Social Network Analysis Applied to Knowledge Creation and Transfer in the Portuguese Agricultural R&D Field: an exploratory study*

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Abstract: There is growing interest in the nature and scale of scientific collaboration regarding the processes involved with knowledge creation and sharing. One of the possible approaches to developing metrics for this area of research is based on the idea that co-authorship creates a social network of researchers.
We present an exploratory study using a social network approach to examine the structure and pattern of knowledge creation and sharing within a Portuguese research community, working in the agricultural field, over the last seven years. The members of this community are with the Instituto Nacional da Investigação Agrária (INIA) which recently became part of a newly created R&D State Laboratory, Instituto Nacional dos Recursos Biológicos (INRB), under the umbrella of the Portuguese Ministry of Agriculture Rural Development and Fisheries.
The social network analysis used data from an information system containing the results from all the scientific activities developed in the last seven years by the research community working in INIA. The information system was the major result of AGRO 444 - Development of an Information System for Knowledge and Innovation Discovery and Diffusion in the Agro-Rural Sector, a project funded by Measure 8.1 of Programa AGRO, one of the policy instruments of "3º Quadro Comunitário de Apoio" (Third European Framework Aid to Portugal, 2000-2006).
From this data, a knowledge network was developed based on co-authorship patterns extracted from the information system, covering the period 2000-2006. This knowledge network supported the analysis of specific paths through which knowledge sharing occurred and by which knowledge capital was nurtured within the agricultural R&D activities of this institution.
The present exploratory study is concerned with the creation and evolution of the network at the biggest research unit within INIA, the Estação Agronómica Nacional (EAN). Here, there are over 140 actors developing research activities in the following sub-domains: natural resources and environment; crops protection; eco-physiology, genetic resources and breeding; production technology; post-harvest technology; and agricultural economics, sociology and development.
The study seeks to understand the evolutionary process and to analyse the network structure, showing how knowledge creation and transfer takes place within this unit. The identification of such networked co-authorship relationships may suggest ways to more effectively utilize knowledge capital and other resources. It is also expected that this approach could be used to analyse the remaining six INIA units.

Keywords: Knowledge creation, Knowledge sharing, Portugal, Agriculture R&D, Social Network Analysis.

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1. INTRODUCTION

Using a social network approach, this study examines the structure and pattern of knowledge creation and sharing among the Portuguese research community working in the agricultural field, within INIA - Instituto Nacional da Investigação Agrária, over the last seven years. INIA which recently became part of a newly created R&D State Laboratory INRB (Instituto Nacional dos Recursos Biológicos), within the umbrella of the Portuguese Ministry of Agriculture Rural Development and Fisheries, is responsible for conducting all public research activities in the agro-rural, fisheries and animal domains and has as its mission the execution of the necessary research, trials and demonstration actions to reinforce agriculture, animal and forest production chains, including any which lead to better production practices and vegetal and animal genetic heritage protection, as well as providing technical and scientific support to the agro-rural sector.

This community, through the research activities undertaken, built a knowledge network based on co-authorship patterns extracted from the information system developed over the period 2000-2006, within the framework of the AGRO 444 project detailed below. This knowledge network supported the analysis of specific paths through which knowledge sharing has occurred and by which knowledge capital has been nurtured within the agricultural R&D activities of this institution.

The present exploratory study is concerned with the creation and evolution of the network at the biggest research unit within INIA, Estação Agronómica Nacional (EAN); here, there are over 140 “active” people developing research activities in the following sub-domains:

- natural resources and environment;
- crops protection;
- eco-physiology, genetic resources and breeding;
- production technology;
- post-harvest technology;
- agricultural economics, sociology and development.

The study seeks to create a comprehensive network structure showing how knowledge creation and sharing is effected within this unit; it is also foreseen that this approach could be used to analyze the remaining six INIAP units. The identification of such network co-authorship relationships may suggest ways to more effectively utilize knowledge capital and other resources.

2. Social Network Analysis

Social Network Analysis (SNA) is a methodology finding ever increasing applications outside the social sciences; to date, it has been applied to areas as diverse as health, psychology, business organization and electronic communication. Its use in the rural field is relatively recent (Clark 2006).

Information and intellectual capital stocks are some of the most important resources that flow through the networks of research communities; in this context SNA is often applied to identify both information flows and bottlenecks. In theory, it should help to identify strategies that encourage participating actors to share knowledge through the improvement of information flows in the existing social system rather then seeking to create new ones. One of the possible approaches to study the social networks existing in a research community is to use the co-authorship relationships that community members develop over time (Hara et al. 2003). Social network studies usually take one of two approaches (Clark 2006): the first with a closed group, for example, to look at the relationships among people working in an institution, whereas

the other focuses on one person and seeks to understand their *egonet* (self centered) social relationships surrounding them.

The existence of informal social networks within organizations has long been recognized as important and the unique working relationships among scientific and technical personnel have been well documented by both academics and practitioners. The growing interest in knowledge sharing methods led to increased attention being paid to SNA as a tool for mapping the nature and membership of informal networks. However, despite the knowledge-intensive nature of R&D activities, social network analysis of the R&D function remains relatively rare (Allen et al., 2007); these authors went on to describe the nature of informal problem-solving networks within R&D and demonstrated how these compare and contrast with equivalent formal organizational structures.

Managerial social network studies have sought to establish the extent of these informal networks within organizations and assess how the informal organization compares with the formal structures prescribed by management (Cross et al. 2001, 2002a, b; Cross and Parker 2004). Critically, they observe that the patterns of collaboration and communication revealed in informal networks are significantly different from the formal organizational structures implemented by managers. Thus, formal organizational structures fail to reflect accurately the true nature of social relationships and the dynamics and dependencies between staff, which can compromise efficient knowledge exchange within the organization.

Despite a general consensus on the important role played by social capital (Napiet and Goshal 1998) in an individual's success or organizational performance, there are two schools of thought regarding the mechanisms by which social capital is created and mobilized (Who et al. 2006). The *network closure* view maintains that social capital is created by a network of strongly interconnected relationships, whereas the *structural hole* theory posits that social capital is produced through a loosely coupled network in which actors can broker connections between otherwise disconnected segments. According to these authors, these two perspectives offer drastically different prescriptions for developing and maintaining social capital.

In fact in recent decades there has been a growing interest in the nature and scale of scientific collaboration and studies into co-authorship have taken two different approaches (Acedo et al. 2006). The first attempts to analyze the reasons why authors collaborate and the consequences of such a decision. The second approach is based on the idea that co-authorship creates a social network of researchers. In this paper we will carry out an exploratory analysis of co-authorships in the Portuguese Agricultural R&D field, following the second approach.

Social network analysis brings two important perspectives to the study of co-authorship (Acedo et al. 2006). The first is a description of the process by which scientific collaboration takes place, including the structural patterns that occur among scientists at the time of publishing the results of their investigations (Newman 2001) or in the process of these collaborations (Barabási et al. 2002). The second is an examination of the community of scientists as a social network of individual actors in which each person occupies a distinctive position that allows him or her to benefit from various opportunities. The patterns of these relationships reflect an underlying social structure that affects production processes and the diffusion of knowledge (Piette and Ross 1992).

3. Project agro 444 framework

AGRO 444 - Development of an Information System for Knowledge and Innovation Discovery and Diffusion in the Agro-Rural Sector was a project funded by Programa AGRO Medida 8.1 which lasted for three years and finished in December 2007.

The project aim was to develop an information system for knowledge sharing and innovation diffusion in the agro-rural sector, supported by Internet related technologies.

The main goal was the information system development, implementation and demonstration which would act as an interface between the producers and users of technical and scientific information, innovative technologies and decision support tools related with agricultural activities and the rural environment. We concentrated on the efficiency of the scientific research and rural development programs undertaken by INIAP - Instituto Nacional de Investigação Agrária e das Pescas, or other national programs planned and executed with its technical participation, as a first stage and on the remaining national community, involved in R&D in this sector, as a second stage.

The information system was made available through a Web interface which acted as a single access point to the R&D community in the Portuguese agro-rural sector. The system is supported by innovative information and communication technologies, mainly Internet-based, integrating an information repository stored in a relational database developed specifically for that purpose and a digital format document repository.

This project connected three partners with distinct and complementary characteristics and functions:

- ISA - Instituto Superior de Agronomia, (a Higher Education Institute within the Technical University of Lisbon), which had experience in information management and information systems development, supported by innovative information and communication technologies - project coordinatinator;
- INIAP - Instituto Nacional de Investigação Agrária e das Pescas, through the participation of all operational units belonging to INIA, assuring the initial existence of an extremely rich and diversified information repository, covering almost all the agro-rural world's scientific areas;
- Secretaria-Geral do Ministério da Agricultura do Desenvolvimento Rural e das Pescas (Ministry of Agriculture, Rural Development and Fisheries), through its Centro de Formação e Produção de Audio-Visuais.

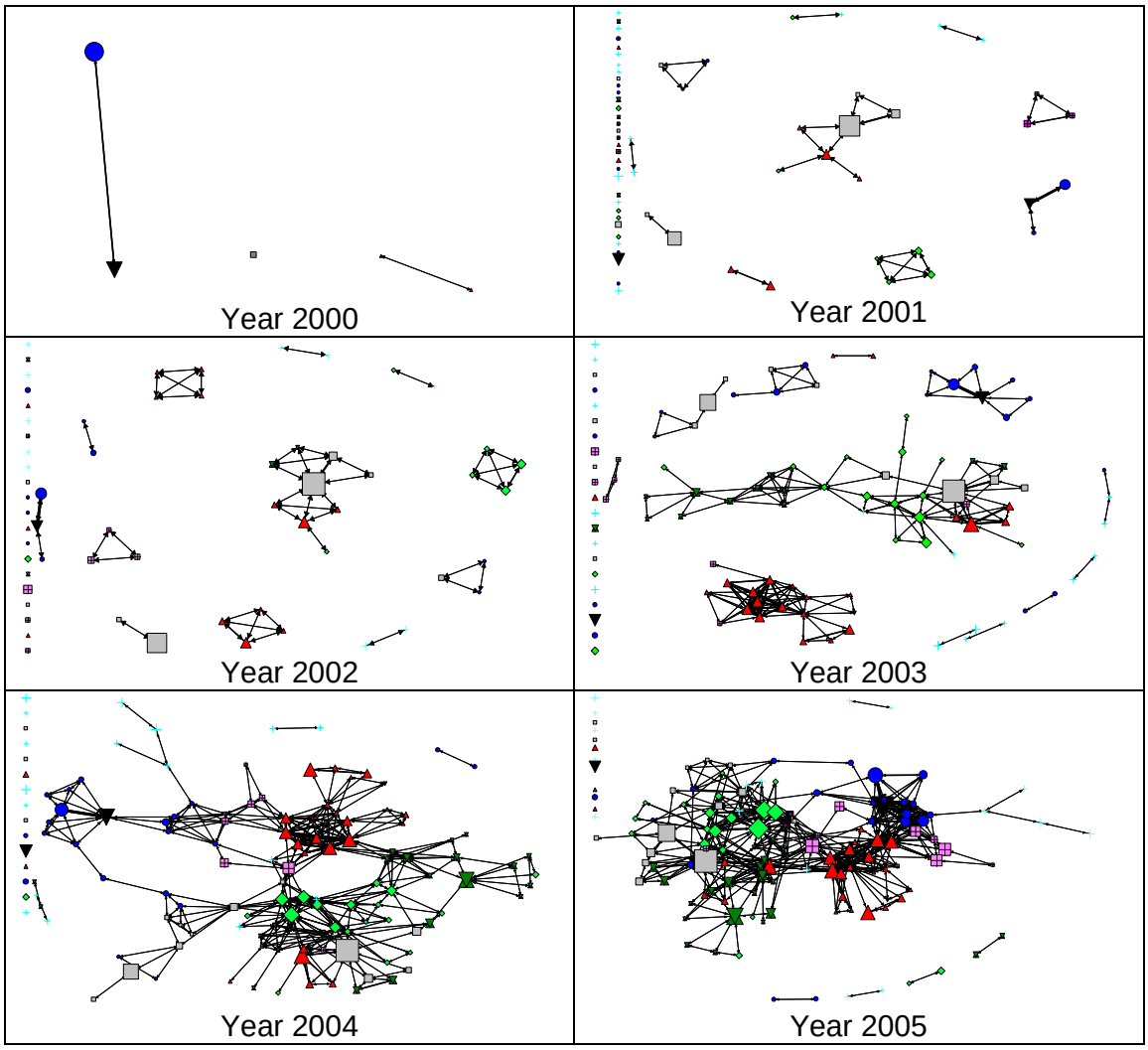
4. The Information System to Promote Knowledge Sharing

The information system was supported by a relational database where, among other information, all the R&D results obtained by INIAP researchers in the last seven years were stored. This was the most important AGRO 444 deliverable and set the foundations for the social network analysis presented in this paper. This system supported the collection, storage and delivery of a wide and diversified amount of information within the Portuguese agricultural R&D sector. Among the different types (entities) of information stored within the context of INIAP were data about the organization, human resources, research projects undertaken, research project results obtained, institution cooperation relationships established, laws and regulations relevant to the sector, training activities offered, news, etc.

For the results of R&D activities undertaken by INIAP research community and used in the work described in this paper, the repository stored information covering the following metadata for each result: title, bibliographic record, date, type, scientific area, author(s). Through the field “author(s)” it is possible to ascertain and to quantify the co-authorship relationships and their unit(s), making it possible to build the relationship matrix for the social network analysis approach described above.

5. Social Network Analysis Application to Estação Agronómica Nacional

Supported by this information system, it was possible to make an exploratory study and to perform a social network analysis of the co-authorship relationships, for the last seven years, within the research community of INIA’s biggest unit, the Estação Agronómica Nacional (EAN).



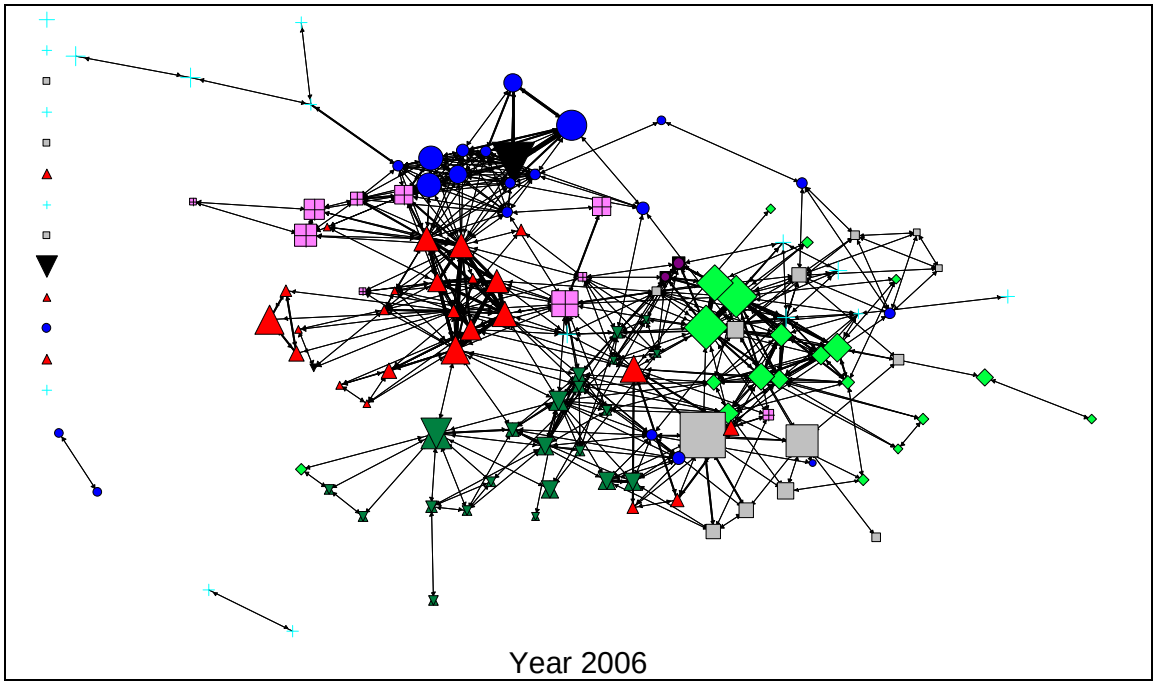


Figure 1: EAN research community co-authorship social network evolution over time

Figure 1 graphically illustrates the evolution of the social network in terms of actors, the relations they have established and their strength. The nodes represent the social network actors, in this case the EAN research community. The size of the nodes indicates the number of research results and the lines the co-authorship relationships, with the line size indicating the strength of the tie; the latter being the number of co-authorships two connected nodes share. In order to facilitate the comparison between years, the colors and shapes remain unchanged over time, meaning for instance that the Plant Protection Unit is always a blue circle. The social networks maps were obtained by using NetDraw (Borgatti 2002), a free software tool used to visualize social networks.

Since the data collection process took place within the last two years, there may be some bias due to the fact that the process only received input from those researchers active over this period.

Analysing the last year's network data in terms of some *centrality* measures we can achieve a better insight into how the network nodes relate with each other. In the following figures we present network node information in terms of centrality measures. Centrality is a structural attribute of nodes in a network and is a measure of the contribution of network position to the importance, influence or prominence of an actor in a network. Centrality translates the extent to which an actor (in this case the researcher) occupies a central position in the network in one of the following ways (Kilduff and Tsai 2003):

- having many ties to other actors - degree of centrality;
- being able to reach many other actors - closeness centrality;
- connecting other actors who have no direct connections - *betweenness centrality*;
- or having connections to centrally located actors - *eigenvector centrality*

In figure 2, we present the year 2006 EAN research community co-authorship social network with the node size and label reflecting the *degree of centrality*, a measure defined as the number of links incident upon a node which can be interpreted as the extent to which a given actor has direct ties to numerous other network actors.

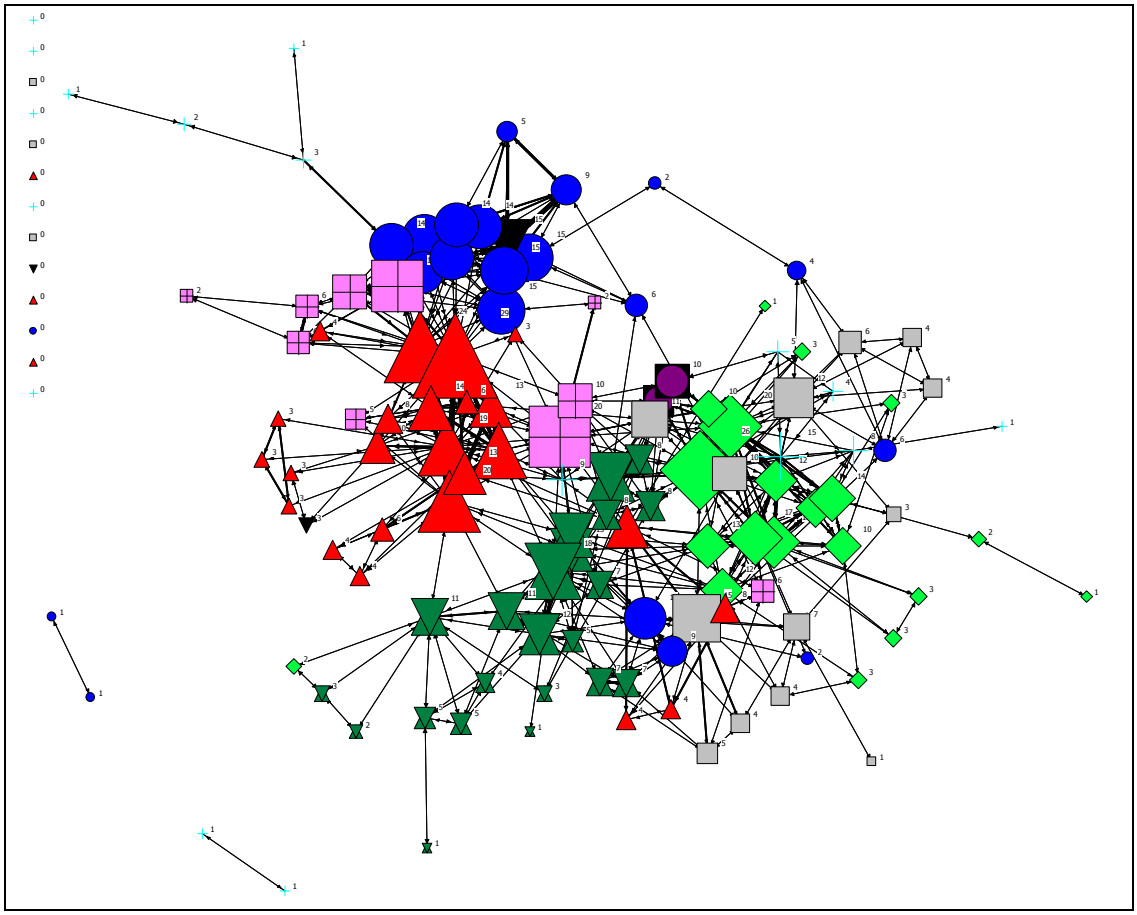


Figure 2: 2006 EAN research community co-authorship social network degree of *centrality*

In figure 3 we can see the same research community co-authorship social network but in this case the nodes size and label reflect the *betweenness* which is seen as the number of geodesic paths that pass through a node, expressed as a measure of centrality. This is the extent to which an actor is positioned to mediate the connection of numerous other actors, or the number of "times" that other nodes use this node to contact other nodes, by the shortest possible route.

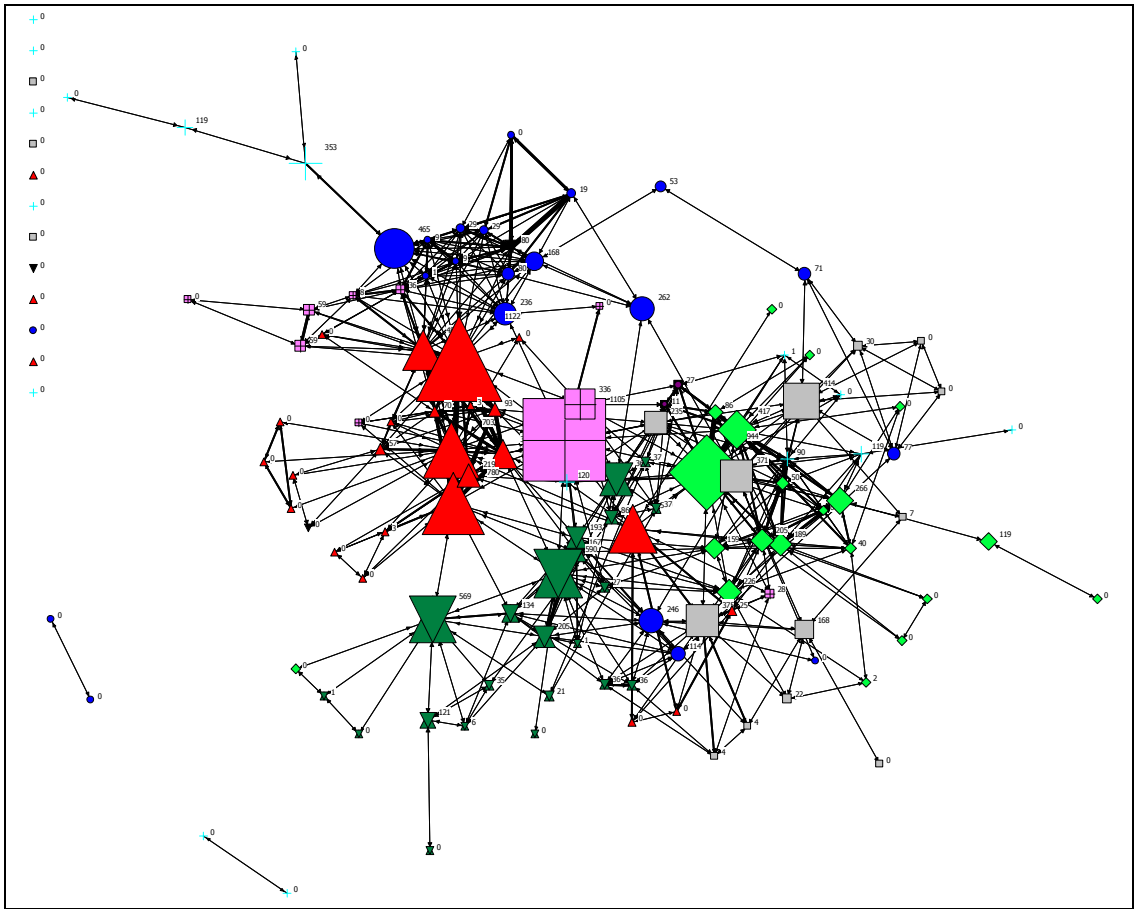


Figure 3: 2006 EAN research community co-authorship social network *betweenness*

6. Conclusion

It is our intention to carry on this exploratory work, applying this analysis methodology to the remaining INIA units, so that the insights offered by social network analysis can be useful for this R&D State Laboratory management.

The continuation of this analysis will provide a deeper knowledge on how the network evolves over time, how different it is from the formal hierarchical structure and identifying the actors with the most significant connections. Perhaps, more importantly, it could also highlight those in danger of becoming isolated from the network. For example, see the left bottom corner of Figure 1 – Year 2002 where a Genetic Resources and Breeding Unit member, although responsible for a significant number of results, has almost no ties with other nodes of the network.

In future, we intend to empirically identify the amount of knowledge capital embedded in the network of individual researchers and explore its influence on the Institution and the way research collaboration evolves across subject areas and/or the formal institutional structure.

Another aspect to be researched is the role that research projects have in social network construction and how public funding policies affect this process.

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