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# 1 MOTHER TREES, ALTRUISTIC FUNGI, AND THE PERILS OF 2 PLANT PERSONIFICATION

3

4 *La grandeur de l'homme est grande en ce qu'il se connaît misérable. Un*  
5 *arbre ne se connaît pas misérable.*

6

7 The greatness of man is great in that he knows himself to be miserable. A tree does  
8 not know itself to be miserable.

9

10 Blaise Pascal, *Pensées* (1670; # 397)

11

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80

81 A recent article in the New York Times [1] has drawn attention to the growing doubts  
82 about the true role of the common mycorrhizal networks (CMN or WWW, wood wide  
83 web) connecting the roots of trees in forests. In particular, the claim of a substantial  
84 carbon transfer from “mother trees” to their offspring and nearby seedlings through the  
85 CMN is being questioned. Recent reviews show that evidence for the Mother Tree  
86 concept is inconclusive or absent. Moreover, this concept contradicts numerous well-  
87 known observations on development patterns of regrowth in forests. The origin of the  
88 Mother Tree Concept seems to stem from a desire to humanize plant life. This may  
89 appeal to many people, but such anthropomorphic perspective and vocabulary can  
90 lead to misunderstandings and false interpretations and may eventually harm rather  
91 than help the commendable cause of preserving forests. Two recent books serve as  
92 examples: “The Hidden Life of Trees” (2017) by Peter Wohlleben [2], and “Finding the  
93 Mother Tree” (2021) by Suzanne Simard [3].

#### 94 **The Hidden Life of Trees: Anthropomorphization and Conjecture, but** 95 **not Science**

96 Probably the best example of anthropomorphizing plants is the book “The Hidden Life  
97 of Trees” [2], which is a best seller with over 35 editions and is available in different  
98 languages all over the world. While mentioning the scientific work of Suzanne Simard,  
99 but by ignoring extensive scientific findings contradicting his viewpoints, Wohlleben  
100 ascribes to plants (in this case trees), a number of human characteristics: feeling pain,  
101 being happy and caring for other trees, being able to communicate with other trees,  
102 and being capable of creating strategies for the benefit of the group. These are  
103 hallmarks of conscious organisms, which plants are definitely not [4, 5]. A striking  
104 example is his claim that a forest has no interest in losing “weaker” members of the  
105 same species, instead postulating that competition between trees is restricted to  
106 interspecific interference, which contradicts fundamental knowledge of forest ecology  
107 (see Box 1).

108 At the end of his book, Wohlleben even goes so far as to propose abolishing the  
109 “arbitrary” separation of animals, plants, and fungi. Even the most benevolent critics of  
110 his book feel this demand goes too far, blatantly disregarding 300 years of biological  
111 research [6]. Consequently, Wohlleben’s book has been severely criticized on

112 numerous occasions for the misinterpretation and distortion of scientific data [7, 8, 9,  
113 10]. We draw attention to the preface of Halbe's book [7] written by the well-known  
114 plant biochemist Nikolaus Amrhein. He states:

115 *"The majority of my colleagues, even if they had read the book at all, hold Wohlleben's*  
116 *ideas so evidently unscientific and untenable, that they did not deem it necessary to*  
117 *criticize it publically". (engl. Translation).*

118 Although several scientists have challenged the claims of Wohlleben, this has had little  
119 influence on the responsiveness of the general public to Wohlleben's pseudo-scientific  
120 interpretations of plant life. He continues to attract new followers, and has even  
121 become a TV personality in Germany. In the meantime, he is also being used by  
122 various groups as a key witness for alleged "forest devastation" caused by false forest  
123 management and is often seen participating as a forest expert in talk shows. The extent  
124 to which his expertise is credible and based on scientific facts is not questioned in  
125 these formats where obviously other mostly economic considerations are important.  
126 This certainly becomes problematic, when politicians and administrators start to rely  
127 on this "expertise", for example, Wohlleben was invited to give an "inspirational speech"  
128 at a scientific symposium on forests, biodiversity and climate change organized by the  
129 European Commission in February 2020. Wohlleben has also been appointed to the  
130 advisory board of the UN Decade of Restoration for his "emotional and unconventional  
131 communication of knowledge", a knowledge which is mainly based on belief and  
132 assumptions. The unwillingness or lack of ability by the media and decision makers to  
133 assess the factual basis of Wohlleben's statements (or the deliberate use for their own  
134 purposes) is a great concern to plant and forest scientists and has in part motivated  
135 this article.

## 136 **Searching for the Mother Tree**

137 In her book: "Finding the Mother Tree" [3] the Canadian forest ecologist Suzanne  
138 Simard submits that trees communicate their needs and send each other energy and  
139 nutrients altruistically via a network of fungal hyphae in the soil, the common mycelial  
140 network (CMN) popularly referred to as the wood wide web (WWW). According to this  
141 hypothesis, "hub" or "mother trees" are highly connected to nearby seedlings via the  
142 CMN and share their excess C and N with them, thereby, increasing seedling survival  
143 and growth. In particular, it is claimed that kin-offspring benefit more from this CMN-  
144 mediated nutrient transfer than non-kin plants.

145 Do Simard's published data and interpretations stand up to a critical analysis? Before  
146 going into detail, it should be pointed out that the Mother Tree concept is incompatible  
147 with many well-known observations on the growth of forest trees. For instance, an early  
148 Finnish study demonstrated that belowground competition hampers seedling  
149 establishment [11]. This has been confirmed in many studies where mature trees have  
150 been shown to suppress growth of seedlings, for example in maple and pine [12, 13,  
151 14]. This finding has a long history of being acknowledged by foresters. For example,  
152 almost a century ago Aaltonen [15] reported that mother trees can greatly impair the  
153 growth of their offspring. In fact, the absence of regeneration in the immediate vicinity  
154 of the "mother tree" is often described as a "plate effect", meaning that belowground  
155 competition from mature trees makes it difficult for regenerating seedlings to establish.  
156 The finding that canopy trees impede the survival and growth of seedlings has been  
157 the basis for timing of removal cuts in shelterwood regeneration systems [16, 17]. In  
158 temperate beech forests, trenching, which prevents root competition by mature trees,  
159 has been shown to stimulate growth of the regeneration [18], a fact, established 95  
160 years ago [19]. Fabricius [20] concluded that competition for water by overstory trees  
161 is decisive for seedling survival and growth when species-specific light requirements  
162 are fulfilled. In contrast, the mother tree concept suggests a negative impact on the  
163 offspring after trenching i.e., in the absence of carbon supplied via mycorrhizal links.  
164 Thus, the mother tree hypothesis is incongruent with observations of seedling  
165 regeneration patterns in forests and also with results from experiments where  
166 interactions between large trees and seedlings via CMNs has been hindered.

167 The seminal publication of Simard et al. [21] demonstrated inter-tree net transfer of  
168 carbon (C) but the mechanism remained unclear. The claim that C transfer occurred  
169 through a common mycorrhizal network (CMN) caused a wave of enthusiasm among  
170 forest ecologists and opened up a new field of research. Following these initial findings,  
171 numerous experiments were performed to establish the role of CMNs in C transfer and  
172 to quantify the amount of C transferred between plants (e.g., [22, 23, 24, 25, 26]. With  
173 the notable exception of Klein et al. [24] and Avital et al. [27], these studies conclude  
174 that only insignificant amounts of C were transferred to the receiver plant. Serious  
175 criticisms regarding the interpretation of the results of the study of Simard et al (21)  
176 were made very early [28, 29], arguing that the transfer mechanism had not been  
177 unequivocally established and that no advantage for the receiving plant had been

178 demonstrated. Thus, it is often unclear as to whether the transferred carbon actually  
179 enters the root tissue of the receiver tree or is simply being retained in the fungal  
180 hyphae at the root-fungal interface [28].

181 The concept of a wood-wide web linking trees in a forest by mycorrhizal hyphae is  
182 based on isotopic evidence [21]. WWW received an additional boost when new genetic  
183 techniques suggested the presence of below-ground links by the same fungal  
184 genotype among many distant trees in a stand [30]. Although the spatial “architecture”  
185 implies physical links, intactness of the fungal connections and carbon distribution  
186 among trees were not demonstrated [30]. Even in studies with remarkable shifts in  
187 abundance of the stable isotope  $^{13}\text{C}$  (by which transfer was assessed; e.g. [24]), the  
188 magnitude of isotopic ratios was close to those which can arise from natural processes  
189 in the tree, rendering the estimates of CMN-driven C transfer in natural ecosystems  
190 uncertain [31].

191 With the notable exception of Klein et al. [24] and Avital et al. [27], these studies  
192 conclude that only insignificant amounts of C were transferred to the receiver plant. As  
193 described by Henriksson et al. [31] the shifts in abundance of the stable isotope  $^{13}\text{C}$   
194 (by which transfer was assessed) that were reported by Klein et al. [24] were close to  
195 the magnitude of isotopic ratios which can arise from natural processes in the tree,  
196 rendering the estimates of CMN-driven C transfer uncertain. For example, release of  
197 root exudates, respiration and re-fixation, degradation of litter and incorporation of the  
198  $^{13}\text{C}$  into amino acids [32] can result in below-ground redistribution of carbon by soil  
199 microbes, soil fauna, and precipitation. Thus, the extent of a directed flux from a donor  
200 to a receiver is unclear. Avital et al. [27] found C transfer of a similar magnitude  
201 between tree species that were assumed to lack mycorrhizal connections. However,  
202 some tree species have the ability for dual mycorrhizal colonization, for example poplar  
203 can host both AM and EM species. This trait may be more widespread than previously  
204 thought [33], thus, permitting in principle linkages between AM and EM hosts.  
205 Therefore, the jury is still out on whether CMNs can play a significant role in C  
206 translocation under certain conditions or not.

207 Recent reviews have also drawn attention to the inconsistency of results obtained from  
208 experiments using different mesh-sizes to include or exclude roots and mycorrhizal  
209 connections between seedlings [34, 35]. In such experiments (see [21, 22, 23]), CMN  
210 exclusion did not always prevent C transfer among plants, indicating that CMNs are

211 not essential for C transfer. However, despite the inclusion of caveats by authors [e.g.  
212 22, 27] to acknowledge that alternative transfer pathways could not be excluded, these  
213 studies are nevertheless cited as providing evidence for CMN-mediated C transfer [34,  
214 35]. Henriksson et al. [34] therefore conclude “that evidence of a significant net C  
215 transfer via common mycelial networks that benefits the recipients is still lacking.  
216 Furthermore, the role of fungi as a C pipeline between trees is difficult to reconcile with  
217 any adaptive advantages for the fungi”. Moreover, preferential transfer of C to the roots  
218 of kin-plants via CMN as claimed by Pickles et al. [36], has not been confirmed. Indeed,  
219 facilitation may be greater when the phylogenetic distance between tree species is  
220 greater [37]. In their laboratory study Pickles et al. [36] showed that in two of four kin-  
221 kin and kin-non-kin pairs a significant  $^{13}\text{C}$  signature was detected in the kin-kin but not  
222 in the kin-non-kin pairs. However, the amount of translocated carbon was marginal.  
223 The amount of translocated carbon between roots in compartments enabling hyphal  
224 connections was similar to that in roots in compartments with pores that did not allow  
225 fungal connections. Therefore, Pickles et al suggested that root exudates were  
226 exchanged between the compartments and likely taken up by mycorrhizae in the  
227 separated compartment.

228 Simard et al. [38] have raised the possibility that organic N could represent C  
229 transferred among plants. However, even if C from a donor plant would be used to  
230 synthesize organic N in a CMN (mainly glutamine and arginine), any receiver plant  
231 (except for mycoheterotrophic plants) would still contribute with C to this CMN, making  
232 the net C gain dependent on the exchange rate of organic N to C which may lead to a  
233 net loss rather than a net gain of C for the receiving plant.

### 234 **CMN Function: Alternative Scenarios**

235 If there is little evidence to support an altruistic function of CMN, are there alternative  
236 scenarios that could involve CMN-mediated C and nutrient transfer? First of all, we  
237 draw attention to mycoheterotrophs, a group of plants that depend fully or partially on  
238 mycorrhizal fungi for their nutrition [39, 40]. They acquire C (and N and other nutrients)  
239 from the fungi, which in turn receives C from a host plant. As such they represent the  
240 best example of C transfer between plants via a CMN. Mycoheterotrophy occurs both  
241 in arbuscular and ectomycorrhizal plants and is the norm for orchids in early  
242 developmental stages. It is therefore possible that non-mycoheterotrophic plants may use  
243 a similar mechanism to acquire C from a host plant via a CMN. Notably, such a parasitic

244 mode of seedlings would predict that seedling growth and performance would be  
245 enhanced in the vicinity of large trees, a pattern that is opposite to the actual pattern  
246 of regeneration observed in forests. As discussed by Henriksson et al. [31], it has been  
247 suggested that conifer seedlings in a CMN acquire N in relation to the C delivered to  
248 the fungi, indicating competition, rather than sharing, among connected plants. This is  
249 in line with studies of arbuscular mycorrhizal interactions as well [41, 42].

250 Another possibility is that if the same fungus connects with two separate tree  
251 individuals via mycorrhizae, the fungus may trade with both these trees for its own  
252 benefit. If such trading invokes transport of organic N compounds from the fungus to  
253 one of the host trees, and C in organic N molecules was derived from trading N for C  
254 from the other tree, then C would arguably be transferred between the tree individuals  
255 through a CMN. However, the organic N absorbed by the first tree would be in  
256 exchange for C, substantially reducing or nullifying any net C transfer. Thus, as shown  
257 above, there are alternative mechanisms explaining how C may move from one  
258 individual to another through a CMN.

## 259 **Public Reception and Criticism of the Mother Tree Concept**

260 As with Wohlleben's book, Simard's book has also become a best seller and has been  
261 praised by a number of plant scientists (see [https://suzannesimard.com/finding-the-mother-treebook/praise-for-finding-the](https://suzannesimard.com/finding-the-mother-treebook/praise-for-finding-the-mothertree/?doing_wp_cron=1679703014.6174020767211914062500)  
262 [mothertree/?doing\\_wp\\_cron=1679703014.6174020767211914062500](https://suzannesimard.com/finding-the-mother-treebook/praise-for-finding-the-mothertree/?doing_wp_cron=1679703014.6174020767211914062500) for examples).  
263 However, the majority of these reviewers lack experience in mycorrhizal research and  
264 from the tone of their reviews are obviously sympathetic to an anthropomorphic  
265 viewpoint. Most recently criticism of Simard's Mother Tree concept has been voiced in  
266 two major reviews. Whereas Henriksson et al. [34] have questioned the validity of the  
267 scientific evidence (see above), Karst et al. [35] have analyzed the citation record of  
268 scientific publications investigating CMNs in relation to the Mother Tree concept. They  
269 identified a gradual shift over time from more nuanced referencing, where caveats and  
270 uncertainties inherent in these studies are mentioned, to a higher frequency of citations  
271 where these problems are no longer acknowledged. This has led to a full-blown  
272 controversy over the Mother Tree concept  
273 (<https://www.saltwire.com/halifax/news/sadly-mother-trees-dont-act-like-mothers-and-avatars-tree-of-souls-doesnt-exist-100842634/>). Interestingly, one of the coauthors of  
274 the Karst et al. [33] review was Melanie Jones who was a coauthor on the 1997 Simard  
275  
276

277 et al. paper where the WWW concept was originally introduced, and the lead author of  
278 this review, Justine Karst, has also published jointly with Suzanne Simard on numerous  
279 occasions. This makes this controversy even more highly charged. Recently, and  
280 together with Melanie Jones, Karst has also written a critical commentary on Simard's  
281 work [43].

282 In addition, and in response to Simard's continued defense of the Mother Tree concept  
283 as given in numerous video presentations, Justine Karst and Jason Hoeksma have  
284 found it necessary to give detailed rebuttals to the various claims of Simard in the form  
285 of open letters to the responsible TV channels:

286 [https://karstlab.ualberta.ca/wp-content/uploads/sites/47/2023/04/BBC-Trees-talk-to-](https://karstlab.ualberta.ca/wp-content/uploads/sites/47/2023/04/BBC-Trees-talk-to-each-other.pdf)  
287 [each-other.pdf](https://karstlab.ualberta.ca/wp-content/uploads/sites/47/2023/04/BBC-Trees-talk-to-each-other.pdf)

288 [https://karstlab.ualberta.ca/wp-content/uploads/sites/47/2023/04/CBC-trees-](https://karstlab.ualberta.ca/wp-content/uploads/sites/47/2023/04/CBC-trees-talking.pdf)  
289 [talking.pdf](https://karstlab.ualberta.ca/wp-content/uploads/sites/47/2023/04/CBC-trees-talking.pdf)

290 In our opinion, not only are the arguments given by Jones, Karst and Hoeksema  
291 convincing, but they reveal that some of the data on which Simard has based her  
292 claims are based upon non-peer reviewed theses work performed under her  
293 supervision. More disturbing is the fact that, especially in regard to kin-recognition and  
294 preference, her claims do not correctly reflect and even contradict the data presented  
295 in these theses. This casts great doubt on the scientific credibility of Simard's book.  
296 Despite its broad appeal, and although being a fascinating personal account of her life  
297 in science, Simard's book lacks a sound scientific basis, and does not even faithfully  
298 represent the published forestry and plant science literature.

### 299 **Publication Policy: Substantiated Facts versus Fiction and Profit**

300 As the experience with the books of Wohlleben and Simard shows, the serious  
301 misrepresentations of plant life which now prevail in the popular press might have been  
302 avoided if established plant scientists had rapidly responded to the publication of such  
303 pseudo-scientific interpretations. But most blame lies with the publishing houses who  
304 do not make the effort to determine whether a submitted book manuscript deals with  
305 facts or fiction. Publishers assume that fact-checking is a responsibility of the authors,  
306 but as we have seen with Wohlleben's book self-regulation does obviously not work. It  
307 might help if book publishers used a peer-reviewing system as in scientific journals.  
308 But where commercial interests prevail, selling fictional accounts (and this in essence  
309 is what the books of Wohlleben and Simard are) to a lay-person audience that is

310 responsive to anthropomorphic language is good for business. This does not mean  
311 that books like those written by Wohlleben and Simard should not appear in print, and  
312 publishers should not be allowed to make profits from their sale. But the general public  
313 has a right to know what kind of a book they are buying, and the publishers should  
314 label them for what they are: factual books or fictional accounts. Unfortunately, the  
315 latter promulgate a distorted and false view of the plant and fungal worlds. More  
316 precariously, the marketing of books like those of Wohlleben and Simard by the media  
317 takes advantage of people's desire for "harmony" und thus influences the public  
318 perception of plants making it harder to base relevant policies and decisions on  
319 verifiable facts. For example, one could easily imagine that basing management  
320 decision on the mother tree concept could result in forests with low vigor regeneration  
321 of a limited set of tree species. This may decrease the resilience and adaptive capacity  
322 of future forests..

### 323 **Anthropomorphism and Plants**

324 Anthropomorphic vocabulary not only allows pedagogic analogies, but it can also be  
325 used to enhance our emotional connection with animals and plants. Specifically, it  
326 leads to a lack of objectivity and to the need to interpret experimental data in the sense  
327 of a recognizable universal life template. The non-human specificity of fungi and plants  
328 is ignored, a gross oversight given that some of the most basic processes, for example,  
329 reproduction, differ greatly among these kingdoms [44, 45]. Nevertheless, the desire  
330 to humanize plant life has been the goal of many recently published books. Some  
331 blatantly propagate a shamanistic viewpoint, claiming that plants can even speak to  
332 one another and to the book's authors (e.g., [46, 47]). Without scientific proof, this is  
333 pure mysticism. The other group of writings expresses the viewpoint that plants are  
334 intelligent conscious organisms and can not only make decisions (e.g., [48, 49]), but  
335 apparently can actively care for each other [3].

336 Opinions on anthropomorphism in the plant sciences range from complete repudiation:  
337 "*Anthropomorphism is taboo in science because it deceives us more often than it*  
338 *helps*" (Flinn [50]), to a hearty embrace ("*Yeah, I love it*", Monica Gagliano in interview  
339 with Andrea Morris, [51]). However, unlike Gagliano who suggests that this is a new  
340 way of thinking about plants, the humanization of plant function has been around since  
341 Victorian times (see [52] and references therein), and continues up to the present time  
342 in the much disputed concept of Plant Neurobiology (see [53, 54] for a discussion).

## 343 **Anthropomorphism and its impact on Forest Management and** 344 **Ecosystem Services**

345 Even in serious newspapers reports are increasingly appearing which question the  
346 idea of managing forests for wood production based on the belief that trees are sentient  
347 beings [55]. In these cases, the system of clear-cutting and planting is used exclusively  
348 as **the** prevailing management scenario while the manifold, well-researched and  
349 effectively practiced alternatives to clear-cutting are ignored, even though these  
350 alternatives show that forests can be managed in a close to natural way while  
351 maintaining their integrity [56, 57, 58]. It remains open whether these omissions are  
352 intentional or the result of too superficial research. Both are unacceptable.

353 The humanization of trees and the description of forest management as a mainly  
354 destructive industry serving purely economic interests have several serious effects on  
355 the public. First, it suggests that selfless, benevolent organisms with feelings, the trees,  
356 are being killed for the sake of a profit-oriented industry. Wohlleben persistently  
357 conceals the fact that the renouncement of wood use (which he does not completely  
358 exclude, but would like to see drastically restricted) and his hostility to the cultivation  
359 of conifers would require either a radical reduction in the use of wood, e.g. in the  
360 building sector, or an increase in imports from other parts of the world, or the  
361 substitution of wood by other materials such as concrete or steel, which typically  
362 require high amounts of fossil energy for their production [59]. However, readers do  
363 not learn that these alternatives to the sustainable use of domestic wood have a  
364 negative influence on greenhouse gas emissions. Thus, they are oblivious about the  
365 environmental costs and likely failure to meet political climate mitigation goals  
366 associated with a massive restriction of the use of wood. The hands-off approach to  
367 forest management promoted by Wohlleben also ignores that maintaining all the  
368 benefits from forests in Central Europe requires in many cases active silvicultural  
369 management to adapt them to global change in pace with rapid environmental changes  
370 [60]. This necessary restoration and adaption comprise for example changes in tree  
371 species composition, the diversification of tree species composition and stand  
372 structures, establishment of advance regeneration, and regular stand tending to  
373 maintain tree diversity and promote individual tree vigor [61].

374 There is wide agreement among forest scientists that natural adaptation of most  
375 forests, suggested as the only suitable way by Wohlleben and others, would not be

376 fast enough to avoid massive disturbances and thus severely restricted provision of  
377 important ecosystem services. This hands-off approach would therefore risk the  
378 development of highly vulnerable instead of resilient and adaptive forests. Spittlehouse  
379 and Stewart [62] made this point very clear 20 years ago and stated “*although forest*  
380 *ecosystems will adapt autonomously, their importance to society means that we may*  
381 *wish to influence the direction and timing of this adaptation at some locations. In other*  
382 *cases, society will have to adjust to whatever change brings. Adaptation is not*  
383 *something to be applied only in the future; actions are needed now in anticipation of*  
384 *future conditions*”. Wohlleben’s and Simard’s readers, however, gain the impression  
385 that restricting forest management would solve all problems related to forests and that  
386 clear-cutting is the only way forestry is practiced. Feasible and proven concepts  
387 available to use the renewable resource wood while preserving the integrity and  
388 functionality of forest ecosystems, for example by close-to-nature forestry approaches  
389 or by managing forests as complex adaptive systems [63], are ignored. It is also widely  
390 ignored that forests in densely populated countries mirror the societal demands at the  
391 time of their establishment by natural regeneration or plantings with a remarkable time  
392 lag. Thus, the composition and structure of today’s forests can only be understood  
393 against a historical background and is not the result of decisions by a small group of  
394 people, the foresters, but by society [64]. If the current societal demands are not met  
395 anymore and/or if adaptations are needed due to changed environmental conditions,  
396 forest stands need to be adapted and restored (see, for example [65]). This is a long-  
397 lasting task under highly uncertain conditions since neither the environmental  
398 conditions of the future are known nor the societal demands of future generations. This  
399 calls for the creation of forests that could be developed in different directions [66] which  
400 require occasional silvicultural interventions.

401 Another problem associated with the portrayal of trees as victims and the forestry  
402 sector as the cause of all problems is that all other non-forestry related impacts on  
403 forests such as climate change, atmospheric pollution, eutrophication, introduction of  
404 new pests and diseases, fragmentation, land-use change, etc. are ignored. At no stage  
405 are readers reminded that it is also their consumption pattern, behavior and mobility  
406 that contributes to negative developments of forest health.

407 Forests have always provided a surface for projection of societal and cultural  
408 perceptions and ideas. For example, thoughts about German forests – irrespective of  
409 the time-period - essentially ran parallel to the national-political developments of the

410 19th and 20th centuries [67]. This ranged from the romantic poets and thinkers who  
411 sought to root the nation in nature, to the National Socialists who exploited the forest  
412 for their ideologies, the production-oriented post-war generation, the turn to close-to-  
413 nature forestry in the last three decades, and now to our present-day society which  
414 partly views a forest as a social utopia where all trees support each other in harmony.  
415 Especially given the future uncertainties, we are most concerned that this kind of  
416 thinking will lead to restrictions on active forest management. Limited choices and  
417 options will likely leaves us with forests that are ill-adapted and cannot provide  
418 essentially needed ecosystem services.

### 419 **Concluding Remarks**

420 In this article, we have critically assessed the value of two books that have enjoyed  
421 enormous success in the popular media. The authors of these two books have used  
422 the stylistic device of anthropomorphizing to convey specific ideas that lack supporting  
423 evidence to make their message most appealing to the general public. However, as  
424 we have demonstrated, although being extremely popular, these books are misleading  
425 when viewed as presenting a scientific understanding of forests. They either rely on  
426 questionable data interpretations coupled with biased citation selection (Finding the  
427 Mother Tree) or lack a solid scientific basis (The Hidden Life of Trees).

428 So, why chose an anthropomorphic portrayal when this leads to lack of objectivity? In  
429 her excellent short opinions paper, Flinn [50] provides us with a clue as to why such  
430 dangerous publication strategies have been chosen. We quote:  
431 *“In interviews, Simard has said that she purposely uses anthropomorphism and*  
432 *culturally weighted words like “mother ... so that people can relate to trees better,*  
433 *because “if we can relate to it, then we’re going to care about it more”.* Reaching out  
434 to the general public to make people care about forests is certainly a praiseworthy goal,  
435 but not when it involves the dissemination of a distorted view of the plant world. In other  
436 words: the end does not justify the means. We agree entirely with Flinn when she  
437 writes: *“... let us seek to understand plants on their own terms. Plants are*  
438 *fundamentally unlike us...”*, and with Fortey [6] who states *“Trees are splendid and*  
439 *interesting enough in their own right without being saddled with a panoply of emotions”*.  
440 In short, anthropomorphism merely clouds the issue at hand. Humanizing plants has  
441 not led to any fundamental advantages for scientists studying plant life and has  
442 obscured ecological facts. Indeed, spreading the view that forests deserve protection

443 because they display human qualities could actually harm the cause of conservation,  
 444 rather than help it.

445 **4463 words**

446

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## 1 **Box 1: Caring trees and depleted soil carbon – Fiction in The Hidden** 2 **Life of Trees**

3 Since the information base of Wohlleben's writing is a mix of a few selected paragraphs  
4 from scientific articles combined with press releases and websites, one finds few clear  
5 factual statements. Yet, some of the cornerstones of his perspective on forests are  
6 completely baseless assertions. Two examples are given below:

7 *„I have already mentioned that beeches are capable of friendship and go so far to feed*  
8 *each other- It is obviously not in a forest's best interest to lose its weaker members (p.*  
9 *15). ... "In such a system, it is not possible for the trees to grow too close to each other.*  
10 *Quite the opposite. Huddling together is desirable ..." (p. 16)*

11 In fact, it has been known for almost a century [68] that as individual trees grow taller,  
12 their demand for space increases and the forest stand approaches a maximum density.  
13 This site-carrying capacity depends on the availability of resources and tree species  
14 [69]. As even-aged groups of trees grow, intraspecific competition results in a  
15 characteristic and mathematically well-described temporal decrease in stem numbers  
16 as the size of the remaining individuals increases, the so-called self-thinning rule [70].  
17 This size and density-dependent mortality results in the death of thousands of  
18 individuals as closed stands develop from saplings to mature trees. In fact, mortality  
19 due to competition is a frequent phenomenon. For example, for European beech it has  
20 been shown that competition-related mortality of standing trees is particularly high in  
21 young and small trees [71]. Ignoring such facts will lead to dense strands with low vigor  
22 trees that are highly susceptible to e.g., beetle attack, drought, fire, wind and snow  
23 damage [72, 73, 74, 75], as well as an understory vegetation layer with low diversity  
24 and associated lower adaptive capacity to climate change [76]. However, in the social  
25 utopia that Wohlleben projects on forests, these small trees are protected and nursed  
26 by mature trees.

27 *„For every log you burn in your fire at home, a similar amount of carbon dioxide is being*  
28 *released from the forest floor outside. And so carbon stores in the ground below trees*  
29 *in our latitudes are being depleted as fast as they are being formed" (p 95).*

30 Soil is one of the world's largest C reservoirs. Land-use changes (e.g., conversion of  
31 forests to arable land, primary forests to plantations) and intensive forms of forest  
32 management (e.g., soil tillage such as ploughing, fertilizing, removal of the forest floor  
33 layer, drainage, large-scale clear-cutting, targeted burning of slash and ground

34 vegetation) can seriously reduce this store. Also, harvesting or thinning procedures at  
35 lower intensity can affect soil carbon stocks via changes in biomass input or in  
36 microclimatic conditions [77]. There is currently an intensive scientific discourse on  
37 this, fueled by the great importance of soil carbon storage in climate change but also  
38 by contradictory results from corresponding studies. A recent review shows that, on a  
39 global scale, forests' biomass production is closely correlated with soil carbon stocks  
40 [78]. However, it is anything but a simple 1:1 correlation (see [79]), as Wohleben  
41 claims in the above quote and interestingly it is the leaf biomass which is correlated  
42 with soil carbon stocks not the wood biomass. A decrease in soil carbon storage due  
43 to timber harvesting can probably be expected especially where the conditions for soil  
44 carbon stabilisation are unfavourable. This seems to be the case, especially on shallow  
45 sites in the Alps [80, 81], or where a large part of the organic matter is stored in the  
46 humus layer [82]. However, not a single study confirms humus losses as a result of  
47 timber harvesting to the extent that Wohleben claims: "... *a similar amount of carbon*  
48 *dioxide is being released ...*". On average, about as much carbon is stored in the  
49 aboveground biomass as in the soil in many temperate forests. This means that if all  
50 trees of a stand were harvested, all the soil carbon would be lost. This is not the case  
51 because in our latitudes the soil organic matter is stabilised in the soil – a fact well-  
52 documented by soil organic matter half-lives in the range of hundreds to thousands of  
53 years [83, 84]. Several studies indicate that the humus content in forest soils is not  
54 limited by biomass input, but rather due to the capacity of the soil to store organic  
55 matter. In case all wood remains in the forest and slowly decomposes as deadwood,  
56 soil carbon may increase locally close to deadwood [85], but there are also studies that  
57 have found no increase in soil carbon under deadwood [86]. At a larger stand scale,  
58 studies that compared soil carbon stocks between managed forest and reserves  
59 without wood extraction, have not been able to find systematic differences.

60

## Box 2: Altruistic Fungi?

Many of the claims made by Simard in her book and in video presentations (TED and BBC talks “How trees talk to each other”) are without supporting evidence. Here we list several examples of such instances:

- *Trees send resources to each other through shared fungal networks, and it is claimed that older trees, known as mother trees, use this fungal network to supply shaded seedlings with sugar. (Finding the Mother Tree, pp. 259-278)*

Studying resource transfer between trees is inherently difficult. Alternative pathways to fungal networks must be controlled for and when this has been done, only minute amounts of resources such as carbon and nitrogen have been detected in a receiving plant. Two studies claimed high rates of C transfer from a donor tree to a receiving tree, but it could not be verified that transfer occurred through fungal networks [24, 27]. Other studies, both in the field and in the lab or the greenhouse arrive at fractions of a percent up to a few percent of root carbon in a receiving plant that could have been transported from a donor plant (e.g. [25]).

- *Mother trees recognize their kin seedlings through the CMN. (Finding the Mother Tree, pp.259-278)*

A study by Pickles et al. [36] claims that higher rates of labelled C and N occurred in seedlings that were genetically closely related to the donor plant compared to seedlings more distantly related. But transfer occurred despite separating seedlings with a mesh that would not have allowed for fungal hyphae to connect seedlings. A second study arrived at the opposite conclusion, i.e., higher rates of resources were transferred to more distantly related plants. Also, a Masters' thesis from Simard's own laboratory contradicts the claim that mycelial networks may be used by mother trees to send resources preferentially to their kin.

<https://open.library.ubc.ca/soa/cIRcle/collections/ubctheses/24/items/1.0103374>.

- *Via the CMN, mother trees give seedlings a better chance of survival. (Finding the Mother Tree, pp. 279-303)*

Field observations often contradict the mother tree hypothesis which predicts a higher growth rate of seedlings in the proximity of large trees [33]. In fact, emergence and

growth of seedlings and saplings are in general negatively affected by proximity to large trees [33].

- *Plants use the CMN to transmit messages to one another. This includes chemical signals to elicit wound responses. (Finding the Mother Tree. pp. 279-303)*

There is only one peer-reviewed study suggesting that tree seedlings can send warning signals to each other through the CMN [87]. However, this was a greenhouse experiment, and this signaling ceased when root interactions were allowed to form, as they always do in forests.

- *Dying Trees send their resources to neighboring trees (kin). (Finding the Mother Tree. pp. 279-303)*

In her book (Chapter 15, pg. 285) Simard refers to a student who reported that “dying Douglas firs transmitted messages to ponderosa pine ... another of my students confirmed it in a second study, as did others around the world”. There are no references to published studies to support this claim, i.e., it is not corroborated by data.

1 **Anthropomorphism:** Is the attribution of human traits, emotions, or intentions to non-  
2 human entities.

3

4 **Arbuscular- and Ectomycorrhizal Plants:** Arbuscular (AM) and ectomycorrhizal (EM)  
5 fungi form symbiotic associations with plants. Both AM and EM fungi grow inside the  
6 root. An arbuscular mycorrhizal fungus forms arbuscules (small tree-like structures) in  
7 the cortical cells of the roots but is still separated from the plant cell content by a  
8 membrane system. An EM fungus enwraps the root tips with its mycelium (mantle) and  
9 grows inside the root between the cells, encapsulating cortical cells by hyphae, termed  
10 "Hartig net". The Hartig net is the exchange surface for nutrients. Outside the root, AM  
11 and EM fungi produce extramatrical mycelia, fine thin fungal strands or thicker root-like  
12 structures (rhizomorphs). The extramatrical mycelia can connect different plant  
13 individuals.

14

15 **Common Mycorrhizal Network (CMN):** A mycorrhizal network is an underground  
16 hyphal network created by mycorrhizal fungi that connects individual plants.

17

18 **Consciousness:** Sensory consciousness is the basic ability to have subjective  
19 experiences that can be accessed and reported. It arises from brain processes that  
20 emerged through evolutionary history (Wikipedia).

21

22 **Interspecific Interference:** Interspecific interference, that is when a species reduces  
23 the ability of other species to make use of a shared resource through its presence or  
24 agonistic interactions, is ubiquitous in nature. This kind of competition usually leads to  
25 restricted growth, survival and/or reproduction. However, whether tree species are less  
26 affected by interspecific competition than by intraspecific interference depends on the  
27 identity of the neighboring species and site conditions.

28

29 **Mother Tree Concept:** As defined by Suzanne Simard they are tall old-growth trees  
30 with vast root systems connected to hundreds of other trees via a network of  
31 fungi that allows them to share resources and information.

32

33 **Myco-Heterotrophy:** Is a symbiotic relationship between certain kinds of plants  
34 and fungi, in which the plant gets all or part of its food from parasitism upon fungi rather

35 than from photosynthesis. A myco-heterotroph is the parasitic plant partner in this  
36 relationship.

37

38 **Plant Neurobiology:** A concept based on metaphors which attempts to show that  
39 plants and animals have similar mechanisms for stimulus perception and electrical  
40 signaling. Very speculative and highly controversial.

41

42 **Plate Effect:** The observation that in dry seasons hardly any germinated seedlings  
43 survive around the stem of a mother tree due to its strong root competition

44

45 **Self-thinning Rule:** The relationship between mean tree size and tree density on a  
46 given area. It describes the decrease in stem number with increasing mean size of the  
47 trees. In a log-log diagram with diameter at breast height as a proxy for tree size it is a  
48 straight line with a slope of around -1.6.

49

50 **Shamanism:** Is a religion which is based on the belief that the world is controlled by  
51 good and evil spirits, and that these spirits can be directed by people  
52 with special powers (Collins Dictionary).

53

54 **Wood-Wide Web (WWW):** The wood-wide web refers to a common mycorrhizal  
55 network where the mycelia of mycorrhizal fungi link the roots of plants of the same or  
56 different species at the scale of a forest stand. The term originated as a cover headline  
57 in the journal *Nature* (7 August 1997), but it now appears frequently in the non-  
58 scientific literature on the subject.

59

60