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## How do plant community ecologists consider the complementarity of observational, experimental and theoretical approaches?

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1 **How do plant community ecologists consider**  
2 **the complementarity of observational,**  
3 **experimental and theoretical modelling**  
4 **approaches?**

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6  
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31 **Running title:** Complementarity of observational, experimental and theoretical approaches

32

## ABSTRACT

33

34 **Background and aims** -- A large variety of methods are used by ecologists for studies at  
35 plant community level. While early works were mainly descriptive, more manipulative  
36 experiments are now being undertaken because they provide a better functional understanding  
37 and a greater insight into underlying mechanisms. Mathematical models are also being  
38 increasingly used, in particular for predicting biodiversity under global change. The aim of  
39 this study is to highlight the strengths, limitations, and advantages of these three approaches,  
40 namely observational, experimental and theoretical modelling.

41 **Methods** -- We assessed 149 papers published during the last four years in three specialized  
42 disciplinary journals (DJ) and 151 papers in three generalist high impact journals (HIJ)  
43 dealing with plant ecology, and checked the methods that were used. We asked participants of  
44 the ECOVEG7 meeting held in Switzerland (Lausanne, April 2011) whether observational,  
45 experimental and theoretical modelling approaches can, or should, be used alone or in  
46 combination when studying plant communities and ecosystem functioning in the context of  
47 global change.

48 **Key results** -- About 50% of articles published in both journal types used only a single  
49 approach. Nevertheless, papers in HIJ used the approaches in similar proportions, while  
50 articles in DJ had 8 times more observational than modelling studies. Combined approaches  
51 represented only 8% in DJ, while this percentage was more than double in HIJ.

52 **Conclusion** -- Plant community ecologists favour a combination of several approaches, but  
53 for practical difficulties (communicating among people using different approaches and  
54 publication strategies), single-approach studies are generally preferred. A combination of the  
55 three highlighted approaches seems to be the most appropriate way to respond to future  
56 challenges in plant community ecology such as biodiversity loss and impact of climate change  
57 as such studies require work on different temporal and spatial scales.

58

59 **Key words** -- Plant ecology, community ecology, approaches, observations, experiments,  
60 modelling, literature review.

61

## INTRODUCTION

62 The field of plant community ecology or vegetation science has a long scientific tradition  
63 starting in the 19<sup>th</sup> century with A. von Humboldt, C. Darwin and E. Haeckel. It played an  
64 important role in the development of key concepts in biogeography and ecology (Deléage  
65 1991). Since the beginning in plant ecology studies, descriptive and experimental approaches  
66 were combined to explain vegetation patterns and processes at various spatial and temporal  
67 scales. The notion of community itself was the object of a long debate between the  
68 Clementsian ‘organismic’ and the Gleasonian ‘individualistic’ concepts of plant communities  
69 (Clements 1916, Gleason 1926). The organismic concept has enabled the emergence and the  
70 development of phytosociology, often presented as a purely descriptive and qualitative  
71 approach of plant communities, although the ecological and functional aspects were already  
72 central to its founders (Braun-Blanquet 1964). The individualistic concept led to the  
73 development of quantitative tools to describe and explain gradients in species assemblages  
74 and diversity. Recently, these two conceptual views have been reconciled to explain the  
75 species assemblages in plant communities by a series of drivers and filters acting on the  
76 species pools at different spatial and temporal scales (Lortie et al. 2004).

77 Early studies in plant ecology were based on the observation of phenomena in nature. They  
78 were descriptive or comparative, including long-term observational studies in environmental  
79 monitoring. At the end of the 19<sup>th</sup> century, advances in plant ecology were often based on  
80 experimental laboratory studies or field experiments under controlled conditions (McIntosh  
81 1986). One reason for this new approach was that observations made in new sites did not  
82 always conform to the expectations that were hypothesis from initial observations, thus  
83 preventing generalisation of the results. Moreover, experiments allowed disentangling factors  
84 at the origin of the observed responses, and could therefore give new insights in ecological  
85 interactions and underlying mechanisms. However, experiments on simplified communities in  
86 controlled conditions, as well as simple mechanistic models developed to explain their results,  
87 often led to paradoxes and controversies when confronted to observations in natural  
88 communities -- e.g. the paradox of the plankton (Hutchinson 1961), or the diversity-  
89 productivity debate (Hector et al. 2007, Loreau et al. 2001). With the increase of data acquired  
90 under diverse conditions and stored in databases (Kleyer et al. 2008), a theoretical approach  
91 has emerged in the 20<sup>th</sup> century (Coudun & Gégout 2006), based on statistical or mechanistic  
92 models which allowed understanding and predicting complex ecological patterns and  
93 interactions.

94 Today this panel of approaches is enlarged by the appropriation of molecular techniques to  
95 study the phylogenetic structure of plant communities in order to answer ecological and  
96 biogeographical questions (Parmentier & Hardy 2009, Webb 2000) or by barcoding for  
97 accurate species and community identifications (Kress et al. 2009). Furthermore, new  
98 concepts such as plant functional traits (Grime 1977, Lavorel & Garnier 2002) together with  
99 the advent of high capacity computers and multivariate statistical frameworks (Borcard et al.  
100 2011, Leps & Smilauer 2003) are deeply modifying the field of plant community ecology and  
101 offer opportunities for cross-level studies (Gégout et al. 2005). For studies at a larger scale,  
102 remote sensing coupled to geographic information systems contribute to a worldwide  
103 assessment of vegetation communities and dynamics, facilitated by imagery allowing  
104 acquiring information for all habitats (Aragón & Oesterheld 2008), and in a short period of  
105 time compared to field-based surveys (Underwood et al. 2003, Xie et al. 2008). Meta-analysis  
106 is another tool allowing integration of information acquired independently in various sites and  
107 extracting general patterns (Dormann & Woodin 2002, van Kleunen et al. 2010).

108 The complementarity of these approaches is highlighted in most standard books on methods  
109 in ecology (see for example Henderson 2003). While most authors emphasise that  
110 experiments cannot be done effectively without knowing the natural history of the studied  
111 organism, community or ecosystem, or the environmental background, many studies are  
112 undertaken without thorough preliminary survey and observation of the studied phenomena in  
113 nature. In many cases, challenges such as time limitation or shortage in funds are put forward  
114 to justify this partial approach. However, we argue that such arguments are blinkered: a  
115 preliminary study may save both money and time in the long run because it reduces the risk of  
116 an inadequate sampling effort or pitfalls in the experimental set-up. Similarly, modellers may  
117 reach more rapidly a representative mathematical model if they have already observed the  
118 phenomena in nature. Obviously, communication among colleagues with different approaches  
119 (i.e. observers, experimentalists, modellers) may help to improve the knowledge of ecological  
120 systems.

121 This paper reviews the approaches used in recently published works in plant community  
122 ecology and summarises the outcome of a plenary discussion devoted to this topic at the  
123 ECOVEG7 international meeting held in Switzerland (Lausanne, April 2011) which brought  
124 together ecologists from mainly French speaking countries. We aimed at characterizing the  
125 approaches currently used in this field and identifying options for their use. We addressed the  
126 following questions more specifically: i) what are the specificity, strength, and limitations of  
127 each of the three approaches (observations, experiments, models)?; ii) are these approaches  
128 exclusive or should they be combined in the study of ecological processes?; and iii) what are  
129 the challenges in combining these approaches? We hypothesised that high impact journals  
130 publish more papers in which combined approaches were used, as their scope is more  
131 generalist than in specialised disciplinary journals, which mainly focus on single-approach  
132 papers.

133

134

## MATERIAL AND METHODS

135 For assessing the methodological approaches used in published works, we compared two  
136 groups of journals formed by three generalist high impact journals (*Nature*, *Proceedings of*  
137 *the National Academy of Sciences*, *Science*; thereafter “HIJ” journals) and by three  
138 disciplinary journals (thereafter “DJ” journals) dealing specifically with plant ecology  
139 (*Perspectives in Plant Ecology and Evolution*; *Plant Ecology and Evolution*; *Plant Ecology &*  
140 *Diversity*). Among the high number of disciplinary journals, these three journals were chosen  
141 as their number of articles published during the selected period was similar to those of the HIJ  
142 (cf. results). We therefore deliberately did not select journals such as *Applied Vegetation*  
143 *Science* (190 published articles during the selected period), *Journal of Vegetation Science*  
144 (353) or *Plant Ecology* (641). The search was performed via the Web of Knowledge (accessed  
145 on 19 May 2011) with the search string “Publication Name=(Plant Ecology & Diversity OR  
146 Perspectives in Plant Ecology and Evolution OR Plant Ecology and Evolution)” and the key  
147 word “plant ecology” in either title or keywords. We restricted the search to the document  
148 type “article” and the time span 2008--2011, as we were interested in recent trends. A similar  
149 search with changed publication name was done for the HIJ. We assessed whether the results  
150 presented in the paper were observational (OBS), experimental (EXP), obtained from a model  
151 (MOD), or any kind of combination of the three approaches. This was done by reading the  
152 abstract, or when the information was not clear from the abstract, by checking the entire

153 paper. Papers primarily focusing on taxonomy, genetics, or literature study were not  
154 considered.

155 During the plenary session at ECOVEG7, a discussion was launched on this topic, animated  
156 by a moderator. The first part of the discussion concerned the specificity, strength, and  
157 limitations of each of the three approaches, the second part was on the usefulness of either  
158 single or complementary approaches, and the third part concerned the challenges of  
159 combining methods. The following questions were submitted to the participants by mail one  
160 week before the conference:

- 161 • What are the criteria allowing you to select or use a particular approach to answer a  
162 scientific question in relation to ecosystem functioning in the context of global  
163 change? What would be your preferred approach in plant community ecology?
- 164 • Would one approach be sufficient to answer your scientific questions? Would it have  
165 been more efficient to combine several approaches (e.g., modelling based on  
166 monitoring data)?
- 167 • Are modelling and short-term observations compatible and complementary when  
168 studying ecosystem functioning in a context of global change?
- 169 • Under what circumstances is a particular approach best adapted and effective? Is one  
170 of these approaches suitable for any situation?

171 Replies were sent by return mail and collected by the organisers of the conference.

172 For identifying what the authors of scientific articles in ecology and plant ecology propose as  
173 methodological outlook, we checked the number of references in Google Scholar (accessed 21  
174 Jun. 2011 and 11 Jul. 2011) that contained “ecology” or “plant ecology” together with 11  
175 formulations calling for either more observations, monitoring, experiments, empirical studies  
176 or modelling. We assessed the trends for these search terms based on the number of hits  
177 obtain in Google Scholar (table 1).

178

## 179 **RESULTS & DISCUSSION**

### 180 **Current approaches used in published studies**

181 Web of Knowledge revealed 186 papers published in the last four years with the keyword  
182 “plant ecology” in the three investigated HIJ journals and 156 papers in the three investigated  
183 DJ journals. After a first screening we excluded 35 papers from HIJ journals as the subject of  
184 the paper did not concern plant ecology, and 7 papers from DJ journals as they were double  
185 entries in the database. This resulted in 300 papers (for the complete list of all papers see app.  
186 1), 151 HIJ-papers and 149 DJ-papers on which the following analysis is based.

187 Out of these 300 papers, 31% HIJ-papers and 42% DJ-papers dealt with non-ecological  
188 subjects (taxonomy, genetics, GIS, etc.). From the remaining, 49% of HIJ-papers and 50% of  
189 DJ-papers used only a single approach, but the partitioning between the three approaches  
190 differed (fig. 1): while papers published in HIJ journals used a similar proportion of each  
191 approach, about 8 times more observational studies were published in DJ journals as  
192 compared to studies using modelling approaches. Combined approaches represented the  
193 minority in DJ journals, with only 8% of the published papers, while this percentage was  
194 more than double in HIJ journals.

195 These results were obtained from journals which we deliberately selected as being not limited  
196 to one approach. However, a tendency towards publishing in specialised journals can be  
197 observed recently. Approach-based journals such as “Ecological Modelling”, “Environmental  
198 Modelling & Software” or “Environmental Modelling & Assessment” have been launched in  
199 the mid-1970s and focus mainly on a single approach (e.g. modelling). Studies dealing with  
200 models in plant community ecology are published in these specific journals and have been  
201 neglected in our analysis. However, articles concerning observational data may also be  
202 published in specific journal such as “Journal of Environmental Monitoring” or  
203 “Environmental Monitoring and Assessment” and therefore similarly omitted from the present  
204 analysis.

### 205 **Observations, Experiments, Models -- Specificities, strengths, and limitations**

206 The participants of ECOVEG7 agreed that observational or descriptive studies constitute a  
207 strong basis for further investigations since they reveal natural patterns and therefore the field  
208 reality to be studied. Observational data are also necessary for long term environmental  
209 studies such as vegetation monitoring. However, acquiring new vegetation relevés is time-  
210 consuming, expensive, and the results are often not publishable. As one of the participants  
211 summed up: “Who is doing the vegetation relevés we’ll use in 50 years?”. Many advances  
212 have been made in recent years to bring together the numerous vegetation data collected by  
213 different institutions and people. However, these data are still dispersed in several databases  
214 such as, in France, SOPHY (<http://sophy.u-3mrs.fr/sophy.htm>), EcoPlant  
215 (<https://www2.nancy.inra.fr/unites/lerfob/ecologie-forestiere/bd/ecoplant.htm>), Phytobase  
216 ([http://www.tela-botanica.org/page:liste\\_projets?id\\_projet=18&act=documents&id\\_repertoire=16428](http://www.tela-botanica.org/page:liste_projets?id_projet=18&act=documents&id_repertoire=16428)), e-Flora-sys (<http://eflorasys.inpl-nancy.fr/>) and FlorEM (Spiegelberger et al. 2010).  
218 Recently some attempts were undertaken to create a global database (Dengler et al. 2011,  
219 Kattge et al. 2011) overcoming geographical limitation. Nevertheless, both regional and  
220 global databases are confronted to similar problems such as the ownership of the data (Janßen  
221 et al. 2011), their accuracy, and the missing coverage in certain regions and for certain periods  
222 (Dengler, et al. 2011).

223 According to the participants, the main drawbacks of experiments in ecology are their  
224 limitation in time and space (Jenkins & Ricklefs 2011) and the difficulty to use their results  
225 beyond the targeted question. As a matter of fact, young researchers at both MSc and PhD  
226 levels often prefer short term experiments since this approach has a higher potential for results  
227 obtained factors, reducing considerably the chances of a good comprehension of the system.  
228 This impedes integration of experimental results in a wider context. To overcome such  
229 limitations, several possibilities were mentioned during the discussion. Multi-site experiments  
230 with a standardised protocol were cited as the best solution to investigate and validate  
231 processes at large spatial scales (e. g. Bernhardt-Romermann et al. 2011). If experiments were  
232 designed independently and a joint data analysis was not planned beforehand, meta-analysis  
233 could be a powerful tool to surmount such limitations (Osenberg et al. 1999). Nevertheless,  
234 this requires the awareness of the existence of similar experiments and the network to join  
235 efforts. The online database PermanentPlots.CH  
236 (<http://www.unil.ch/ecospat/page48113.html>), which stores historical data about permanent  
237 plots in Switzerland was mentioned as an example of an integrating research initiative.

238 Model calibration and validation require sound data originating from both observational and  
239 experimental studies. It is therefore an important prerequisite, as mentioned during the  
240 discussion, that the data are adapted to the model. For example, fine-scale observations are

241 not appropriate for predictions at broad scale, and experiments focusing only on one or two  
242 factors rarely represent the complex interactions that operate in real systems that a model  
243 wants to reproduce.

#### 244 **Methodological choices -- science-driven or fashion-driven?**

245 Interestingly, the percentage of experimental studies has changed during the last 5 decades: in  
246 1959 (Hairston 1989), experimental studies represented only about 4 % of the articles  
247 published in both *Journal of Animal Ecology* and *Ecology* and 16% in *Journal of Ecology*, but  
248 this percentage increased to about 33% in 1987 for the first two journals, and 26% for the  
249 latter. In our literature study, this percentage was about 15% for both, disciplinary and high  
250 impact journals. Such trend to more experimental studies has also been observed by the  
251 participants of ECOVEG7 and was explained by the opportunistic behaviour of researchers  
252 who choose the approach that allows them to increase the probability of being rapidly  
253 published. While everybody agrees that the choice of an approach should be science-driven,  
254 the pressure to publish apparently overwhelms this.

255 From a scientific perspective, all three approaches have their limitations and advantages, as  
256 raised by the participants of ECOVEG7. The choice of the appropriate approach is however a  
257 trade-off between the initial scientific question (patterns, processes, predictions; applied vs.  
258 theoretical ecology), personal or institutional skills, and publication strategy. Personal  
259 limitations, as most researchers do not possess the knowledge necessary to apply all methods,  
260 but also infrastructure, budget, institutional structure and science-policy, guide in many cases  
261 the decision in favour of one approach over another. In addition, as mentioned repeatedly,  
262 fashion is also governing science (Belovsky et al. 2004). Trends such as the increase of  
263 models and the decrease in observational studies published in the last years may represent  
264 such fashions. However, the scope of journals or subjective preferences of editors or  
265 reviewers may contribute equally to the high number of publications using models in HIJ  
266 journals, and to their low percentage in DJ (fig. 1).

267 Experimental results often fail to explain properly the patterns and processes being studied,  
268 which is at least partly due to the diverse methodological approaches and lack of concerted  
269 protocols based on sound observation and coordination between scientists. The difficulty of  
270 correct interpretation of observed patterns by means of experimental evidence has been raised  
271 many times. Science historian H. Cravens stated that in the early 20<sup>th</sup> century experimentalists  
272 overshadowed people doing observations or descriptive work, and that the context or nature in  
273 which the experiment was done did not get enough consideration (Cravens 1978). The  
274 steadily increasing body of literature based on experiments is one evidence of the trend  
275 (Jenkins & Ricklefs 2011). Today, this trend seems to be reversed, as observational  
276 approaches are greatly enhanced by technological advances in remote sensing, microscopy,  
277 genetics, animal-borne sensors, and computing which make basic observational approaches in  
278 ecology far more powerful than at any point in scientific history (Sagarin & Pauchard 2010).

#### 279 **Combining approaches -- difficult, but promising**

280 Participants of ECOVEG7 agreed that for a more complete study of ecosystems, approaches  
281 should be combined. However, our literature study revealed only three papers published in  
282 HIJ journals (Brando et al. 2010, Desurmont et al. 2011, Roper et al. 2010) in which all three  
283 approaches were combined



284 As requested for ecology in general, vegetation studies should be more integrative and  
285 incorporate observational approaches in experimental studies and experimental approaches in  
286 modelling (Belovsky, et al. 2004). As a consequence, studies would become more  
287 comprehensive if experiments were based on patterns observed in nature, then hypotheses  
288 clearly formulated and tested individually with experiments. However, too often “hypotheses  
289 are generated by « vote » within teams or dictated by the funding agency, which make no  
290 sense scientifically” (Likens 1998, p.255). Results obtained from observations and  
291 experiments should be used to build models allowing a more mechanistic understanding of  
292 the ecosystem and predictions about its future development. While it would be wishful to see  
293 more researchers who possess a background in all three approaches, participants emphasised  
294 the fact that institutions, such as universities and research institutes, may be the best place  
295 where people with different methodological background could be associated. Affiliations of  
296 researchers using different approaches will promote integrated research spanning from the  
297 observation of phenomena in nature over experiments to prediction by models.

298 Several of the participants underlined the need for combining the three approaches for a better  
299 understanding of ecosystem processes and functioning and the response of plant populations  
300 and communities to global change. This motion is in accordance with recent ideas on  
301 combining observations and experiments in the study of global change, as both are  
302 strengthened when reconciled (Sagarin & Pauchard 2010). The ideal way to study plant  
303 communities and interactions is to observe patterns in nature, which allows for the  
304 formulation of hypotheses that are focused on a number of factors of potentially high  
305 importance as drivers of the patterns observed. These factors should be prioritised according  
306 to the patterns observed, but also with respect to future modelling and therefore be elaborated  
307 in partnership among the modeller, the experimentalist and the observer. Depending on the  
308 outcome of a first modelling step, the experimentalists and the observers should continue to  
309 acquire field data or do further experiments, but with a more focused perspective. With this  
310 iterative process, a more realistic or general model can evolve and experiments or  
311 observations will in turn be more specific. The methodological triad (fig. 2) conceptualises  
312 the complementarity of the three approaches and shows their interplay. Hypotheses can either  
313 be formulated based on observations in the field or - if already existing - on models. These  
314 hypotheses can then be tested with empirical explanatory models, either directly by  
315 manipulative experiments or indirectly by targeted observations along environmental  
316 gradients. In the first case it yields a predictive model based on explicit causality, in the  
317 second it yields a forecasting static model with implicit causality. The hypotheses can also be  
318 verified by means of theoretical models that are based on given reciprocal interactions and  
319 yield predictive dynamical models based on causal processes. However, confirming  
320 hypotheses derived from observations may lead to vicious circles if hypothesis creation and  
321 their testing are based on the same data. It is therefore crucial to resample an independent data  
322 set. Similarly, the theoretical models need to be validated with an additional data set.

323  
324 It is obvious that this iterative approach is time consuming and expensive, and can only be  
325 rarely achieved in a single project, considering their average duration of one to three years, or  
326 by a single person. A proposition that emerged at ECOVEG7 was that research institutions  
327 should pay more attention to the complementarity of scientist’s background, so that groups  
328 with large and various expertise could be built. Interdisciplinary approaches should be  
329 favoured (Likens 1998), even though the communication between different scientific  
330 communities could be difficult (Miller et al. 2008). It would also be necessary that such  
331 groups can work on a common topic for several years. Other ways to overcome an individual  
332 researcher’s incomplete expertise and to excel in several approaches is to bring people

333 together to tackle a common project, as it is done, for example, in the long-term ecological  
334 research (LTER) sites (Likens 1998). Such an approach was recently promoted with the  
335 establishment of the Central French Alps long-term socio-ecological research platform  
336 (LTSER Central French Alps, Lavorel et al. 2012). Based on earlier observational studies, a  
337 common project was developed which brought together researchers from different disciplines,  
338 but also those who used different approaches. This paves the way for more in-depth study of  
339 ecological questions. The advantage of such research structures would be manifold and would  
340 trigger breakthrough research in deepening the functional approach and also result in  
341 increasing individual competences. Such groups have a high potential for outputs publishable  
342 in HIJ journals, as demonstrated by our literature review.

343 Nevertheless, even if there was general agreement at ECOVEG7 that the approaches are  
344 complementary, it is often difficult to promote such integrative projects. For instance,  
345 scientists are evaluated on the basis of published articles, and in many cases it is thought to be  
346 easier and more productive to conduct small experiments, rather than trying to have a more  
347 complete view requiring several approaches and surely more time. Moreover, a common  
348 problem encountered during collaborative, interdisciplinary projects that combine  
349 experiments and models, is that people performing the experiment and researchers elaborating  
350 the model do not use the same technical language, and often do not have the same objectives  
351 (Miller, et al. 2008). As a consequence, a huge experimental effort is sometimes  
352 accomplished, but only a conceptual model is developed, or the results obtained by  
353 experiments cannot be used properly to validate the model.

#### 354 **Today's observations -- tomorrow's bases for experiments and models**

355 Our investigation concerning the future directions of research reveals a similar demand from  
356 both authors of published articles and participants of ECOVEG7. In total, the combination of  
357 the search terms revealed 2,466 hits in Google Scholar with the broader term "ecology" and  
358 117 when restricted to "plant ecology" (tab. 1). In most cases, authors propose to continue or  
359 underpin their study with more long-term observations (50% in ecology and 56% in plant  
360 ecology) or with further experiments (38% in ecology and 25% in plant ecology), while none  
361 of the papers argued for more models in plant ecology. Similarly, the contributors to the  
362 plenary discussion at ECOVEG7 expressed concern about the difficulty of collecting field  
363 data. However, some of the currently highly cited papers in ecology are based on the  
364 exploitation of large databases (Lenoir et al. 2008, Thuiller et al. 2005), which were fed by  
365 vegetation relevés done in earlier years when field observation was more fashionable. Today,  
366 such data are mainly collected by organisations in charge of inventories and biodiversity  
367 surveys, such as national botanical conservatories and national/regional parks. This is a  
368 valuable step, but the objectives of the above-mentioned institutions might not be the same as  
369 for plant community ecologists concerned with ecosystem functioning and their response to  
370 global change. As a consequence, the collected data may neither meet the requirements for  
371 topical research questions, nor for sound statistical analyses. Collaboration between  
372 conservatories and national/regional parks on one hand, and universities or research institutes  
373 on the other hand may help to optimize the invested time and money. Beforehand,  
374 cooperation during the design of monitoring programs would probably increase the added  
375 value of such databases. In particular, the task of conservatories and parks for acquiring  
376 information on the current vegetation could be efficiently linked to scientific goals such as  
377 future analysis of impact of land-use or climate changes on plant communities. As an  
378 important side effect, some difficulties in relation to the data ownership may be avoided.

379 **Expert knowledge & financial funding-- sufficiently available and well distributed**  
380 Acquiring sound data from observational studies is a main issue in general, but in particular in  
381 the current context of global change, where simulations are needed to guide public decision  
382 (Sutherland 2006). The experience to accurately conduct field observation, i.e. the expertise to  
383 correctly identify species and to describe a plant community, needs to be recognised as an  
384 important scientific aspect for high quality data and their subsequent potential use. Otherwise,  
385 and this can already be observed today, young scientists are discouraged to specialize in  
386 taxonomy or plant community description (Pearson et al. 2011). Moreover, human resources  
387 are unevenly distributed with a high number of taxonomists in well-developed countries,  
388 while less developed countries, which harbours comparatively a higher number of species,  
389 have only limited expert knowledge (Gaston & May 1992). A further aspect concerns easy  
390 access to software and computers, or - more generally - to financial support needed to use  
391 experimental or modelling approaches. Most of the plant biodiversity is located in developing  
392 tropical countries where good quality descriptive information is essential for biodiversity  
393 conservation programs (Ahrends et al. 2011).

394

395

## CONCLUSION

396 We found that plant community ecologists mainly publish descriptive and experimental  
397 studies in disciplinary journals, a conclusion which was also made by the plant community  
398 ecologists attending ECOVEG7. They favoured a more comprehensive approach, but  
399 practical difficulties (e.g. to communicate between people using different methods) and an  
400 increasing need for specialization drive them to carry out single-method studies, despite the  
401 fact that multi-method studies allow to assess ecological processes in a more complex way  
402 and have a higher potential for being published in generalist high impact journals. The  
403 importance of using combined approaches will probably increase in the future because studies  
404 on key issues in the context of global changes, such as biodiversity loss and impact of climate  
405 change, require approaches that can be used at different temporal and spatial scales. A  
406 combination of the three highlighted approaches seems to be the most appropriate to respond  
407 to these challenges in plant community ecology.

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## Figure captions

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Table 1 -- Combined search on Google Scholar with two search terms. Accessed 21 June 2011 and 11 July 2011.

Figure 1 -- Percentages and absolute numbers of papers dealing with plant ecology using different approaches. The sample was restricted to articles published between 2008 and mid 2011. Grey bars: High Impact Journals (Nature, PNAS, Science); black bars: disciplinary journals (Plant Ecol Divers, Perspec Plant Ecol, Plant Ecol Evo). OBS, observation; EXP, experiment; MOD, modelling; EXP-OBS, EXP-MOD, OBS-MOD, EXP-OBS-MOD, combination of different approaches; TAX-GEN, taxonomic and genetic approaches; OTHER, other approaches like literature studies, cost-benefits analysis, etc.

Figure 2 -- The methodological triad and its application to plant community ecology.

584 **TABLE 1**

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586 **Table 1 -- Combined search on Google Scholar with two search terms.** Accessed 21 June  
 587 2011 and 11 July 2011.

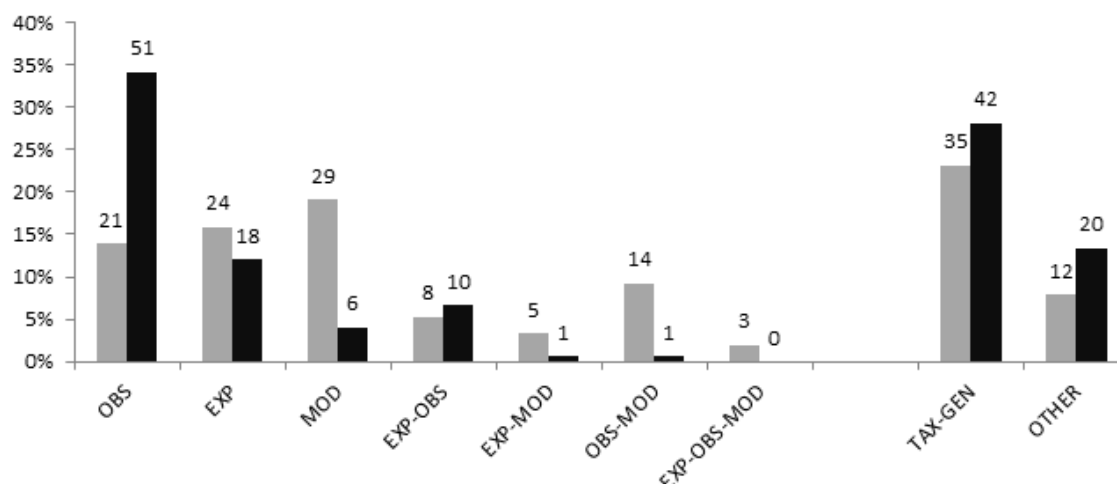
Search term	"plant ecology"		"ecology"	
	Hits	%	Hits	%
"more observational studies are needed"	0	0,0%	3	0,1%
"more observations are needed"	8	6,8%	203	8,2%
"new observations are needed"	0	0,0%	6	0,2%
"further observations are needed"	5	4,3%	179	7,3%
"more monitoring is needed"	1	0,9%	30	1,2%
"monitoring is needed"	57	48,7%	1350	54,7%
"more experimental studies are needed"	13	11,1%	62	2,5%
"more experiments are needed"	24	20,5%	436	17,7%
"more empirical studies are needed"	7	6,0%	117	4,7%
"more models are needed"	0	0,0%	12	0,5%
"new models are needed"	2	1,7%	68	2,8%
<b>Total hits</b>	<b>117</b>	<b>100%</b>	<b>2466</b>	<b>100%</b>

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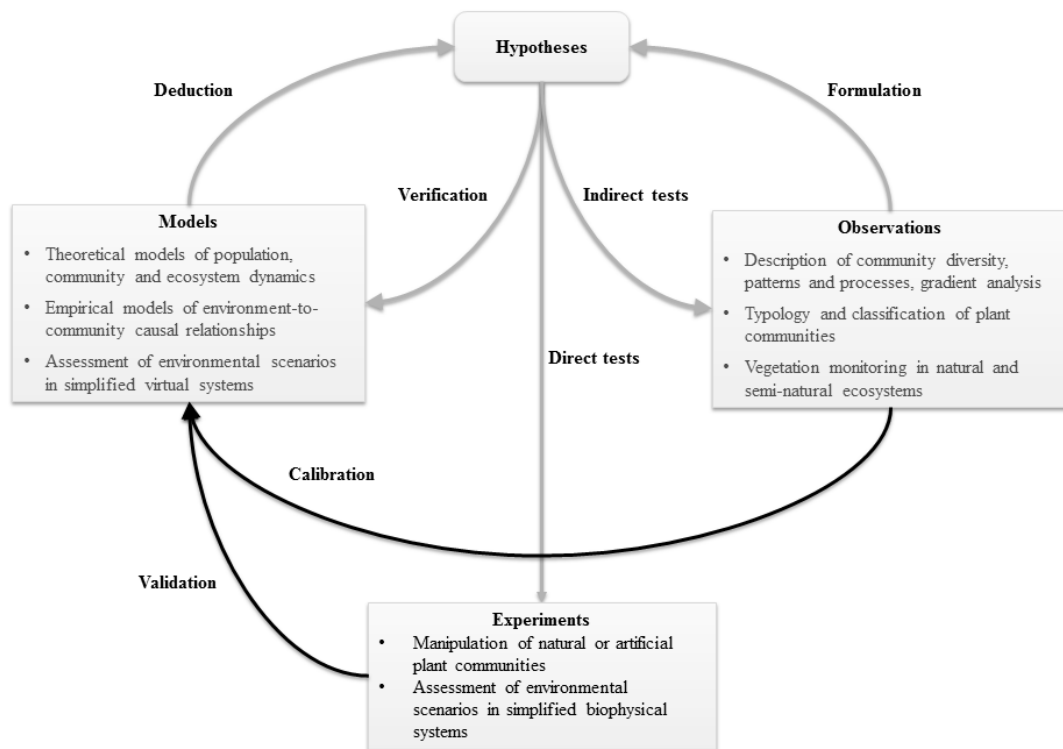
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 592 Figure 1 -- Percentages and absolute numbers of papers dealing with plant ecology using  
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601 Figure 2 -- The methodological triad and its application to plant community ecology.