31.6	14/17	6/5
Prefecture (local authority)	Prefecture_K	Gov.	All	28.9	17/14	4/3
Chigata	Chigata	NGO	Cashew	13.2	13/16	0/0
IvoireCoton	IvoireCoton	Comp.	Cotton	36.8	14/15	6/6
United Nations Development Program	PNUD_K	Interna.	Food	36.8	13/14	6/6
Rural Animation of Korhogo	ARK	NGO	Food & Breed.	60.5	13/13	3/3
Office to Support Commercialisation of Food Crops	OCPV_K	Gov.	Food	2.6	13/13	0/0
Union of Cooperatives for Agricultural Development	UCODACI	Coop.	All	7.9	13/13	0/0
Cooperative "Womiengnon"	Womiengnon	Coop.	Food	21.1	12/12	3/4
Ministry of Animal and Fish Resources	MIRAH_K	Gov.	Breed.	26.3	12/12	1/0
German International Collaboration Society	GIZ_K	Interna.	Food & Breed.	31.6	12/9	0/0
Development and Extension Formation Bureau	BFGD	R&D	All	50.0	11/11	1/0
OLAM-SECO	OLAM-SECO	Comp.	Cotton	28.9	10/11	2/2
Regional Union of Cooperative Enterprises of the Region "Savanes"	URECOSCI	Coop.	Cotton	36.8	10/10	2/5
Union of Cooperatives For Food Crops in the Region "Savanes"	UCOVISA	Coop.	Food	13.2	8/9	1/0

Notes

¹ Gov. = governmental; R&D = Research and Development; Interna. = international organization; Coop. = farmers' cooperative; Comp. = company; Assoc. = association

African Cashew Initiative	ICA	NGO	Cashew	13.2	8/8	1/1
Regulation Agency for Cotton and Cashew	ARECA	Gov.	Cash	13.2	7/8	3/4
Society for Forest Development	SODEFOR_K	Gov.	Forestry	13.2	8/7	2/2
Cashew Inter-Professional Association	Intercajou	IPA	Cashew	7.9	8/7	0/0
Under-prefectures (subdivisions)	Sous-préfecture_K	Gov.	All	13.2	8/5	0/0
Interregional Union of Cooperatives for Tropical Agricultural Products	UIRECOPATCI	Coop.	Cash	18.4	7/7	2/2
European Union	UE	Interna.	All	26.3	7/6	1/2
Action Against Hunger	ACF	Interna.	Food	26.3	7/6	0/0
Swiss Centre for Scientific Research in Côte d'Ivoire	CSRS_K	Research	Food	23.7	6/5	4/4
Cooperative "Gninngnon"	Gninngnon	Coop.	Cash	2.6	6/5	0/0
General Council of Toumodi	CG Korhogo	Gov.	All	15.8	6/4	2/2
Union of Agricultural Cooperatives from "Bafiné"	UCAB-CI	Coop.	Cash	15.8	4/6	0/0
Association of Professionals from the Cotton Sector	APROCOT-CI	Assoc.	Cotton	7.9	5/5	3/3
Cooperative "Yebe-wognon"	Yebe-wognon	Coop.	Cotton	26.3	5/4	0/0
Cooperative of Cattle Breeders of the Region "Savanes"	COOPERSA	Coop.	Breed.	0	2/5	0/0
I Cotoni del Firello	iCotoni	Comp.	Cotton	2.6	4/4	2/2
World Bank	BM	Interna.	All	10.5	4/4	1/1
Cooperative "Namougou" of Karkoro-Komboro	CONAKAKO	Coop.	Cash	7.9	4/4	1/1
Industrial Cotton Company from Savanna	SICOSA	Comp.	Cotton	5.3	3/4	1/1
Bio-Economy Africa	BEA	NGO	All	0	3/4	0/0
National Office for Rice Development	ONDR	R&D	Food	10.5	3/3	0/0
African Development Bank	BAD	Interna.	All	5.3	3/3	0/0
Cooperative "COD-CI"	COD-CI	Coop.	Unknown	5.3	3/3	0/0
Fund	FIDA	Interna.	All	13.2	3/2	0/0
State of Côte d'Ivoire	CI	Gov.	All	7.9	2/2	0/0
Umbrella Organization of Cooperatives of Côte d'Ivoire	UFACOCI	Coop.	Unknown	5.3	2/2	0/0
Society for Management and Development of Airports, Aviation and Meteorology	SODEXAM_K	Gov.	All	10.5	1/2	0/0
Association of Cotton and Cashew Producers	ASPROCA	Coop.	Cash	2.6	1/2	0/0
National Federation of Food Crops Cooperatives in Côte d'Ivoire	FENACOVICI	Coop.	Food	0	1/1	0/0
Agri-aménagistes	Agri-aménagistes	R&D	All	10.5	0/0	0/0
MEAN				20.3	9.3/9.3	1.9/1.9

² Breed. = breeding; «Food» includes all food crops such as rice, maize, tubers, and vegetables. «Cash» includes all export cash crops such as cocoa, coffee, cotton, and cashew.

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