1   **Who is researching biodiversity hotspots in Eastern Europe? A case study on grasslands**

2   **from Romania**

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9   **Abstract**

10   Farming landscapes of Europe are vital arenas for social-ecological sustainability because of

11   their significant coverage and potential to integrate food production with biodiversity

12   conservation. Knowledge gathered by scientific research is a critical ingredient for developing

13   and implementing socio-economically and ecologically sustainable grassland management

14   strategies for grasslands. The quality of scientific knowledge and its potential to address

15   grasslands as complex social-ecological systems is strongly dependent on the creativity and

16   scientific ambition of the researcher, but also on the network (from academic and non-academic

17   sectors) around the researcher. The goal of this paper is to map the research network around

18   Romania's grasslands. These systems have exceptional socio-cultural and economic values and

19   are between the most biodiverse ecosystems of the world. Considering the multiple threats to

20   these grasslands, it is an urgent need to understand the existing scientific knowledge profile

21   around these systems. This paper aims at using bibliometrics analysis, a well-developed

22   scientific domain that envisages network theory to analyze relationships between affiliations

23   network, co-authorship network, and co-word analysis. The number of studies targeting

24   grassland management in Romania is increasing mainly thanks to international involvement.

25   However, the management of the grasslands is still deficient and the contribution of science to

26   the process is virtually absent. The subject of research is mainly related to the biological and

27   ecological characteristics of grasslands, a notable absence from internationally visible research

28   being the management of grasslands, especially in the context of EU Common Agricultural

29   Policies. To increase scientific performance, and better inform EU and local policies on

30   grassland management, Romanian researchers should better capitalize on international

31   collaborations and local academic leaders. Our findings can be used to identify research gaps and

32 to improve collaboration and knowledge exchange between practitioners, scientists, policy

33 makers, and stakeholders.

34 **Keywords**

35 affiliations network; co-occurrence keyword network; co-authorship network; grasslands

36 specialists; bibliometrics analysis

37 **Introduction**

38 The integration of agricultural production, biodiversity conservation, and socio-cultural values is

39 a key challenge for the sustainability of social-ecological systems (Fischer et al. 2012). Current

40 grasslands of Europe developed under millennia-long human management, typically by livestock

41 grazing and hay production. Grasslands have a substantial contribution to the high nature value

42 farmlands o the European Union (Veen et al. 2009, Plieninger and Bieling 2013, Lomba et al.

43 2014). Several protected species and habitats are linked to grasslands and are dependent on some

44 form of extensive, multifunctional management of these ecosystems (Halada et al. 2011,

45 Dorresteijn et al. 2017). Furthermore, wooded meadows and wood-pastures are considered as an

46 archetypical manifestation of HNV farmlands in Europe (Plieninger et al. 2015).

47 Many EU countries already lost culturally and naturally important grasslands due to changes in

48 management practices (Pe'er et al. 2014). The intensive, highly specialized management of the

49 grasslands resulted in the sharp decrease in their biodiversity, aesthetic and cultural values or

50 even the disappearance of the grasslands. On the other hand, land abandonment also threatens

51 several species and habitats (however also creating opportunities for conserving others) as well

52 as ecosystem services of grasslands, commonly through woody vegetation encroachment (Stoate

53 et al. 2009, Bugalho et al. 2011, Queiroz et al. 2014, Michielsen et al. 2017).

54 Knowledge is essential for a socioeconomically and ecologically sustainable grassland

55 management (Fischer et al. 2012). In one hand, scientific knowledge can generate a contextual

56 understanding of the relationship between the management intensity and the biodiversity and

57 productivity of the grasslands (Kleijn et al. 2009). On the other hand, scientific research is

58 important in developing new types of conceptualizations of the grasslands, for example as

59 complex, adaptive systems which can exist in multiple social-ecological states (Sutcliffe et al.

60 2014, Hartel et al. 2018). Nevertheless, scientific knowledge can contribute to re-addressing

61 current management paradigms around the management of production landscapes (Abson et al.

62 2017), including grasslands. Since grasslands can simultaneously fulfill multiple social-

63 ecological values and roles (e.g., production, biodiversity conservation, recreational and cultural

64 values), an overly narrow (e.g., disciplinary) scientific approach for understanding them could

65 promote simplistic management measures which often lack socio-cultural contextualization. The

66 quality of scientific knowledge and its potential to address grasslands as complex social-

67 ecological systems is strongly dependent on the creativity and scientific ambition of the

68 researcher, but also on the social network (from academic and non-academic sectors) around the

69 researcher (Lescourret et al. 2015).

70 In this study, we address the collaboration network between the academics and the diversity of

71 research domains around the Romanian grasslands. The importance of our research is fourfold.

72 First, Romanian grasslands are between the best biodiversity hotspots at the global level (Wilson

73 et al. 2012), with several ancient land-use forms such as wood-pastures (Cremene et al. 2005,

74 Plieninger et al. 2015), traditional stewardship and management forms (Babai and Molnár 2014).

75 These grasslands are under threat from overgrazing, changes in management and stewardship

76 and abandonment (Baur et al. 2006, Ruprecht 2006, Sutcliffe et al. 2014, Peringer et al. 2017).

77 Second, Romania is a developing country in Eastern Europe, where research is suffering from

78 lack of funds, institutional instability and intense political pressure (David and Marko 2018,

79 Miclaus and Micu 2018). This overall harsh conjuncture for research is hampering the

80 production of holistic knowledge (Hanspach et al. 2014) and innovation which will be

81 indispensable for Romania in order to navigate challenges of globalization, including its

82 increasing role in the global food security (Benton et al. 2011), coping with extreme climate

83 variations (Azadi et al. 2018) and land grabbing (Petrescu-Mag et al. 2017). Third, the academic

84 world in Romania is still transitioning from a local/regional, disciplinary thinking and

85 approaches towards adopting international standards of scientific rigor and holistic, inter- and

86 transdisciplinary approaches. Because of this, Romania is sharply underrepresented in the

87 international scientific databases while publishing in local journals (i.e., hosted by the academic

88 institutions) is still actively promoted by academic institutions. Fourth, management of

89 grasslands in Romania is still deficient (Pătru-Stupariu et al. 2017) despite the latest legal

90 motions, which most often do not consider the contribution of science to the process.

91   Collaboration between academics and knowledge creation have been extensively studied using

92   network analysis framework. Analyses span from understanding of patterns of scientific

93   collaboration as resulted from co-authorship and institutional networks (Newman 2004, Hancean

94   et al. 2014, Hancean and Perc 2016) to knowledge creation (Wang 2016), to prediction of

95   productivity (Barabási et al. 2002) or trends (Chen et al. 2010). In this paper we use network

96   analysis, to characterize the status of scientific research in the field of grassland governance in

97   Romania and suggests ways to improve scientific performance by: 1) revealing internationally

98   visible research around Romania's grasslands published after 1990; 2) highlighting most

99   important institutions generating the research, and mapping the invisible authors and academic

100   leaders as resulted from the co-authorship network, and 3) analyzing the co-occurrence keyword

101   network to discover the most common keywords, research topics, and scientific interest.

102   **Methods**

103   To identify the research related to grasslands in Romania, we extracted from the Scopus database

104   (Elsevier B.V.) 602 articles, book chapters, and conference proceedings potentially related to the

105   investigated subject. We obtained these publications by searching simultaneously abstracts,

106   titles, and keywords sections with the following keywords: *Common Agricultural Policy*, *CAP,*

107   *pasture, grassland, meadow, lawn, greensward, grazing, graze, silvopastoral, pastureland,*

108   *rangeland, mowing* (and adding *Romania* to each of them, e.g., "pasture" AND "Romania").

109   Then, we went through each of these publications and removed those who do not contain

110   information about the subject of our review (e.g., paleoecology, paleobotany) and published

111   before 1990. In this way, we obtained a final database that includes 197 publications relevant to

112   the grasslands of Romania (Figure 1). For each article, we extracted the list of keywords, authors

113   and their affiliations as stated in the papers. Figure 1 shows an ascending trend in the number of

114   publications, which can be interpreted as an indicator of increasing interest of scientific

115   researchers on grasslands from Romania

116   The scientific articles targeting Romanian grasslands were published in 107 journals and

117   proceedings. Top journals in our network, with more than 5 publications are: *Quality-Access to*

118   *Success* (15 publications), *International Multidisciplinary Scientific GeoConference Surveying*

119   *Geology and Mining Ecology Management* (SGEM) (14), *Notulae Botanicae Horti Agrobotanici*

120   *Cluj-Napoca* (8), *PLoS ONE* (6), *Applied Vegetation Science* (5), *Biodiversity and Conservation*

121 (5), *Environmental Engineering and Management Journal* (5), and *North-Western Journal of*

122 *Zoology* (5).
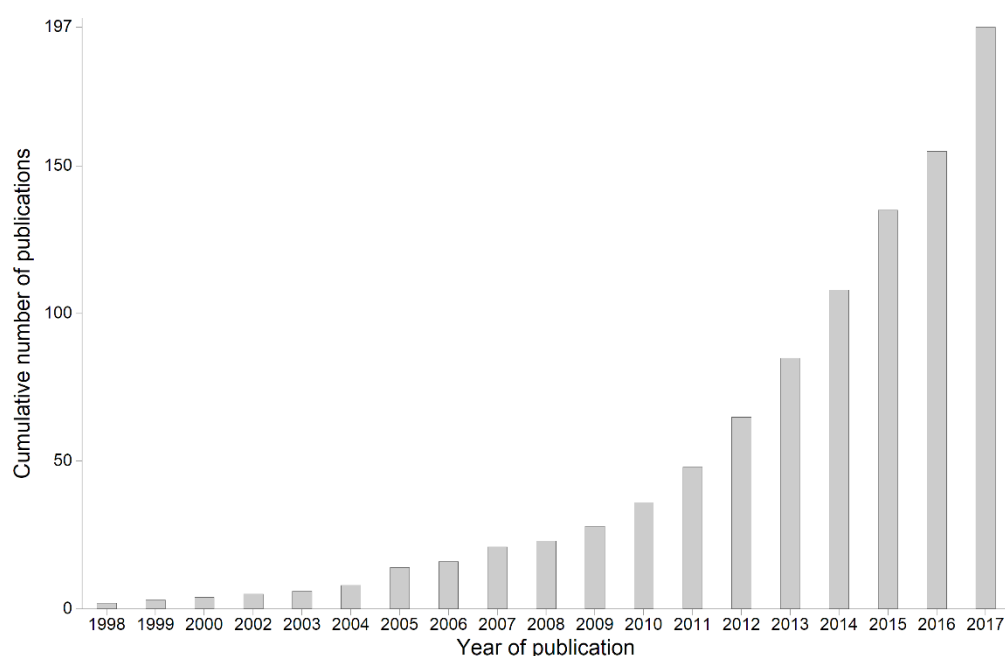
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124 *Figure 1 – Cumulative number of publications targeting Romania's grasslands accessible on the Scopus database (1998-2017).*

125 For the bibliometric analysis, we constructed three network matrices: (i) an affiliations network,

126 to infer about inter-institutional cooperation; (ii) a co-authorship network, which highlight

127 invisible authors and academic leaders, and (iii) and a co-occurrence keyword network to

128 discover hidden connections between the most common keywords, research topics and scientific

129 interest. For these analyses, we created distinct databases which we then cleaned and unified

130 (i.e., standardize the name of institutions, authors, and keywords to avoid duplication of entries

131 due to different spelling). The cleaned matrices include 192 unique affiliations (516 entries

132 initially), 517 unique authors (755 entries initially) and 577 unique keywords (1019 entries

133 initially). The methodology workflow is presented in Figure 2.

134 *(i) Affiliations analysis*

135 We used *bi-component analysis* to identity blocks (bi-connected subnetworks) and the cut-points

136 (articulation points) in the affiliation graph (Hanneman and Riddle 2005). If removed, cut point

137 institutions break the affiliation network into one or more bi-connected subnetworks

138 (Leydesdorff 2004). Such institutions are important for cohesivity of research network focused

139 on Romanian pastures and might act as research brokers among otherwise disconnected groups

140   (Borgatti et al. 2018). An affiliation subgraph is bi-connected if every institution in the subgraph

141   (minimum three) has direct connections to other and even removing any node, the subgraph

142   remains connected (Hanneman and Riddle 2005). The number and size of blocks is an indication

143   of network fragmentation. If a network is dominated by one block, then most institutions

144   cooperate during the research. Smaller blocks include isolated institutions, which published a

145   small number of papers on the subject or on uncommon topics (Leydesdorff 2004).
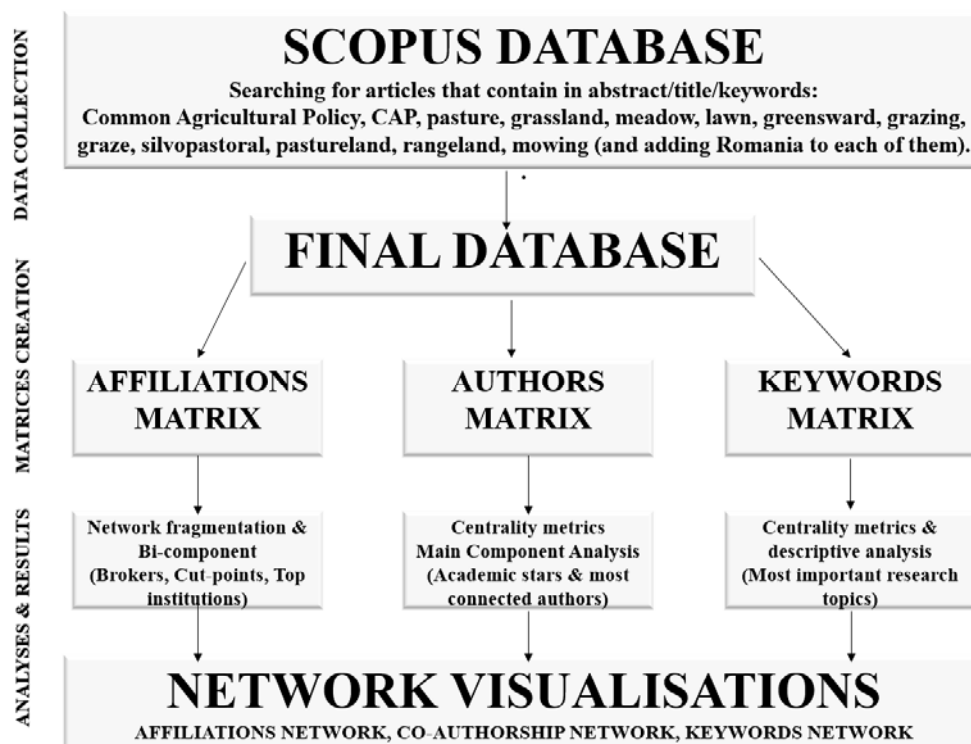
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147   *Figure 2 - Workflow of network analyses of internationally visible research related to grasslands of Romania.*

148   We also calculated several node-level centrality metrics: degree, betweenness, and eigenvector.

149   *Degree centrality* of an institution represents the number of direct connections (Abbasi et al.

150   2012, Borgatti et al. 2018). The metric identifies the most collaborative institutions, i.e., the

151   institutions with the highest number of connections to other research units in Romanian

152   grassland research. The metric does not account for how important the institutions are linked to

153   the node of interest. Thus, an institution can be considered as collaborative even if it is linked

154   only to institutions that have no other collaborations in the network. *Eigenvector centrality* is

155   similar to degree centrality but scores higher connections with institutions which are themselves

156   well connected (Borgatti et al. 2018). It represents the sum of the eigenvectors of the institutions

6

157 that the institution of interest is connected to, and reveal the best options for future partnerships

158 (most influent institutions, which can further promote partnership in research) (Borgatti et al.

159 2018). *Betweennesses centrality* measures the extent to which an institution lies on paths

160 between other institutions from the research network. Such institutions can control the flow of

161 information in the network if we assume that every pair of connected institutions exchanges

162 information with equal probability and information flow on a short path chosen at random

163 (Barabási 2016). Such institutions can be seen as bridge affiliations, e.g., can control the research

164 subjects in a partnership (Leydesdorff 2004). Relationships among countries and within

165 countries, resulted from affiliations declared by the authors, were represented using a chord

166 diagram (Flor 2018).

167 *(ii) Authors analysis*

168 We use authors' matrix to analyze the co-authorship network created around Romanian grassland

169 research and to illustrate the patterns of cooperation between the scientists in this research

170 domain (Barabási et al. 2002, Ding et al. 2014). We calculated the *network fragmentation* metric,

171 which in our case indicates the proportion of pairs of authors that cannot reach each other

172 (Borgatti et al. 2018). Large datasets, as it is the case of our database, typically involve many

173 small independent clusters around larger ones and one large and dense cluster (Hancean and Perc

174 2016). Thus, we assessed the distribution of components in the co-authorship network and

175 extracted the largest connected component (main component) that shows the group of highly

176 active authors focused on grasslands at the national level (subnetworks of authors that are

177 maximally connected between each other). We also, calculated the *degree centrality* in order to

178 find out which are the most collaborative authors within the network, and compared the results

179 with the *betweenness centrality* to highlight the "academic stars" within the network – authors

180 with high degree and betweenness centralities (Glänzel and Schubert 2004, Ding et al. 2014).

181 To better understand the motivations for scientific collaboration the Romanian grassland

182 research, three authors with key positions in the research network were asked to respond to an

183 interview on the opportunities and constraints of research in this domain. A network leader

184 affiliated to a Romanian institution (*network leader a*), a foreign author continuing scientific

185 work in Romania (*network leader b*), and a foreign author who works abroad (*network leader c*),

186 *(iii) Keywords network*

7

187 Analyses based on keywords have been applied in various techniques such as text mining, data

188 reduction and clustering (Cobo et al. 2011, Ding et al. 2014, Popescu et al. 2014) to identify

189 emerging research. Keywords are also good representatives for the main topics addressed by

190 research in general (Dotsika and Watkins 2017), and co-occurrence *keywords network* analysis

191 can be used to highlight the most common and important research keywords (Ding et al. 2014).

192 Hence, to infer about most common, popular, and bridge keywords featured in Romanian

193 grasslands research, we used the degree, eigenvector, and betweenness centralities (see

194 affiliations networks for details about these network-level metrics).

195 Network analyses were performed in UCINET software (Borgatti et al. 2002), and the networks

196 were graphically represented using Netdraw (Borgatti 2002), and *chorddiag* R package (Flor

197 2018).

Results

Affiliations network

200 The network of organizations hosting researchers publishing about grasslands from Romania

201 includes 192 distinct institutions from 36 countries out of which 14 are isolated institutions (i.e.

202 only collaborates inside their institution). Nine of the isolated affiliations are from foreign

203 countries (Japan, Poland, Italy, Spain, Germany, Switzerland, Ukraine), but there are also 5

204 isolated institutions from Romania: Politehnica University of Timisoara, University of Pitesti,

205 Technical University of Cluj-Napoca, University Bogdan Voda, and Danube Delta National

206 Institute for Research and Development. The best-represented affiliations involved in Romanian

207 grassland research are from Romania (53), Germany (23), United Kingdom (13) and Hungary

208 (13).

209 Researchers from Romanian institutions collaborate mostly with researchers from Romania (138

210 institutional collaborations), Germany (92), Hungary (29), Czech Republic (19), and UK (18).

211 Also, the next best-represented country, Germany, collaborate mostly with institutions from

212 Romania and Germany (Figure 3).
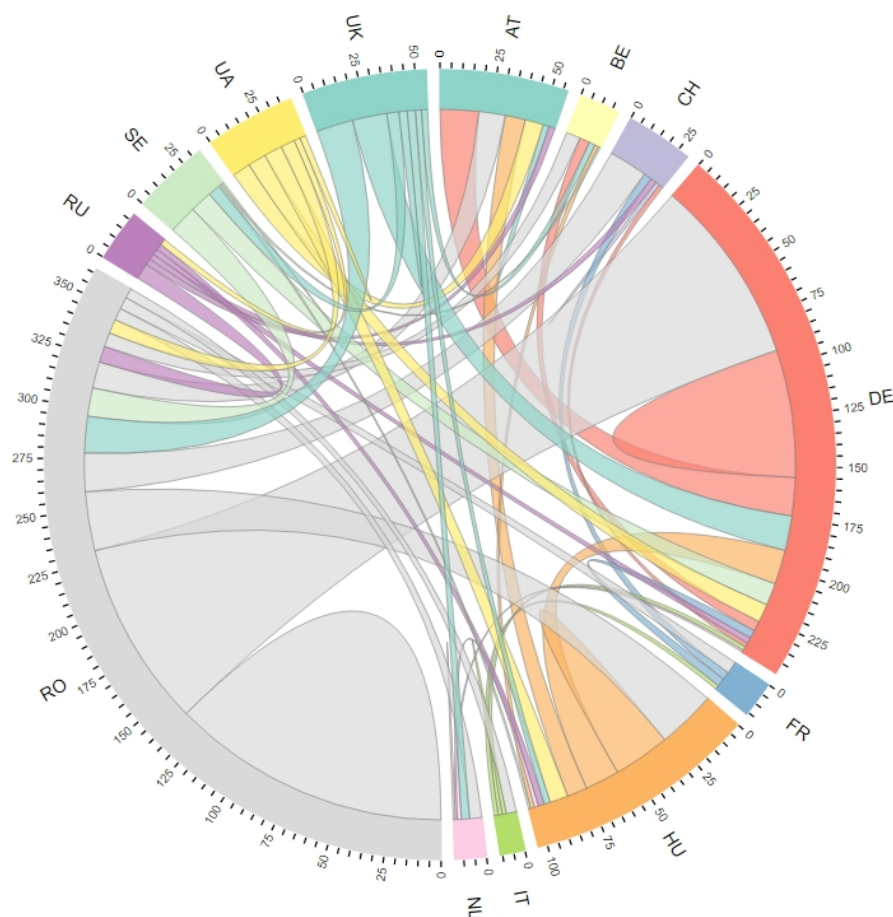
Figure 3 – Chord diagram showing international and national collaborative pattern as resulted from internationally visible publications related to grasslands in Romania (links = co-occurring countries in an article; only countries with > 10 collaborations with institutions from Romania are shown).

The Bi-components analysis generated 45 blocks (Supplementary Table 1) held by 25 cut points/affiliation brokers (Figure 4), which if they were to be removed, the structure of the network would become divided into unconnected parts. Block 31 has the highest number of affiliations (101, out of which 20 are from Romania). Institutions acting as affiliation brokers are from Romania (16 institutions), Hungary (3), Slovenia (1), Czech Republic (1), Germany (2), Sweden (1) and Italy (1).

Figure 4 presents the affiliations ranked by their importance in terms of best position within the bibliometric network (betweennesses centrality), influence (eigenvector centrality), and number of network connections relevant for Romanian grassland research (degree centrality). The *Babes-Bolyai University* (Romania) control the flow of information (betweenness), has the highest number of connections (degree), and is the most influent institution (eigenvector) within the

9

228   network (Supplementary Table 1). The *Romanian Academy* (Romania) also has the control over

229   the entire network from the scientific cooperation point of view and occupies the second position

230   in term of number of connections and influence (Figure 4 and 5) while on the 3rd position is the

231   *Hungarian Academy of Sciences* (Hungary).
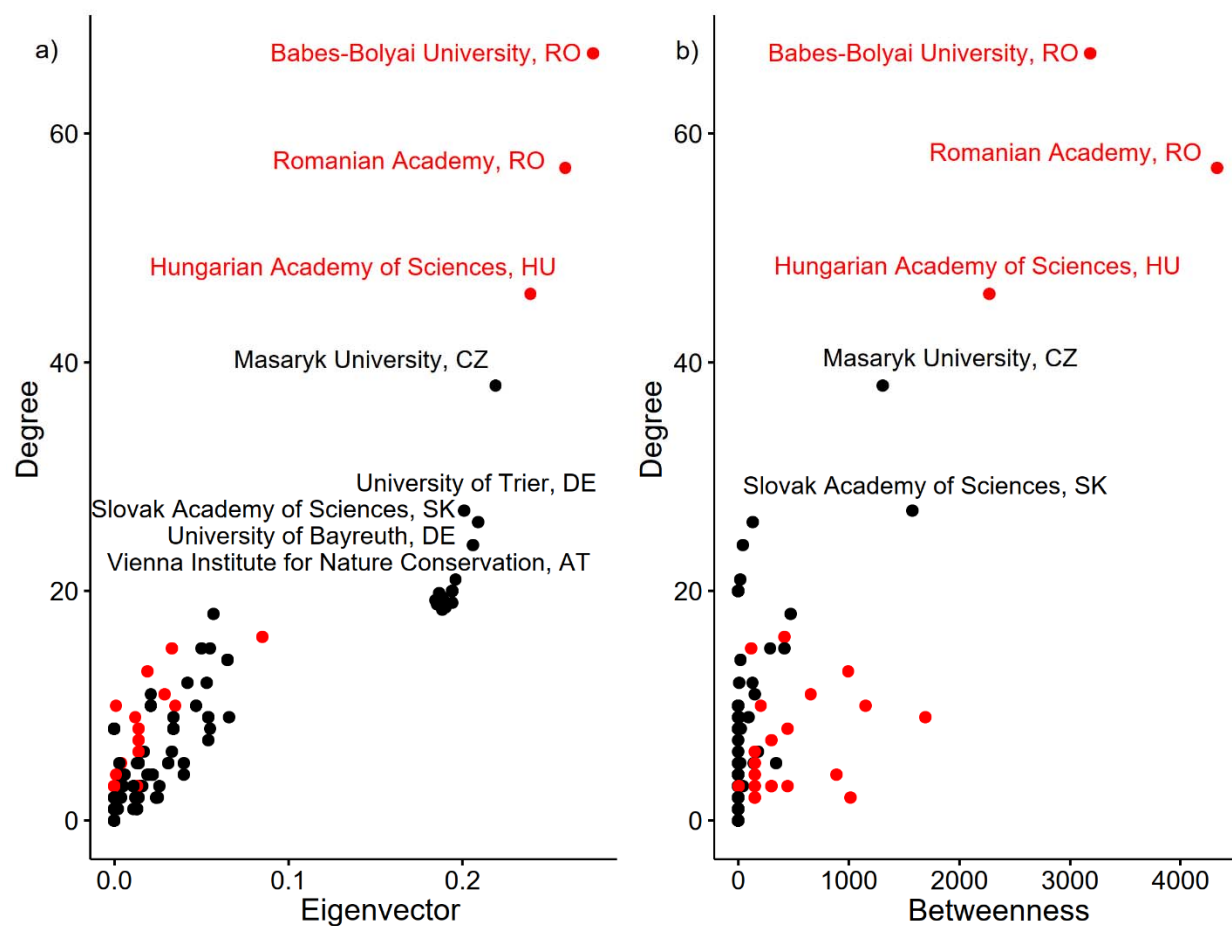
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233   *Figure 4 – Degree versus eigenvector (a) and betweenness (b) centralities of institution hosting researchers publishing about*
234   *Romania's grasslands (cut points/affiliation brokers are in red).*

235
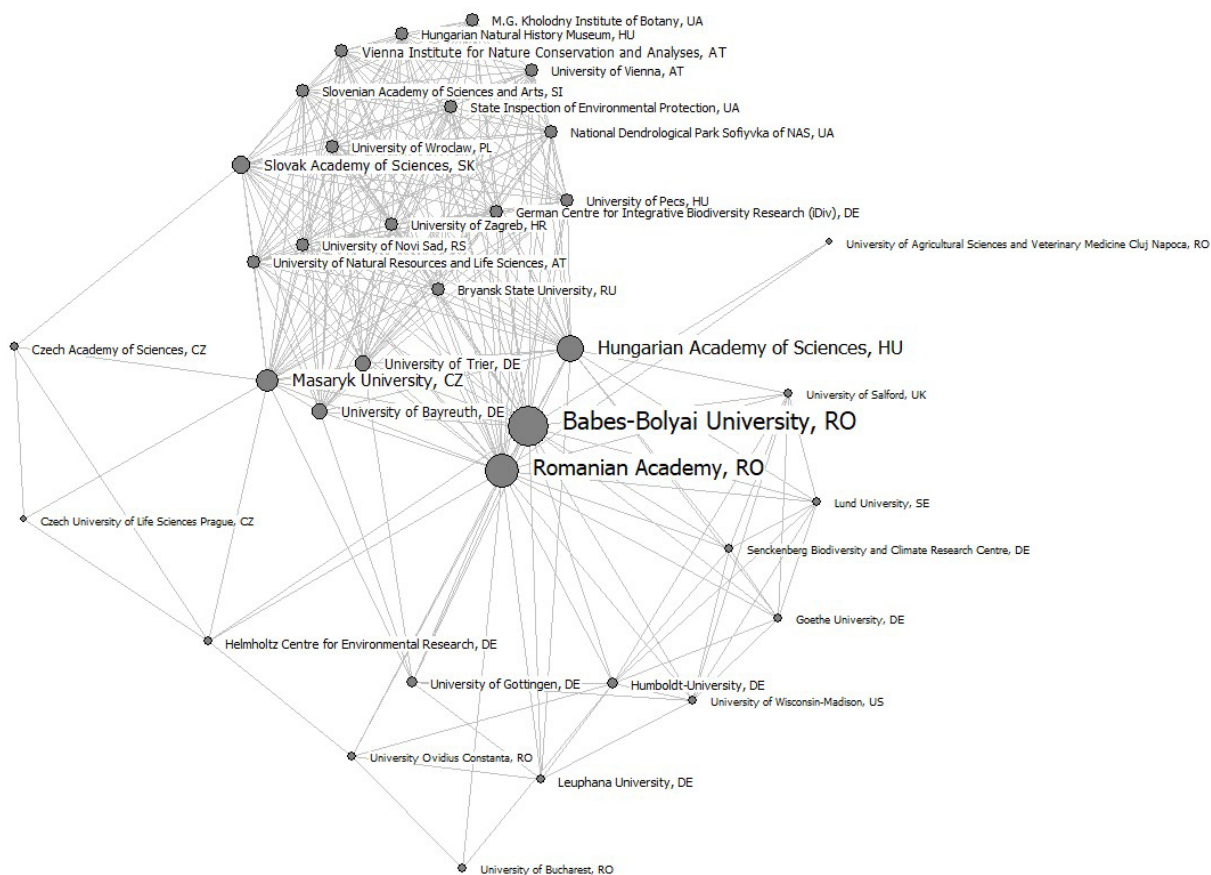
Figure 5 – Network of the affiliations of authors publishing about Romania's grasslands with a degree centrality >10 (size of nodes and labels given by degree).
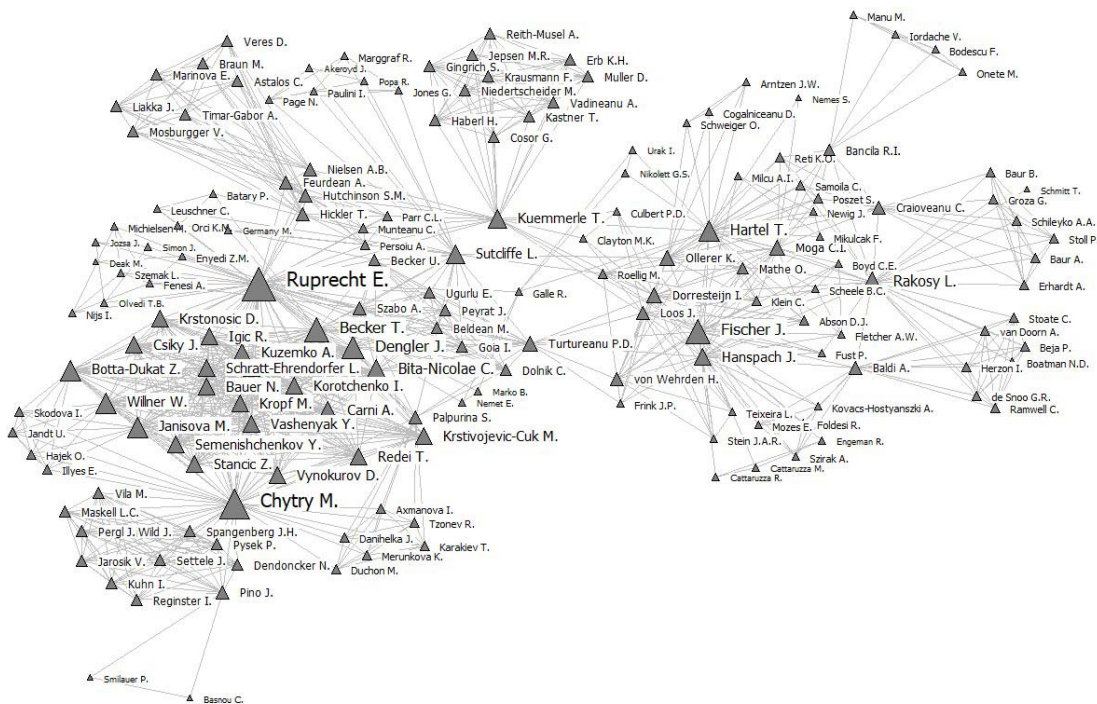
Authors network

The network of authors is composed of 517 authors and has a high fragmentation (0.886). The main component analysis divided the fragmented network into 92 clusters (Supplementary Table 1). Cluster 6 is the densest component and sums up 168 authors (Figure 6), while the rest of the clusters have a mean of 3.83 authors (stdev = 3.97). Giving its importance, we further mapped Cluster 6 to have a closer look at its structure (Figure 6). Most of the authors forming part of the main component are not Romanians, hence, many important authors within the Romanian grassland research network are foreigners (Figure 7).
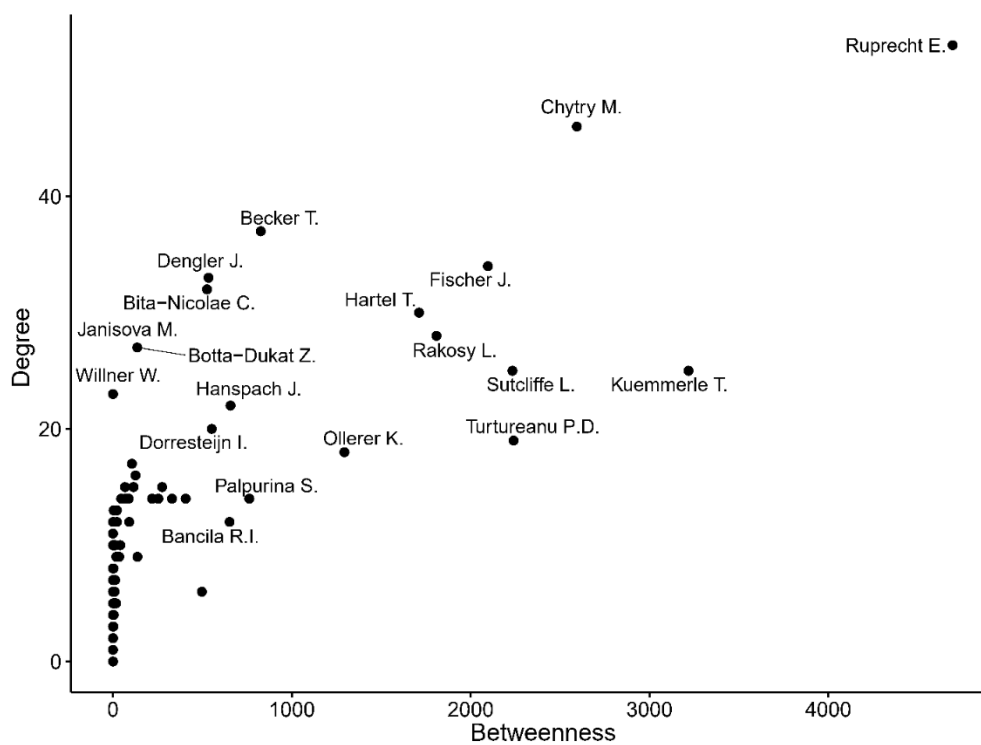
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250   *Figure 6 – Main component of the network of authors publishing about Romania's grasslands (size of nodes given by degree).*

251

252   *Figure 7 - Top academic authors publishing about Romania's grasslands in terms of number of connections (degree) and*
253   *position in the network (betweenness).*

254 Based on this result, we carried out a short interview with three network leaders in order to

255 conclude how they have evolved in their professional career, who inspired them to research the

256 grasslands of Romania and what is the key to their success in terms of national and international

257 partnerships made in this field. The authors were anonymized as "*network leader a"* (NLa),

258 "*network leader b*" (NLb), and "*network leader c*" (NLc).

259 The paragraph below summarizes the answers of interviewed network leaders for the following

260 questions.

261 **Q1. Who inspired you to research grasslands in Romania (e.g., researchers, articles,**

262 **institutions from Romania or foreign).**

263 **NLa:** *After finishing my studies at the Babe□-Bolyai University from Cluj-Napoca, Romania, I*

264 *have met a Romanian grassland researcher with a great expertise and a passion for rare plants*

265 *of steppe habitats. Field trips to beautiful steppe-like grasslands and the concern about their*

266 *transformation or loss inspired me to study grasslands. Later on, my Ph.D. supervisor, especially*

267 *his way of thinking about diversity, inspired me a lot, thus I have worked with him and some of*

268 *his colleagues for several years.*

269 **NLb:** *A friend was researching High Nature Value Farmland in Europe and told me about the*

270 *species-rich grasslands in Transylvania that she had visited. I was curious, and with her*

271 *assistance and the help of local partners, I was lucky enough to be able to do some fieldwork for*

272 *a scientific study there.*

273 **NLc:** *It was in 1997 before I studied Biology when I first came to Transylvania. I stayed for a*

274 *few days with some friends in a small village not far from Sighisoara. It was summer and one*

275 *evening we climbed a hill behind the houses to watch the sunset. I don't remember the sunset, but*

276 *I do remember the meadows we walked through. They were so amazing. Although I have grown*

277 *up on a farm myself, I hadn't seen nor smelled nor heard such a meadow before. Every plant*

278 *seemed to be blooming and every insect buzzing. It was such richness and beauty. That was the*

279 *thing that made me most enthusiastic about grasslands in Transylvania, even if I only later*

280 *learned to put scientific labels on that richness.*

281 **Q2. How did you form your co-authorship or partnership network? What were the main**

282 **challenges and opportunities in this respect?**

283 **NLa:** *At the very beginning of my career, personal contacts have been the most important in*
284 *finding mentors, since there was a limited access to scientific literature and even to the internet*
285 *in my home country in the 1990s. These first mentors gave me opportunities to further develop*
286 *my 'partnership network' by inviting me to their institutions abroad (in Hungary, where I had no*
287 *language or cultural barriers) and to conferences, where I could meet other scientists. Later on,*
288 *I have contacted scientists from abroad (outside of Hungary), whose papers raised my interest*
289 *the most, by e-mail, and looked for scholarships for research stays at their host institutions.*
290 *Nowadays, there are scientists from European institutions contacting me and asking me for*
291 *collaboration within the framework of scientific projects.*

292 **NLb:** *The Romanian conservation NGO Foundation ADEPT generously hosted my work in*
293 *Romania, and through them, I met many, many interesting people involved in all aspects of*
294 *conservation (academic and non-academic). Perhaps the most difficult thing was to stay in touch*
295 *with all of them!*

296 **NLc:** *My network developed through a social-ecological research project which included*
297 *research on vascular plant diversity in the farming landscape of Southern Transylvania*
298 *(Sighisoara). That means through multiple pathways including cooperation with local NGOs,*
299 *scientists, field assistants, and friends. Opportunities clearly included to learn from knowledge*
300 *and experiences from others and to join skills for getting fieldwork and analysis done. As a*
301 *challenge, I see the language barrier and also that we didn't do a classic vegetation study but*
302 *applied a random sampling design for putting survey sites (which didn't match with the more*
303 *traditional vegetation research).*

304 **Q3. How would you describe the collaboration between Romanian grassland researchers?**

305 **NLa:** *There are few collaborations, and the majority is based on personal acquaintance.*
306 *Confidence or convenience (people working at the same institution) have important roles in*
307 *forming research teams around a certain project.*

308 **NLb:** *I only have experience of my own collaboration with Romanian grassland researchers,*
309 *which was pleasant and productive.*

310   **NLc:** *To be honest, I don't feel I can say much about this. I don't have much insight into their*

311   *collaboration. Also, I don't consider myself a grassland expert and therefore I am not so deep*

312   *into this network.*

313   **Q4. How would you describe the role of foreign scientists in Romanian grassland research?**

314   **NLa:** *Foreign scientists find Romanian grasslands remarkable, and they come to work in*

315   *Romania with very specific research questions. They often look for a local expert in Romanian*

316   *grasslands to involve in their project, and by this means collaborations arise. I consider foreign*

317   *scientists bring in many interesting research questions, achieve nice results and invigorate*

318   *Romanian grassland research.*

319   **NLb:** *My impression is that scientists from northern and western Europe are very aware of the*

320   *grassland diversity that has been lost in the more intensified regions of Europe. I think in any*

321   *ecosystem there is always value in combining observations from local researchers who*

322   *intimately know the area and can interpret its subtleties, and "outsiders" who can maybe bring a*

323   *fresh perspective and spot parallels with other systems.*

324   **NLc:** *From my limited perspective they seem to have a strong influence or at least they seem to*

325   *stand out for me. I could name a few foreign grassland researchers but would struggle to name*

326   *the same number of Romanians. However, this is probably biased because I am a foreigner*

327   *myself, I might pay more attention to fellow foreigners that are active in this field.*

328   *Keywords network*

329   To find the most researched topics focused on grasslands, we mapped the keyword network after

330   excluding the occasionally used keywords, that is, those who had a degree of less than 10 (Figure

331   8). Not considering the words that were used to search for the articles that were used for creating

332   the study database, the keywords most influent and important within the network were

333   *Biodiversity* and *Conservation* (Figures 8, 9). Also, our results showed that terms such as *Farm*

334   *management*, *Pastoral value*, *Landscape pattern, Ancient trees* are among many other keywords

335   on the bottom positions, both from the perspective of their use and their importance within the

336   network (Supplementary Table 1).

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337

338 *Figure 8 – Top keywords used in publications about Romania's grasslands by degree (size of labels and nodes by degree, for a*
339 *better visualization we illustrate only the keywords with a degree > 10).*

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341 *Figure 9 – Top 25 keywords used in publications about Romania's grasslands by degree versus a) betweenness and b)*
342 *eigenvector centralities (blue = keywords used for data collection).*

343 **Discussion**

344 We provide a comprehensive analysis of the research network around grasslands in an Eastern

345 European country, Romania. Grasslands have key socio-cultural, economic and natural values

346 and can be approached from several disciplinary perspectives (Veen et al. 2009). Thus, research

347 on grasslands are important contributions to the knowledge because of the several perspectives

348 within which these systems can be understood, including agronomy, nature conservation,

349 ecology, sociology, statistics, sociology, anthropology, economics, political sciences, geography.

350 We found that both national and international researchers and institutions contribute to scientific

351 knowledge regarding Romanian grasslands, with a higher influence from foreign researchers.

352 Furthermore, we identified the most commonly addressed and the most influential research

353 topics regarding Romanian grasslands.

354 *Who is researching Romanian grasslands?*

355 Considering the limited number of articles, our result shows a great international coverage of

356 institutions and researchers involved in Romanian grassland research (192 institutions, 517

357 coauthors, 197 articles). By analyzing the co-authorship centrality metrics, we showed that the

358 contribution of foreign institutions and researchers to grasslands research is high, while there are

359 also key institutions from Romanian which have an important role as brokers. We are aware of

360 the fact that a single author can name several host institutions in the research papers, however,

361 first nominated institution usually is the home institution (Glänzel and Schubert 2004) which

362 reduce the potential bias. This redundancy (i.e., one author feeling a responsibility to indicate

363 multiple institutional addresses) also may represent opportunities for innovative knowledge

364 generation which can flow into the cumulative knowledge pool (Leydesdorff 2004, Newman

365 2004). For example, one of the authors of the present manuscript (TH) adopted a social-

366 ecological approach for understanding wood-pasture systems of Romania and Europe; this

367 approach was adopted as a result of a postdoctoral research period spent at Leuphana University

368 (Lüneburg, Germany), where the research team addressed a holistic understanding of the

369 sustainability challenges of cultural landscapes in Romania.

17

370   We found that a researcher can have an outstanding contribution to the knowledge of Romanian

371   grasslands not only as 'grassland specialist' but also as an ecological modeler, trans-disciplinary

372   researcher or economist (see also the interviews for the profile of three researchers highlighted

373   by our analysis), as being part of a larger, interdisciplinary research group. While internationally

374   visible scientific production sharply increased to a maximum of 42 papers in 2017, relatively few

375   papers are published in top-tier journals, as in other Eastern European countries (Kozak et al.

376   2015). The lack of improvement in the publishing performance can be explained by the limited

377   funding (David and Marko 2018, Miclaus and Micu 2018) as well as by the established traditions

378   in choosing the target journals (Campos-Arceiz et al. 2015). Inter-disciplinary and international

379   expertise is an important driver of the knowledge generation (Gazni et al. 2012) for grasslands

380   management, and researchers of Romania could capitalize on this even more. International

381   collaborations are increasingly possible and encouraged, e.g., within Horizon 2020 and

382   Biodiversa-EraNet project partnerships (Granieri and Renda 2012). These collaborations can

383   allow knowledge flow, the development of new coauthorship networks (Hancean and Perc 2016)

384   and also can buffer the unstable funding which characterizes Romanian research (Miclaus and

385   Micu 2018). Our results suggest several ways in which a local researcher can increase its

386   attractivity for international research projects, including a keen interest in a holistic

387   understanding of the cultural landscapes (of which grasslands are part), active and long-term

388   engagement with local stakeholders and partners and increased scientific productivity (Balvanera

389   et al. 2017). The interviews of the academic stars of the network show, irrespective of the origin

390   of the author that answered, that the cooperation to investigate Romanian grasslands is made

391   more by means of recommendations and by common knowledge, the role of foreign authors and

392   institutions being of defining importance regarding research initiatives and partnerships.

393   *What were the research topics addressing Romanian grasslands?*

394   We identified 577 keywords in internationally visible research addressing Romanian grasslands.

395   Few keywords have high importance in the overall keyword network; this can be interpreted as

396   the main topics driving grassland research in Romania. These keywords (Figures 8, 9) are mostly

397   related to the high natural values of grasslands, ecosystem services and the land-use practices

398   (including abandonment) related to grasslands. The results can be explained in multiple ways.

399   First, there was a momentum generated by the accession of Romania to the European Union

400   (2007), where the delineation of Natura 2000 sites and the development of management plans for

401   them was and are still an ongoing process (Manolache et al. 2017). Second, the establishment of

402   conservation biology as a research discipline in the academic environment of Romania (besides

403   the classical ecology research, especially in the 2000s, also resulted in research projects which

404   targeted rare species and habitats as well as the negative impact of management (especially

405   overgrazing) on these. Third, several Non-Governmental Organizations also increased the social

406   awareness about the decline of biodiversity (especially in the protected areas but also beyond)

407   (Rozylowicz et al. 2017), this again motivating research targeting the biodiversity and

408   conservation of grasslands. Within this, the mountain hay meadows have outstanding importance

409   (this is why 'Carpathians' were highlighted as important, Figures 8 and 9), being highly

410   biodiverse as well as threatened by overgrazing and abandonment (Cremene et al. 2005, Sutcliffe

411   et al. 2014, Michielsen et al. 2017). A relatively recent overview of the research targeting Natura

412   2000 sites in the European Union showed that research supporting Natura 2000 network is

413   dominated by ecological research while the policy and social aspects are underrepresented

414   (Popescu et al. 2014). Our analysis on Romanian grasslands research suggests a similar pattern.

415   We identified several research topics which we would expect to be better represented (i.e., more

416   influential) in the network, because of their crucial importance in the management of the

417   grasslands. Less important topics from the perspective of network analysis are the economy of

418   grasslands, the traditional ecological knowledge related to grasslands, stakeholders and the non-

419   herbaceous elements across the grasslands. From the perspective of holistic understanding

420   (Hanspach et al. 2014), there are recently established research projects in different regions of

421   Romania (i.e., 'Sustainable Landscapes in Central Romania'), which aim to contribute to a

422   socially and ecologically sustainable farming system in Romania. Romania hosts some of the

423   most representative wood-pasture systems of Central and Eastern Europe (Roellig et al. 2018).

424   Despite their common occurrence in Romania and their relative scarcity in Western Europe

425   (Plieninger et al. 2015), we found a surprisingly low number of papers addressing these systems.

426   Since wood-pastures of Romania suffered from the lack of tree regeneration (Roellig et al. 2018)

427   and the erosion of values related to scattered trees (Torralba et al. 2018), it is of utmost

428   importance to amplify the holistic research on these systems. Based on our collective, long-term

429   experience as researchers within the Romanian academic system, we believe that Romanian

430   academia still has much to do for implementing holistic, trans-disciplinary research to address

431 sustainability problems related to farming landscapes in general and pastures in particular. One

432 major barrier of adopting an integrative approach is the strong tradition of disciplinary research

433 which still dominates research and teaching at the universities. This is also reflected in the

434 dominant research themes identified in Figures 8 and 9.

435 **Conclusions**

436 Although grasslands are complex social-ecological systems which can be studied in several

437 scientific domains or interdisciplinary, internationally visible research networks around

438 Romania's grasslands is still undeveloped (e.g., relatively low number of papers in top-tier, low

439 number of visible researchers with institutional affiliation from Romania). The co-authorship

440 network structure reveals several institutional leaders who can further promote the research in

441 this area. These top institutions are prestigious institutions from Romania closely followed by

442 foreign collaborators (e.g., from Hungary, Germany). Based on their academic profile, top

443 researchers are from diverse scientific fields (plant ecology, conservation biology, population

444 ecology, etc.), a feature favoring the scientific performance by increasing the interdisciplinary

445 and relevancy of research. The subject of research is mainly related to the biological and

446 ecological characteristics of grasslands, a notable absence from internationally visible research

447 being the management of grasslands, especially in the context of EU Common Agricultural

448 Policies. To increase scientific performance, and better inform EU and local policies on

449 grassland management, Romanian researchers should better capitalize on international

450 collaborations and local academic leaders.

451 **Acknowledgments**

455 **References**

456 Abbasi, A., K. S. K. Chung, and L. Hossain. 2012. Egocentric analysis of co-authorship network structure,
457   position and performance. Information Processing & Management **48**:671-679.
458 Abson, D. J., J. Fischer, J. Leventon, J. Newig, T. Schomerus, U. Vilsmaier, H. von Wehrden, P. Abernethy,
459   C. D. Ives, N. W. Jager, and D. J. Lang. 2017. Leverage points for sustainability transformation.
460   Ambio **46**:30-39.

461 Azadi, H., P. Keramati, F. Taheri, P. Rafiaani, D. Teklemariam, K. Gebrehiwot, G. Hosseininia, S. Van
462   Passel, P. Lebailly, and F. Witlox. 2018. Agricultural land conversion: Reviewing drought impacts
463   and coping strategies. International Journal of Disaster Risk Reduction **31**:184-195.
464 Babai, D., and Z. Molnár. 2014. Small-scale traditional management of highly species-rich grasslands in
465   the Carpathians. Agriculture, Ecosystems & Environment **182**:123-130.
466 Balvanera, P., T. M. Daw, T. A. Gardner, B. Martín-López, A. V. Norström, C. Ifejika Speranza, M.
467   Spierenburg, E. M. Bennett, M. Farfan, M. Hamann, J. N. Kittinger, T. Luthe, M. Maass, G. D.
468   Peterson, and G. Perez-Verdin. 2017. Key features for more successful place-based sustainability
469   research on social-ecological systems: a Programme on Ecosystem Change and Society (PECS)
470   perspective. Ecology and Society **22**.
471 Barabási, A. L. 2016. Network science. Cambridge University Press.
472 Barabási, A. L., H. Jeong, Z. Néda, E. Ravasz, A. Schubert, and T. Vicsek. 2002. Evolution of the social
473   network of scientific collaborations. Physica A: Statistical Mechanics and its Applications
474   **311**:590-614.
475 Baur, B., C. Cremene, G. Groza, L. Rakosy, A. A. Schileyko, A. Baur, P. Stoll, and A. Erhardt. 2006. Effects
476   of abandonment of subalpine hay meadows on plant and invertebrate diversity in Transylvania,
477   Romania. Biological Conservation **132**:261-273.
478 Benton, T., T. Hartel, and J. Settele. 2011. Food security: A role for Europe. Nature **480**:39.
479 Borgatti, S., M. Everett, and J. Johnson. 2018. Analyzing social networks. 2nd edition. SAGE Publications,
480   London.
481 Borgatti, S. P. 2002. Netdraw Network Visualisation. SAGE Publications.
482 Borgatti, S. P., M. G. Everett, and L. C. Freeman. 2002. Ucinet for Windows: Software for Social Network
483   Analysis. Analytic Technologies, Harvard.
484 Bugalho, M. N., M. C. Caldeira, J. S. Pereira, J. Aronson, and J. G. Pausas. 2011. Mediterranean cork oak
485   savannas require human use to sustain biodiversity and ecosystem services. Frontiers in Ecology
486   and the Environment **9**:278-286.
487 Campos-Arceiz, A., R. B. Primack, and L. P. Koh. 2015. Reviewer recommendations and editors' decisions
488   for a conservation journal: Is it just a crapshoot? And do Chinese authors get a fair shot?
489   Biological Conservation **186**:22-27.
490 Chen, C., F. Ibekwe-SanJuan, and J. Hou. 2010. The structure and dynamics of cocitation clusters: A
491   multiple-perspective cocitation analysis. **61**:1386-1409.
492 Cobo, M. J., A. G. López-Herrera, E. Herrera-Viedma, and F. Herrera. 2011. Science mapping software
493   tools: Review, analysis, and cooperative study among tools. **62**:1382-1402.
494 Cremene, C., G. Groza, L. Rakosy, A. A. Schileyko, A. Baur, A. Erhardt, and B. Baur. 2005. Alterations of
495   Steppe-Like Grasslands in Eastern Europe: a Threat to Regional Biodiversity Hotspots.
496   Conservation Biology **19**:1606-1618.
497 David, D., and B. Marko. 2018. Political pressures on Romania's research. Nature **560**:167-167.
498 Ding, Y., R. Rousseau, and D. Wolfram, editors. 2014. Measuring Scholarly Impact. Methods and Practice.
499   Springer International Publishing.
500 Dorresteijn, I., J. Loos, J. Hanspach, and J. Fischer. 2017. Socioecological drivers facilitating biodiversity
501   conservation in traditional farming landscapes. Ecosystem Health and Sustainability **1**:1-9.
502 Dotsika, F., and A. Watkins. 2017. Identifying potentially disruptive trends by means of keyword network
503   analysis. Technological Forecasting and Social Change **119**:114-127.
504 Fischer, J., T. Hartel, and T. Kuemmerle. 2012. Conservation policy in traditional farming landscapes.
505   Conservation Letters **5**:167-175.
506 Flor, M. 2018. Creating D3 Chord Diagrams. https://github.com/mattflor/chorddiag.
507 Gazni, A., C. R. Sugimoto, and F. Didegah. 2012. Mapping world scientific collaboration: Authors,
508   institutions, and countries. **63**:323-335.

509   Glänzel, W., and A. Schubert. 2004. Analysing scientific networks through co-authorship. Pages 257-276
510   Handbook of quantitative science and technology research. Springer.
511   Granieri, M., and A. Renda. 2012. Innovation law and policy in the European Union: towards Horizon
512   2020. Springer Science & Business Media.
513   Halada, L., D. Evans, C. Romão, and J.-E. Petersen. 2011. Which habitats of European importance depend
514   on agricultural practices? Biodiversity and Conservation **20**:2365-2378.
515   Hancean, M.-G., M. Perc, and L. Vlasceanu. 2014. Fragmented Romanian Sociology: Growth and
516   Structure of the Collaboration Network. PLoS One **9**:e113271.
517   Hancean, M. G., and M. Perc. 2016. Homophily in coauthorship networks of East European sociologists.
518   Sci Rep **6**:36152.
519   Hanneman, R., and M. Riddle. 2005. Introduction to social network methods. Riverside, CA: University
520   of California, Riverside.
521   Hanspach, J., T. Hartel, A. I. Milcu, F. Mikulcak, I. Dorresteijn, J. Loos, H. von Wehrden, T. Kuemmerle, D.
522   Abson, A. Kovács-Hostyánszki, A. Báldi, and J. Fischer. 2014. A holistic approach to studying
523   social-ecological systems and its application to southern Transylvania. Ecology and Society **19**.
524   Hartel, T., N. Fagerholm, M. Torralba, Á. Balázsi, and T. Plieninger. 2018. Forum: Social-Ecological System
525   Archetypes for European Rangelands. Rangeland Ecology & Management **71**:536-544.
526   Kleijn, D., F. Kohler, A. Báldi, P. Batáry, E. D. Concepción, Y. Clough, M. Díaz, D. Gabriel, A. Holzschuh, E.
527   Knop, A. Kovács, E. J. P. Marshall, T. Tscharntke, and J. Verhulst. 2009. On the relationship
528   between farmland biodiversity and land-use intensity in Europe. Proceedings of the Royal
529   Society B: Biological Sciences **276**:903.
530   Kozak, M., L. Bornmann, and L. Leydesdorff. 2015. How have the Eastern European countries of the
531   former Warsaw Pact developed since 1990? A bibliometric study. Scientometrics **102**:1101-
532   1117.
533   Lescourret, F., D. Magda, G. Richard, A.-F. Adam-Blondon, M. Bardy, J. Baudry, I. Doussan, B. Dumont, F.
534   Lefèvre, I. Litrico, R. Martin-Clouaire, B. Montuelle, S. Pellerin, M. Plantegenest, E. Tancoigne, A.
535   Thomas, H. Guyomard, and J.-F. Soussana. 2015. A social–ecological approach to managing
536   multiple agro-ecosystem services. Current Opinion in Environmental Sustainability **14**:68-75.
537   Leydesdorff, L. 2004. Clusters and maps of science journals based on bi-connected graphs in Journal
538   Citation Reports. Journal of Documentation **60**:371-427.
539   Lomba, A., C. Guerra, J. Alonso, J. P. Honrado, R. Jongman, and D. McCracken. 2014. Mapping and
540   monitoring High Nature Value farmlands: challenges in European landscapes. J Environ Manage
541   **143**:140-150.
542   Manolache, S., C. M. Ciocanea, L. Rozylowicz, and A. J. E. J. G. Nita. 2017. Natura 2000 in Romania–a
543   decade of governance challenges. **8**:24-34.
544   Michielsen, M., L. Szemák, A. Fenesi, I. Nijs, and E. Ruprecht. 2017. Resprouting of woody species
545   encroaching temperate European grasslands after cutting and burning. Applied Vegetation
546   Science **20**:388-396.
547   Miclaus, M., and O. Micu. 2018. Reform Romania's grant-review system. Nature **558**:189-189.
548   Newman, M. E. J. 2004. Coauthorship networks and patterns of scientific collaboration. **101**:5200-5205.
549   Pătru-Stupariu, I., M.-S. Stupariu, I. Stoicescu, A. Peringer, A. Buttler, and C. Fürst. 2017. Integrating geo-
550   biodiversity features in the analysis of landscape patterns. Ecological Indicators **80**:363-375.
551   Pe'er, G., L. V. Dicks, i. P. Viscont, R. Arlettaz, A. Báldi, T. G. Benton, S. Collins, M. Dieterich, R. D.
552   Gregory, F. Hartig, K. Henle, P. R. Hobson, D. Kleijn, R. K. Neumann, T. Robijns, J. Schmidt, A.
553   Shwartz, W. J. Sutherland, A. Turbé, F. Wulf, and A. V. Scott. 2014. EU agricultural reform fails on
554   biodiversity. Science **344**:1090-1092.

555 Peringer, A., A. Buttler, F. Gillet, I. Pătru-Stupariu, K. A. Schulze, M.-S. Stupariu, and G. Rosenthal. 2017.
556   Disturbance-grazer-vegetation interactions maintain habitat diversity in mountain pasture-
557   woodlands. Ecological Modelling **359**:301-310.
558 Petrescu-Mag, R. M., D. C. Petrescu, and I. V. Petrescu-Mag. 2017. Whereto land fragmentation–land
559   grabbing in Romania? The place of negotiation in reaching win–win community-based solutions.
560   Land Use Policy **64**:174-185.
561 Plieninger, T., and C. Bieling. 2013. Resilience-Based Perspectives to Guiding High-Nature-Value
562   Farmland through Socioeconomic Change. Ecology and Society **18**.
563 Plieninger, T., T. Hartel, B. Martín-López, G. Beaufoy, E. Bergmeier, K. Kirby, M. J. Montero, G. Moreno,
564   E. Oteros-Rozas, and J. Van Uytvanck. 2015. Wood-pastures of Europe: Geographic coverage,
565   social–ecological values, conservation management, and policy implications. Biological
566   Conservation **190**:70-79.
567 Popescu, V. D., L. Rozylowicz, I. M. Niculae, A. L. Cucu, and T. Hartel. 2014. Species, habitats, society: an
568   evaluation of research supporting EU's Natura 2000 network. PLoS One **9**:e113648.
569 Queiroz, C., R. Beilin, C. Folke, and R. Lindborg. 2014. Farmland abandonment: threat or opportunity for
570   biodiversity conservation? A global review. Frontiers in Ecology and the Environment **12**:288-
571   296.
572 Roellig, M., A. Costa, M. Garbarino, J. Hanspach, T. Hartel, S. Jakobsson, R. Lindborg, S. Mayr, T.
573   Plieninger, M. Sammul, A. Varga, and J. Fischer. 2018. Post Hoc Assessment of Stand Structure
574   Across European Wood-Pastures: Implications for Land Use Policy. Rangeland Ecology &
575   Management **71**:526-535.
576 Rozylowicz, L., A. Nita, S. Manolache, C. M. Ciocanea, and V. D. Popescu. 2017. Recipe for success: A
577   network perspective of partnership in nature conservation. Journal for Nature Conservation
578   **38**:21-29.
579 Ruprecht, E. 2006. Successfully Recovered Grassland: A Promising Example from Romanian Old-Fields.
580   Restoration Ecology **14**:473-480.
581 Stoate, C., A. Baldi, P. Beja, N. D. Boatman, I. Herzon, A. van Doorn, G. R. de Snoo, L. Rakosy, and C.
582   Ramwell. 2009. Ecological impacts of early 21st century agricultural change in Europe--a review.
583   J Environ Manage **91**:22-46.
584 Sutcliffe, L. M. E., P. Batáry, U. Kormann, A. Báldi, L. V. Dicks, I. Herzon, D. Kleijn, P. Tryjanowski, I.
585   Apostolova, R. Arlettaz, A. Aunins, S. Aviron, L. Baležentienė, C. Fischer, L. Halada, T. Hartel, A.
586   Helm, I. Hristov, S. D. Jelaska, M. Kaligarič, J. Kamp, S. Klimek, P. Koorberg, J. Kostiuková, A.
587   Kovács-Hostyánszki, T. Kuemmerle, C. Leuschner, R. Lindborg, J. Loos, S. Maccherini, R. Marja, O.
588   Máthé, I. Paulini, V. Proença, J. Rey-Benayas, F. X. Sans, C. Seifert, J. Stalenga, J. Timaeus, P.
589   Török, C. Swaay, E. Viik, and T. Tscharntke. 2014. Harnessing the biodiversity value of Central
590   and Eastern European farmland. Diversity and Distributions **21**:722-730.
591 Torralba, M., N. Fagerholm, T. Hartel, G. Moreno, and T. Plieninger. 2018. A social-ecological analysis of
592   ecosystem services supply and trade-offs in European wood-pastures. Science Advances **4**.
593 Veen, P., R. Jefferson, J. de Smidt, and J. van der Straaten. 2009. Grasslands in Europe: Of High Nature
594   Value. BRILL.
595 Wang, J. 2016. Knowledge creation in collaboration networks: Effects of tie configuration. Research
596   Policy **45**:68-80.
597 Wilson, J. B., R. K. Peet, J. Dengler, and M. Pärtel. 2012. Plant species richness: the world records.
598   Journal of Vegetation Science **23**:796-802.

599