2020 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM)

Dynamics of the international environmental treaties - perspectives for future cooperation

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***Abstract* - International treaties and multilateral agreements are undoubtedly based on networks, which, considering the magnitude of the environmental issues or resources conflicts that we are facing, become complex networks. Implementing a strategy that easily integrates all these problems is particularly difficult to develop or apply, and the disengagement has no way to help. To achieve successful environmental governance is only possible with the involvement of all parties or stakeholders. This paper illustrates the evolution of the cooperation network established between the international parties that ratified the most important environmental treaties at international level discussing transboundary issues. By applying a network analysis perspective, we explore the dynamics of the cooperation considering 3-time intervals, namely: collaboration for the implementation of the treaties before 1990 (1), before 2000 (2), and before 2020 (i.e., the cooperation established so far within the most common environmental agreements). We further examine the network structure by investigating the core-periphery model, which shows the current situation in terms of level of involvement in the ratification and application of the principles of the international environmental treaties established. Our findings suggest that a complex and more functional system is needed to manage both common biodiversity resources and solve existing transboundary environmental conflicts.**

Keywords—Environmental treaties, core, periphery, cooperation, fragmentation

I. INTRODUCTION

Improving the quality of the environment and preserving natural resources for future generations has been a priority subject of national policies in the last centuries. Cooperation between states started in the 1800s with a bilateral environmental agreement between Austria and Switzerland [1, 2].

From then on, international environmental agreements have become an increasingly frequent solution to solve stringent transboundary environmental problems that required urgent action and collective environmental governance [3]. The large number of such multinational agreements is a result of a more cooperative world and the severity of environmental issues and the increasingly degraded environment worldwide [1].

These treaties have helped reduce several environmental issues, but because the demand for resources is soaring, our society still faces stringent global environmental problems such as climate changes, land-use change, species extinction, excessive pollution, and massive deforestation [4]. Over the last decade, scientific research shows that the optimal solution for better environmental governance and management relies on collaboration between institutions and stakeholders at multiple scales, from local to regional, national and international [5, 6]. Nevertheless, research articles are paying particular attention to the socio-ecological perspective and the collaboration patterns to implement good practices in environmental issues [7].

Social network analysis represents a well-developed research field and uses network theory to analyze the (random or not) relationships between nodes or vertices [8]. These types of analyses have been used in a wide range of disciplines, including the investigation of networks involved in environmental conservation and management [9-11].

Environmental treaties are arenas of collaboration between states, the latter sending and receiving information or, respectively, jointly carrying out activities with a common purpose. This is the way most of the international protocols or treaties can be seen as: "communities" [12] with the same goal or as networks, considering that they can be defined as: "*a combination of two or more actors that repeatedly interact, exchange relations, and resolve disputes between actors*" [1, 13].

Furthermore, these types of research perspectives contribute to the analysis of collaboration for complex structures in order to approach or define influence in a network setting [14]. Thus, the investigation of the treaties cooperation can lead to finding out some structural features that can offer advice for improvement and, respectively, ways to overcome existing barriers in effective environmental management and collaborative impact minimization [3]. However, the gap between the legislative and implementation part of the environmental treaties is being discussed as the main cause of

This research was supported by a grant of the Romanian National Authority for Scientific Research (https ://uefiscdi.gov.ro), PN-III-P1-1.1-TE-2019-1039.

IEEE/ACM ASONAM 2020, December 7-10, 2020
978-1-7281-1056-1/20/$31.00 © 2020 IEEE

the environmental problems that society is currently experiencing [15].

Many important questions remain unexplored regarding the collaboration patterns established for solving environmental issues, and a more in-depth structural analysis of the network created around the states involved in promoting and implementing environmental legislative landmarks imposed by the United Nations protocols along with an analysis of the dynamics of these coalitions in the last 30 years is imperative.

In this study, we use a network-based framework to: a) investigate the dynamics of most popular and important international environmental treaties; b) analyze the structural patterns of the cooperation network in order to identify key promoters of worldwide cooperation, most collaborative countries and most important environmental problems tackled by international agreements.

II. METHODS AND DATA COLLECTION

To analyse the network created around the most popular and important environmental treaties, we extracted the name of the environmental treaty, signatory parties and the year of ratification for each signatory country, year of adoption and main environmental issues tackled from United Nations Treaty (available online at https://treaties.un.org/, accessed on 1st of August 2020, Table I).

TABLE I. LIST OF ANALYZED MULTILATERAL TREATIES

Name of the multilateral treaty	Place, date	ID
1. Convention on Long-Range Transboundary Air Pollution	Geneva, 13 November 1979	1
2. Vienna Convention for the Protection of the Ozone Layer	Vienna, 22 March 1985	2
3. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	Basel, 22 March 1989	3
4. Convention on Environmental Impact Assessment in a Transboundary Context	Espoo, Finland, 25 February 1991	4
5. Convention on the Protection and Use of Transboundary Watercourses and International Lakes	Helsinki, 17 March 1992	5
6. Convention on the Transboundary Effects of Industrial Accidents	Helsinki, 17 March 1992	6
7. United Nations Framework Convention on Climate Change	New York, 9 May 1992	7
8. Convention on Biological Diversity	Rio de Janeiro, 5 June 1992	8
9. Agreement on the Conservation of Small Cetaceans of the Baltic North-East Atlantic, Irish and North Seas"	New York, 17 March 1992	9
10. United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa	Paris, 14 October 1994	10
11. Lusaka Agreement on Co-operative Enforcement Operations Directed at Illegal Trade in Wild Fauna and Flora	Lusaka, 8 September 1994	11
12. Convention on the Law of the Non-Navigational Uses of International Watercourses	New York, 21 May 1997	12
13. Convention on Access to Information, Public Participation in Decision-Making & Access to Justice in Environmental Matters	Aarhus, Denmark, 25 June 1998	13
14. Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals & Pesticides in International Trade	Rotterdam, 10 September 1998	14
15. Stockholm Convention on Persistent Organic Pollutants	Stockholm, 22 May 2001	15
16. Protocol on Civil Liability and Compensation for Damage Caused by the Transboundary Effects of Industrial Accidents on Transboundary Waters to the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes and to the 1992 Convention on the Transboundary Effects of Industrial Accidents	Kiev, 21 May 2003	16
17. Minamata Convention on Mercury	Kumamoto, 10 October 2013	17
18. Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean	Escazú, 4 March 2018	18

In our analysis, we considered as popular and important environmental treaties which are under Collection Chapter XXVII: Environment, and we envisage the parties for network identification and characterization.

Using environmental treaties data, we created a two-mode network [16, 17], containing multilateral treaties (i.e., first set of nodes – which can be consulted in Table I) and the parties that ratified them (i.e., countries – the second set of nodes). To illustrate the level of involvement and interest, we also added as attributes the date of ratification for each state. To investigate the dynamics of cooperation in this field, we use the timeline information to investigate the structure of the subgraphs in the following periods: before 1990, before 2000, and before 2020.

Through the present network analysis perspective, we investigate concepts and perform analyses, such as fragmentation or cohesion of the network, two-mode categorial core/periphery model and centrality of actors (i.e., degree and eigenvector centrality) [18]. We calculate these metrics in order to identify the intensities or strengths on the one hand and to pursue potential opportunities for information exchange [19].

Table II contains the definitions of these concepts according to the field's scientific literature [20, 21]. The network matrix and subgraphs were analyzed using UCINET software [21], while the resulted graphs were performed by using software such as Netdraw [22] and Vosviewer [23].

TABLE II. NETWORK ANALYSIS CONCEPTS AND ANALYSES PERFORMED

Concept / analysis	Definition & Interpretation
Cohesion of the network	The analysis provides information on the Density, Average Distance, Diameter, Fragmentation [20, 21]
Categorial core-periphery model	Simultaneously fits a core/periphery model to the data network, and identifies which actors belong in the core and which belong in the periphery. [20, 21] $\rho = \sum_{i,j} a_{ij}\delta_{ij}$ $\delta_{ij} = \begin{cases} 1 \text{ if } c_i = \text{CORE or } c_j = \text{CORE} \\ 0 \text{ otherwise} \end{cases}$ [24]
Centrality of the network	Any two-mode network can be represented as a bipartite graph and this can be submitted to the standard single mode centrality routines. [20, 21]

To sum up, this study investigates the structure of the networks created over time and tries to determine the most important promotors of environmental principles and the treaties that gather the largest number of actors, determining the most widespread environmental problems at the international level. The innovative thing that this approach brings is given by the fact that using network analysis in analyzing the collaboration aimed at protecting the environment and minimizing the environmental impact. Thus, we can find results that can indicate network leaders and hidden links that can be useful in creating future collaborations and partnerships. The methodological flowchart and main results are presented in Fig. 1.

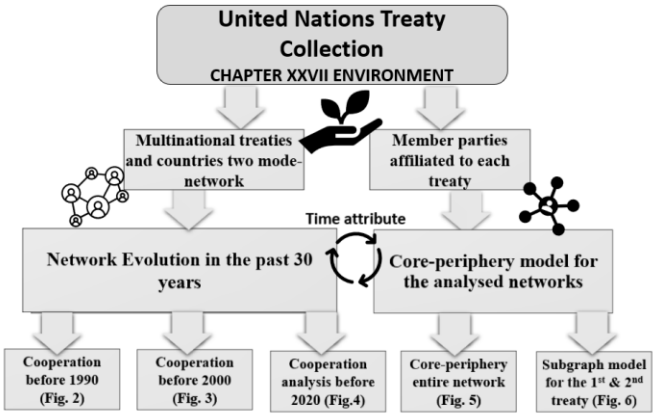

Fig. 1. Methodology and main results of the analyses.

III. RESULTS

Our results show the evolution of the parties linked to the existing treaty from the investigated list. First, it can be observed that before 1990 only 3 treaties (i.e. 1. Convention on Long-Range Transboundary Air Pollution and 2. Vienna Convention for the Protection of the Ozone Layer Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal – see Table 1, Figure 2) atrracted a significant number of states, the density of the network increasing between 1990 and 2000 (Figure 3) and is completed by 2020 (Figure 4), reaching 195 independent countries/states/regions involved, taking into account the fact that the number of agreements has increased during the analysed period. These results draw attention to the fact that there is an urgent need to work together for the sustainability of the planet, well known fact. In particular, the following agreements Vienna Convention for the Protection of the Ozone Layer, United Nations Framework Convention on Climate Change, Convention on Biological Diversity and United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (nodes number 2, 7, 8, and 10 in Figs. 2-4) in the network are evident, these having the largest number of signatory states. Among the countries with high centrality, we mention Denmark, Finland, Sweden, the United Kingdom (degree centrality - 0.889, eigenvector scores - 0.087), followed by France, Germany, Greece, Hungary, Netherlands, Norway, Portugal, Belgium, Poland (degree centrality - 0.833, eigenvector scores - 0.085). As shown in Figs. 2-4 and in the centrality results, most of the European countries are at the top of the ranking.

We then obtained a model with a starting fitness of 0.925 for the Categorical Core-periphery analysis and a final fitness of 0.867, showing a close to excellent fit for the entire analysed network. The block matrix resulted from the core-periphery model performed for the network of all analysed treaties, showed a "core" containing 99 out of 195 states, while the rest are part of the periphery (Fig. 5). As many studies highlight the general features of core-periphery complex network structures [25], our results could characterize partner signatory states as more efficient countries but with lower dynamics and variability (core), or as non-central states sparsely connected, which are linked to the core actors [25]. The rest of the states are grouped into a peripheral group, being part of fewer treaties and having fewer environmental agreements in common. Since a perfect core-periphery model for the 1,1 block should have a density of 1, and for the 2,2 block should have a density of zero, our results (Table III) show a significant core-periphery model. The density matrix also reveals that core parties cooperate more with states from the periphery, while the latter only interact to some degree with core countries. An interesting result is highlighted by the high level of cooperation established between the core parties (see Table III).

TABLE III. CORE-PERIPHERY DENSITY MATRIX

Density	1- Core	2- Periphery
1- Core	0.964	0.224
2- Periphery	0.911	0.102

A notable result is presented in Fig. 4, which highlights the fact that the collaboration network established around Treaties no. 1 and 2 before 2020 gathers most countries that cooperate in all international treaties. This fact demonstrates that the Transboundary Air Pollution and Protection of the Ozone layer discusses issues that date before 1990 and continue to be relevant in the current climate change context.

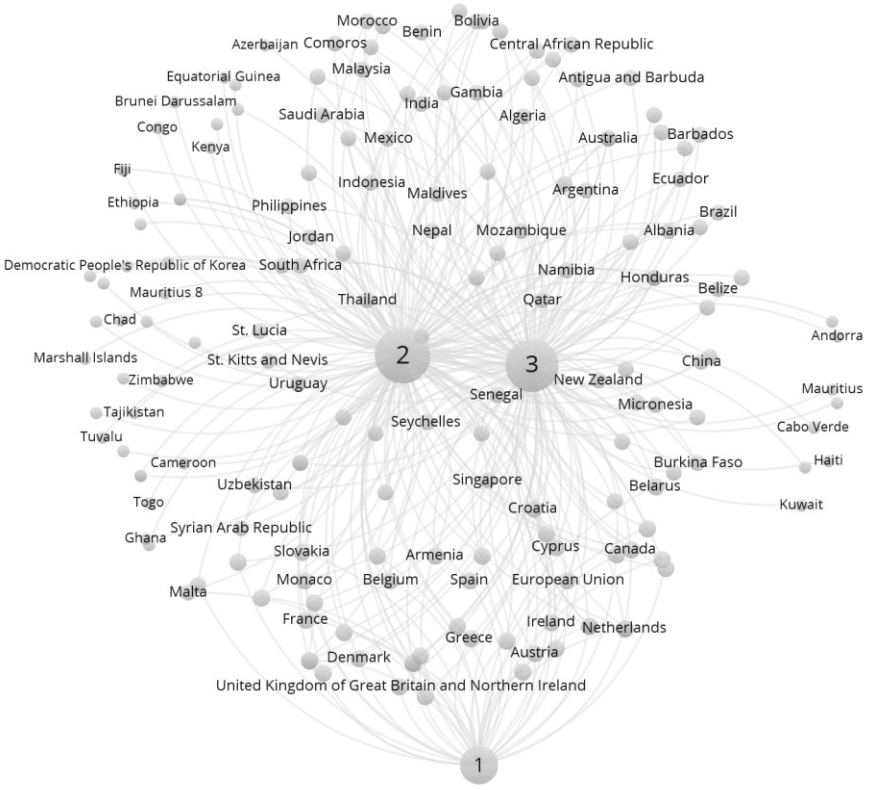

Fig. 2. Network Cooperation before 1990 (size of treaties given by degree centrality scores).

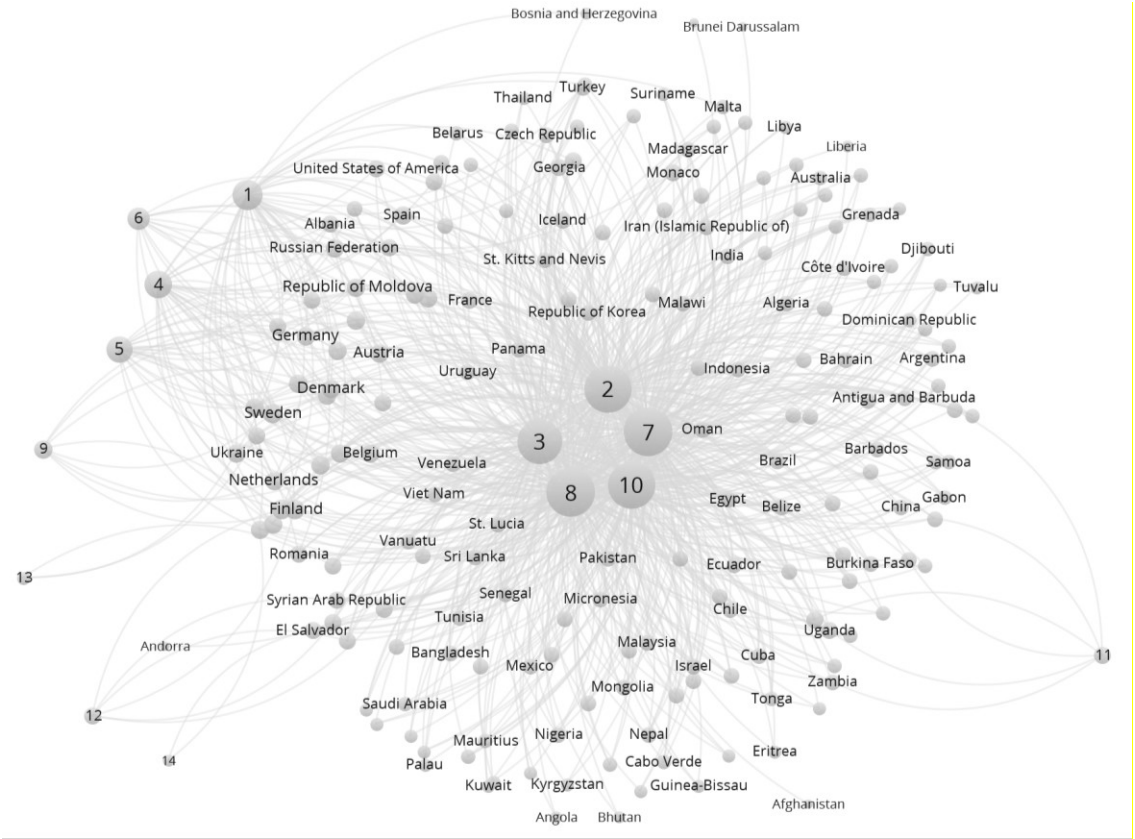

Fig. 3. Network cooperation before 2000 (size of treaties given by degree centrality scores).

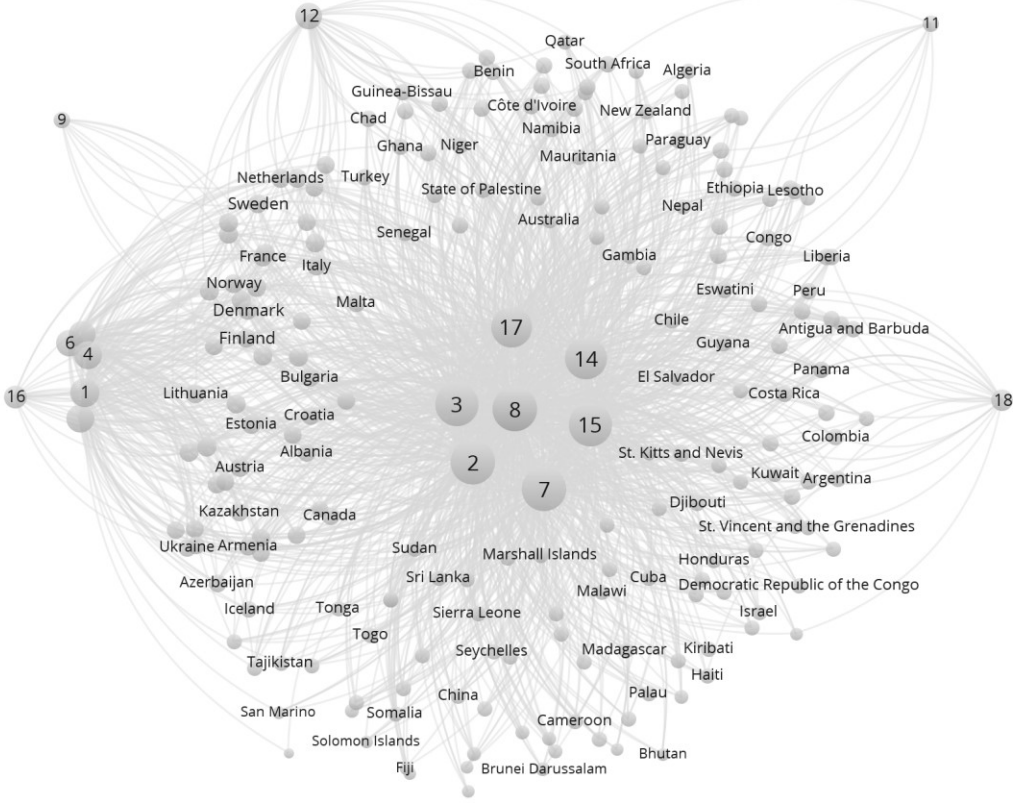

Fig. 4. Network cooperation in the past 30 years (before 2020) (size of treaties given by degree centrality scores).

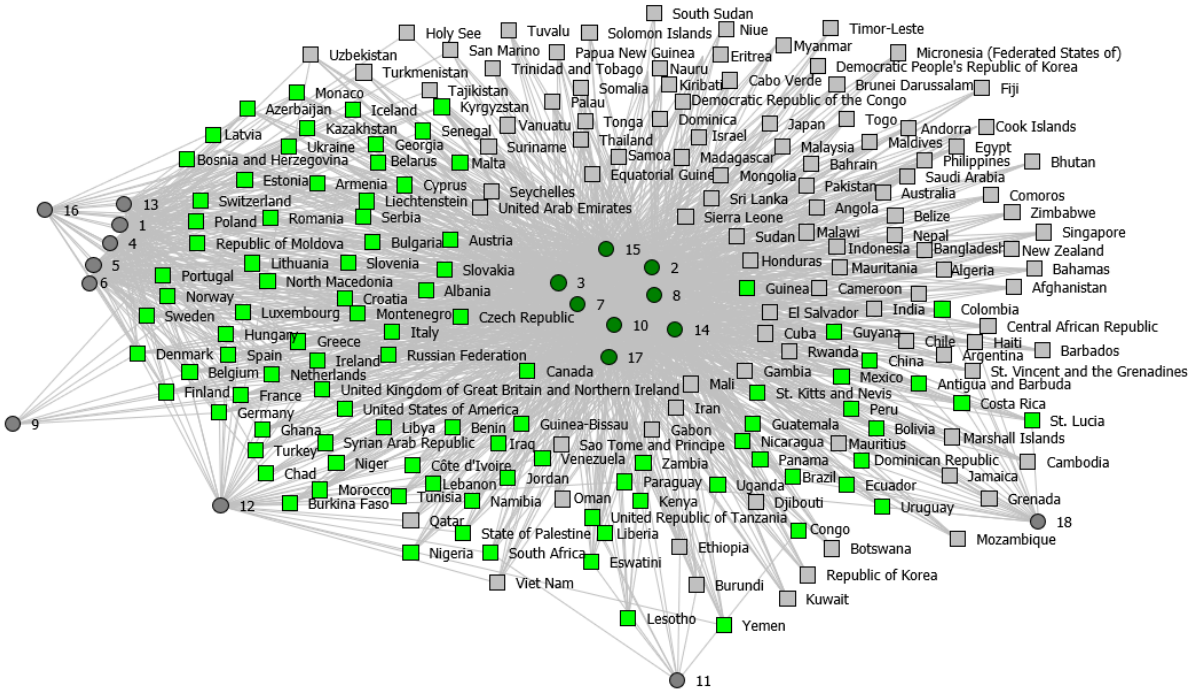

Fig. 5. Core-periphery model for the analyzed network (green circles – core treaties, grey circles - peripheral treaties, green squares – core states, grey squares – peripheral states).

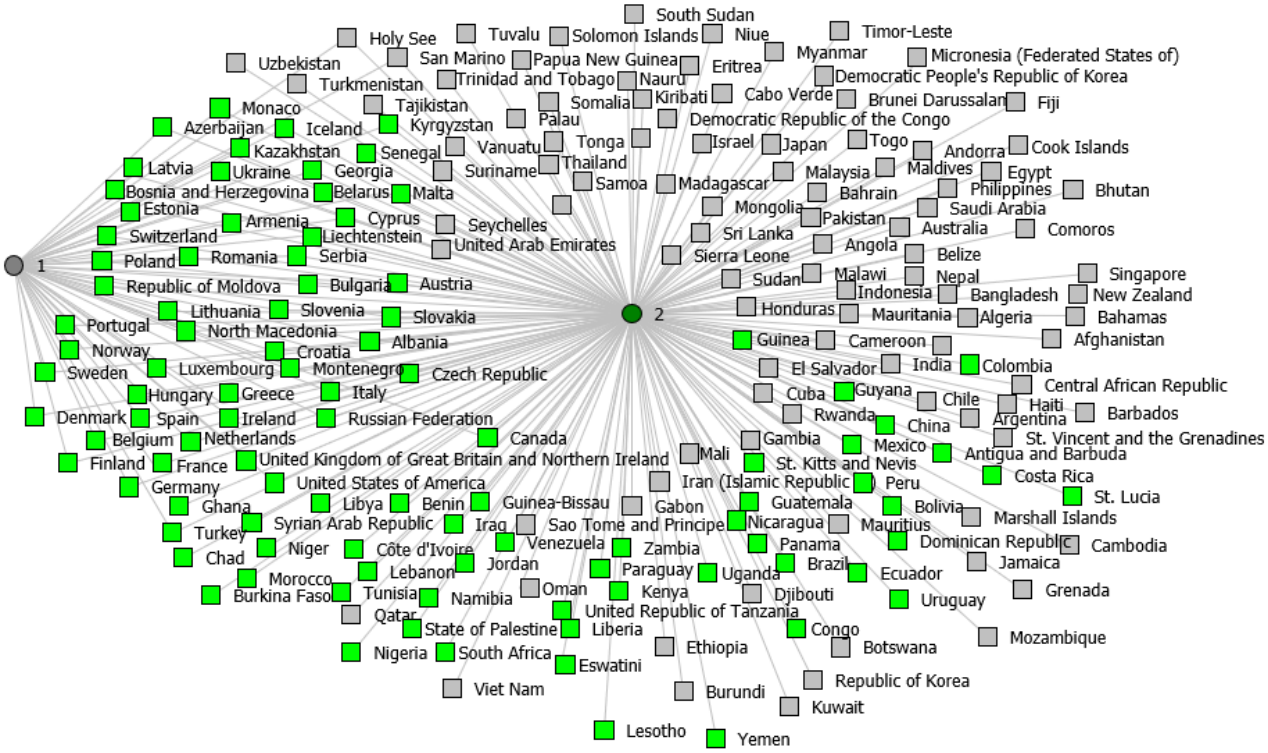

Fig. 6. Subgraph of the core-periphery model for the 1st and 2nd treaties (green circles – core treaties, grey circles - peripheral treaties, green squares – core states, grey squares – peripheral states).

IV. Discussion and conclusions

The present research explored the dynamic of the states' ratifications and implementation of the most important 18 international environmental treaties to better identify the interest at international level regarding the most serious environmental problems we face. Our results (Figs. 2-4) showed a significant evolution in time regarding the international interest of the countries in view of the common collaboration to address or diminution of environmental issues. The basis of these partnerships and agreements are the networks of countries [13]. Thus, the results of our research can be important for policymakers and other stakeholders to establish future strategies and promote the principles of protection and international collaboration, taking into account other economic, social, and political issues[4].

As shown by the core-periphery model, one can observe a pattern of association of states in partnerships considering the neighborhood of states, which is justified by neighboring countries' interest to solve and prevent cross-border environmental issues. Furthermore, the popularity of a state might be due to the requirements to comply with other supranational rules such as the European Union states that must comply with EU Directives (e.g., EIA Directive 85/337/EEC or Directive 2001/42/EEC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programs on the environment).

Globally, the high level of cooperation established between the core parties in most of the international environmental treaties demonstrates the ability of core actors to identify pathways ensuring cooperation in order to ensure optimal network flow along with proper implementation of the environmental treaties [25].

Given that environmental problems can only be solved with the general public's involvement and cannot be stopped by a single state or union, environmental policies must be redesigned to ensure the participation of all countries that have or may have issues regarding the subject debated. In this way, it will be possible to ensure the achievement of the objectives and targets established both in the analyzed international treaties and in the future actions taken for a sustainable environment and for proper prevention, biodiversity conservation, considering the perfect match between socio-ecological structures and complex processes [26].

Our results have shown that a complex and functional system is needed to manage both common problems and existing environmental conflicts [27] or specific situations that may arise from case to case or from nation to nation. In addition to these structural aspects of the analyzed network, practical elements must also be taken into account, which still

poses problems even by the states that are part of these networks and that are developing.

The shortcoming of our approach could envisage the fact that in our analysis we focused only on the most important environmental treaties and not on the sub-actors. From this point of view, some might argue that the boundaries of our network might invalidate the findings [19] with respect to the environmental treaties analysed. However, our results can be considered relevant due to the importance of the analyzed treaties and the fact that all countries of the world are part of the investigated network.

Another issue affecting environmental cooperation worldwide is the gap between practice and research, and to our knowledge, no current approach captures the level of cooperation among actors at international level. Consequently, the implicit benefits of using network analysis in investigating the trend of the international cooperation established for solving transboundary environmental issues, comes from the important highlights that reveal the role of each actor within the network, along with highlighting the brokers that can positively influence. This information provides the necessary framework to be considered, regarding the structure of the network. These findings contribute to the research field by offering the possibility to predict different scenarios [28] and to shape the 2050 long-term strategy for the environment [29].

Furthermore, the network approach presented in this paper contributes to the research field by trying to analyse and integrate both social and ecological data, fundamentals in creating a coherent implementation of the environmental treaties and also in changing management actions, so that ecological goals can be achieved without the emergence of social conflicts or environmental hazards. From this perspective, our work tries to promote innovative concepts such as: co-management, adaptive management [30].

A joint effort at international level must be made for proper integration of environmental objectives into policy and practice [31]. Given that actors cooperate, compete, conflict, and support one another [27], these ties make a difference in finding the key to success [32]. Furthermore, international environmental treaties are increasingly asking member states to include policy and societal dimensions into their work plans and strengthen their dissemination and science-policy interface activities. In this regard, better communication and transparency between practitioners, researchers, policymakers and other stakeholders have become a priority at international level.

ACKNOWLEDGMENT

We thank the anonymous reviewers for their helpful comments and suggestions.

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