TITLE: Network structure in sustainable agro-industrial parks

Highlights

- *Decentralized network structures facilitate collaboration in agro-industrial parks.*
- *Building ties via few intermediaries is preferable to having many direct ties.*
- *Efficient positioning in networks improves sustainability performance perception.*
- *Environmental performance is positively associated with interdependency.*
- *High interdependency may increase reluctance to collaborate.*

Abstract

Recently several agro-industrial parks have been developed as applications of industrial ecology to agriculture, aiming at improved sustainability performance. Grounded in industrial ecology and the literature on inter-organizational networks, this study explores the social structure of sustainability oriented collaborations in agro-industrial parks. Empirical data from sixty four organizations in three Dutch agro-industrial parks are analyzed at network and at organizational level. At network level, the results show that network decentralization comes along with a high density of formal ties. At organizational level, the results show that the organizations in agro-industrial parks are more efficiently positioned (i.e. more positively perceive sustainability performance) in the network of formal ties if they can build ties with other organizations via a small number of intermediary partners (i.e. high closeness centrality) instead of having a large number of direct ties. A decentralized structure of formal ties in combination with sparse interdependency has a relatively positive influence on sustainability improvement perceptions. In conclusion, network decentralization is important for the organizations that avoid dependency on one (or a small number of) central and/or powerful actor(s). The preferable decentralized formal ties and sparse interdependencies were (quantitatively and qualitatively) most evident in the self-organized parks, confirming that, for the sake of sustainability improvements, a self-organized agro-industrial park is preferable to a planned park.

With regard to the theoretical contribution, this study opened up a new area of research for waste streams exchanges among co-located heterogeneous companies by examining them as inter-organizational networks in agro-industrial parks. With regard to the practical implications, the study suggests that organizations seeking advanced environmental performance should build ties by optimizing the number of intermediary partners.

Keywords:

Inter-organizational networks, agro-industrial parks, sustainability performance

1. Introduction

The growing societal demand for more sustainable sourcing, production and waste-management stimulates inter-organizational networks (Albino et al., 2012; Seitanidi and Crane, 2013). Within this context, several sustainability oriented inter-organizational networks have emerged, such as industrial symbiosis (Cohen-Rosenthal, 2000; Lambert and Boons, 2002). While industrial symbiosis is already an established type of inter-organizational network (Jacobsen, 2006; Heeres et al., 2000), other types of networks that connect heterogeneous organizations emerge, for example in agro-industrial parks (Beers et al, 2014; Smeets, 2011). Within the boundaries of agro-industrial parks, organizations are connected to exchange waste, by-product, and share resources and information (Corsaro et al., 2012; Smeets, 2011; Spekkink, 2015). Heterogeneity refers to core organizational activities, such as horticulture, chemical, processing, logistics, food and bio-based production, and provides opportunities to combine diverse but complementary resources (Beckman and Haunschild, 2002; Corsaro et al., 2012) and by that further enhances sustainability. Despite high expectations and major endeavors when realizing agro-industrial parks in the Netherlands, not all socio-economic and environmental opportunities have been exploited (Spekkink, 2013; Smeets, 2011).

Sustainability oriented inter-organizational networks have been intensely discussed in the field of industrial ecology (e.g. Albino et al., 2012; Ehrenfeld and Gertler, 1997). Industrial ecology scholars increasingly pay attention to the network analysis of symbiotic ties (e.g. Ashton, 2008; Seitanidi and Crane, 2013), according to which inter-organizational networks in agro-industrial parks can be described as compositions of complex inter-organizational ties (Smeets, 2011). A comprehensive approach to study the structure of inter-organizational networks is via the application of social network analysis (Bergenholtz and Waldstrøm, 2011; Schiller et al, 2014). Social network analysis focuses on ties (or lack thereof) and provides appropriate tools to analyze network structures (Borgatti and Foster, 2003; Freeman, 1978).

Inter-organizational networks among co-located heterogeneous organizations are focused on sustainability related activities, such as reduced emissions, renewable energy production, or bio-waste valorization through waste streams processing (Anbumozhi et al., 2010; Mirata and Emtairah, 2005; Spekkink, 2013). Organizations often build network ties to enhance their sustainability performance (Friedkin, 1991; Lozano, 2007; Powell et al. 1996). Decisions to build network ties are usually motivated by expected and perceived sustainable performances by organization managers (Székely and Knirsch, 2005). Managers' expectations and perceptions drive the network strategies that create networks structures. Thus, managers' perceptions regarding sustainability improvement can explain network formation (Kumar and van Dissel, 1996) and network strategies of different organizations (Boons and Roome, 2000).

Unfortunately, the available literature often discusses inter-organizational networks either across supply chain partners or among homogeneous actors, although the sustainability performance is claimed to have association with the network structures and network strategies (Ahuja et al., 2009; Baum et al. 2000). Inter-organizational networks and sustainability performance of organizations are frequently discussed in the literature (Ashton 2008; Santoyo-Castelazo, 2014; Schiller et al., 2014), but the relations between these two concepts have not so far been studied empirically. The objective of this study is, therefore, to explore network structures of inter-organizational ties that can enhance perceptions of sustainability performance in agro-industrial parks.

To meet the study objective, a multiple case study approach was used combining quantitative and qualitative methods (Morgan, 2013). Through quantitative methods, the network structures and managers' perceptions of sustainability performance, as well as the relation between these two were studied. Through qualitative methods, the findings were complemented with deeper insights to provide a better understanding (Eisenhardt, 1989). This study brings the concept of waste streams exchanges among co-located heterogeneous organizations to a new field of analysis by examining them as inter-organizational networks in agro-industrial parks.

Three agro-industrial parks in the Netherlands, including 64 organizations in total, were included in the study sample. The Dutch cases were chosen because the Netherlands is active in initiating and developing agro-industrial parks. Moreover, the Netherlands is the world's third largest exporter of agricultural products, and recognized for being a frontrunner with techno-managerial innovations in this industry (Ministry of Agriculture, 2008).

The following section presents recent scholarly discussions on inter-organizational networks and sustainability performance perception. Section 3 elaborates on the methods used for data collection and data analysis. Section 4 presents the results, and Section 5 discusses the results followed by main conclusions in Section 6.

2. Social structure for inter-organizational networks

Agro-industrial parks encompass complex inter-organizational networks of heterogeneous organizations that are geographically proximate (Baas, 2011; Smeets, 2011). Inter-organizational networks are defined as collaborations between more than two organizations (Albino, et al., 2012; Bergenholtz and

Waldstrøm 2011), in contrast to collaborations among entities within a single organization. Due to the complexity of network structures in agro-industrial parks, two levels of network analysis are differentiated: network level and organizational level (Albino et al. 2012; Wasserman and Faust, 1994).

2.1. Network Level

At the network level, agro-industrial parks are conceptualized as planned or self-organized networks, in which geographically co-located organizations create networks for waste streams exchanges (Baas, 2011; Smeets, 2011). While planned networks can be formed under certain institutional settings, self-organized networks often involve informal ties (Chertow and Ehrenfeld, 2012). In line with social network theory, the structure at network level can be described by the concepts centralization and density (Ahuja, 2000; Bergenholtz and Waldstrøm, 2011; Wasserman and Faust, 1994).

Centralization gives an indication of the power distribution among the collaborating organizations (Wasserman and Faust, 1994) and encompasses the degree to which networks are managed by hierarchies (Ahuja, 2000). Decentralized structures indicate well-balanced power distribution among the collaborating organizations may prevent conflicts and attain more agreements (Lawler and Yoon, 1993). Considering the heterogeneity of collaborating organizations in agro-industrial parks, it is expected that decentralized structures indicating similar embeddedness of organizations within the network, may further expand the networks. Decentralization, however, may cause inefficiencies and so requires extra resources for network maintenance, especially in large networks (Provan et al., 2007).

Density indicates the proportion of actual to total potential ties (Burt, 2000; Rowley, 1997). High density may facilitate knowledge diffusion, stimulate imitative behavior, and shorten cognitive distance among heterogeneous organizations (Rowley, 1997). High density, however, can also create network inefficiencies, increasing network redundancies (Burt, 2000). Dense networks are considered to be beneficial, especially in heterogeneous networks such as agro-industrial parks, to overcome opportunism, to reduce large cognitive distance, to avoid opportunistic behavior, and to breed trust (Gilsing and Nooteboom, 2005). Therefore, dense networks are expected to suit to agro-industrial parks encouraging sustainability performance.

In sum, centralization and density of ties indicate the embeddedness of organizations within the networks and the degree to which the inter-organizational network structure can influence physical exchanges (Ashton, 2008). To understand the network ties of organizations nested within agro-industrial parks, the research considers network structures at organization level.

2.2. Organizational level

At the organizational level, the focus is on bilateral ties and centrality of individual organizations (Bergenholtz and Waldstrøm, 2011; Provan et al., 2007). Bilateral ties among heterogeneous organizations are differentiated as formal, informal, and interdependency (Ashton, 2008). The centrality of individual organizations is differentiated as degree, betweenness and closeness.

Formal ties are sustainability oriented contractual ties, such as exchanging waste and by-products, and sharing resources (Ackermann and Eden, 2011). Formal ties are core in agro-industrial parks, because these ties are instruments to advance sustainability performance. Informal ties are non-contractual ties reflecting non-contractual agreements, exchanging information and advice (Ackermann and Eden, 2011; Kreiner and Schultz, 1993). Informal ties may be latent and not directly related to sustainability performance, but they may help in developing new businesses and thereby new formal ties. Informal ties, although subtle and pervasive, can help the development of formal ties (Pina-Stranger and Lazega, 2011) and, in reverse, formal ties can stimulate informal ties (Ashton, 2008). Informal ties connecting the representatives of individual organizations are always present in inter-organizational collaborations alongside the network of physical exchanges (Chertow and Ehrenfeld, 2012).

Interdependency ties reflect mutual dependencies of collaborating organizations that (to a certain extent) have to rely on collaborating partners for the achievement of common goals (Gulati, 2007; Tina Dacin et al., 2007). Interdependencies may indicate the strength of ties that influences managers' willingness to collaborate. Managers of autonomous organizations are often reluctant to collaborate in a highly interdependent network. Therefore, it is expected that a strong interdependency may discourage the establishment of additional formal ties. The operationalization of formal, informal and interdependency ties is presented in Appendix A (d).

Centrality of an individual organization indicates the organization's position in formal, informal and interdependency networks. In general, an organization with a central position has more opportunities than others to gather essential information and access to necessary resources (Ackermann and Eden, 2011; Powell et al., 1996). Literature suggests three main centrality measures for inter-organizational networks: degree, betweenness, and closeness centralities (Borgatti, 2005). **Degree centrality** indicates the number of direct ties of an organization. Usually, an organization with a higher degree centrality has more alternatives, more autonomy, and less dependency. **Betweenness centrality** indicates the extent to which an organization connects two other organizations (Borgatti, 2005). Betweenness centrality is often used to find the gatekeepers in a network (Sueur et al., 2012). **Closeness centrality** indicates the length of the shortest path between collaborating organizations (Freeman, 1978). An organization with a shorter distance to all other collaborating partners has a more central position than other collaborating partners (Friedkin, 1991). An organization with high closeness centrality is less dependent on others and can profit from the networks by being able to build ties with other organizations via a small number of intermediary partners (Friedkin, 1991; Powell et al., 1996). Although organizations with high degree and betweenness centrality may have a greater influence on the network, it is expected that organizations with high closeness centrality may benefit the most from their central positioning.

As mentioned in the Section 1, organizations build ties in agro-industrial parks with a perception to enhance their sustainability performance (Lozano, 2007; Smeets, 2011; Székely and Knirsch, 2005). Therefore this research considers the perception of sustainability performance in agro-industrial parks.

2.3. Sustainability performance perception

Sustainability performance is a multifaceted concept as it encompasses various implications given by scientists of different backgrounds (Gerdessen and Pascucci, 2013). In general, sustainability performance refers to the three dimensions: environmentally friendly, economically beneficial, and socially supportive (Elkington, 1998; Jung et al., 2013; Santoyo-Castelazo and Azapagic, 2014). Although the separation of the three dimensions reduces the complexity of the concept, the underlying indicators in each dimension remain complex and unstandardized. The sustainability indicators developed by different scholars, for example by Elghali et al. (2007), Gerdessen and Pascucci (2013) and Santoyo-Castelazo and Azapagic (2014), are context-, space- and time-dependent. These indicators are not always directly applicable to agro-industrial parks that are networks of heterogeneous organizations. Therefore, in this study, the available indicators for the three dimensions are integrated and tailored to sustainability in agro-industrial parks (Fig. 1).

Another complexity of the sustainability concept is related to the measurement of the indicators. From management science perspective, expectations and motivations of organization managers are considered essential in decision-making processes. Dealing with perceptions is as relevant as dealing with objective measures (Kumar and van Dissel, 1996), since perceptions shape decisions to build inter-organizational ties (Székely and Knirsch, 2005). Additionally, Boons and Roome (2000) claim that the perceptions of managers may influence the outcome of networks. These perceptions, via individual decision-making, can drive the networks towards desired outcomes (Boons and Roome, 2000). Although perceptions are subjective, they are claimed to uncover latent performance paradigms (Richard et al., 2009). Therefore, this study considers the perception of managers of organizations within agro-industrial parks as a valid measure of sustainability performance indicators (Fig. 1).

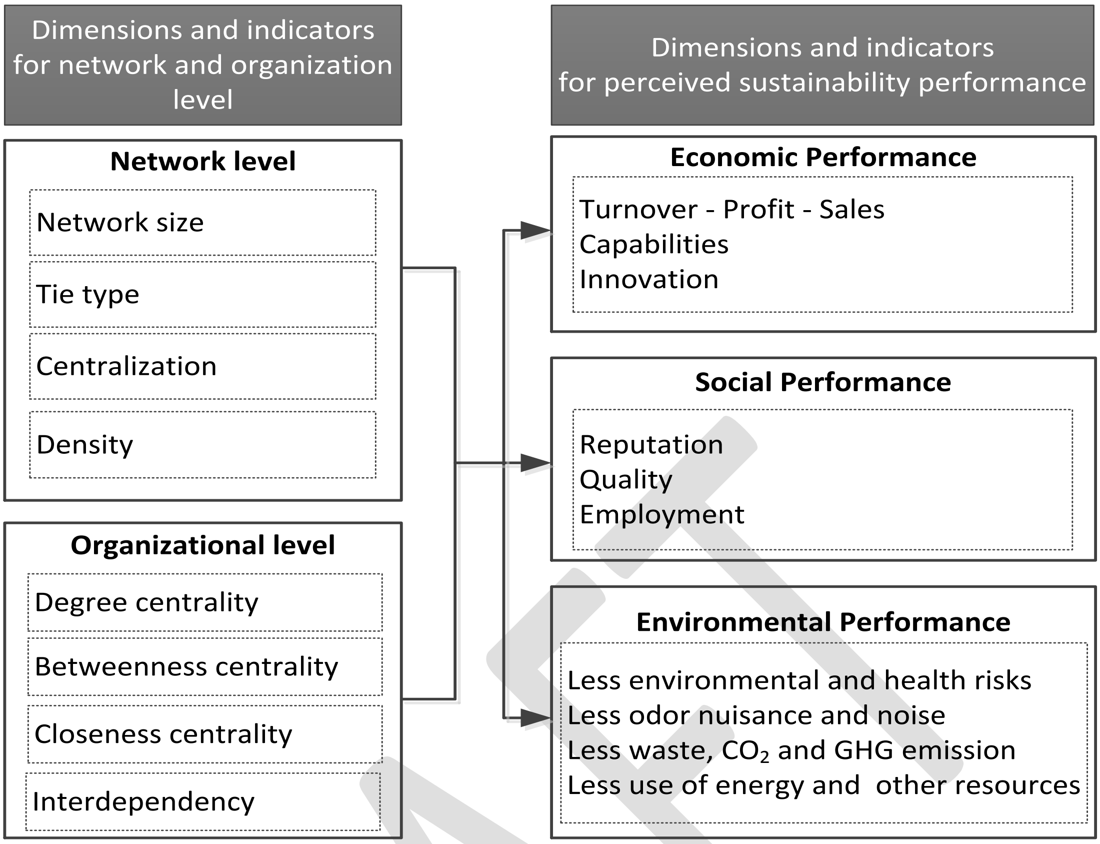

Fig. 1: Conceptual framework relating inter-organizational network structure with perceived sustainability improvement performance.

Fig. 1 shows the conceptual framework that relates inter-organizational network structure with perceived sustainability improvement performance. The conceptual framework assumes that the dimensions and indicators of the network structural properties are connected with the dimensions and indicators of perceptive sustainability improvement performance. The sustainability performance indicators have been mainly derived from Smeets (2011). However, the literature is not clear regarding the significance of the linkages between these different dimensions and indicators. Therefore, this research presents an explorative multiple case studies to find empirical evidence of associations between dimensions and indicators of the network structural properties and perceived sustainability performance. The methods used for empirical study are presented in the following section.

3. Research methods

Based on the grounded theory-approach, inter-organizational networks in agro-industrial parks were studied by means of multiple case studies (Yin, 2009). The multiple case study approach was a necessary and sufficient method to explore the concepts given (Eisenhardt, 1989). In this study, agro-industrial parks that encompass inter-organizational networks towards enhanced sustainable production have been considered. The dimensions and indicators of network structural properties and perceived sustainability performance (Fig. 1) required a convergence of findings using qualitative and quantitative methods (Flyvbjerg, 2006; Morgan, 2013). Quantitative methods were used to find general patterns in network structures, and to relate these with perceived sustainability performance. Qualitative methods were used to get insight in the background of the quantitative findings and to provide a better understanding of the different variables.

3.1. Case selection

The cases for this study have been strategically selected with the objective to collect the greatest amount of information on the network strategies and sustainability improvement perceptions (Flyvbjerg, 2006). The case selection criteria were (i) being an agro-industrial park operating in the Netherlands, (ii) being focused on agri-food activities and processes; (iii) having an explicit collaboration strategy between agricultural and non-agricultural actors. The Dutch cases were chosen because the Netherlands is active in initiating and developing agro-industrial parks. Moreover, the Netherlands is the world's third largest exporter of agricultural products, and is recognized for being a frontrunner with many techno-managerial innovations in this industry. Using the case selection criteria led to the three agro-industrial parks in the Netherlands: AgriportA7, Bergerden, and Biopark Terneuzen, where several sustainability-oriented collaborations among local organizations have been identified. The selected parks where comparable in size (amount of local organizations) that allowed to constrain extraneous variation and sharpened external validity (Eisenhardt, 1989).

Agriport A7 is a self-organizing agro-industrial park located in the province of North Holland. Initiated in 2003 and established in 2006, Agriport A7 connects 24 organizations at 930 hectare area. The companies are heterogeneous according to their main activity, such as energy distributors, horticultural growers, logistics companies, a combined heat and power plant, an auction house, a feed producer, a construction business, a consultancy company, a food supplier, a network-brokering agency, and a human resource recruitment agency. Agriport A7 aims to create economic synergies, reduce the environmental burden, create social and environmental benefits, reduce traffic, and enhance innovation performance of networking organizations. Agriport A7 created a joint logistics system and a joint ownership of an energy company that produces energy via a geothermal heat and power system which supplies heat, gas, and electricity to all the glasshouses.

Bergerden is a self-organizing agro-industrial park located in the province of Gelderland. Initiated in 1990 and established in 2000, Bergerden connects 17 organizations at 320 hectare area. Bergerden connects horticultural growers, an energy distributor, a human resource recruitment agency, and a local development agency. Bergerden aims to establish synergies via joint heat, electricity, water, and CO_2 exchange systems. Moreover, Bergerden aims to use the rest heat and electricity created by bio-energy production technologies to recycle and reuse the bio-waste from greenhouses and to produce bio-energy and bio-fertilizer. Remarkably, twelve horticultural growers are co-located, allowing the establishment of formal ties among them via shared energy and water systems.

Biopark Terneuzen is a planned agro-industrial park located in the province of Zeeland. Initiated in 2005 and established in 2007, Biopark Terneuzen connects 23 organizations at 445 hectare area. The park connects energy generators and distributors, chemical companies, food and feed producers, horticultural growers, waste/recycling companies, and business consultants. Biopark Terneuzen aims to strengthen the regional economy, attract new companies, create new employment and business opportunities, reduce environmental burden, increase the economic performance of local companies, and develop bio-based businesses. Biopark Terneuzen established a waste heat and CO_2 supply system from the industrial companies to the local horticultural companies.

These three agro-industrial parks are spread over the country, being located in three different provinces of the Netherlands. Organizations in these three agro-industrial parks are expected to improve their environmental performance, such as reduced greenhouse gas emission, and to provide opportunities for biomass use and bioenergy production (Smeets, 2011). Although different in occupied areas, the three agro-industrial parks studied are comparable in network size, which is the number of organizations engaged in networks. The comparability of network size allowed us to pool the collaborating organizations when conducting the quantitative study.

Organizations engaged in the three agro-industrial parks are heterogeneous not only according to their main activities, but also to their age and size. Table 1 groups organizations by age (years since establishment at the location) and size (fte: categorized according to the EU definition (2003/361/EC) of micro, small and medium-sized enterprises) across the agro-industrial parks.

Table 1

Number of organizations grouped by age and size across the three agro-industrial parks.

	Agriport A7	Bergerden	Biopark Terneuzen
Organizations grouped by age (years)			
1–9	8 (33%)	8 (47%)	8 (35%)
10–19	4 (17%)	2 (12%)	3 (13 %)
20–29	3 (13%)	–	4 (17%)
30–39	1 (4%)	3 (18%)	2 (9%)
> 40	8 (33%)	4 (23%)	6 (26%)
Organizations grouped by size (fte)			
Micro: 1–9	9 (25%)	9 (53%)	7 (30%)
Small: 10–49	4 (29%)	7 (41%)	6 (26%)
Medium: 50–249	6 (25%)	1 (6%)	5 (22%)
Large: ≥ 250	5 (21%)	–	5 (22%)
Total (network size)	*24 (100%)*	*17 (100%)*	*23 (100%)*

As Table 1 shows, the organizations are more or less similarly grouped by size and age in Agriport A7 and in Biopark Terneuzen. In these two agro-industrial parks, the age and size of organizations are more or less uniformly distributed. In Bergerden, however, organizations established less than ten years ago (47%) and organizations with micro size (53%) are dominant. Overall, organizations differ not only in their main activities, but also in their size and age across the three agro-industrial parks.

3.2. Data collection and analysis

The data was collected primarily from interviews, the official websites of the agro-industrial parks and the individual organizations within the parks, scientific and professional publications.

For network analysis, the local organizations were indicated and listed in advance. During the interviews, the respondents were asked to check the list and add missing relevant organizations. All organizations that had at least one formal tie with another local organization were considered. The organizations that were co-located at agro-industrial parks for different reasons (for example, availability of land and cheap rent), but had no formal ties – the so-called isolates – were excluded from the network analysis.

In total, sixty four organizations that collaborate in one of the three parks have been contacted. One respondent per organization was selected. The respondents were managers involved in decision-making regarding the collaborations in agro-industrial parks (Ackermann and Eden, 2011; McDonald and Westphal, 2003). They were the most knowledgeable to provide the required information (Galaskiewicz and Burt, 1991; Pina-Stranger and Lazega, 2011). Face-to-face interviews with 44 managers and online or phone interviews with 16 managers were conducted, adding up to 60 organizations [1]. The respondents included 39 CEOs, 12 business development managers, four strategic managers, two financial managers, two managers of spatial development, and one operational manager. The respondents provided general information about the park and the organization (for the qualitative study), about the network ties and their sustainability improvement perceptions (for the quantitative study).

As explained in Section 2.3, a tailored questionnaire was created using 7-point Likert scales considering the dimensions and indicators of sustainability performance perception (Fig. 1). Specifically, respondents reported on economic, environmental, and social performance, as well as the extent to which the collaborations in agro-industrial parks were perceived as productive and satisfactory (Appendix A, part b. and c.). The respondents reported the point of view of the representing organizations. Therefore, controlling for their personal characteristics, such as age and education level, was considered less relevant in this study than in other perception-based studies. Instead, the size and the age of the organizations have been controlled while running the linear multivariate hierarchical regression analysis (Section 4.2). The responses of the interviewees have been cross-checked with the information found in (online) documents to ensure accuracy. If mismatch was found, the respondents have been contacted once again for clarification. Eventually, the analysis relied on the responses of the interviewees, because they provided the most recent views.

Dichotomous questions were asked to find formal, informal, and interdependency ties. The formal ties encompass four, informal ties three, and interdependency ties two sub-variables (Appendix A, part d.) that were grouped and counted according to the tie type. The assumption was that if organization A answered “yes” to any sub-variable or a combination of them that formed a tie with organization B, then the value of the related tie A→B was one. Whereas, if A answered “no” to all sub-variables, then the value of the related tie A→B was zero. The ties were non-directional allowing to symmetrize the matrix, assuming that if A indicated a tie with B, then the reverse was as likely to be the case (Ashton, 2008; Ashton, 2012).

Using UCINET/NetDraw network analysis software (Borgatti et al., 2002), the ties were coded, analyzed, and mapped. Accordingly, network centralization and density have been calculated using the algorithms (Appendix B). The binary coding (1:0) indicated the presence or absence of a particular tie among each pair of organizations (Ashton, 2012). A scheme suggested by Sueur et al. (2012) was used to classify the networks according to centralization (Table 2).

[1] Unfortunately, managers from four organizations were unwilling to participate in the study. The missing values of perceived performance are, therefore, replaced with the overall mean.

Table 2

Classification of inter-organizational networks according to centralization score.

Network classification	Centralization score (%)
Absolute centralized	100
Highly centralized	> 75
Moderate centralized	> 50
Moderate decentralized	> 25
Highly decentralized	> 12.5
Absolute decentralized	> 0 or $1/(n-1)$

Source: Sueur et al., (2012).

Next, the three centralities (i.e. degree, betweenness, and closeness) were calculated for every organization separately. The centrality scores of individual organizations together with the perceived performances were inserted into SPSS statistical software for further quantitative analysis. The measures of network structural properties and related algorithms are presented in Appendix B.

Network analysis was run in UCINET software, version 6.587 (Borgatti et al., 2002), and the statistical analysis at organizational level was run in SPSS Statistics 22 software. In SPSS, the number of variables was reduced by running a principal components analysis (PCA). Finally, a hierarchical regression analysis of the extracted factors controlling for size and age of the organizations was conducted.

4. Sustainability oriented network structures

In this section, the results of the qualitative and quantitative analysis are presented first at network level followed by the analysis at organizational level.

4.1. Network level

Network size. Network size indicates the number of collaborating organizations at the agro-industrial park location. A larger inter-organizational network size enables a wider access to necessary resources and may attract external businesses (Anbumozhi et al., 2010). However, increased network size may bring complexity because of increased heterogeneity and interdependency (Van de Ven and Fery, 1980). Consequently, achieving an alignment of strategies and overcoming complexity becomes more challenging in larger agro-industrial parks. The respondents often emphasized that the collaboration for a long time period with many heterogeneous organizations was complex and challenging, although a growing network could guarantee improved perception of sustainability performance through successful exchanges.

Tie type and centralization. Table 3 presents the centralization of the networks, tie types and the number of ties in the three agro-industrial parks.

Table 3

Network centralizations (C) and number of ties (No.) by tie type in the three agro-industrial parks.

	Agriport A7		Bergerden		Biopark Terneuzen	
Tie type	C (%)	No.	C (%)	No.	C (%)	No.
Formal	22.3	211	37.9	178	57.6	148
Informal	49.8	128	72.5	65	48.7	120
Interdependency	27.9	41	35.9	129	50.5	93

As Table 3 shows, in Agriport A7, as a self-organizing agro-industrial park, the network of formal ties is highly decentralized (see Table 2 for classification of centralization), while the network of informal ties is moderately centralized. Moreover, the network of interdependency ties in Agriport A7 is moderately decentralized with a very low number of ties. A closer look at the data indicates that about 13 organizations in Agriport A7– including horticultural companies, an energy company, and a network broker – share the same amount of formal ties and perceive low interdependencies.

In Bergerden, as a self-organizing agro-industrial park, the networks of formal ties and of interdependency ties are moderately decentralized, whereas the network of informal ties is nearly highly centralized (Table 3). The network of informal ties in Bergerden is the most centralized, with a small number of ties. In the network of formal ties, seven organizations – including six horticultural firms and an energy company – show the highest degree centrality (Fig. 2). Instead, in the network of informal ties, only two organizations, both horticultural firms, take the lead (nodes AB and AM in Fig. 2). Remarkably, the number of formal ties is about 2.5 times larger than the number of informal ties (Table 3).

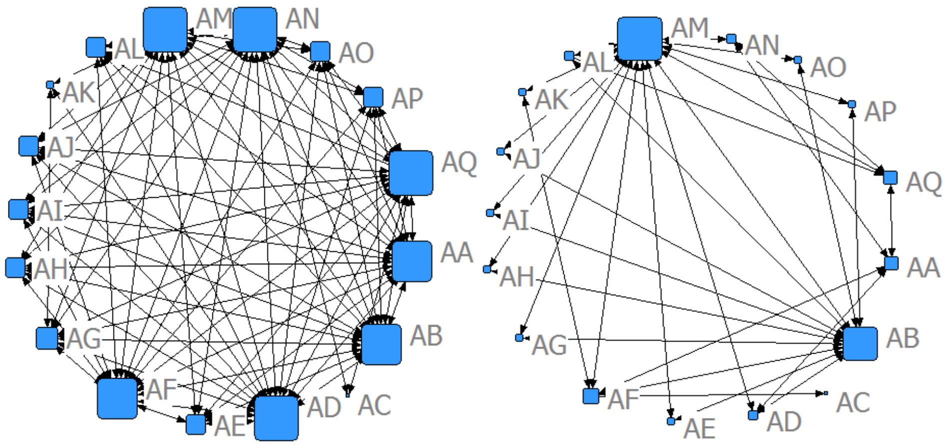

Fig. 2. Network of formal and informal ties in Bergerden in 2013: each node represents one organization; node size by degree centrality; each edge indicates a tie between two nodes; relations are non-directional. *Left:* Network of formal ties; *Right:* Network of informal ties.

In Biopark Terneuzen, as a planned agro-industrial park, the networks of formal and interdependency ties are moderately centralized (Table 3), while the network of informal ties is moderately decentralized. Two organizations are central in the network of formal ties (nodes W and U in Fig. 3); one of these is a semi-governmental organization that provides financial, human, and other resources to local companies, whilst the other is a network-broker organization active in bringing local organizations together. These two central organizations in the network of formal ties are also central in the network of interdependency ties. A closer look at the data indicates that the network of informal ties is led by a different organization (node F in Fig. 3), which is involved in bio-based business.

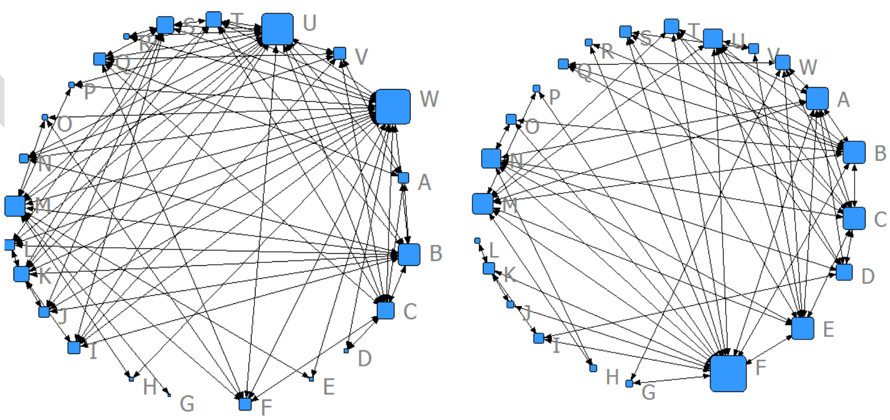

Fig. 3. Network of formal and informal ties in Biopark Terneuzen in 2013: each node represents one organization; node size by degree centrality; each edge indicates a tie between two nodes; relations are non-directional.

Left: Network of formal ties; Right: Network of informal ties.

Tie type and density. Table 4 presents the densities of formal, informal and interdependency ties in the three agro-industrial parks.

Table 4

Network density (D) and number of ties (No.) by tie type in the three agro-industrial parks.

	Agriport A7		Bergerden		Biopark Terneuzen	
Tie type	*D (%)*	*No.*	*D (%)*	*No.*	*D (%)*	*No.*
Formal	38.2	211	65.4	178	29.2	148
Informal	23.2	128	23.9	65	23.7	120
Interdependency	7.4	41	47.4	129	18.4	93

As Table 4 shows, the networks of formal ties are denser with higher number of ties than the networks of informal ties across the three parks. The formal ties in Bergerden have the highest density (65.4%), while the interdependency ties in Agriport A7 has the lowest density (7.4%). In contrast, the network of interdependency ties in Bergerden is very dense with a large number of ties.

In general, Agriport A7 has well established formal ties, which are perceived as decentralized, dense and less interdependent; whereas, in Bergerden the formal and interdependency ties are decentralized and dense. The formal ties in Biopark Terneuzen are centralized and relatively sparse. The densities of the informal ties in all three parks are rather sparse and relatively centralized.

4.2. Organizational level

Table 5 presents the factor loadings of the extracted components of network structural properties at organizational level, i.e. individual centralities – degree, normalized degree, betweenness, and closeness – in networks of formal, informal, and interdependency ties. The Cronbach's $\alpha = 0.846$ and the Cronbach's α of standardized 12 items = 0.893.

Table 5

Factor loadings, means and standard deviations (SD) of network structural properties.

	Loadings	Mean	SD
(1) Interdependency			
• Dependency of own organization on others	0.929	3.09	1.66
• Dependency of others on own organization	0.890	2.98	1.62
(2) Centrality informal ties			
• Betweenness centrality informal	0.970	12.34	25.47
• Degree centrality informal	0.954	4.99	3.81
• Normalized degree centrality informal	0.926	24.54	19.18
(3) Centrality formal ties			
• Betweenness centrality formal	–0.932	9.87	17.26
• Degree centrality formal	–0.832	8.22	5.06
• Normalized degree centrality formal	–0.692	41.71	26.78
(4) Closeness centrality			
• Closeness centrality informal	–0.946	41.43	16.46
• Closeness centrality formal	–0.881	48.68	22.89

Table 5 shows the loadings, means, and standard deviations of each variable under the four extracted components. These four extracted components are network properties that indicate the network structures of inter-organizational ties that can enhance perception of sustainability performance. The negative scores suggest the presence of contrasting measures of network structural properties. The rotation method is direct oblimin with Kaiser normalization (KMO = 0.614; $p < 0.01$), which resulted in the following correlation matrix of extracted network properties (Table 6).

Table 6

Component correlation matrix of network structural properties; VIF = variance inflation factor

Network properties	(1)	(2)	(3)	(4)	VIF
(1) Interdependency	1.0				1.24
(2) Central informal ties	0.079	1.0			1.09
(3) Central formal ties	–0.304*	–0.237^{+}	1.0		1.17
(4) Closeness centrality	–0.341**	–0.176	0.234^{+}	1.0	1.18

Notes: asterisks $^{+}$, * and ** respectively denote significance at 10%, 5% and 1% levels.

Table 6 shows significant negative correlations between interdependency and centrality of formal ties (r = -0.304, $p < 0.05$), and between interdependency and closeness centrality (r = -0. 341, $p < 0.01$). Thus, interdependencies are perceived decreasing when organizations are more central. The centralization does not, however, evidently result in positive perception of sustainability performance, as shown below.

The PCA of the managers' perceptions of sustainability performance extracted six components (Table 7): innovation, satisfaction and reputation, economic performance, environmental benefits for local population, environmental performance, and employment performance. The Cronbach's α = 0.886, and the Cronbach's α of standardized 18 items = 0.887.

Table 7

Factor loadings, means and standard deviations (SD) of perceived sustainability performances.

Perceived performance improvement	Loadings	Mean	SD
(1) Innovation			
• Product and/or service quality has improved	0.864	4.78	1.32
• Number of innovations has increased	0.852	5.08	1.29
• We got new and innovative ideas	0.839	5.27	1.31
• Product or service capabilities have improved	0.759	4.75	1.35
(2) Satisfaction and reputation			
• We are satisfied with the collaborations within the park	0.926	5.25	1.16
• Our collaborations within the park are productive	0.817	5.41	1.12
• Reputation of our organization has improved	0.733	5.20	1.29
(3) Economic performance			
• Profits have increased	0.780	4.33	1.45
• Turnover has increased	0.764	4.61	1.29
• We became economically stronger	0.613	4.91	1.50
(4) Environmental benefits for local population			
• Odor nuisance and noise are decreased	0.894	4.39	1.29
• Environmental and health risks are decreased	0.512	4.78	1.05
(5) Environmental performance			
• We have less waste and CO_2 and greenhouse gas emission	0.907	5.14	1.29
• We use less energy and other resources	0.879	4.94	1.49
(6) Employment performance			
• Number of qualified workers has increased	-0.921	4.42	1.25
• Number of employees has increased	-0.839	4.44	1.39

Table 7 shows the loadings, means, and standard deviations of each variable under the six extracted components. While most loadings are positive, the employment performance loadings are negative, and the decrease in environment and health risks has a rather low loading. The rotation method is direct oblimin with Kaiser normalization (KMO = 0.692; $p < 0.01$), which resulted in the correlation matrix of extracted perceived performance (Table 8).

Table 8

Component correlations matrix of perceived sustainability performances; VIF = variance inflation factor.

Components	(1)	(2)	(3)	(4)	(5)	(6)	VIF
(1) Innovation performance	1.0						1.36
(2) Satisfaction and reputation	0.35**	1.0					1.19
(3) Economic performance	0.18	0.15	1.0				1.09
(4) Environmental benefits for local population	0.04	0.01	–0.052	1.0			1.03
(5) Environmental performance	0.40***	0.11	0.093	0.13	1.0		1.22
(6) Employment performance	-0.22^{+}	-0.26*	-0.244^{+}	-0.07	-0.16	1.0	1.16

Notes: asterisks +, *, **, *** respectively denote significance at 10%, 5%, 1% , and 0,1% levels.

A remarkable outcome of Table 8 is the strong positive correlations between innovation performance and satisfaction and reputation (r = 0.346, p < 0.01), and between innovation performance and environmental performance of organizations (r = 0.400, p < 0.001).

Next, according to the research objective, a linear hierarchical regression analysis was run to explore significant associations of network structural properties with perceived performance of sustainability improvement in agro-industrial parks (Table 9).

Table 9

Network structural properties as predictors of perceived sustainability improvement performance.

Sustainability improvement performance	Network structural properties	B	Control variables
Environmental performance	Interdependency	0.261*	ln size β = –0.152**
	Centrality formal ties	–0.236+	ln size β = –0.152**
Employment performance	Interdependency	–0.296*	ln size β = –0.149**
	Closeness centrality	–0.398**	ln size β = –0.149**
Satisfaction and reputation	Centrality formal ties	–0.262*	_
	Centrality informal ties	0.254*	_
	Closeness centrality	0.472***	_
Economic performance	Closeness centrality	0.329*	_
Innovation performance	Centrality formal ties	–0.351**	_
	Closeness centrality	0.243+	_

Notes: Control variables are organizations' ln age and organizations' ln size; only significant results are shown; asterisks +,*, **, *** respectively denote significance at 10%, 5%, 1% , and 0,1% levels.

Table 9 presents the relevant associations of network structural properties as predictors of perceived sustainability performance at organizational level. The non-significant results are excluded from the table.

First, Table 9 illustrates that interdependency in the agro-industrial parks is positively associated with environmental performance. However, during the interviews the respondents mentioned that formal contracts hindered organizations to build new or additional ties in waste stream exchanges. Although formal ties decreased the flexibility, organizations perceived improved environmental performance when interdependent.

Second, Table 9 shows that closeness centrality is positively associated with economic performance and with innovation performance. Moreover, the organizations that are more central according to this measure are more satisfied with the collaboration and perceive their reputation positively. In contrast to this, the organizations that are more central according to degree and betweenness centrality in the formal networks perceived their reputation and satisfaction negatively. Respondents of organizations with high degree and betweenness centrality in formal networks mentioned that they had high expectations for improved environmental performance, such as CO_2 reduction, waste heat use, waste water use, bio-waste valorization, and energy efficiency, when signing formal contracts. Achieved improvements in environmental performance, however, did not always reach the expectations, causing dissatisfaction.

Third, the higher is the degree centrality in formal networks, the more negative the managers' perception become regarding innovation and environmental performance (Table 9). The respondents related the negative perceptions to the high ambitions and expectations at the time the agro-industrial parks were established. The horticultural organizations, for instance, expected to increase energy use efficiency and reduce costs by using waste heat and CO_2 from other local organizations. However, the supply of waste heat and CO_2 appeared to be insufficient to cover the demand of the glasshouses, especially in the winter. Moreover, in all three parks, after local protests, intensive livestock farming had to be banned, so the possibility to use the bio-waste from intensive livestock farming to produce bio-energy and compost was lost.

The perception of sustainability performance has also been influenced by the economic crisis right after the establishment of the agro-industrial parks. A number of companies in horticultural production and in bio-based businesses went bankrupt, creating a chain effect for the other network partners. The bankruptcy of local organizations together with the financial and economic downturn created negative perception on employment performance.

In summary, the results at the organizational level suggest that the enhanced environmental performance is associated with high interdependency. Organizations with resource commitments that have many direct formal ties in the network of formal ties perceive their sustainability performances negatively. Whereas, organizations that can build ties with other organization via a small number of intermediary partners (high closeness centrality), perceive their sustainability performance relatively positively.

5. Discussion

This study explored the network structures of inter-organizational ties that can lead to improved perception of sustainability performance of organizations in agro-industrial parks. The following sub-sections discuss the structures of the three agro-industrial parks at network level and at organizational level.

5.1. Network level

At the network level, the main structural properties considered were network size, centralization, and density. Compared to large industrial parks, where usually more than 100 organizations collaborate (e.g. Albino, 2012), the size of the studied networks in agro-industrial parks (about twenty organizations each) can be indicated as medium. The parks vary less in network size than in organizations' size, with Bergerden being dominated by micro and small organizations. Size variation between organizations might impact the network centralization and density.

In line with the expectation (Section 2), decentralized networks are composed of more formal ties than centralized networks (Table 3). The two self-organized agro-industrial parks indicated decentralized structures of formal networks, whereas the planned park showed a centralized structure of formal networks. The distribution of formal ties and the risk of dependency were essential for enhanced perception of sustainability performance. Therefore, a decentralized structure of formal ties seemed to be more preferable than a centralized one (Chertow and Ehrenfeld, 2012).

Although Ashton (2008) found a correlation between informal and formal ties in industrial symbioses, no confirmation could be found for the networks in agro-industrial parks. Moreover, Chertow and Ehrenfeld (2012) state that self-organized networks often involve informal ties. However, the results of this study show that the formal ties dominate informal ties in self-organized parks (Table 3). This contrast is most probably caused by the organizations being more heterogeneous in agro-industrial parks than in industrial parks. The high density of formal ties indicates well-established exchanges. However, the low density of informal ties can be interpreted as a missed opportunity to exchange knowledge, information, and eventually to advance the collaborations in waste streams processing. This argument is supported by the literature (McDonald and Westphal, 2003; Pina-Stranger and Lazega, 2011). But not confirmed by the empirical evidence.

5.2. Organizational level

At the organizational level the managers' sustainability improvement perceptions are explored. The results confirm that inter-organizational networking enhances the environmental performance, but not specifically the economic and social performance (Table 8). However, environmental performance is strongly associated with interdependencies (Table 9). Organizations enhance their environmental performance through dense interdependent networks, and have to rely on others in achieving common sustainability goals.

Respondents from organizations with many formal ties often associated the agro-industrial parks with increased interdependency that may increase the environmental performance, but also the risk of failure. For instance, the respondents from Agriport A7, that had a sparse interdependency network, often positively perceived the formal ties as a way to use waste and by-product, such as CO_2, heat, and water. Whereas, the respondents from Bergerden, that had a dense interdependency network, often showed more negative perceptions if the formal ties led to increased interdependencies.

Although the informal ties are less dense than formal ties at network level, the individual organizations that are central in the network of informal ties perceived their reputation positively and felt more satisfied with their collaborations. This result is in line with previous studies showing the relevance of informal ties (Muller-Seitz, 2012; Pina-Stranger and Lazega, 2011). However, a strong evidence to show the impact of informal ties on formal ties was not found, most probably because of the sparsity of informal ties.

In line with expectations (Section 2), organizations that can build ties with other organizations via a small number of intermediary partners (i.e. high closeness centrality), have relatively positive perceptions of many indications. In contrast, organizations with relatively more direct ties (i.e. a high degree centrality), and more bridging ties (i.e. high betweenness centrality), have poor innovation performance, and environmental performance (Table 9). These findings are unexpected because dyadic direct exchanges are considered critical in waste streams processing. One explanation of these findings might be that a large number of direct ties of a central organization in networks of heterogeneous organizations bring about a higher (perceived) risk of network failure, if such an organization fails to deliver upon promises (Ashton, 2008). Another explanation might be that firms with a large number of formal ties are often identified as anchor firms with a centralized network position. The associated unequal distribution of power relationships, may negatively influence collaborations.

This study brings the concept of waste streams exchanges among co-located companies in agro-industrial parks to a new field of analysis by examining them as inter-organizational networks. Contributing to the discussion of power distribution and network success, as well as the discussion of network structure and sustainability improvement performance, the study shows the importance of decentralized network structures. Moreover, it contributes to the discussion on efficient network positioning by showing the importance of the quality of indirect ties instead of the quantity of direct ties. With regard to practical implications, the study suggests that organizations seeking advanced environmental performance should build ties with other organizations. However, collaborations create interdependency, a high level of which may increase reluctance to expand the network.

Additionally, organizations can enhance their innovation performance and economic performance if they position themselves in a formal network such that the network provides access to other organizations via a small number of intermediary partners (i.e. high closeness centrality). Finally, organizations may enhance their reputation if they build informal ties with other local organizations in agro-industrial parks.

6. Conclusions

This study grounds in industrial ecology and the literature on inter-organizational networks through the application of social network analysis. The exploration of the social structure of sustainability oriented inter-organizational networks in agro-industrial parks resulted in expected and unexpected insights leading to the following conclusions.

First, this study confirms the social network theory on closeness centrality as indication of efficient positioning of individual organizations in a network. The organizations in agro-industrial parks are more efficiently positioned (i.e. perceive more positive sustainability performance) in the network of formal ties if they can build ties with other organizations via a small number of intermediary partners (i.e. high closeness centrality) instead of having a large number of direct ties. Second, according to the findings, a decentralized structure of formal ties in combination with a sparse interdependency has shown a relatively positive influence on sustainability improvement perceptions. The decentralized formal ties and sparse interdependencies were (quantitatively and qualitatively) most clearly indicated in the self-organized parks, confirming that, for the sake of sustainability improvement, a self-organized agro-industrial park is preferable to a planned park. Third, this study accentuates that at network level the number of informal ties among the organizations in agro-industrial parks is rather sparse, which could be interpreted as a missed opportunity to achieve the necessary resources and knowledge through informal contacts (Section 5.2.). Finally, formal ties are dominant in decentralized networks, showing the importance of power distribution for the collaborating organizations to avoid dependency on one (or a small number of) central and/or powerful actor(s).

The following limitations of this study should be considered in future research of social structures for inter-organizational networks. First, a binary coding was used to find and analyze the ties. However, the binary coding ignores the intensity of the ties, which can play a role in perceptions. Second, the managers' characteristics, such as age, education and experience, are considered less relevant for the objective of this study (Section 3: Methods). However, these characteristics can be relevant for further studies focusing more on personal relations among influential persons in agro-industrial parks. Third, the measures of sustainability performance are perceptual. Although justified for the current study, the perceptual measures may not always reflect the objective reality. Therefore, future studies can consider developing objective measurement units, applicable to heterogeneous organizations, in order to reduce the potential issues of embeddedness and biases. Moreover, future research should consider the organizations that have no formal ties (i.e. isolates) especially if these organizations can potentially influence on sustainability perceptions. Finally, the fact that the studied agro-industrial parks were not yet fully realized, providing room to exploit additional economic and environmental opportunities, advocates conducting a longitudinal follow-up study.

Acknowledgment

Financial support from the ERDF-grant, via the EU-Interreg IV-B NEW project ARBOR, is gratefully acknowledged. The statements made in this paper are the sole responsibility of the authors.

References

Ackermann, F., Eden, C., 2011. Strategic management of stakeholders: Theory and practice. Long Range Planning 44, 179–196.

Ahuja, G., 2000. Collaboration networks, structural holes, and innovation: A longitudinal study. Adm. Sci. Q. 45, 425–455.

Ahuja, G., Polidoro, F., Mitchell, W., 2009. Structural homophily or social asymmetry? The formation of alliances by poorly embedded firms. Strategic Management Journal 30, 941–958.

Albino, V., Dangelico, R.M., Pontrandolfo, P., 2012. Do inter-organizational collaborations enhance a firm's environmental performance? A study of the largest U.S. companies. Journal of Cleaner Production 37, 304–315.

Anbumozhi, V., Gunjima, T., Prem Ananth, A., Visvanathan, C., 2010. An assessment of inter-firm networks in a wood biomass industrial cluster: Lessons for integrated policymaking. Clean Technology and Environmental Policy 12, 365–372.

Ashton, W.S., Bain, A.C., 2012. Assessing the "short mental distance" in eco-industrial networks. Journal of Industrial Ecology 16, 70–82.

Baas, L., 2011. Planning and uncovering industrial symbiosis: Comparing the Rotterdam and Ostergotland regions. Business Strategy and the Environment 20, 428–440.

Baum, J.A.C., Calabrese, T., Silverman, B.S., 2000. Don't go it alone: Alliance network composition and startups' performance in Canadian biotechnology. Strategic Management Journal 21, 267–294.

Beckman, C.M., Haunschild, P.R., 2002. Network learning: The effects of partners' heterogeneity of experience on corporate acquisitions. Administrative Science Quarterly 47, 92–124.

Beers, P.J., Hermans, F., Veldkamp, T., Hinssen, J., 2014. Social learning inside and outside transition projects: Playing free jazz for a heavy metal audience. NJAS – Wageningen Journal of Life Sciences 69, 5–13.

Bergenholtz, C., Waldstrøm, C., 2011. Inter-organizational network studies — A literature review. Industry and Innovation 18, 539–562.

Boons, F., Roome, N., 2000. Industrial Ecology as a Cultural Phenomenon: On Objectivity as a Normative Position. Journal of Industrial Ecology 4, 49-54.

Borgatti, S.P., 2005. Centrality and network flow. Social Networks 27, 55–71.

Borgatti, S.P., Everett, M.G., Freeman, L.C., 2002. UCINET for Windows, Version 6.59: Software for Social Network Analysis. Analytic Technologies, Harvard, MA

Borgatti, S.P., Foster, P.C., 2003. The network paradigm in organizational research: A review and typology. Journal of Management 29, 991–1013.

Burt, R.S., 2000. The network structure of social capital. Research in Organizational Behavior 22, 345–423.

Chertow, M., Ehrenfeld, J., 2012. Organizing self-organizing systems. Journal of Industrial Ecology 16, 13-27.

Cohen-Rosenthal, E., 2000. A Walk on the human side of industrial ecology. American Behavioral Scientist 44, 245–264.

Corsaro, D., Cantu, C., Tunisini, A., 2012. Actors' heterogeneity in innovation networks. Industrial Marketing Management 41, 780–789.

Dacin, M.T., Oliver, C., Roy, J.P., 2007. The legitimacy of strategic alliances: An institutional perspective. Strategic Management Journal 28, 169–187.

Ehrenfeld, J., Gertler, N., 1997. Industrial ecology in practice: The evolution of interdependence at Kalundborg. Journal of Industrial Ecology 1, 67–79.

Eisenhardt, K.M., 1989. Building theories from case study research. The Academy of Management Review 14, 532-550.

European Commission, 2003. Commission recommendation concerning the definition of micro, small and medium-sized enterprises, European Commission (Ed.), C (2003) 1422.

Flyvbjerg, B., 2006. Five misunderstandings about case-study research. Qualitative Inquiry 12, 219-245.

Freeman, L.C., 1978. Centrality in social networks conceptual clarification. Social Networks 1, 215–239.

Friedkin, N.E., 1991. Theoretical foundations for centrality measures. American Journal of Sociology 96, 1478–1504.

Galaskiewicz, J., Burt, R.S., 1991. Interorganization contagion in corporate philanthropy. Administrative Science Quarterly 36, 88–105.

Gerdessen, J.C., Pascucci, S., 2013. Data envelopment analysis of sustainability indicators of European agricultural systems at regional level. Agricultural Systems 118, 78-90.

Gilsing, V.A., Nooteboom, B., 2005. Density and strength of ties in innovation networks: An analysis of multimedia and biotechnology. European Management Review 2, 179–197.

Gulati, R., 2007. Managing Network Resources: Alliances, Affiliations and Other Relational Assets. Oxford University Press, Oxford.

Heeres, R.R., Vermeulen, W.J.V., De Walle, F.B., 2000. Eco-industrial park initiatives in the USA and the Netherlands: first lessons. Journal of Cleaner Production 12, 985–995.

Jacobsen, N.B., 2006. Industrial symbiosis in Kalundborg, Denmark – A quantitative assessment of economic and environmental aspects. Journal of Industrial Ecology 10, 239–255.

Kreiner, K., Schultz, M., 1993. Informal collaboration in research-and-development – the formation of networks across organizations. Organizational Studies 14, 189–209.

Kumar, K., van Dissel, H.G., 1996. Sustainable collaboration: Managing conflict and cooperation in inter-organizational systems. MIS Quarterly 20, 279-300.

Lambert, A.J.D., Boons, F.A., 2002. Eco-industrial parks: stimulating sustainable development in mixed industrial parks. Technovation 22, 471–484.

Lawler, E.J., Yoon, J., 1993. Power and the emergence of commitment behavior in negotiated exchange. American Sociology Review 58, 465–481.

Lozano, R., 2007. Collaboration as a pathway for sustainability. Sustainable Development 15, 370-381.

McDonald, M.L., Westphal, J.D., 2003. Getting by with the advice of their friends: CEOs' advice networks and firms' strategic responses to poor performance. Administrative Science Quarterly 48, 1–32.

Ministry of Agriculture, N.A.F.Q., 2008. The Netherlands: Second National Report on Plant Genetic Resources for Food and Agriculture, Country report for the FAO Second State of the World's Plant Genetic Resources for Food and Agriculture, The Hague.

Mirata, M., Emtairah, T., 2005. Industrial symbiosis networks and the contribution to environmental innovation – The case of the Landskrona industrial symbiosis programme. Journal of Cleaner Production 13, 993–1002.

Morgan, D.L., 2013. Integrating qualitative and quantitative methods: A pragmatic approach. SAGE Publications.

Muller-Seitz, G., 2012. Leadership in inter-organizational networks: A literature review and suggestions for future research. International Journal of Management Review 14, 428–443.

Pina-Stranger, A., Lazega, E., 2011. Bringing personalized ties back in: their added value for biotech entrepreneurs and venture capitalists inter-organizational networks. Sociological Quarterly 52, 268–292.

Powell, W.W., Koput, K.W., Smith-Doerr, L., 1996. Inter-organizational collaboration and the locus of innovation: Networks of learning in biotechnology. Administrative Science Quarterly 41, 116–145.

Provan, K.G., Fish, A., Sydow, J., 2007. Inter-organizational networks at the network level: A review of the empirical literature on whole networks. Journal of Management 33, 479–516.

Richard, P.J., Devinney, T.M., Yip, G.S., Johnson, G., 2009. Measuring organizational performance: Towards methodological best practice. Journal of Management 35, 718–804.

Rowley, T.J., 1997. Moving beyond dyadic ties: A network theory of stakeholder influences. Academic Management Review 22, 887–910.

Schiller, F., Penn, A.S., Basson, L., 2014. Analyzing networks in industrial ecology – A review of social-material network analyses. Journal of Cleaner Production 76, 1–11.

Seitanidi, M., Crane, A. (eds.), 2013. Social Partnerships and Responsible Business: A Research Handbook. Taylor & Francis, Abingdon, UK.

Smeets, P.J.A.M., 2011. Expedition Agroparks: Research by Design into Sustainable Development and Agriculture in Network Society. Wageningen Academic Publishers, Wageningen.

Spekkink, W., 2013. Institutional capacity building for industrial symbiosis in the Canal Zone of Zeeland in the Netherlands: a process analysis. Journal of Cleaner Production 52, 342–355.

Spekkink, W., 2015. Building capacity for sustainable regional industrial systems: An event sequence analysis of developments in the sloe area and canal zone. Journal of Cleaner Production 98, 133-144.

Sueur, C., Deneubourg, J.-L., Petit, O., 2012. From social network (centralized vs. decentralized) to collective decision-making (unshared vs. shared consensus). PLoS ONE 7, e32566.

Székely, F., Knirsch, M., 2005. Responsible leadership and corporate social responsibility: Metrics for sustainable performance. European Management Journal 23, 628-647.

Van de Ven, A.H., Fery, D.L., 1980. Measuring and Assessing Organizations. John Wiley & Sons, New York, NY.

Wasserman, S., Faust, K., 1994. Social Network Analysis: Methods and Applications. Cambridge University Press, Cambridge.

Yin, R.K., 2009. Case study research : Design and methods. Sage, Los Angeles, CA [etc.].

Appendix A: Questions of structural interviews

a. General

1. Respondent name
2. Respondent job title
3. Name of the organization
4. Organization main activity
5. Total number of employees (fte)
6. Organization exist since (year)
7. Organization is active in the agro-industrial park since (year)

b. Perceived performances on a [1–7] Likert scale: 1 – Strongly disagree, 7 – Strongly agree

Since we participate in the collaboration...	
We became economically stronger	☐
The turnover of our organization has increased	☐
The profits have increased	☐
The sales have increased	☐
The product and/or service quality has improved	☐
We got new and innovative ideas	☐
The number of innovations has increased	☐
The reputation of our organization has improved	☐
The product or service capabilities have improved	☐
We became socially stronger	☐
The number of employees has increased	☐
The number of qualified workers has increased	☐
The environmental and health risks are decreased	☐
The odor nuisance and noise are decreased	☐
We have less waste and CO_2 and GHG emission	☐
We use less energy and other resources	☐

c. Perceived satisfaction on a 7-point Likert scale: 1 – Strongly disagree, 7 – Strongly agree

Overall, ...	
our collaborations with other organizations are productive	☐
we are satisfied with the collaboration of our organization with other organizations	☐

d. Questions on network ties (yes/no)

		Organization A	Organization B	Organization C	Etc.
	Formal ties				
1.	We have signed formal contract with				
2.	We exchange waste and by-products on a regular basis with				
3.	We share resources (e.g. infrastructure, facilities, logistics, human) with				
4.	We work together as a formal team with				
	Informal ties				
5.	We work together, but have not established a formal agreement with				
6.	We have social (informal) contacts, e.g. via e-mails or social network websites with				
7.	We discuss new ideas, exchange information or advice with				
	Interdependency				
8.	Our organization will experience negative effects (delay, reduction in the scope or quality) if these organizations delay, cancel, or significantly alter the agreements				
9.	These organizations will experience negative effects if our organization (delay, cancel or significantly alter the agreements				

Appendix B: Measures of network structural properties and related algorithms at network and at organizational level.

Network structure measure	**Algorithm**	**Explanation**
Network level		
Centralization (Freeman, 1978)	$C = \frac{\sum_{i=1}^{n}[C^* - C_i]}{(n-2)(n-1)}$	C = centralization of entire network: percentage in the scale of [0;100] n = network size: n > 2

		C_i = centrality of organization i: percentage in the scale of [0;100] C^* = largest value of centrality within the network: percentage in the scale of [0;100]
Density (Ahuja, 2000)	$D = \frac{N}{n * (n-1)}$	D = network density: percentage in the scale of [0;100] D = 0 if no ties exist D = 100 if all possible ties exist N = total number of connections n = network size
Organizational level		
Degree centrality (Borgatti, 2005; Freeman, 1978)	$C_{Di} = [1;\ n-1]$	C_{Di} = degree centrality of organization i n = network size
Normalized degree centrality (Borgatti, 2005)	$C_{\mathrm{Dinrm}} = \frac{C_{\mathrm{D}}}{n-1}$	$C_{D i\mathrm{nrm}}$ = the normalized degree centrality of organization i, C_{D} = degree centrality n = network size
Betweenness centrality (Borgatti, 2005; Freeman, 1978)	$C_{\mathrm{B}i} = \sum_i \sum_j \frac{g_{kij}}{g_{kj}}$	i, j, k = organizations in the network; $i \neq j \neq k$ $C_{\mathrm{B}i}$ = the betweenness centrality of organization i g_{kj} = geodesic path (the shortest way) for k to reach j g_{kij} = number of geodesic paths between k and j through i
Closeness centrality (Borgatti, 2005)	$C_{\mathrm{c}i} = \sum_j [g_{ij}]^{-1}$	$C_{\mathrm{c}i}$ = closeness centrality of organization i g_{ij} = geodesic path between i and j (the shortest way for i to reach j); $i \neq j$