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Intermediary Organisations in Collaborative Environmental Governance: evidence of the EU-funded LIFE Sub-Programme for the Environment (LIFE-ENV)

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Abstract

In the framework of the collaborative environmental governance and specifically of network concepts, this study makes an exploratory analysis of the EU-funded LIFE sub-programme for the Environment (LIFE-ENV) and its priority area Environment and Resource Efficiency focused on the role of networks and in particular of intermediary organizations by using Social Network Analysis (SNA). More specifically, by investigating the evolving pattern of key statistics (density, clustering coefficient, betweenness and degree centrality) related to bipartite (organisations and projects) and dynamic (eleven years) networks, we identified 3003 organisations and 1006 projects and studied how they operate by forming new relations and reorganising existing connections. Results evidence that the LIFE-ENV attests a structural coherence and a stable structure over time and it is characterised by four different structures of network components, namely isolated coordinating beneficiary, isolated components, small components and giant components. Moreover, the LIFE-ENV is not a cohesive network, due to low values of both density and clustering coefficient. Based on betweenness centrality and degree centrality measures, the LIFE-ENV sub-programme has facilitated the emergence of 4855 intermediary

organisations, which equals 29.5% of the total number of coordinating and associate beneficiaries involved in the programme in the eleven years considered. Transnational cooperation in the LIFE-ENV sub-programme is characterised by a different intensity of relations: some countries (i.e. Italy, Spain and Belgium) implement transnational cooperation with multiple European countries in both the North and South of Europe, while others tend to cluster with countries in the same geographical area, and lastly East European countries have limited participation in transnational cooperation. Our analysis supports the hypothesis of a declining collective action in the LIFE-ENV sub-programme.

1. Introduction

Economic activities may lead to the intensive and often irreversible consumption of natural capital. Based on time series from 1990 to 2014, Ahmad et al. (2018) estimate that in the next 30 years the natural capital in 140 countries will continue to decrease in quality and quantity. Moreover, by projecting the current trends in the future, the authors find that countries with low human and produced capitals, but high natural capital (e.g., Brazil, Republic of the Congo and the Islamic Republic of Iran), will fail to sustain their natural capital in the near future. Humanity is entering in the Anthropocene, a new geological era where human agency is at the centre of the temporal and long-term problems of the earth system (Crutzen and Stoermer, 2000; Crutzen, 2002; Steffen et al., 2011; Dash, 2019). With agricultural and industrial revolutions humans came to dominate the earth's biophysical processes. At the same time, they caused a significant state shift in the earth's biosphere threatening to disrupt human civilisation (Gowdy and Krall, 2013).

In response to these worldwide environmental and human challenges, the scientific literature highlights the effectiveness of multiple governance approaches to manage temporal and long-term environmental problems that cross different geographical and temporal scales and include diverse jurisdictions and organizational hierarchies (Bodin et al., 2016). Studies on the positive effects determined by environmental governance are proposed by Todić and Zlatić (2018), Lipponen and Chilton (2018), and Dinar et al. (2019) concerning water and groundwater management, by Zisenis (2017) and Fernandes et al. (2019) for nature conservation, and by Ilankoon et al. (2018) for waste management. By engaging public and private actors and stakeholders, collaborative environmental governance (hereinafter CEG) aligns human actions to ecosystem protection by proposing effective solutions through learning processes, coordination and cooperation (Bodin, 2017). This approach is also relevant to policy makers. By conveying that environmental challenges cannot be resolved merely at a national level, the European Union (EU) sustains multi-level governance based on cross-border cooperation among social and institutional actors with diverse backgrounds, interests and objectives to tackle environmental challenges at different levels, scales and dimensions (European Commission, 2014). Among the various European funds, the EU Programme for the Environment and Climate Action, better known with the acronym LIFE, aims to finance projects based on a collaborative governance approach to reach the EU environmental objectives. Specifically, the LIFE sub-programme for the Environment supports the efficient and respectful use of natural resources and the implementation of environmental policies through different thematic priorities (namely: water management, waste management, promotion of the circular economy, sustainable use of soil and forests, containment of the use of chemicals, noise, air and the urban environment). Since its creation in 1992, LIFE has co-financed more than four thousand projects in 28 European countries, thus becoming the largest and most relevant funding programme for environment sustainable management in Europe. The LIFE programme ultimately aims to catalyse synergies among actors, to promote and disseminate good practices and best solutions needed to achieve environmental and climate change objectives and to encourage innovative and eco-friendly technologies (EU Regulation No. 1293/2013), by promoting networking and knowledge sharing.

The scientific literature shows that synergies between multiple institutional and social realities facilitate sharing of different skills, knowledge and resources. These are useful to reach a new equilibrium in the balance between human agency and natural resources (Li and Mauerhofer, 2016; Sayles and Baggio, 2017; Baggio and Hillis, 2018; Barnes et al., 2019). Nevertheless, as Bodin (2017) observes, CEG also testifies to criticisms in multiple circumstances (e.g. the time required to overcome initial collaborative barriers, such as lack of trust; environmental hazards calling for immediate top-down actions; environmental issues particularly contested by the civil society and characterised by high asymmetry in power relations of stakeholders). In addition, information sharing among actors does not necessarily determine *per se* changes in values, beliefs, and behaviours and, consequently, desired outcomes (Mont et al., 2014). Thus, studies evidencing *when* and *how* CEG is effective are much needed, by focusing on who are the actors involved, with whom they collaborate, how these collaborative networks are formed and how they address different environmental problems by considering –among others– the temporal and spatial features of the ecosystems (Crona and Bodin, 2006).

In more detail, within the broad realm of collaborative environmental governance we can refer to the concept of network governance (Rhodes, 1996, 1998) (hereinafter NG), which is becoming an increasingly popular approach for dealing with complex and dynamic issues that characterise environmental policies (e.g. Aggestam, 2018; Perkins and Nachmany, 2019). Studies have observed the importance of networking in CEG in relation to conservation of nature (Snijders et al., 2017), transition to a green economy (Imbert et al., 2018), management of protected areas within the Natura 2000 network (Manolache et al., 2018), management of water resources (Lienert et al., 2013; Edens and Graveland, 2014), management of forest resources (Kleinschmit et al., 2018), and analysis of regional governance (Grönholm, 2018). Recent literature has focused on specific research questions such as: (i) why organisations decide to join a governance network (Barrutia and Echebarria, 2019); (ii) how the structural characteristics of the social-ecological network –determined by the specific position of actors in the web of connections– affect the ability of the entire network to solve collective action problems (Bodin, 2017); (iii) how organizations perceive the risk of others defecting from a network and how they reduce the risk by connecting to organisations where trust is already well established (Schoon et al., 2017); (iv) how “intermediaries” or brokers affect the network governance and its dynamics (Beveridge, 2019).

For the purpose of this paper, we would like to focus on this last question which represents a key issue to be observed and analysed when analysing huge environmental programmes where multiple actors, who are operative in diverse geographical scales and jurisdictions, operate through transnational cooperation in order to handle common environmental problems through a NG approach. This is exactly the case for the LIFE sub-programme for the Environment within the EU. As mentioned, the purpose of the LIFE-ENV projects is primarily to develop, test and demonstrate political or management approaches, good practices and solutions related to the environmental-related thematic priorities by co-financing different types of interventions (e.g., pilot and demonstration projects, good practices, integrated projects) with an added value at the European level. The LIFE-ENV network is formed by actors involved in project partnerships composed of coordinating and associated beneficiaries. The coordinating beneficiary is responsible for ensuring implementation of the action, constitutes the single point of contact for the contracting authority, and guarantees the distribution of financial resources as specified in the partnership agreements established with the associated beneficiaries (if any). The coordinating beneficiary must be directly involved in the technical implementation of the LIFE-ENV project and dissemination of its results. The coordinating beneficiary must bear part of the project costs and thus contributes financially to the project budget. The associated beneficiary has to contribute technically and financially to the proposal, being responsible for the implementation of one or several project actions (European Commission, 2018).

In this EU funded programme for the environment, networks and NG clearly have a paramount role in defining effective interventions for natural capital and environmental protection. By observing the structures and dynamics of a network composition it is possible to analyse the presence of central actors or intermediary organisations. Intermediary organisations manoeuvre among other actors in a network, making new relations and reorganising existing connections between individuals or organisations through bridging ties. By occupying a specific central location in a social network, actors can exert influences over others, they have access to valuable information, which can put them at an advantage as brokers (Bodin and Crona, 2009; Abrahams et al., 2019). Studies on intermediaries investigate their roles, interests and motivations, importance and influence, and their impact on networks (Beveridge, 2019; Burt, 2009). In NG, the positive effect of bridging ties extends beyond the exchange of information, knowledge and resources among actors. Over time, these ties can foster normative social values such as trust, sustaining future actions, adaptation capacity, etc., or, on the contrary, they can bond actors preventing the others' participation in future initiatives.

In the framework of the CEG and NG concepts, this study makes an exploratory analysis of the LIFE-ENV sub-programme and its priority area Environment and Resource Efficiency focused on the role of networks and in particular of intermediary organizations by using Social Network Analysis (SNA). More specifically, by investigating the evolving pattern of key statistics (density, clustering coefficient, betweenness and degree centrality) related to bipartite (organisations and projects) and dynamic (eleven years) networks, we identify intermediary organisations and how they operate by forming new relations and reorganising existing connections within the context of the EU LIFE programme.

The study has been detailed in the following guiding research questions:

Q1. To what extent have organisations and projects within the LIFE-ENV sub-programme been connected?

Q2. To what extent have new relations been established among organizations and projects within the LIFE-ENV sub-programme or existing relations ceased? To what extent has the LIFE-ENV sub-programme been cohesive and clustered?

Q3. To what extent has the LIFE-ENV sub-programme facilitated the emergence of intermediary organisations? What are the types of organisations that maximise the transmission and control of information and resources among projects? What is the level of influence of these key central actors (degree centrality)?

Q4. To what extent has the LIFE-ENV sub-programme financed partnerships across Europe? Which are the countries attesting to a better performance in terms of transnational cooperation for the environment?

The paper is organised in four sections. After this introduction, section two presents materials and methods, which are detailed for each specific research question. Section three provides the results, again detailed for the four research questions and consequently split into four different sub-sections. Finally, section four presents discussions and conclusions.

2. Materials and Methods

SNA allows the NG of the LIFE-ENV sub-programme to be measured and represented graphically by (i) measuring the evolution of environmental collaborations in different moments of time and (ii) observing the dynamic pattern of organisations who enter or exit LIFE-ENV projects by forming or ceasing partnerships. By using the network property of indirect structural relations, SNA reveals the hidden ties among actors who are effectively involved in common activities (Borgatti et al., 2014). The study proposes the analysis of the entire set of LIFE-ENV projects referred to the priority area Environment and Resource Efficiency, composed by 1006 initiatives financed from 2007 to 2017 and graphically represented as bipartite networks that consist of two disjointed sets of nodes where ties connect nodes of both sets. Nodes of set 1 are organisations benefitting from the LIFE-ENV financing, while nodes of set two are projects, and ties among the two sets symbolise the participation of organisations in LIFE-ENV projects as coordinating and associate beneficiaries. In the eleven years considered, the EU has revised the structure of the LIFE programme, which was organised in three components from 2007 to 2013, and two sub-programmes from 2014 to 2020. The data elaborated in this study refer explicitly to projects characterised by the strand “environment” and financed via the LIFE programme in 2007-2013 and 2014-2020. Data referred to 2018 and 2019 are not included in the analysis because not available on the database.

In order to access detailed data and information regarding LIFE-ENV projects, the LIFE website has been consulted (https://ec.europa.eu/environment/life/project/Projects/index.cfm) where the complete database of projects is available since the first edition of the Programme. Querying by theme and period, it is possible to obtain the full list of projects carrying the desired characteristics and thus accessing the general project information (i.e., title, project reference, duration, total budget, EU contribution, project location), and specific information related to the beneficiaries (i.e., coordinating beneficiary, type of organisation, description, and partners except for co-financiers). Data collected from the LIFE projects database were exported into two separate MS Excel spreadsheets. The first one –nodes file– contains all the information concerning the two sets of nodes: beneficiaries, both coordinating and associated (i.e., name, ID number, country), and projects (i.e. title, project reference, duration and location). The second file –edges file– includes all the relations established by the different project partnerships (*source*, i.e., the observed project; *target*, i.e., the specific coordinating or associate beneficiary; *type of relation*, undirected). The type of relationship is undirected because the lack of directionality among nodes has been assumed. Data in the spreadsheets have been used as input data for the SNA, implemented via GEPHY® and UCINET® softwares for computation of statistics on two-mode betweenness centrality. Additional statistical elaborations have been performed using R statistical software. The dataset is available at https://data.mendeley.com/datasets/p9yxnh3yyd/2 [**DOI:** 10.17632/p9yxnh3yyd.2]. From a methodological viewpoint, the analysis has been differently structured by considering each specific research question.

Q1. To what extent have organisations and projects within the LIFE-ENV sub-programme been connected?

Organisations involved in the LIFE-ENV programme and its projects represent the nodes of the network. Moving from Schoon et al. (2017), we investigate eleven bipartite networks by comparing evolving numbers of nodes, relations, and components along years. In network analysis, components are sub-parts of the network characterised by ties that interlink through common nodes, creating chains or paths of nodes and linking endpoints indirectly. "*Part of the power of the network concept is that it provides a mechanism – indirect connections – by which disparate parts of a system may affect each other*" (Borgatti et al., 2013: 2). The aim is to understand how LIFE-ENV sub-programme-related organisations and projects connect over time by considering the evolving pattern of the structural features of different network components. By observing graphical representations and using the statistic called "component" computed by GEPHY, we can determine the number of components and which are the organisations taking part in them. By extracting the data into an excel file, we can isolate different structures characterising the LIFE-ENV networks, allowing the process of aggregation of projects and organisations in the network over time to be evidenced.

Q2. To what extent new relations among organizations and projects within the LIFE-ENV sub-programme have been established or existing relations ceased? To what extent has the LIFE-ENV sub-programme been cohesive and clustered?

For a specific year of analysis, the dynamic pattern of relations in the network is formed by two possible situations, i.e. (i) "existing relation" and (ii) "ceasing relation" in the network. Moreover, the existing relation is characterised by either an "entering condition" or a "permanence condition". In other words, the entering condition concerns organisations and projects coming into the network after the selection process and establishing their relations (thus, organisations formalise collaborative relations with others through the selected project). The permanence condition refers to organisations and projects selected in previous years and which are still active in the network due to the implementation of defined activities (thus, they keep their relations for that specific year of analysis). The ceasing relation concerns organisations and projects leaving the network due to the fulfilment of their action. Thus, their formal relations cease, nevertheless their informal relations can of course either continue or cease.

For a longitudinal assessment, the dynamic pattern of networks can be analysed by observing if nodes of the set organisations change their "attribute" of coordinating and associate beneficiaries when moving from one project to another along the timeframe considered. This allows all possible choices to be specified and, consequently, trajectories performed by organisations in the decade. The hypothetical trajectories of coordinating and associate beneficiaries (C and A respectively) are defined in number and can be longitudinally traced and measured by paralleling two consecutive years where different paths can emerge: a coordinating beneficiary can enter the network (0→C), confirm its role (C→C), or leave the network (C→0). Similarly, an associate beneficiary can join the network (0→A), set its role (A→A), or abandon the network (A→0). Moreover, an associate beneficiary can upgrade its role (A→C), and a coordinating beneficiary can downgrade its role (C→A). The last two cases indicate the condition of an actor starting a new project after having just completed a previous one.

As for questions Q3, Q4 and Q5, different network statistics have to be computed. Specifically, density, clustering coefficient, betweenness centrality and degree centrality.

The density represents the level of cohesiveness of the network. The graph density represents the proportion of observed connections between nodes to the maximum number of possible connections. It also reflects the degree of interconnectivity between nodes. In the case of a bipartite network, the density is computed as "*the number of edges divided the number of pairs of nodes using unordered pairs in the case of undirected graphs*" (Borgatti and Everett, 1997: 254). In the case of bipartite networks only relations between the two sets of nodes are possible. Consequently, the density formula for an undirected bipartite network suggested by the authors is:

$$D = \frac{n_{org} n_{proj}}{(N_{org} + N_{proj})(N_{org} + N_{proj} - 1)} \quad (1)$$

where $n_{org} n_{proj}$ is the number of relations among the two sets and the denominator computes the maximum possible numbers of relations among the two sets (N_{org} and N_{proj} are the total number of nodes in the two sets).

The clustering coefficient relates to the tendency of nodes to aggregate together by forming densely connected groups within the network. Thus, a high clustering could relate to a higher level of collaborations within the network where organisations collaborate with others based on trust relations or perceived trustworthiness of nodes. However, it could be connected to a higher level of bonding relations among similar actors unwilling to collaborate with other external actors and thus limiting the possibility of future collaborations with new actors. The clustering coefficient can be computed as a global clustering coefficient measuring the overall level of clustering in the network or a local clustering coefficient observing how a specific node clusters with its neighbours. In the case of a one mode network, the global clustering coefficient is measured as the proportion of closed number of triplets (i.e. three nodes connected by three ties) over the total number of triplets in the network (i.e. three nodes connected by two ties), while the local clustering coefficient is the fraction of the number of actual ties among node *i*'s contacts over the possible number of ties among them. In the case of bipartite networks, there are different methods to compute the clustering coefficient. In this research, we use what has been proposed by Opsahl (2013), who identifies new indicators for computing clustering coefficients for bipartite networks without using the projection of a bipartite network into a one-mode network, which is normally characterised by an overestimation of the clustering coefficient. Opsahl (2013) formally defines the clustering coefficient as:

$$(2) \quad C^* = \frac{Closed\ 4\ paths}{4\ paths} = \frac{\tau * \Delta}{\tau_*}$$

where τ^* is the number of 4-paths in the network, and $\tau * \Delta$ is the number of these 4-paths that are closed by being part of at least one 6-cycle (i.e., a loop composed of six ties connecting five nodes), which could range between 0 (minimum value) and 1 (maximum value).

Q3. To what extent has the LIFE-ENV sub-programme facilitated the emergence of intermediary organisations? What are the types of organisations that maximise the transmission and control of information and resources among projects? What is the level of influence of these key actors?

Betweenness centrality index can be used to understand whether the LIFE-ENV sub-programme has facilitated the emergence of intermediary organisations. In fact, it measures "*the frequency with which a point falls between pairs of other points on the shortest or geodesic paths connecting them*" (Freeman, 1978: 221). Thus, the betweenness of a node *i* is defined as the fraction of shortest paths between pairs of nodes in a network that passes through *i*. The betweenness centrality evidences a key feature of a node in the network, specifically its capacity to act as a gatekeeper by facilitating the stream of what passes through the web of connections. A node's betweenness centrality equals zero when the node is never along the shortest path between two other nodes (i.e., the node is isolated). When the node lies along every shortest path between every pair of nodes, the betweenness centrality reaches the maximum value. If nodes with higher betweenness centrality measures were removed, the functioning of the entire network would be compromised due to its reduced bridging capacity among clusters. Betweenness is considered a measure of the influence of the node on the entire network. A central node can be an intermediary organisation playing a key role in the implementation of the LIFE-ENV programme. In the case of bipartite networks, the procedure proposed by Borgatti and Halgin (2011) for the analysis of 2-mode data has been implemented. Formally, the betweenness is computed as in an ordinary graph:

$$(3) \qquad b_k = \frac{1}{2} \sum_{i \neq k}^{n} \sum_{j \neq k,i}^{n} \frac{g_{ikj}}{g_{ij}}$$

where b_k is the betweenness of the node k, g_{ikj} is the number of geodesic paths between i and j that pass through k, and g_{ij} is the total number of geodesic paths that pass from node i to node j. In the case of bipartite networks, the values of b_k have to be normalised for the maximum betweenness that any node can achieve in a graph of S_1 organisations and S_2 projects formalized by Borgatti and Halgin (2011).

The degree centrality, d_i, represents the number of relations that a specific node has and it is normalised by dividing by the maximum number of possible ties, $d_i^* = d_i/(n-1)$. Thus, in the case of LIFE-ENV network, degree centrality measures the level of influence or level of involvement that a j_{org} node or an i_{proj} node has on the entire network of collaborations (Opsahl et al., 2010). In the case of bipartite networks, ties are only among the two sets. Consequently, the normalised degree centrality can be computed via two different formulas:

$$(4) \qquad d^*_{j_{org}} = \frac{d_{j_{org}}}{N_{proj}} \quad for\ j_{org} \in S_1$$

$$(5) \qquad d^*_{i_{proj}} = \frac{d_{i_{proj}}}{N_{org}} \quad for\ i_{proj} \in S_2$$

In the case of (4), a node belonging to the first set (S_1) can be connected to a maximum number of ties equal to N_{proj} while in the case of (5) a node in the second set (S_2) can be connected to a maximum number of ties equal to N_{org}. The focus in this study is on intermediary organisations which are considered as primary nodes, observing that it is the organisation which decides to take part in the project and not *vice versa*, so formula (4) will be used for computation. This measure focuses on the local structure around the node by evidencing its level of influence on the surroundings, but it does not consider the entire structure of the network. So, a node could have a high degree but, at the same time, it could be located in a part of the network not well connected to others, undermining its capacity to act as intermediary in the flow of resources and information (Opsahl et al., 2010).

The two measures of centrality –i.e., betweenness and degree centrality– represent two different concepts. In a one mode network, a node with a high degree centrality endows a large number of connections, but it could belong to a unique partnership (thus, with zero betweenness centrality). In this case, the high degree centrality is not indicative of a higher capacity to control whatever flows in the network. When considering betweenness centrality, instead, the main focus is on the presence of nodes acting as brokers in the network. The betweenness is usually interpreted as the potential of the node to control the flows through the network acting as a gatekeeper or a toll-taking actor. Moreover, those actors normally filter the information, so many nodes need that specific node to reach others by using an efficient path (i.e., the shortest). Of course, these concepts have to be adapted to the case of 2-mode networks, by considering the previously presented formula.

Q4. To what extent has the LIFE-ENV sub-programme financed partnerships across Europe? Which are the countries attesting a better performance in terms of transnational cooperation for the environment?

The transnational cooperation can be represented graphically by using two specific layouts of the GEPHY software, specifically Maps of Country and Geo-Layout. Based on information on the national or transnational composition of the partnership for each specific project it is possible to graphically represent with weighted ties the connections among countries in terms of transnational cooperation.

3. Results

From 2007 to 2017 the priority area Environment and Resource Efficiency in the LIFE-ENV Programme has co-financed 1006 projects, reaching 1006 coordinating beneficiaries and 3363 associated beneficiaries. Thus, a total number of 4369 organisations distributed in the 28 European countries have benefitted from the European financing system for the environment and some of them more than once. In fact, the total number of "single" organisations participating in LIFE-ENV Programme were 3003, of which 1366 (45.5%) decided to repeat their participation in different years and also with different roles. In the eleven years considered by our analysis, the countries most benefitting from LIFE-ENV financing have been Spain (337 projects) and Italy (262), followed by France (63) and Greece (58). The average financial dimension of a single LIFE-ENV project is 3,106,712 euro (with a minimum value of 417,759 euro, a maximum of 21,424,942 euro, and a standard deviation (SD) of ± 2,894,458 euro). In the programming period 2007-2013 (the first 7 years of our dataset), the European Commission contributed to financing a total budget of 1,973,187,801 euro to LIFE-ENV projects, while in 2014-2017 (the last four years of our analysis) the amount was 568,834,190 euro.

R1. Nodes and structures of network components

From 2007 to 2017, the 1006 projects have on average 4.4 relations each. For each of the eleven years considered, a network has been built and descriptive statistics computed. Descriptive data on networks built are summarised in Table 1, in which only three years (namely 2007, 2012, 2017) are described as examples, focusing on the evolving pattern in the total numbers of coordinating beneficiaries, associate beneficiaries, projects, nodes, relations, components, and budget of the actions.

Table 1: Descriptive statistics of the LIFE-ENV programme from 2007 to 2017

Source: our elaboration based on LIFE dataset

The number of coordinating beneficiaries (which corresponds to the total number of projects financed) evolves in the timeframe considered: it starts from 72 in 2007, then reaches its maximum value of 147 in 2012 before descending to 55 in 2017. The number of associate beneficiaries follows a similar path: it equals 286 in 2007, touches its highest value (424) in 2012, and then descends to 212 in 2017. The three networks are characterised by a number of nodes totalling 430 in 2007, 718 in 2012 and 322 in 2017. Both organisations (mode 1) and projects (mode 2) are connected through 358 relations in 2007, which rise to 2574 in 2012, and finally descend to 2004 in 2017. Table 1 also reports the budget for all the LIFE-ENV projects financed across the EU during the eleven years considered (see "The LIFE-ENV 2007-2017 dynamic and bi-partite graph" in Supplementary Materials).

Figure 1 presents the three networks for the three selected years (2007, 2012 and 2017). Analysing the graphical representation of these networks, one can observe their structural evolution during the time considered: from a first network of 61 quite homogeneous and very small components (2007), to other two networks with 195 and 151 components (in 2012 and 2017 respectively). The most distinctive feature emerging by comparing the three graphs is the presence of a giant component in both the second and third network, while this feature is not present in 2007. The graphic representation also highlights the substantial increase in the number of nodes and relations from the first network to the second and third ones. Table 2 specifies the key structural features of the different components in the three graphs.

Four different structures have been identified for network components. The first structure refers to "isolated coordinating beneficiaries": they are 10, 50 and 28 respectively for the three years considered and, of course, are connected to the same number of projects. The second structure denotes "isolated components", i.e., a coordinating beneficiary and its associate beneficiaries connected to a single project: their number equals 245 organisations and 45 projects in 2007, 463 organisations and 120 projects in 2012, and 404 organisations and 104 projects in 2017. The third structure represents the initial process of aggregation into multiple "small components" (e.g., beneficiaries connected by more than one project where few coordinating and associate beneficiaries connect with other coordinating or associate beneficiaries). Based on the data, this structure is characterized by a number of small components ranging from a minimum of two projects to a maximum of seven. Specifically, in 2012 the range is between two and five projects, while in 2017 it is between two and seven projects. Moreover, in structure 3 the organisations connected through small components are 87 in total in 2007, 171 in 2012 and 153 in 2017. Finally, the process of aggregation reaches it maximum level with structure four corresponding to a "giant component" (i.e., representing a subset of organisations and projects all linked through bridging ties). In 2007, no giant component is present, while in 2012, the giant component relates 1589 nodes (i.e., 380 projects and 1209 organisations) equivalent to 63.3% of total nodes. In 2017, the structure four connects 1239 nodes (i.e., 266 projects and 973 organisations) corresponding to 61.8% of total nodes (see Table 2 for additional data).

Figure 1: Two-mode networks of the LIFE-ENV programme in 2007, 2012 and 2017

(Mode 1 – organisations in black colour; Mode 2 – projects in red colour)

Source: our elaboration based on LIFE dataset by using GEPHY

Table 2: Four structures of network components in the LIFE-ENV programme from 2007 to 2017

Source: our elaboration based on LIFE dataset

R2. The evolving pattern of relations among organisations and projects and the cohesiveness and density of the sub-programme

Bridging relations in a given period –i.e., the number of relations connecting two or more projects and consequently multiple organisations– are 15 in 2007, 324 in 2012 and 224 in 2017. Thus, the bridging capacity of the entire network (i.e., the number of bridging relations over the total number of relations in the network) equals 4.2% in 2007, 12.6% in 2012 and 11.2% in 2017. On average the value corresponds to 10.9% for the entire period. It can be noted that these relations represent a minority of the total number of possible relations in the networks. Furthermore, the bridging capacity rises substantially from 2007 to 2012 and then slightly reduces in 2017 (Table 3). For a specific year of analysis, the dynamic pattern of existing and ceasing relations has been measured by computing the number of relations referred to each of the three different conditions specified in the Materials and Methods section: entering, permanence and ceasing conditions. The total number of existing relations equals the number of new (i.e. entering) relations plus the number of relations that persist (i.e. permanence) with reference to a specific year of analysis vis-a-vis previous years. Their number equals 358 in 2007, then shifts to 571 in 2012 when it reaches its maximum value, and finally progressively reduces to 267 in 2017. For relations in the permanence condition, their number of course equals 0 in 2007, then it shifts to 2003 in 2012, reaches its maximum in 2014 (2287), and then progressively reduces to 1737 in 2017. Ceasing relations start to be observed in 2011 and progressively increase in the following years reaching the final value of 483 (the maximum) in 2017 (Table 4). In order to further detail the information provided in Table 4, Table 5 shows how many coordinating and associate beneficiaries maintain or change their formal role in the implementation of LIFE-ENV projects from 2007 to 2017. Of course, the analysis of maintaining or changing patterns has been proposed by observing if a specific organisation maintains or changes its role within two consecutive years. It is possible to observe that coordinating and associate beneficiaries have a very similar dynamic movement during different years. The highest number of both coordinating and associate beneficiaries entering the network is observed between 2011 and 2012. The highest number of coordinating and associate beneficiaries confirming their role in the network is between 2013 and 2014, while the highest number of both coordinating and associate beneficiaries exiting the network is between 2017 and 2018. Specifically, the LIFE-ENV sub-programme started the 2007-2013 programming period with a reduced number of both coordinating and associate beneficiaries entering the programme, then their number has substantially increased till 2011/12. From 2012/13 till recent years, the level of restructuring of LIFE-ENV has progressively reduced with a decreasing number of both types of beneficiaries entering the sub-programme, which has to be combined with an increasing number of both coordinating and associate beneficiaries leaving the programme. Moreover, from 2014/2015 till recent years, the number of beneficiaries confirming their role has progressively reduced. This is probably due to the change of the entire structure of the LIFE programme in the new programming period (2014-2020) with the creation of two new sub-programmes: one for the environment and the other for climate action. Of course, such a change could have meant that in the new programming period, projects can split into different segments, while they firstly belong only to LIFE+ Environmental policy and governance programme.

Table 3: Relations in the LIFE-ENV programme from 2007 to 2017

Source: our elaboration based on LIFE dataset

Table 4: Existing and ceasing relations in the LIFE-ENV programme from 2007 to 2017

Source: our elaboration based on LIFE dataset

Table 5: Passages in role in the LIFE-ENV programme from 2007 to 2017

Source: our elaboration based on LIFE dataset

Figure 2 represents the density computed by using the formula of Borgatti and Everett (1997) for a two-mode network. Data on the eleven networks show a decreasing density from 2007 to 2013, with a limited increase from 2014 to 2017 which refers to the new EU programming period. Nevertheless, the values of density are very low, ranging between 0.0042 in 2007 and 0.0010 in 2017. This means that in 2007 the existing relations equal 0.4% of all possible relations in the network, while in 2017 this descends to 0.1%, attesting to a very limited cohesiveness of the networks. Of course, if we consider that the LIFE-ENV Programme has a European dimension this value can be expected. Figure 3 presents the global clustering coefficient of the LIFE-ENV networks, which doesn't follow a homogenous path: initially, a rising trend is observed till 2012, although with a temporary decline in 2010, consequently, there is a decreasing pattern from 2012 to 2016, and finally, a very limited recovery in 2017.

Figure 2: Density in the LIFE-ENV networks from 2007 to 2017

Source: our elaboration based on LIFE dataset

Figure 3: Clustering coefficient of the LIFE-ENV networks trend from 2007 to 2017

Source: our elaboration based on Tnet package (R software)

R3. Betweenness and degree centrality of the sub-programme

Figure 4 and Table 6 report the graphical representation and statistics for the normalised average betweenness centrality. The measure of centrality reveals a nonlinear pattern, which is characterised by a sequence of increasing and decreasing trends over the eleven years. Values of the centrality measure are in general very low: the highest is 0.00189 in 2008, while the lowest corresponds to 0.00009 in 2017, with an overall average value for the entire period considered of 0.0059.

In 2007, 21.3% of organisations have a positive value in betweenness centrality characterised by a relatively high value of the measure if compared to the following years (0.00095). Subsequently, in 2013, the LIFE-ENV programme reaches the highest number of organisations (33.8%) with a positive betweenness centrality, but, at the same time, the statistic has a very low value (0.00034). In other words, in 2013 more organisations act as intermediary organisations or brokers, but their brokerage strength is substantially reduced. In 2017 fewer organisations (28.8%) have a positive betweenness centrality, but with the lowest value ever seen (0.0009).
Table 7 shows organisations characterised by the five highest values of betweenness centrality in 2007, 2012 and 2017, categorised by country and type of organisation in accordance with the LIFE classification. By considering the total figures over the 11 years considered for the aims of this study, research institutions represent 27.3% of the selected 55 organisations endowed with highest values of betweenness centrality, while universities equal 23.6%: the two categories together reach a total value of 50.9%. International enterprises and foundations also play an important role: they represent 14.6% and 12.7% of the total organisations respectively. Other organisations include regional public authorities (7.3%); small and medium enterprises (5.4%), large enterprises (1.8%) and local public authorities (1.8%). These central actors are mainly from the South of Europe, specifically Spain (34.5%), Italy (27.3%), and Greece (12.7%). Organisations from these three countries represent 74.5% of total organisations showing the 5 highest values in betweenness centrality.

Figure 4: Average normalised betweenness centrality from 2007 to 2017

Source: our elaboration based on UCINET®

Table 6: Normalised average betweenness centrality in the LIFE-ENV programme from 2007 to 2017

Source: our elaboration based on LIFE dataset

The normalised average betweenness centrality refers to the brokerage capacity of intermediary organisations in the entire European network. In order to add to this information, Figure 5 shows the normalised average degree centrality focusing on the local structure around the node by evidencing its level of influence in the surroundings. The statistic decreases from 2007 to 2013 and then starts to slowly increase in the last three years. By comparing the five highest values of betweenness centrality in relation to the previously selected 55 organizations which are used here as a sample, with their degree centrality values it is possible to observe four different patterns in which an organisation could be included: (i) a high degree centrality (high local influence) but a relatively lower betweenness centrality; (ii) a low degree centrality (low local influence) but a high betweenness centrality; (iii) a high degree centrality (high local influence) and a high betweenness centrality; and (iv) a low degree centrality (low local influence) and a relatively low betweenness centrality.

Figure 5: Normalised Average Degree from 2007 to 2017

Source: our elaboration based on UCINET®

Table 7: LIFE-ENV programme (2007, 2012, 2017). Organisations with the five highest values in betweenness centrality measure

Source: our elaboration based on GEPHY

R4. Transnational cooperation among organisations in different European countries of the sub-programme

The LIFE Programme database allows distinguishing between beneficiaries, both coordinating and associate beneficiaries, based on their country. Thus, it is possible to identify countries that have been funded more often than others, and the extent of transnational cooperation determined thanks to LIFE-ENV sub-programme. Southern European countries are more funded than others, and in particular in 2014 and 2015, these countries have benefitted from more than one-third of the total Programme budget (European Commission, 2018). In the creation of partnerships, the LIFE programme promotes transnationality, thanks to synergies among organisations from different countries. To understand how organisations in different countries relate to one another, we opted for a graphical representation in relation to 2007, 2012 and 2017. Figure 6 illustrates which countries form trans-boundary partnerships and depicts which countries tend to create more synergies with other countries, and, conversely, it reveals the opposite pattern. Results show that EU countries have a different intensity of relations.

Figure 6: Geographical relations among LIFE-ENV projects (2007-2017)

Source: own elaboration based on GEPHY ® - Map of countries layout

It is possible to note that countries like Italy, Spain and Belgium tend to create ties with many other countries in both the North and South of Europe. Apart from these three countries, in general terms organisations tend to relate especially with other organisations operating in the same geographical area (e.g. Greek organisations tends to relate with organisations based in other South-European countries, while Swedish organisations tend to relate with organisations based in other North-European countries). Finally, countries that recently joined the EU (i.e., the East-European countries) have a limited participation in transnational cooperation.

4. Discussions and conclusions

This exploratory study has analysed to what extent the priority area Environment and Resource Efficiency of the LIFE-ENV sub-programme has facilitated the emergence and dynamic evolution of intermediary organisations supporting environmental initiatives in the framework of the CEG and, specifically, NG theoretical discussion. In particular, the study has analysed the structures and dynamics of the LIFE-ENV sub-programme in eleven years in order to identify, through SNA, intermediary organisations that have emerged thanks to the financial support offered by the EU. The analysis has focused on the evolving pattern of key statistics (i.e., density, clustering coefficient, betweenness and degree centrality) related to bipartite and dynamic networks. The four key findings are now discussed in light of the scientific literature presented in the introduction, then conclusions are proposed.

F1. Key finding on structures of network components in the sub-programme

R1. (in short) From 2007 to 2017, the LIFE-ENV sub-programme has financed 1006 projects which have on average 4.4 relations each with an average budget of 3.1 million euro. Moreover, the LIFE-ENV sub-programme is characterised by four different structures of network components, namely isolated coordinating beneficiary, isolated components, small components and giant components. Of the three graphical representations proposed, the fourth structure –giant component– is present twice (2012 and 2017).

Based on R1, it is possible to state that the LIFE-ENV sub-programme has a structural coherence: in other words, a stable structure over the time, evidencing a not transient feature of the network characterised by the fact that coordinating and associate beneficiaries connect systematically in a standard set of structures of network components. The results point out the changing number of intermediary organisations over time, which allow the formation of environmental collaborations in NG (Bodin, 2017). Moreover, they also clarify in what way intermediary organisations are actually included in different collaboration structures. For an organisation to be part of a specific collaboration structure could, in turn, affect the magnitude of its collaboration success if, as suggested by Sandströn and Carlsson (2008), we relate actual network composition to collaboration success. So future studies should verify in the specific case of LIFE-ENV sub-programme if, as Boding and Crona (2009) suggest, environmental outcomes achieved are related to the participation of an organisation in a specific collaboration structure. Moreover, the participation of a specific organisation in the particular structure of a giant component could determine a greater capacity to reach environmental goals, if compared to its inclusion in the structure of a small or isolated component or coordinating beneficiary. We could thus suppose the presence of a multiplier effect on environmental outcomes achieved, determined by the specific structure the organisation takes part in, of course on the premise of a *ceteris paribus* condition.

F2. Key finding on the evolving pattern of relations, and on the cohesiveness and density of sub-programme

R2. (in short). Bridging relations are on average 10.9% of total relations. Existing relations are based on both entering (30% of existing relations on average) and permanence (70% of existing relations on average) conditions. Ceasing relations start to be observed in 2011 and progressively increase in the following years. The LIFE-ENV programme is not a cohesive network, due to low density values. Moreover, the global clustering coefficient increases till 2012, and then progressively decreases in recent years. So, the tendency to form closed groups characterised by bonding relations appears to be very limited.

Based on R2, it is possible to state that both coordinating and associate beneficiaries have increasingly confirmed their role and the number of bridging relations concerns on average 11% of total ones. These two factors together have determined a better dissemination of information and sharing of knowledge within the network. Conversely, the level of restructuring of the network has progressively reduced, and the number of organisations leaving the system increased. This pattern can probably be attributed to two components: (i) a frictional dynamic of the network where coordinating beneficiaries enter and leave; (ii) an effect determined by the restructuring of the LIFE programme in the 2014-2020 period. In particular, the creation of a specific sub-programme for climate action has probably pushed some beneficiaries to choose this new opportunity, determining a contraction in projects financed by the original LIFE-ENV programme.

Based on R2, it is also possible to state that the density values observed (i.e., the capacity to aggregate actors) are consistent with the specific features of a European programme where the beneficiaries are spread over 28 countries (now 27) and related to different project topics. As a consequence, densities of both the giant and minor components, in these specific circumstances, are normally reduced. As reported in Buchner and Cruickshank (2008) this particular feature has also been observed in other European programmes. Moreover, if the clustering coefficient can be interpreted as a possible measure of bonding relations among organisations that could prevent future initiatives with other external organisations (Schoon et al., 2017), the LIFE-ENV networks attest to very low values (all below 0.08), so it is possible to conclude that bonding relations do not characterise the relations among organisations in the years observed.

The values of density can be interpreted in different ways from the existing literature. Some authors, such as Sandström and Carlsson (2008), observed the relationship between network structure and performance in policy networks, concluding that an increasing density pattern and a differentiation in the type of actors help common efforts in policy networks to be reached. A decreasing density could instead signify the decreasing risk of a possible "collaboration fatigue" which could be present if density continued to increase and organisations participated in multiple projects without terminating other collaborations.

Nevertheless, the emerging results could also support the hypothesis of a declining collective action in the LIFE-ENV sub-programme, which is probably taking place although the data on density are extremely low. In this regard, Schoon (2012) has observed that a declining collective action takes place when the density values are progressively reaching the maximum of 1, which the author typifies as an increasing pattern of new collaborations emerging without others terminating. The two elements together can determine a sort of "fatigue effect" in collaborations, putting the network in a critical condition that could undermine the capacity of the collective action to continue. In this case, data on density do not indicate the weariness of collaborations, but the lower level of restructuring and reducing number of organisations involved in the sub-programme (if compared to the initial years) is a phenomenon occurring in LIFE-ENV. Consequently, the network conditions in which collective action in a wide programme declines require a new hypothesis to be considered. Our hypothesis is that the declining pattern could be attributed to the limited number of bridging relations over total ones. This feature, in huge networks, undermines the capacity to further enlarge the network through new collaborations and, thus, the declining pattern of collective action occurs, precisely because of the low value of density.

F3. Key finding on betweenness and degree centrality of the sub-programme

R3. (in short). LIFE-ENV sub-programme has facilitated the emergence of 4855 intermediary organisations, which equals 29.5% of the total number of coordinating and associate beneficiaries involved in the programme in the eleven years considered. Nevertheless, normalised average betweenness centrality measures evidence a very reduced brokerage capacity, especially from 2010 to 2017. Research institutions and universities represent 50.9% of the 55 organisations with the highest 5 values in betweenness centrality. Moreover, organisations from Spain, Italy and Greece represent 74.5% of organisations with the highest values in betweenness centrality.

Based on R3, it is possible to argue that in the LIFE-ENV programme the number of actors that both transmit information between groups and, at the same time, have a high probability of receiving new information and knowledge is quite limited. Values of normalised average betweenness centrality measure attest to a very reduced brokerage capacity of the organisations specifically in relation to networks from 2010 to 2017. This tendency undermines the possibility of coordinating and associate beneficiaries to affect the entire network structure and the dynamics of future collaborations in the environment and resource efficiency strand of the LIFE Programme. This result confirms what R2 and F2 indicated in terms of bridging relations, density and clustering coefficient of the network. Results have also shown that research institutions and universities are the key actors in the brokering role within the network, whereas most projects coordinated by private bodies are situated at the network border or, in the worst case, are isolated. Consequently, a more sustained approach in favour of private enterprises could ensure a higher flow of private funds which, in addition to public ones, could determine multiplier effects on the environment and, thus, support the environmental transition. Moreover, results demonstrate the role of research institutions and universities especially in South-European countries (specifically Spain and Italy) who are relevant actors that spread and disseminate information within the network.

F4. Key finding on transnational cooperation in the sub-programme

R4. (in short). Spain and Italy report the highest number of financed projects in the eleven years considered and in 2014 and 2015, these two countries have benefitted from more than one-third of the total Programme budget. Transnational cooperation in the LIFE-ENV sub-programme is characterised by a different intensity of relations: some countries (i.e. Italy, Spain and Belgium) implement transnational cooperation with multiple European countries in both the North and South of Europe, while others tend to cluster with countries in the same geographical area, and lastly East European countries have limited participation in transnational cooperation.

Based on R4, it is possible to state that the LIFE-ENV sub-programme constitutes an important financing tool in many South-European countries that normally have limited national and regional funds for tackling environmental challenges (Eder and Kousis, 2001). It could be speculated that, in those countries, European funds would also determine additional positive effects such as improved European project design and management capacity.

Moreover, the centrality measures indicate that central actors from Southern Europe are fundamental to the LIFE-ENV sub-programme: if they do not take part in it, then the results in terms of collective actions for the environment would be substantially reduced also in terms of networking efficiency and effectiveness. By acknowledging the interdependence between South-European actors and the LIFE-ENV sub-programme, it is possible to state that LIFE is fundamental for the implementation of environmental actions in Mediterranean countries. But, *vice versa*, based on the actual environmental governance system, South-European actors are also central to the LIFE-ENV sub-programme and its efficient continuation. Without the Mediterranean actors with a high degree and betweenness centrality, LIFE-ENV would very likely be characterised by smaller project networks and, in the worst case, a separate group of projects limited to national boundaries. This configuration could lead to a substantial risk of less transnational cooperation on the environment, for which, at present, Mediterranean countries perform better in terms of collaborative and network governance as centrality measures attest, and a possible risk of uniformity in interests. If actors do not interact and share their knowledge beyond national borders, then the risk could emerge of a decreasing interest in collaborative joint actions for the environment. On the contrary, transnational cooperation can contribute to enhancing the level of project results and impacts, through the sharing of different beneficiaries' world vision, ways of life, shared values, and ways to deal with environmental problems based on different geographical contextual conditions. The importance of transnational cooperation in the Mediterranean basin has to be stressed, as it is one of the 35 biodiversity hotspots identified by Conservation International (https://www.conservation.org/How/Pages/Hotspots.aspx). At the same time, among all bioclimatic regions, the Mediterranean appears to be the most vulnerable to global change. Most of this vulnerability is associated to the general atmospheric circulation and the role of water as a limiting resource for Mediterranean ecosystems (Palahi et al., 2008).

Final remarks, study limitations and recommendations

As an additional observation with respect to the findings discussed above, it is worth mentioning that SNA, which is at the core of this study, has been demonstrated as a relevant tool for contributing to the analysis of intermediary organisations in the LIFE-ENV sub-programme. Nonetheless, some caveats and limitations should also be taken into account. First of all, the possibility to have access to specific information about every beneficiary involved in the LIFE programme is, at present, limited. In the LIFE programme database, the only information on recipients relates to the summary sheets. However, these sheets have some weaknesses and gaps, in particular related to the associated beneficiaries: there are often some uncertainties about their names, and there is a lack of information on their organisation type. Secondly, other essential information to be used in SNA, as an evaluation tool, is the amount of budget allocated to each beneficiary. Having information on the budget distribution would allow the network to be characterised also from a financial point of view. Moreover, having additional information on who the project co-financiers are as well as the supporting institutions or organisations would allow to both increase the level of transparency and better represent the network of actors involved in the LIFE-ENV sub-programme.

For this reason, on the one hand, this study lacks specification on co-financers and donors, therefore results do not refer to these actors and, as a consequence, have to be considered with caution; on the other hand, we recommend that information on budget distribution is made available for further and better exploring the effectiveness of large policy programmes like LIFE-ENV, which invest billions of euros in environment management projects with a limited transparency on financial resources allocation. Lastly, it was not possible to find any quantitative information on outcomes and impacts achieved by LIFE-ENV projects. This information would be essential in future research, in order to measure if CEG and specifically NG is really contributing, and how/to what extent, to an effective change in environmental problems of the EU, and how collaborations among organisations affect the environmental impacts achieved. Despite these gaps, results from the research can provide some preliminary but still promising inputs as well as research hypotheses for future developments. Future studies could build on these first findings and follow different but complementary research lines. For instance, they could investigate how environmental project outcomes are influenced by the composition of projects' partnerships, among other variables, and how Bayesian random graph models could be applied to the evaluation of the environmental project networks.

Supplementary Materials

The LIFE-ENV 2007-2017 dynamic and bipartite graph.

Source: own elaboration based on LIFE dataset

The video of the dynamic and bipartite network is available at http://dx.doi.org/10.17632/dpnd3tzhvr.1

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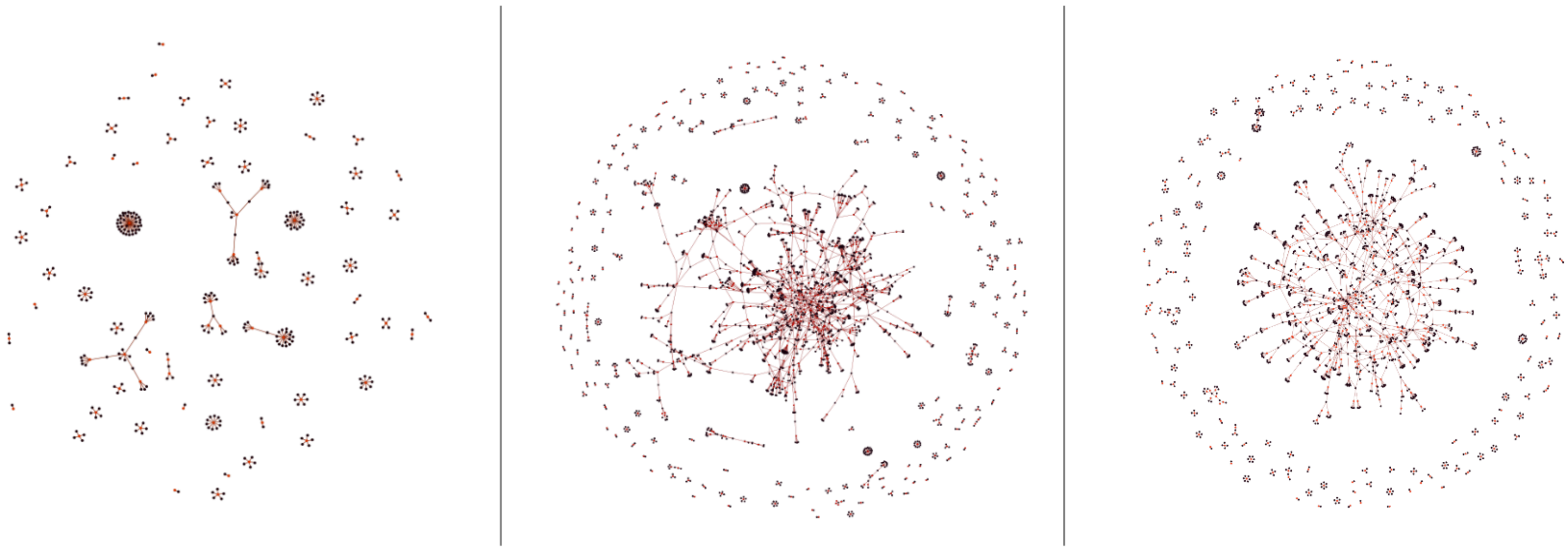
LIFE-ENV		*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Coordinating beneficiary	(C)	72	99	116	103	113	147	128	55	56	62	55
Associate beneficiary	(A)	286	301	402	319	345	424	385	212	228	249	212
Organisations	(C)+(A)	358	400	518	422	458	571	513	267	284	311	267
Projects	(P)	72	99	116	103	113	147	128	55	56	62	55
Nodes	(C)+(A)+(P)	430	499	634	525	571	718	641	322	340	373	322
Relations	Number	358	758	1276	1698	2147	2574	2725	2553	2388	2220	2004
Components	Number	61	100	128	150	177	195	200	186	178	153	151
Total Budget per year (EU28)	Thousand Euro	180369	334021	270102	265116	292670	304150	326759	121039	142177	139139	163442

Table 1: Descriptive statistics of the LIFE-ENV programme from 2007 to 2017

Source: our elaboration based on LIFE dataset



2007 2012 2017

Figure 1: Two-mode networks of the LIFE-ENV programme in 2007, 2012 and 2017
(Mode 1 – organisations in black colour; Mode 2 – projects in red colour)
Source: our elaboration based on LIFE dataset by using GEPHY

		Structure 1 Isolated coordinating beneficiaries		*Structure 2* Isolated components		*Structure 3* Small components		*Structure 4* Giant component		*Entire Network*		
		Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2	Total
2007	Number	10	10	245	45	87	17	0	0	342	72	414
2012	Number	50	50	463	120	171	68	1209	380	1064	1447	2511
2017	Number	28	28	404	104	153	48	973	266	1558	446	2004
2007	%	2.92	13.89	71.64	62.50	25.44	23.61	0.00	0.00	82.61	17.39	100.00
2012	%	4.70	3.46	43.52	8.29	16.07	4.70	35.71	83.55	42.37	57.63	100.00
2017	%	1.80	6.28	25.93	23.32	9.82	10.76	62.45	59.64	77.74	22.26	100.00

Table 2: Four structures of network components in the LIFE-ENV programme from 2007 to 2017

Source: our elaboration based on LIFE dataset

Relations	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
From 0 to 1	327	608	921	1132	1373	1567	1625	1562	1493	1411	1332
From 2 to 4	15	56	121	188	242	280	292	265	243	225	197
From 5 to 10	0	4	11	17	23	35	45	43	36	27	23
From 11 to 20	0	0	1	2	5	8	6	4	5	4	3
From 21 to 30	0	0	0	0	1	1	2	2	2	2	1
Total number of relations	358	758	1276	1698	2147	2574	2725	2553	2388	2220	2004
Bridging relations	15	60	133	207	271	324	345	314	286	258	224
Percentage of bridging relations over total relations	4.19%	7.92%	10.42%	12.19%	12.62%	12.59%	12.66%	12.30%	11.98%	11.62%	11.18%

Table 3: Relations in the LIFE-ENV programme from 2007 to 2017

Source: our elaboration based on LIFE dataset

		2007	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Existing relations:	Number	358	758	1276	1698	2147	2574	2725	2553	2388	2220	2004
(a) *Entering*	Number	358	400	518	422	458	571	513	267	284	311	267
(b) *Permanence*	Number	0	358	758	1276	1689	2003	2212	2286	2104	1909	1737
Ceasing relations	Number	0	0	0	0	9	144	362	439	449	479	483
Existing relations:	%	100	100	100	100	100	100	100	100	100	100	100
(a) *Entering*	%	100	53	41	25	21	22	19	10	12	14	13
(b) *Permanence*	%	0	47	59	75	79	78	81	90	88	86	87

Table 4: Existing and ceasing relations in the LIFE-ENV programme from 2007 to 2017

Source: our elaboration based on LIFE dataset

	2007/08	*2008/09*	*2009/10*	*2010/11*	*2011/12*	*2012/13*	*2013/14*	*2014/15*	*2015/16*	*2016/17*	*2017/18*
C→C	72	171	287	386	473	540	567	520	451	393	311
A→A	286	587	989	1303	1530	1672	1719	1584	1458	1344	1147
C→0	0	0	0	4	26	80	101	102	125	120	137
A→0	0	0	0	5	118	282	338	347	354	363	409
0→C	99	116	103	113	147	128	55	56	62	55	0
0→A	301	402	319	345	424	385	212	228	249	212	0
C→A	0	0	0	0	0	0	0	0	0	0	0
A→C	0	0	0	0	0	0	0	0	0	0	0
0→0	3611	3093	2671	2213	1651	1282	1377	1532	1670	1882	2365
Total organisations	4369	4369	4369	4369	4369	4369	4369	4369	4369	4369	4369

Table 5: Passages in role in the LIFE-ENV programme from 2007 to 2017

Source: our elaboration based on LIFE dataset

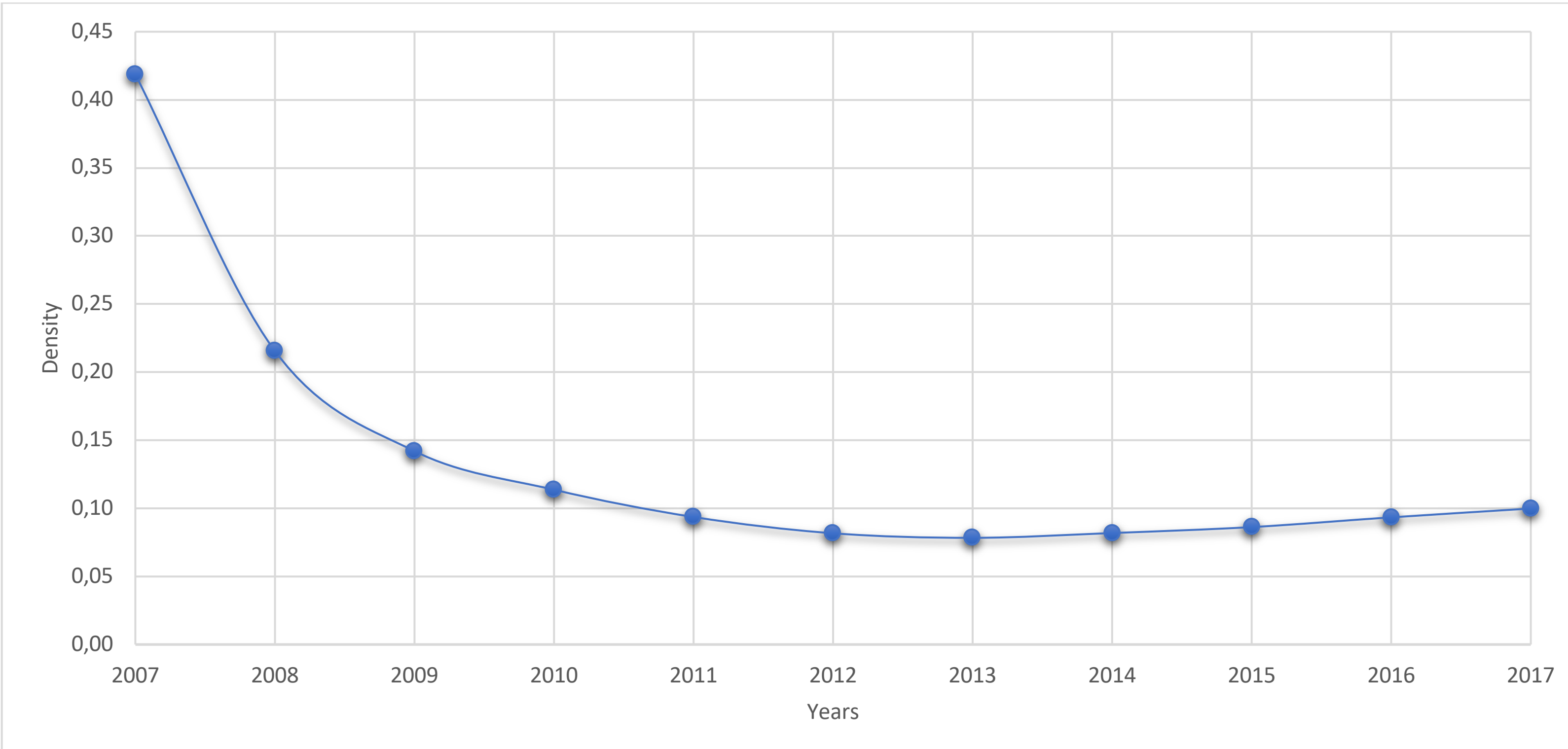


Figure 2: Density in the LIFE-ENV networks from 2007 to 2017

Source: our elaboration based on LIFE dataset

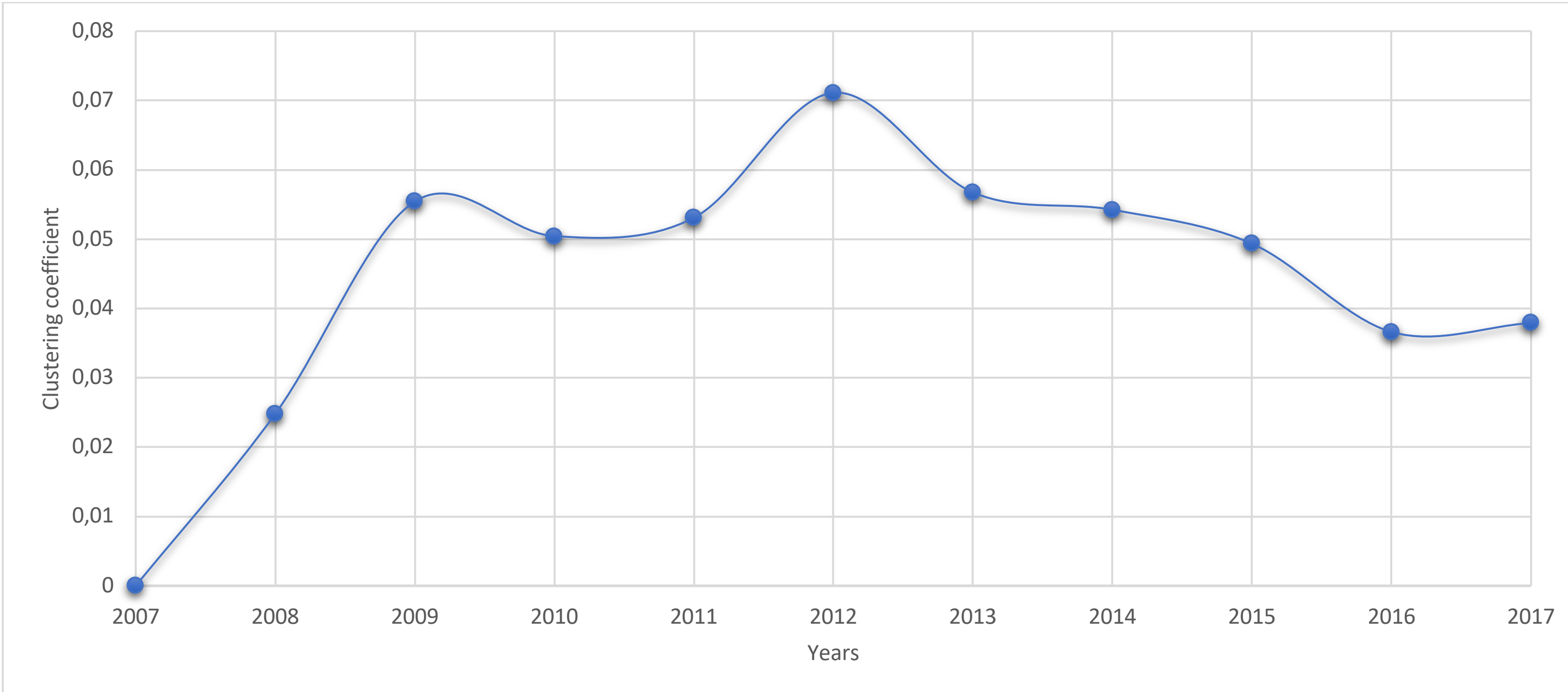


Figure 3: Clustering coefficient of the LIFE-ENV networks trend from 2007 to 2017

Source: our elaboration based on Tnet package (R software)

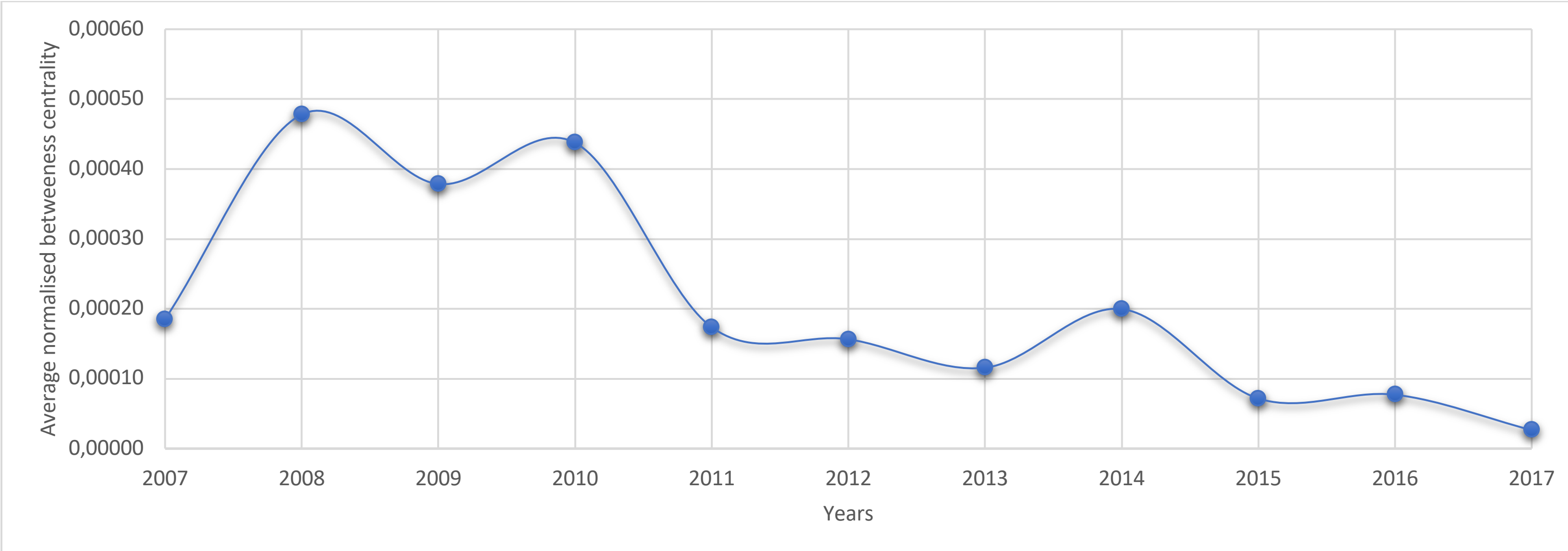


Figure 4: Average normalised betweenness centrality from 2007 to 2017

Source: our elaboration based on UCINET®

	2007	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Min	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Max	0.00569	0.01142	0.01283	0.01028	0.00888	0.01579	0.00579	0.01229	0.01096	0.00722	0.00219
Average	0.00095	0.00189	0.00139	0.00150	0.00057	0.00048	0.00034	0.00060	0.00022	0.00025	0.00009
Standard Deviation	0.00148	0.00281	0.00227	0.00201	0.00110	0.00137	0.00083	0.00144	0.00086	0.00074	0.00021
Organizations with a positive betweenness	73	169	287	390	498	619	665	620	575	511	448
Total organisations	342	668	1054	1339	1643	1891	1970	1876	1778	1668	1556
% of organisations with a positive betweenness	21.35	25.30	27.23	29.13	30.31	32.73	33.76	33.05	32.34	30.64	28.79

Table 6: Normalised average betweenness centrality in the LIFE-ENV programme from 2007 to 2017

Source: our elaboration based on LIFE dataset

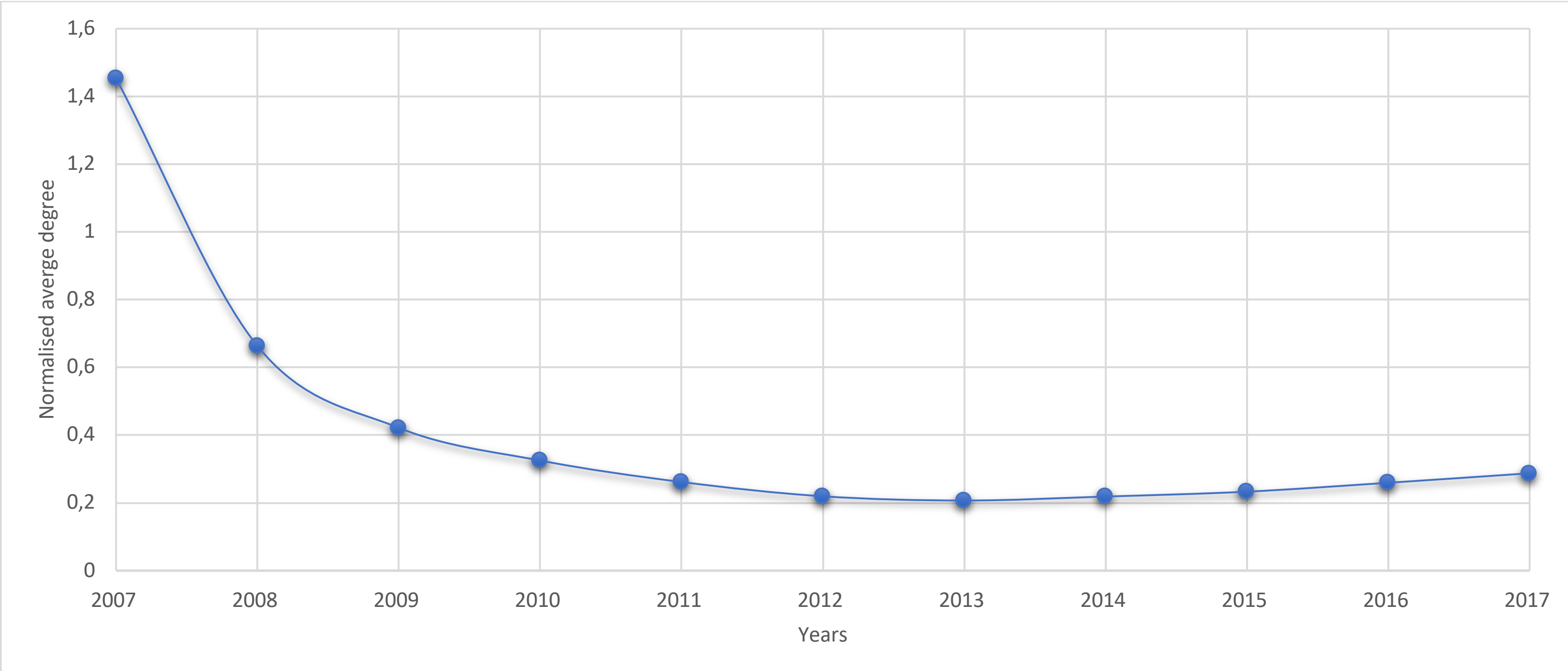


Figure 5: Normalised Average Degree from 2007 to 2017

Source: our elaboration based on UCINET®

	id	*Label*	*Country*	*Type*	*Betweenness*	*Degree*
2007	72	Regione Marche	Italy	Regional Authority	0.005693	0.013889
	23	University of Athens National Technical (NTUA)	Greece	University	0.005110	0.013889
	106	Centro Tecnológico del Mar. Fundación CETMAR	Spain	Foundation	0.004864	0.013889
	51	Coordinamento Agende 21 Locali Italiane	Italy	Foundation	0.004433	0.027778
	68	ARPA Emilia-Romagna	Italy	Regional Authority	0.004424	0.013889
2012	3754	Agrifood Research Finland MTT	Finland	Research Institute	0.015791	0.006452
	327	University of Torino	Italy	University	0.012031	0.008065
	3746	Vapo	Finland	International enterprise	0.011900	0.001613
	474	Hellenic Agricultural Organisation "DEMETER"	Greece	Research Institute	0.011539	0.008065
	23	University of Athens National Technical (NTUA)	Greece	University	0.010555	0.027419
2017	803	Politecnico di Milano	Italy	University	0.002193	0.008929
	805	University Cattolica del Sacro Cuore Milano	Italy	University	0.001751	0.006696
	958	Foundation CTM CENTRE TECNOLOGIC	Spain	Foundation	0.001665	0.013393
	526	AGC Glass Europe S.A.	Belgium	International enterprise	0.000999	0.004464
	918	Lyonnaise Des Eaux France	France	Large Enterprise	0.000946	0.006696

Table 7: LIFE-ENV programme (2007, 2012, 2017). Organisations with the five highest values in betweenness centrality measure

Source: our elaboration based on GEPHY

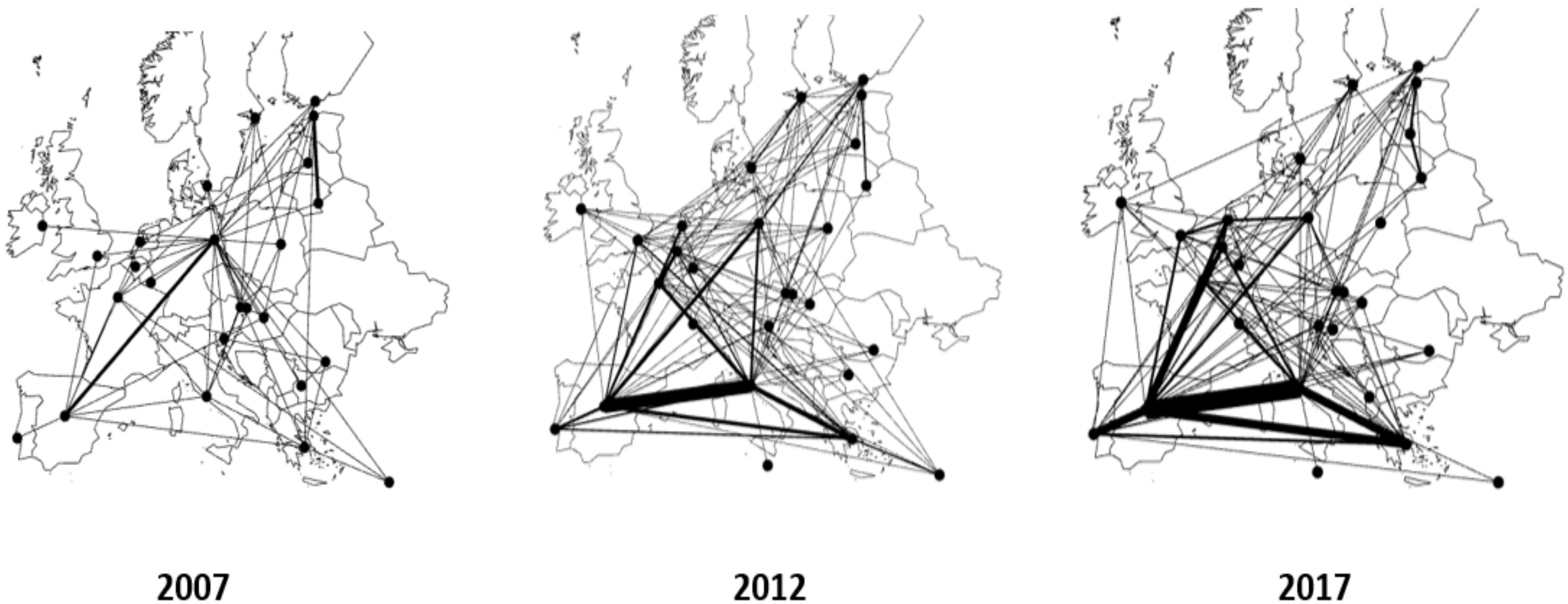


Figure 6: Geographical relations among LIFE-ENV projects (2007-2017)

Source: own elaboration based on GEPHY ® - Map of countries layout