MARNEY ISAAC AND EVANS DAWOE

13

Agrarian communication networks: consequences for agroforestry

13.1 INTRODUCTION: AGRARIAN NETWORKS

Current challenges associated with soil degradation and land scarcity will have significant impacts on agricultural productivity, with far-reaching consequences for agroecosystem services and food security (Altieri, 2002; Sanchez, 2002; Lal, 2004; Vitousek *et al.*, 2009). Research has shown that by increasing agrodiversity, ecological benefits operating at various spatial and temporal scales mitigate environmental risks (Sanchez, 2002; Garcia-Barrios and Ong, 2004; Nair, 2007). Accordingly, the implementation of diverse agricultural systems has become of increasing interest (Pattanayak *et al.*, 2003). Of particular importance is the distribution of information on agrodiversity, and agroforestry, management (Montambault and Alavalapati, 2005; Isaac *et al.*, 2007a; Isaac *et al*. 2009).

As continuously changing biophysical interactions operate in diverse agricultural systems, producers require access to specialized information in order to appropriately manage productive and persistent systems. However, institutionally derived agrarian information and technologies may in fact not reach the desired recipients, confounded by irregular diffusion of agrarian information (Boahene *et al.*, 1999; Warner, 2007). Presumably, the development of informal information on relevant management may counteract such barriers to information flow between producers and from regional institutions. Bodin *et al.* (2006) and Janssen *et al.* (2006) recognized the importance of informal social networks to resource management, however there are

Social Networks and Natural Resource Management: Uncovering the Fabric of Environmental Governance, ed. Ö. Bodin and C. Prell. Published by Cambridge University Press.

currently few empirical studies that investigate the effects of such informal networks on agricultural information transfer as well as consequences for agrarian management.

Based on data from cocoa producers in Ghana, this chapter presents informal communication networks, with particular emphasis on the potential flow of agrarian management information through these networks. Increasingly, regional response to agrarian-derived environmental degradation in Ghana is made through practices that enhance agrodiversity, such as agroforestry, particularly in the economically important cocoa sector (Amanor, 1994; Boni *et al.*, 2004). There is an urgency to uncover information barriers on such practices and subsequent environmental decision-making. Therefore, we apply a social networks approach to identify such critical aspects of agro-environmental management.

13.2 ANALYTICAL FRAMEWORK: SOCIAL NETWORKS AND INFORMATION FLOW

The adoption of new techniques within an agricultural context is shown to partially depend on ties within social systems (Valente, 1995; Rogers, 2003). A focus on these relationships and the resultant structure of such relations is considered a social network. Network theory in part describes the transfer of information via network ties, while the concurrent use of network analysis allows for the measure and examination of ties and network characteristics (Wasserman and Faust, 1994). The flow of information embedded in these networks may be more evident in the context of relationships and interactions between actors (Granovetter, 1973; Burt, 1992; Burt, 2000; Lin, 2002; Davidson-Hunt, 2006).

For the agrarian context discussed in this chapter, minimal sources of formal information on pertinent agricultural techniques exist, particularly official and verifiable information derived from regional institutions or organizations. Communication networks are important for the transfer of such formally sourced information on agriculture management (Foster and Rosenzweig, 1995; Conley and Udry, 2001; Lyon, 2000; Romani, 2003; Kiptot *et al.*, 2006; Davidson-Hunt, 2006). However, it can be assumed that to balance a deficit of formal information, particularly in remote farming areas, other types of informal information are produced and endure within farming communities (Mortimore and Adams, 2001; Campbell, 2004), creating two pools of knowledge. Farmers who cannot access information from external sources, such as government or academic institutions, presumably draw on knowledge within their social networks and access agricultural information via social interactions (Boahene *et al.*, 1999; Conley and Udry, 2001). The diffusion of information and the process of adopting farm-management techniques may rely heavily on social relationships in the larger farming community and subsequent informal networks (Foster and Rosenzweig, 1995; Valente, 1995; Lyon, 2000; Romani, 2003; Kiptot *et al.*, 2006; Davidson-Hunt, 2006). It is the structure of these networks that can play a key role in the success of social processes to advance or weaken sustainable agrarian management.

Organizationally, local network structures may in fact be subgroups of larger regional-scale networks. Dependent on geographic locations, regional institutions, rural actors, and/or agencies may include extension and government agencies, formal research institutions, local support providers, non-governmental organizations (NGOs), local expert sources, informal opinion leaders, or even buyers (Allen, 1977; Pretty and Smith, 2004; Matuschke *et al.*, 2007; Bodin and Crona, 2009). Hoang *et al.* (2006) illustrated that agricultural extension and research-development institutions, as well as community-based sources of informal information, were very active; the latter was used effectively to supplement extension agents' work in the diffusion of agrarian practices. However, regardless of the network scope, the identification of emerging network structures and the position of key actors in the transfer of agroecological techniques will help define pools of information and highlight diffusion of information on agrarian management.

Communication patterns may evolve into multiple forms of social networks with structural characteristics that may either impede or promote information diffusion. Two basic measures of a network are size, composed of the number of actors, and ties, the number and direction of connections in a network. Networks can be at the individual scale (ego-network) or larger scale, such as at a community level (whole-network). Regardless of scale, structural features such as density have implications for transfer of information within a network. For instance, density, the percentage of actual ties out of all possible ties in a network, is an important structural attribute for information flow (Scott, 1991; Knoke and Yang, 2008). A greater understanding of barriers to information flow may require an examination of network density at either the ego-network or whole-network level. A highly dense network can have an elevated frequency of communication amongst actors but may not receive new information (Valente, 1995), whereas a low-density network may have new information but low information flow. The density level may not be equal throughout the network but may vary within subsections of a network. For example, a core–periphery structure may arise in the form of a high-density group (core) surrounded by a low-density group (periphery) (Wasserman and Faust, 1994). The core position in this type of structure generally exhibits a high density of ties, whereas the periphery position is minimally connected to each other (Borgatti and Everett, 1999). Such a high density between actors in the core can be positive for information exchange when members of that core are connected to actors in a low-density, weakly tied periphery. Therefore, unlike a hierarchical structure for example, a web-like core–periphery structure can facilitate information flow through low-density elements (Muller-Prothmann, 2005), as in this case for information flow on agrarian management techniques.

Although limited, recent studies have investigated informal communication networks in agroecology and agroforestry management (Hoang *et al.*, 2006; Kiptot *et al.*, 2006; Isaac *et al.*, 2007a; Warner, 2007; Isaac *et al.*, 2009). It has been shown that agroforestry producers play an active role in the development and transfer of management knowledge, particularly for rural and remote producers. We respond to the current discourse on social networks and resource management by examining emerging communication patterns, and consequences of such patterns to the use of agroforestry practices and resource management in general. To investigate these phenomena, we examine whole-network communication structures, particularly advice seeking, at the community level in order to characterize network positions and to determine the consequences of such structures on management information and agroforestry practices. Subsequently, a structural examination of personal producer-to-producer and producer-to-rural institution networks is undertaken to investigate the larger regional features of agrarian management. Individual network metrics are correlated to management, using species richness as an estimate of agroforestry management intensity, in order to establish some measures between network structural characteristics and sustainable agrarian management.

C:/ITOOLS/WMS/CUP-NEW/2517161/WORKINGFOLDER/BBD/9780521766296C13.3D 326 [322–344] 8.3.2011 1:34AM

13.3 BACKGROUND

13.3.1 Agroforestry management

Agroforestry, a diverse system incorporating and/or maintaining trees in the agricultural landscape for both production and function purposes, is emerging as a win-win production system, mitigating risk in regions facing ecological and economic challenges (Nair, 1998; Sanchez, 2002; Garrity, 2004). While agroforestry principles have shaped and guided international policy and on-farm management over the years (Nair, 2007), new insights and advances in system management are still required to overcome barriers to diverse crop production and sustainable rural livelihoods.

The general principle of minimizing competition and maximizing facilitation between species in agroforestry systems remains a primary focus of research for successful agroforestry management practices. By managing agroforestry systems in accordance with ecological processes, many different benefits can be achieved (Beer *et al.*, 1998; Garcia-Barrios and Ong, 2004). Montagnini *et al.* (2000) demonstrated effective nutrient uptake, nutrient interception, recycling of nutrients, and synchronization of nutrient release with crop uptake under agroforestry management. Appropriate light-level regulation for target shade-tolerant species grown in agroforestry systems has been documented, while interactions between light and nutrient resources in perennial- and annual-based systems remain critical (Garcia-Barrios and Ong, 2004; Isaac *et al.*, 2007b).

13.3.2 Cocoa agroforestry in Ghana

Cocoa, a tree crop of high economic importance throughout the tropics, is particularly prevalent in Ghana. Small-scale farm production of cocoa in Ghana has developed from a minimal proportion of world production in the early nineteenth century to currently Ghana being the second largest global producer, maintaining 1 200 000 ha of land in cocoa production (Amoah, 1995; ICCO, 2004). Currently, the expansion rate of agricultural land in Ghana is 2.5% annually for tree and food crops, exhibiting like neighboring Cote D'Ivoire, Cameroon, and Nigeria, widespread deforestation through forest conversion to cocoa production (MOFA, 1991). However, current production is low due to multiple factors, including aging farms, high production costs, and climate change challenges. Long-term on-site consequences of nutrient depletion and unpredictable rainfall patterns have resulted in declining crop yields. Moreover, additional costs originating from environmental impacts such as accumulation of fertilizer residues and soil degradation accompany this decline (Nyanteng, 1993; Amanor, 1994). A large portion of the cocoa-farming population in Ghana is dependent on successful production of cocoa (*Theobroma cacao* L.) while simultaneously producing subsistence food crops and commodity tree crops (Asare, 2006). Amid low soil fertility and constraints to fertilizer access, farmers have developed techniques to promote soil and crop nutrition as well as maintain shade for healthy plants (Amanor, 1994; Boni *et al.*, 2004).

In response to the economic and ecological needs of smallholder farmers in Ghana, agroforestry practices are an option in cocoa ecosystems. Intricate small-scale production systems, incorporating trees and understory crops integrated with the cocoa stratum, have advanced farm health and production in Ghana (Isaac *et al.*, 2005; Asare, 2006, 2007b; Dawoe *et al.*, 2010). These techniques of farmer-based system management are often put into action through means such as planting schemes and species selection (Isaac *et al.*, 2009). Farmers have been active in managing forest timber species on their cocoa farms for shade and other functions. These upper canopy trees are retained or planted during farm establishment for light regulation and enhancement of biomass inputs for improved soil fertility and plant nutrition, which consequently increases farm diversity (Beer *et al.*, 1998; Hartemink, 2005).

Although some conflicting results exist on the success of cocoa-shade systems, a number of trends can be noted. In general, most cocoa research demonstrates high levels of nutrient transfer, providing evidence for nutrient-use efficiency and nutrient cycling (Hartemink, 2005). While shade trees have been shown to compete for soil resources, ameliorative effects have also been demonstrated, particularly through changes in microclimatic conditions, reduction in soil erosion, and as mentioned above, nutrient use efficiency (Beer *et al.*, 1998; Hartemink, 2005; Isaac *et al.*, 2007b). Generally, these cocoa-shade systems are emerging as a sustainable form of diverse cash crop production.

13.4 METHODS

13.4.1 Study regions

Gathering of empirical data for network analysis took place in two regions of Ghana: in the Western region (Region 1: 06°12′ N and

02°29′ W) and in the Ashanti region (Region 2: 60°75′ N and 10°40′ W). Communities in these regions were selected as representational of the respective regions. Both regions are characterized by a natural vegetation of semi-deciduous forests with predominantly smallholder farms, typically for cocoa perennial systems. Region 1 is characterized by highly weathered ochrosol-oxisol intergrades (Rhodic Ferralsol). Region 2 is characterized by deep, moderately well-drained silty-loam soils of the classification Ferric Lixisol (Soils Survey Division, 1969). Both regions have bi-modal rainfall, ranging from 1300 mm per year to 1850 mm per year. Similarly, the dominant naturally regenerated non-cocoa species in the region, on cocoa farms and in taungya systems, are *Terminalia superba* Engl. & Diels, *Triplochiton scleroxylon* K. Schum., *Alstonia boonei* de Wild and *Ceiba pentandra* (L.) Gaertn. Fruit trees may also be planted; e.g. orange (*Citrus sinensis* (L.) Osbeck), avocado (*Persea americana*), and mango (*Mangifera indica* L.) (Isaac and Dawoe, 2009).

Regions 1 and 2 vary in accessibility to formal information accessed through institutions or rural agencies/actors. Region 2 is approximately 30 km from Kumasi, the second largest city in Ghana and has a much greater access to markets, extension agents, research for development organizations, and educational institutions, whereas Region 1 is approximately 120 km from Kumasi, located in a more remote area of Ghana near the Ivory Coast border. In Region 1, extension agencies have a much less frequent visitation pattern to farms than Region 2. Furthermore, in Region 1, the presence of NGOs that prioritize agriculture research for development is inconsistent as compared to Region 2. If a local development project is active in the region, there is a high level of contact but when no projects are active, there is little to no formal contact with NGOs.

13.4.2 Approach

Both whole-network (community) and ego-network (individual) scales were used to study the flow of agrarian management information, particularly the structure of communication networks and network features in relation to agroforestry adoption. Specifically, whole-network data (an exhaustive list of ties within a geographically bounded community) from Region 1 was derived from on-site producer interviews. All participants were asked questions on socio-demographics and specific management practices, as well as advice seeking and communication patterns. We specifically asked: “Whom do you go to for advice on agroforestry techniques and management?”

Such network data were collected through the name-generator technique (Marsden, 2004). Region 1 interviews were conducted in four separate agrarian communities, creating four whole-networks. These communities were similar in population, location (distance from markets and towns), and access to land, but had no apparent cross-over in social relations. The adult farming population of the village was interviewed (~22 people per community), where a producer is one who currently owns or rents land and has established a cocoa farm. Data for individual networks (bounded to one step from ego) were extracted from the whole network data set for Region 1. For Region 2, data for individual networks was gathered through a comparable interview process to Region 1, with alters and alter ties identified by ego as well as determined from pooled ego-network data. Twelve individual networks, representing half of a community network, from Region 1 and 11 individual networks from Region 2 were analyzed. As described above, based on geographical distance of the two regions, participants in Region 2 also included non-producers, in particular rural institutional actors (extension agency officers, research for development agencies employees, and local development actors) in the network data-gathering process on information seeking, whereas Region 1 participants did not. Once a producer in Region 2 identified a non-producer as a source of information in their ego-network, semi-structured interviews were conducted with individuals from each institution, which again focused on information seeking in agroforestry practices. Participant responses were coded as binary variables, i.e. the presence (1) or absence (0) of a tie, and entered into an actor-by-actor adjacency matrix (Hanneman, 2001).

Data for the advice networks in the four communities in Region 1 were analyzed with a core–periphery model to test for a group of actors with high density and groups with low density. The density of ties within each group was determined based on a predefined algorithm by Borgatti and Everett (1999) for categorical core–periphery structures. Again, core members were those that had a significantly higher density of ties amongst themselves as compared with others in the network. Participant attributes were then tested to see whether they correlated with core membership. Here, we present one attribute: "producer origin" which is divided into local (producer is from the community) and settler (producer migrated to the community). This attribute was selected to investigate the strength of pre-existing ties and social proximity as drivers of core–periphery formation. Ego-network data were analyzed for size (number of actors), ties (number of connections), and density (a measure of existing ties as a percentage of all possible ties).

Some farm physical attributes were also recorded. Producers were asked to report on the quantity and diversity of species established on their farms. Specifically, we employed the number of tree species on a farm plot basis (species richness) as a measure of agrodiversity and used this as a correlate of the intensity of agroforestry adoption. We tested correlations between relational attributes of actors (individual density score) to a non-relational variable (species richness).

All network analysis was conducted with UCINET (Borgatti *et al.*, 2002) and visualization in Netdraw (Borgatti, 2002). Although the data are not presented, note that for whole-networks, we used four independent replications of whole-networks to test for core–periphery structures. Density data derived from the core–periphery analysis was then subjected to analysis of variance to test for differences between networks in this region. Again, although the raw data are not presented, we relate an attribute (origin of producer) to a measure of the actor's position in a network (core or periphery) with t-tests (see Isaac *et al.*, 2007a for data). Density data from ego-networks had 12 replications for Region 1 and 11 replications for Region 2. All statistical tests were performed using SAS version 8.0.

13.5 EMPIRICAL FINDINGS: ADVICE NETWORKS AND INDIVIDUAL NETWORK STRUCTURE

In all four communities, information on agrarian management was noticeably sought from within a smaller, densely connected group (core) compared with a loosely connected periphery. Low tie density was observed between these two structural positions and within the periphery group (example network in Figure 13.1; see Isaac *et al.*, 2007a for core–periphery data). Follow-up interviews showed that of these highly sought core producers, 84% explored some level of formal information, predominately from government institutions (Table 13.1). Although producers in the peripheral positions sought a similar type of externally sourced information, peripherally positioned actors sought such information much less frequently than core-positioned actors (Table 13.1). Information on general farm techniques, such as species selection, organic matter management, and tree and crop densities, tended to be sought from producer-to-producer ties within communities (Table 13.1). Although core membership was not significantly

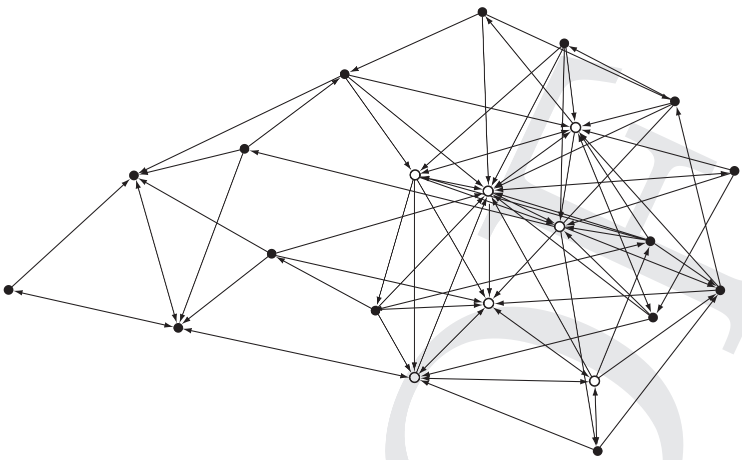

Figure 13.1 An example of one of the four community networks on agrarian management advice seeking from Region 1. Nodes represent individual producers and directed arrows represent advice ties. Filled nodes are periphery members and empty nodes are core members.

dependent on origin of producer, a slight over-representation of settler producers was found in the core. Community members at large were approximately evenly divided between local and settler producers, however, self-identified settlers comprised 73% ± 20% of the core.

To further uncover factors affecting agrarian information for individual producers in the larger organizational landscape, we undertook a comparative analysis of individual network structural measures, using informal producer-to-producer communication ties for Region 1 and 2 but also institutional ties for Region 2. This allowed for an assessment of emergent network structures with varying sources on agrarian management. Individual networks composed exclusively of producers had significantly greater number of ties (P = 0.029) in Region 1 compared with Region 2. When institutions were included, ego-network density scores were significantly lower (P = 0.005) in Region 2 (Table 13.2; Figure 13.2). In this region, 69% of all producers had immediate ties with non-producer actors, such as individuals from institutions. However, even when exclusively comparing producer networks by removing institutional ties from the analysis, ego-networks were overall much more dense with lower access to institutions (Table 13.2).

Although we tested ego-network density scores from Regions 1 and 2 individually, to determine correlations between density and tree species richness (number of species reported on-farm), the data

Table 13.1. *Percentage of producers averaged over the four community networks (N = 4 ± S.D.) in Region 1 seeking information from various sources: informal information and on-farm experimentation for producers positioned in the core and formal information categorized into core and periphery positions. The most highly mentioned types of information are also provided.*

Source of information	Farmers seeking information (%)	Type of information
	Core members	
Informal	100	• Species selection • Farm establishment • Planting patterns • Shade management • Organic matter management
Experimentation	92.5 ± 9.57	• Species selection • Planting densities • Organic matter management
Formal	84 ± 17.05	• Pest control • Disease control • Planting densities
Periphery members		
Formal	32.3 ± 9.43	• Pest control • Disease control • Planting densities

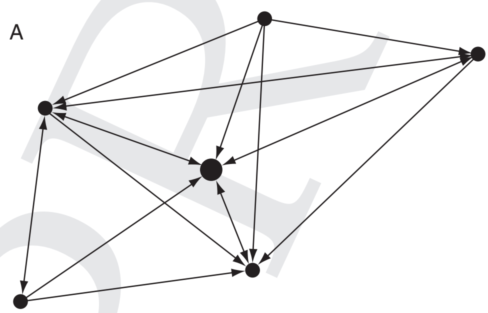

Figure 13.2 Example individual networks on advice seeking for agrarian management information in (A) Region 1 and (B) Region 2. The larger nodes represent the target individual (ego), the other nodes represent individual alters. Directed arrows represent advice ties. Filled circular nodes are producers and empty circular nodes are actors from regional institutions. Note that alter ties were not recorded between institutions.

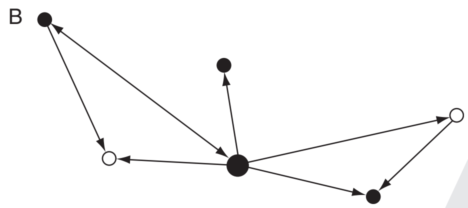

Figure 13.2 (Cont.)

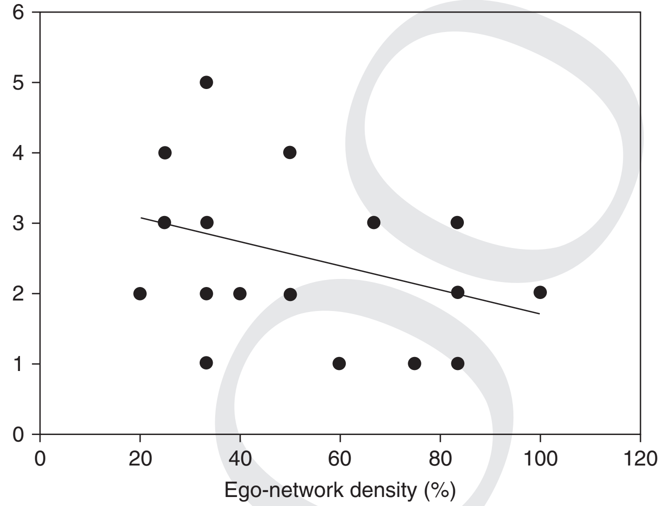

Figure 13.3 Correlation between individual network density (%) and species richness (number of tree species reported on farm) pooled for Region 1 and 2 (r = 0.35; P < 0.100).

presented here are pooled from the two regions. In doing so, we found a negative relationship between individual network density (excluding institutions) and the number of shade tree species (r = 0.35) (Figure 13.3). This suggests that increasing ties between community members did not forecast adoption of agroforestry practices as approximated by agrodiversity. Regardless of weak or strong institutional support, higher reporting of agrodiversity occurred from individuals with relatively low-density ego-networks. However, some caution should be noted. Although variation in data-collection procedures in the two regions was minimized (see Methods section) and density scores were not significantly different between the two regions, correlations using pooled data may be influenced by other confounding methodological factors.

Table 13.2. *Mean (± SD) individual network measures [number of actors (size), number of connections (ties) and percentage of ties (density)] for producer networks in Region 1 and Region 2 and producer + institution network for Region 2 (Region 1: N = 12; Region 2: N = 11).*

Location	Mean ego-network measure Size*	Ties**	Density (%)
Region 1 [Producer]	3.4 ± 1.00a	5.8 ± 3.52a	64.6 ± 20.59a
Region 2 [Producer]	3.3 ± 1.01a	2.9 ± 1.04b	48.0 ± 27.56ab
Region 2 [Producer + institutions]***	4.1 ± 1.30a	3.7 ± 2.10ab	30.3 ± 8.39b

* Including ego
** Directed ties
*** Institutional alters have been added.
Means within a column followed by the same letter are not significantly different accordingly to Tukeys test, $P < 0.05$.

13.6 DISCUSSION

13.6.1 Advice networks: informal ties and agroforestry management

Due to increasing commodity prices of cocoa, and the availability of land in the western region of Ghana, many people from outside this region are buying or renting land for cocoa production; thus farmers from other areas of Ghana as well as neighboring countries are often attracted to this region. Furthermore, as a result of long-term fluctuating cocoa prices, local community members have both started and abandoned cocoa farming (Boni *et al.*, 2004). Consequently, both "local" farmers with a family history from the dominant lineage in the community and newer "settler" farmers (migrant farmers from an external group) reside together within these communities. A slight over-representation of settler farmers was found in the core position (see Isaac *et al.*, 2007a for data), which is presumably a result of multiple factors. For instance, settler individuals may more easily adopt innovations because of less pressure for social conformity. The introduction of new producers who have lost previous associations may have a greater willingness to implement new techniques and an enhanced opportunity to activate new ties, thus resulting in a core advice-seeking position. Although kin ties can encourage information flow, the similarity of actor characteristics or actor homophily can impede transfer (Warriner and Moul, 1992). The low level of homophily (in this case, similar origin) found amongst core-positioned producers might in fact lead to a higher likelihood of information transfer. This suggests that advice ties were indeed motivated by farming practices, and social proximity was not a driving factor in forming network structure.

Interestingly, agrarian practices leading to meaningful advice may be derived from settler producers who have adapted their management to a new environment and/or condition; or settler producers may have pertinent adaptive management strategies from previous experience in other regions. It should be noted that these migrating settler producers are primarily from northern regions of Ghana. Climate change impacts in the north of the country may in fact be acting as a push factor leading to southern migration into cocoa-growing regions. There are as of yet undetermined consequences of drought-related farmer migration on localized agroforestry management (Van der Geest and de Jeu, 2008; Gyampoh *et al.*, 2009), forces of which are presumably strongest in countries with a large ecological transition zone such as Ghana. The resultant impacts of farmer migration on agricultural innovation and land-use management may be of particular interest as locally developed technologies under climate change scenarios may be easily transferred to new recipient groups currently coping with unpredictable climate. This is particularly important in southern Ghana which is currently experiencing unpredictable rainfall.

Core- and periphery-positioned producers within each community used informal ties as a means to access agroforestry information. Generally, producers relied on pre-existing local information and on-farm experimentation. These experiments investigated, amongst other management practices, growth comparisons under different shade trees, testing previously unused species on small plots of land. Information derived from these experiments indicates a new pool of knowledge and a source of original information on farming practices under local conditions. Further studies on decision-making and management in these cocoa-growing communities showed that the most prominent variable in farm management was managing the tree stratum (Isaac *et al.*, 2009). This was not unexpected as management of the tree canopy is frequently the focus of farming practices, either for ecological advantages, such as shade and nutrient additions or financial benefits from on-farm products, such as fruits or fuelwood (Beer *et al.*, 1998; McNeely, 2004).

Core and periphery producers gathered technical information on farm pests and diseases; they sourced answers to current farm problems predominately from outside the community. However, core members of the whole advice networks had a much higher level of contact with institutions from outside the immediate community, thus functioning as bridging links. The presence of these bridging ties formed between the community and outside institutions, suggests a path of information diffusion. These connections to external sources may increase the flow of information into the community and/or counteract the frequently observed low level of information flow to all community members (Boahene *et al.*, 1999).

13.6.2 Individual networks: institutional ties and consequences for agroforestry adoption

Previous work has shown that adoption of agricultural technologies is typically linked to access to information and resources, such as credit (Valente, 1995; Rogers, 2003; Matuschke *et al.*, 2007). Remembering that Region 2 is characterized by higher access to formal information and institutions such as extension agents, government ministries, NGOs and local development support, we recorded a decrease in the number of ties of informal networks. This may be a result of increased resources, thus a decrease in dependence on community members. As ties become more formalized, producer-to-producer reliance declines, and perhaps results in a simultaneous decline in localized knowledge. This also shows that individual networks are not restricted to producers. And some level of reciprocity exists insofar as actors from institutions may seek information from producers.

New approaches to information distribution, particularly through development agencies such as farmer field school, may complement information provided by traditional extension services (Hoang *et al.*, 2006). For instance, Prell *et al.* (2009) demonstrated that agricultural extension services might utilize well-selected community members as demonstrators of new practices. This may promote the formation of stronger informal networks for information flow, particularly under scenarios with strong institutional contact. With weak support from rural agencies and a corresponding large producer-dominated individual network, bridging ties could be activated to source formal information on management, as was the case with core actors in our community-level advice networks.

It is also possible that with increasing ties, information becomes redundant or even conflicting. We showed that higher individual network density does not necessarily lead to adoption of agroforestry practices as approximated by on-farm species richness. Although with time this abundance of information may in fact be successful at providing a full spectrum of support for rural producers, more ties do not necessarily mean better information. Information excess may lead to information homogenization and thus declining sustainable resource use. This saturation may also lead to an abandonment of innovative ideas and suggests a need for greater focus on optimal information flow, rather than the amount of information – quality over quantity. Although it has been suggested that a greater number of ties and hence network density, would positively impact resource governance (Bodin and Crona, 2009) and improve information exchange (Pretty and Ward, 2001), other studies showed that agrarian innovativeness had no relationship to network density (Valente, 1995). Conversely, Bodin and Norberg (2005) demonstrated a positive consequence of low to moderate number of ties on the potential of diverse management practices. Low numbers of ego-network ties and/or densities are derived from either small network size or nominal levels of alter ties. As our data set captured no ego-networks with very low densities, it is difficult to say whether even at lower densities we would find a corresponding positive impact on adoption of agroforestry practices. This may be a function of our methods insofar as complete lists of ego-identified alters may be quite difficult to recall, leading to smaller ego-networks and perhaps artificially capturing high density.

13.6.3 Scaling-up agroforestry practices with social networks

Under agrarian scenarios, a networks approach exhibits sources of innovation and information on sustainable management (Warner, 2007). And with appropriate institutional networks, higher rates of sustainable management adoption can be encouraged with proper organizational structures. Sustainable agrarian systems can be additionally promoted by scaling up environmentally appropriate practices. This may be achieved through networks of varying scales; specifically in this case, plot-to-community-to-regional levels. This work empirically studied informal communication networks at individual actor as well as more regional levels. By investigating common management issues such as the flow of information on agroforestry practices at various scales, obstacles to diffusion may become evident. However, comprehensive policy is needed due to the large geographical, as well as social, distance that may play a significant role in the movement of information (Schneider *et al.*, 2003). Less formally, local management networks can be encouraged to compensate for barriers to specialized information. Crossing such scales for improved resource management may be achieved through subgroup connections (Berkes, 2008; Bodin and Crona, 2009). This bottom–up focus is essential to the improvement of rural livelihoods, because large-scale policy that is dependent on global markets yet enforced at the local scale could be ineffectual. Over time, the passive yet persistent adoption of sustainable agroforestry management practices through previously established communication networks may be of use. This would ensure on-ground permanence of agroforestry practices and subsequent landscape-scale benefits of such practices.

13.7 CONCLUSIONS

Under weak institutional support and in the face of large ecological challenges, further investigation into the barriers and benefits of social networks to agrarian management information is critical. Although specific predictions may be unfeasible, data are emerging on network characteristics and natural resource management, particularly in this case for agrarian management. Network heterogeneity and bridging ties between networks have been regularly positively linked to sustainable management practices (Crona and Bodin, 2006; Isaac *et al.*, 2007a; Newman and Dale, 2007; Prell *et al.*, 2009). Our work showed a lack of homophily between highly sought producers, which in turn could lead to a higher likelihood of information transfer.

The structure of informal communication networks in relation to small-scale agricultural production varied with the degree of access to formal information; individual producer networks had fewer ties with increasing dependency on formal institutions. Regardless of where a producer sourced information (producer-derived or formally sourced), higher agrodiversity was correlated to individual networks with low density. This may be a product of greater institutional ties or in fact, a higher adoption frequency with fewer informal ties, particularly among alters. Despite this, characterization of emerging network structure and density as well as the identification of highly sought producers may play a critical role in the introduction, transfer, and implementation of new agroforestry techniques.

C:/ITOOLS/WMS/CUP-NEW/2517161/WORKINGFOLDER/BBD/9780521766296C13.3D 339 [322–344] 8.3.2011 1:34AM

Reflections

Network boundary, ecological boundaries, and unit of analysis

In the advice network, our unit of analysis is the whole-network. To determine the boundaries of each network, we relied on the name-generator technique. Participants provided names of community members from who they seek advice on farm management until no new names were provided, creating a complete list. We found the name-generator approach in this situation appropriate for two reasons: (1) we were working in a similar socio-economic group, reducing dissimilar interpretation of questions and (2) we assessed unidirectional ties, which presumably increased the stability of the network measures.

The individual (ego) networks were bounded by a one-step "neighborhood" from the central individual. Both individual producers and other actors in the rural landscape such as extension agents, non-governmental agencies, and rural development support, were included in this neighborhood. Unlike common pooled resources, we deemed ecological boundaries as simple to define. We used the farm plot as an ecological unit of analysis, which was defined by the producer. For instance, when we gathered data on species richness, the unit of analysis was the farm plot. Therefore, our network boundary (ego-network) and our ecological boundaries (farm plot managed by that individual) corresponded.

Data-gathering issues

To resolve obstacles associated with social network universality for agrarian resource management, we undertook a variety of steps to overcome barriers to data rigor and richness. First, a multi-community approach was carried out; similar whole-network analysis was conducted in geographically separate but socio-economically comparable communities. With regard to such community networks, we were interested in the variability and consistency among the distinct advice networks of four communities. Specifically, we asked: "Do informal advice networks within these farming communities have comparable structures, and can some general statements be made about farming advice networks?" By focusing on one type of relationship in multiple communities, we sought to increase the rigor and accuracy of the analysis and to test whether the emerging communication patterns were community specific or whether structural characteristics were generalized. The replication among communities allowed whole-network characteristics to be compared statistically, revealing general attributes of network structure for advice and information transfer. The applicability of a multi-communities approach enhanced our ability to state with some certainty the existence of a particular network structure as well as testing of network similarity.

Explanatory power of social network analysis

The explanatory power of our social network analysis lies in the qualitative data and additional quantitative data that were collected. The advice-seeking tie structure in and of itself is informative but is practical only when placed in context of position attributes, e.g. who seeks who and for what type of information? We used (and highly recommend) a multi-methods approach. Further work on cocoa agroforestry management was undertaken using cognitive mapping and decision-making models as a unit of analysis to assess the process of local knowledge use (Isaac *et al.*, 2009). This allowed for comparison between individual producers to determine the degree of similarity among on-farm decision makers and to expand information on the quality of information being transferred through social networks.

When examining biophysical attributes of a resource, quantitative data were essential as a dependent variable. As we were interested in using network structure as a correlate to agrarian management techniques, it became invaluable to select a quantifiable variable, for instance biodiversity indices, yields, or growth rates. By collecting data on farm species richness, we operationalized farm management into a measurable variable. We then linked this variable, as an estimate of management, to an aspect of network structure, specifically density, in order to establish some measures between network structural characteristics and agrarian management.

In the current discourse on localized information in natural resource management, importance should be placed on the dynamic nature of information production and flow. This work conducted on cocoa agroforestry in Ghana explored the process-oriented nature of information seeking, decision-making, and management of on-farm practices by employing social network analysis. Access to both informal and formal information sources as well as the structural characteristics of local social networks among producers influenced decision making to adopt more sustainable practices. Collectively, informal networks remain instrumental for the successful transfer of this information throughout the farming community and provide a foundation for sustainable agrarian management.

ACKNOWLEDGMENTS

We would like to acknowledge helpful comments from colleagues at the University of Toronto. We are grateful to field support provided by J. Hagan (Sefwi Wiawso) and A. Owusu (Kumasi), Ghana. This work was financially supported by Natural Science and Engineering Research Council of Canada.

REFERENCES

Allen, T. J. (1977). *Managing the Flow of Technology, Technology Transfer and the Dissemination of Technological Information within the R & D Organization*. Cambridge, MA: MIT Press.

Altieri, M. (2002). Agroecology: the science of natural resource management for poor farmers in marginal environments. *Agriculture Ecosystems and Environment*, **93**, 1–24.

Amanor, K. S. (1994). *The New Frontier; Farmers' Response to Land Degradation: A West African Study*. London: UNRISD.

Amoah, J. E. K. (1995). *Cocoa Outline Series: Development of Consumption, Commercial Production and Marketing*. Takoradi, Ghana: Jemre Enterprises Limited.

Asare, R. (2006). *A Review on Cocoa Agroforestry as a Means for Biodiversity Conservation*. Brussels: World Cocoa Foundation Partnership Conference.

Beer, J., R. Muschler, D. Kass and E. Somarriba (1998). Shade management in coffee and cacao plantations. *Agroforestry Systems*, **38**, 139–164.

Berkes, F. (2008). Commons in a multi-level world. *International Journal of the Commons*, **2**, 1–6.

Boahene, K., T. Snijders and H. Folmer (1999). An integrated socioeconomic analysis of innovation adoption: the case of hybrid cocoa in Ghana. *Journal of Policy Modeling*, **21**, 167–184.

Bodin, O. and J. Norberg (2005). Information network topologies for enhanced local adaptive management. *Environmental Management*, **35**, 175–193.

Bodin, O. and B. Crona (2009). The role of social networks in natural resource governance: what relational patterns make a difference? *global Environmental Change*, **19**, 366–374.

Bodin, O., B. Crona and H. Ernstson (2006). Social networks in natural resource management – what's there to learn from a structural perspective? *Ecology and Society*, **11**(2), r2 (online).

Boni, S., R. I. Nuhu, F. Reuter and G. Da Re (2004). *Anthropological, Environmental and Soils Assessment of the Sefwi Wiawso District, Ghana*. Italy: Ricerca e Cooperazione.

Borgatti, S. P. (2002). *Netdraw Network Visualization*. Harvard, MA: Analytic Technologies.

Borgatti, S. P. and M. G. Everett (1999). Models of core/periphery structures. *Social Networks*, **21**, 375–395.

Borgatti, S. P., M. G. Everett and L. C. Freeman (2002). *UCINET for Windows: Software for Social Network Analysis*. Harvard, MA: Analytic Technologies.

Burt, R. (1992). *Structural Holes: The Social Structure of Competition*. Cambridge, MA: Harvard University Press.

Burt, R. (2000). The network structure of social capital. In R. I. Sutton and B. M. Staw (Eds.), *Research in Organizational Behaviour*. Greenwich, CT: JAI Press, pp. 213–243.

Conley, T. and C. Udry (2001). Social learning through networks: the adoption of new agricultural technologies in Ghana. *American Journal of Agricultural Economics*, **83**, 668–673.

Crona, B. and O. 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 (online).

Campbell, M. O. (2004). The role of socio-environmental networking in the sustainability of rain-fed agriculture in the coastal savanna of Ghana. *Geojournal*, **61**, 79–88.

Dawoe, E, M. E. Isaac and S. J. Quashie-Sam (2010). Litterfall dynamics in cocoa-agroforestry systems of lowland Ghana. *Plant and Soil*, **330**, 55–64.

Davidson-Hunt, I. J. (2006). Adaptive learning networks: developing resource management knowledge through social learning forums. *Human Ecology*, **34**, 593–614.

Foster, A. and M. Rosenzweig (1995). Learning by doing and learning from others: human capital and technical change in agriculture. *Journal of Political Economy*, **103**, 1176–1209.

Garcia-Barrios, L. and C. K. Ong (2004). Ecological interactions, management lessons and design tools in tropical agroforestry systems. *Agroforestry Systems*, **61**, 221–236.

Garrity, D. (2004). Agroforestry and the achievement of the Millennium Development Goals. *Agroforestry Systems*, **61**, 5–17.

Granovetter, M. (1973). The strength of weak ties. *American Journal of Sociology*, **78**, 1360–1380.

Gyampoh, B. A., S. Amisah, M. Idinoba and J. Nkem (2009). Using traditional knowledge to cope with climate change in rural Ghana. *Unasylva*, **60**, 70–74.

Hanneman, R. A. (2001). *Introduction to Social Network Methods*. Riverside, CA: University of California, Riverside.

Hartemink, A. E. (2005). Nutrient stocks, nutrient cycling, and soil changes in cocoa ecosystems: a review. *Advances in Agronomy*, **86**, 227–253.

Hoang, L. A., J. C. Castella and P. Novosad (2006). Social networks and information access: implications for agricultural extension in a rice farming community in northern Vietnam. *Agriculture and Human Values*, **23**, 513–527.

ICCO (International Cocoa Organization) (2004). *International Cocoa Organization's Quarterly Bulletin of Cocoa Statistics*.

Isaac, M. E. and E. Dawoe (2009). Promoting long-term farm diversity: Integrative management of cocoa agroforestry systems in Ghana. *Journal of Science and Technology, Ghana*, **26**, 26–33.

Isaac, M. E., E. Dawoe and K. Sieciechowicz (2009). Assessing localized knowledge use in agroforestry management with cognitive maps. *Environmental Management*, **43**, 1321–1329.

Isaac, M. E., B. Erickson, J. Quashie-Sam and V. R. Timmer (2007a). Transfer of knowledge on agroforestry management practices: structure of informal advice networks. *Ecology and Society*, **12**(2): 32 (online).

Isaac, M. E., A. M. Gordon, N. Thevathasan, S. K. Oppong and S. J. Quashie-Sam (2005). Temporal changes in soil carbon and nitrogen dynamics in tropical multistrata agroforestry systems: a chronosequence of pools and fluxes. *Agroforestry Systems*, **65**, 23–31.

Isaac, M. E., V. R. Timmer and S. J. Quashie-Sam (2007b). Shade tree effects in an 8-year-old cocoa agroforestry system: biomass and nutrient diagnosis of *Theobroma cacao* by vector analysis. *Nutrient Cycling in Agroecosystems*, **78**, 155–165.

Janssen, M. A., O. Bodin, J. M. Anderies *et al.* (2006). A network perspective on the resilience of social-ecological systems. *Ecology and Society*, **11**(1), 15 (online).

Kiptot, E., S. Franzel, P. Hebinck and P. Richards (2006). Sharing seed and knowledge: farmer to farmer dissemination of agroforestry technologies in western Kenya. *Agroforestry Systems*, **68**, 167–179.

Knoke, D. and S. Yang (2008). Social Network Analysis, 2nd Edition. Thousand Oaks, CA: Sage.

Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *Science*, **304**, 1623–1627.

Lin, N. (2002). *Social Capital*. New York, NY: Cambridge University Press.

Lyon, F. (2000). Trust, networks and norms: the creation of social capital in agricultural economies in Ghana. *World Development*, **28**, 663–682.

Marsden, P. (2004). Recent developments in network measurement. In P. Carrington, J. Scott and S. Wasserman (Eds.), *Models and Methods in Social Network Analysis*. New York, NY: Cambridge University Press, pp. 8–30.

Matuschke, I., R. Mishra and M. Qaim (2007). Adoption and impact of hybrid wheat in India. *World Development*, **35**, 1422–1435.

McNeely, J. A. (2004). Nature vs. nurture: managing relationships between forests, agroforestry and wild biodiversity. *Agroforestry System*, **61**, 155–165.

MOFA (Ministry of Agriculture). (1991). *Agriculture in Ghana: Facts and Figures*. Accra: Policy Planning, Monitoring and Evaluation Department, Ministry of Agriculture, Ghana.

Montagnini, F., C.F. Jordan and R.M. Machado (2000). Nutrient cycling and nutrient use efficiency in agroforestry systems. In M.S. Ashton and F. Montagnini (Eds.), *Silvicultural Basis for Agroforestry Sysytems*. Boca Raton, FL: CRC Press, pp. 131–160.

Montambault, J. and J. R. R. Alavalapati (2005). Socioeconomic research in agroforestry: a decade in review. *Agroforestry Systems*, **65**, 151–161.

Mortimore, M. J. and W. M. Adams (2001). Farmer adaptation, change and 'crisis' in the Sahel. *Global Environmental Change*, **11**, 49–57.

Muller-Prothmann, T. (2005). *Leveraging Knowledge Communication for Innovation: Framework, Methods and Application of Social Network Analysis in Research and Development*. Frankfurt: Peter Lang.

Nyanteng, V. K. (1993). The prospect of the Ghanaian cocoa industry in the 21st century. Paper presented at the *International Conference on Cocoa Economy*. Bali, Indonesia, October 19–22.

Nair, P. K. R. (1998). Directions in tropical agroforestry research: past, present and future. *Agroforestry Systems*, **38**, 223–245.

Nair, P. K. R. (2007). The coming of age of agroforestry. *Journal of the Science of Food and Agriculture*, **87**, 1613–1619.

Newman, L. and A. Dale (2007). Homophily and agency: creating effective sustainable development networks. *Environment, Development and Sustainability*, **9**, 79–90.

Prell, C., K. Hubacek and M. Reed (2009). Stakeholder analysis and social network analysis in natural resource management. *Society and Natural Resources*, **22**, 501–518.

Pretty, J. and H. Ward (2001). Social capital and the environment. *World Development*, **29**, 209–227.

Pretty, J. and D. Smith (2004). Social capital in biodiversity conservation and management. *Conservation Biology*, **18**, 631–638.

Pattanayak, S., D. E. Mercer, E. Sills and J. Yang (2003). Taking stock of agroforestry adoption studies. *Agroforestry Systems*, **57**, 173–186.

Rogers, E. M. (2003). *Diffusion of Innovations*, 5th Edition. New York, NY: Free Press.

Romani, M. (2003). Love thy neighbor? Evidence from ethnic discrimination in information sharing within villages in Côte d'Ivoire. *Journal of African Economies*, **12**, 533–563.

Sanchez, P. (2002). Soil fertility and hunger in Africa. *Science*, **295**, 2019–2020.

Schneider, M., J. Scholy, M. Lubell, D. Mindruta and M. Edwardsen (2003). Building consensual Institutions: networks and the National Estuary Program. *American Journal of Political Science*, **47**, 143–158.

Scott, J. (1991). *Social Network Analysis*. London: Sage.

Soils Survey Division (1969). *Great Soil Groups*. Accra: Survey of Ghana.

Van der Geest, K. and R. de Jeu (2008). Climate change and displacement: Ghana. *Forced Migration Review*, **16**, 31.

Valente, T. W. (1995). *Network Models of the Diffusion of Innovations*. Cresskill, NJ: Hampton Press.

Vitousek, P. M., R. Naylor, T. Crews *et al.* (2009). Nutrient imbalances in agricultural development. *Science*, **324**, 1519–1520.

Warner, K. D. (2007). *Agroecology in Action: Extending Alternative Agriculture through Social Networks*. Cambridge, MA: MIT Press.

Warriner, G. K. and T. M. Moul (1992). Kinship and personal communication network diffusion in the adoption of agriculture conservation technology. *Journal of Rural Studies*, **8**, 279–291.

Wasserman, S. and K. Faust (1994). *Social Network Analysis – Methods and Applications*. Cambridge, MA: Cambridge University Press.