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## **Human-nature connectedness and sustainability across lifetimes: a comparative cross-sectional study in France and Colombia**

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29 **Abstract**

30 1) To face the environmental crisis, international panels called for a transformative  
31 change of human-nature interactions which promotes a sustainable relationship  
32 between humans and nature. The extent to which people considered themselves as part  
33 of nature - known as Human-nature connectedness - has been shown to be a key  
34 societal trait for achieving such a transformative change. Human-nature connectedness  
35 is linked to improved human welfare and actions for nature conservation and can be  
36 increased by direct contact with natural environments in adults living in the Global  
37 North. It has not been shown whether these relations are true across lifetimes and in  
38 the Global South, making it difficult to generalise about the effects of human-nature  
39 connectedness globally.

40

41 2) Here, we conducted a cross-sectional study to examine and compare human-nature  
42 connectedness across ages in 1858 participants aged 3 to 87 years from two countries:  
43 France (N=1059) and Colombia (N= 799). We also investigated the links between  
44 human-nature connectedness, pro-environmental behaviours, well-being and two  
45 indicators of opportunity to experience nature (i.e., degree of urbanisation and forest  
46 cover around the participants' municipality of residence).

47

48 3) Results show that human-nature connectedness is positively related to well-being and  
49 pro-environmental behaviours in both countries. Analyses revealed an age-related  
50 pattern of human-nature connectedness with a significant decline from childhood to  
51 the mid-teens in both countries. Overall, Colombian participants have a higher human-  
52 nature connectedness than French participants and individuals' human-nature  
53 connectedness was negatively linked to the urbanisation's indices in both countries.

54

55 4) Here, we show that human-nature connectedness is linked to sustainable outcomes in a  
56 Global South country, just as it is in the Global North. Our study also suggests that  
57 increasing contact with nature during formative teenage years could mitigate the  
58 observed decline in human-nature connectedness. Future studies are warranted  
59 combining qualitative and quantitative measures related to human-nature  
60 connectedness, nature experiences, values and practices in relation to nature, in  
61 multiple countries from the global South. Our study indicates that enhancing human-  
62 nature connectedness could provide an additional tool for achieving sustainable targets  
63 *globally*, not just in highly-developed northern-hemisphere countries.

64 **Keywords**

65 human-nature interactions; well-being; human-nature connectedness; one health;  
66 conservation; pro-environmental behaviour; sustainability; landscape ecology

67 **Introduction**

68 Human activities are one major driver of biodiversity loss and climate change (1,2).  
69 International groups of experts such as the Intergovernmental Science-Policy Platform on  
70 Biodiversity and Ecosystem Services (IPBES) and the Intergovernmental Panel on Climate  
71 Change (IPCC) have called for a *transformative change* of human-nature interactions to  
72 achieve sustainable targets including a better valuation of nature (1–4) and a greater  
73 understanding of practices fostering sustainable human actions (3). “Values of nature”  
74 encompass the various ways in which nature holds significance for humans (4). They can be  
75 broadly classified into instrumental (nature's utility in achieving human objectives), intrinsic  
76 (the inherent worth of nature, independent of human influence), and relational (importance  
77 individuals place on nature, based on their interactions with it) categories. In the realm of  
78 conservation, the relational value of nature has received little attention (4), yet, it has been  
79 regarded as crucial for fostering a sustainable and synergistic relationship between humans  
80 and other living beings, through frameworks like the “People and Nature” conservation  
81 strategy (5); also referred to as “Nature's Contributions to People” (NCP; 6) and the concept  
82 of “One Health” that recognizes the interconnectedness between humans, animals, and  
83 environmental health (7).

84

85 The extent to which humans consider themselves as part of the natural world - known as  
86 human-nature connectedness - has been shown to be a key societal trait for achieving a  
87 synergistic transformative change (8–10). Human-nature connectedness refers to the  
88 psychological and emotional connections that individuals have with nature, and has been  
89 widely measured using validated quantitative questionnaires (11–13). Hundreds of studies  
90 show that human-nature connectedness is significantly positively linked to human well-being,  
91 mental and physical health as well as values (e.g. social, relational and ecological) and

92 behaviours (e.g. pro-environmental actions) that favour nature welfare (9,14,15). Thus,  
93 enhancing human-nature connectedness can be a leverage point for achieving sustainable  
94 targets (16–21). But how can we mobilise this leverage?

95

96 Human-nature connectedness is influenced by the opportunity to experience nature (8,22). At  
97 a country-level, human-nature connectedness is significantly positively correlated with the  
98 level of biodiversity (i.e. species richness) of the country, and significantly negatively  
99 correlated with the proportion of urban areas in European countries at least (10). Numerous  
100 experimental and interventional studies further show that physical contact with nature  
101 causally increases human-nature connectedness, especially when individuals focus their  
102 attention on the present moment and environment through mindfulness (8,23,24). Contact  
103 with nature also has a direct, significant positive impact on human health (9,25,26). The  
104 positive impact of nature on human health is significantly positively associated with the  
105 ongoing level of biodiversity. Meta-analysis has revealed a causal and significant positive  
106 impact of acoustic biodiversity (i.e. specific richness of birdsong) on human physical and  
107 psychological health (9,25,26). Furthermore, a recent survey of European adults shows that  
108 the proportion of elders in the population was positively correlated with the level of human-  
109 nature connectedness in that country (10). The authors suggested that this relationship may be  
110 due to older generations having a richer experience of nature than younger adults since they  
111 lived in a less urbanised area during childhood (10).

112

113 Human-nature connectedness varies with age (27,28). In a recent study measuring human-  
114 nature connectedness in ~2500 UK citizens, the authors described an age-related pattern with  
115 a high human-nature connectedness described for childhood, followed by a strong decrease  
116 across teenagers, and a steep increase that plateaus after the twenties (27). This suggests that

117 young children have a higher human-nature connectedness than adolescents and adults, and  
118 adolescents were lowest (27). As strong human-nature connectedness during childhood has  
119 been linked to greater care for the environment in adulthood (29), these researchers targeted  
120 teenagers as critical for interventions aimed at improving human-nature connectedness in the  
121 UK (27).

122

123 Human-nature connectedness could also be impacted by culture and worldview (30,31). Yet,  
124 there is a lack of published research on societies living close to nature (e.g. Kogis in the Sierra  
125 Nevada de Santa Marta or the Kichwas in the Amazonian forests of Colombia, 8,9). Such  
126 societies of *Native populations*, often express values advocating the interdependence of living  
127 beings, and set up sustainable interactions with natural spaces based on respect for the  
128 interconnections between living beings (32–35). For instance, the Kogis, a Native population  
129 of around 6,000 individuals living in the Sierra Nevada de Santa Marta, Colombia, advocate a  
130 way of living in harmony with nature. They emphasise the importance of “keeping population  
131 density below the carrying capacity limit of the fields, and their associated technology, and to  
132 maintain areas of non-degraded environment” (33).

133

134 A recent global study shows that increasing urbanisation is associated with people living  
135 increasingly more distant from natural environments over time (36). In 2020, people lived on  
136 average 10 km from low-impact areas. Low-impact maps were calculated by combining  
137 human population density (37) with human footprint (38). These distances were greater for  
138 people living in Europe, South-East Asia and North America. For instance, British and French  
139 residents live as far as 14 km and 16 km respectively, from a natural area. In contrast,  
140 Ecuadorians and Colombians live at distances of 5 and 6 km respectively (36). Overall,  
141 citizens from many countries in Africa, South America and Central Asia live relatively close

142 to low-impact areas (36). However, the average distance between home and a low-impact area  
143 increased by 0.64 km (7%) between 2000 and 2020 worldwide due to increased urbanisation  
144 and deforestation. This trend was mainly observed in Asia, Africa and Latin America where  
145 biodiversity hotspots are located. An extreme example can be found in Angola, where the  
146 average distance between home and a low-impact area increased by 6 km in the last 20 years  
147 (36).

148

149 Urbanisation and deforestation are increasing rapidly, especially in developing countries  
150 situated in the Global South (36), and the resulting physical disconnection with nature will  
151 likely decrease human-nature connectedness globally (30). Yet, most of the studies on human-  
152 nature connectedness have been conducted on adults and in wealthy, industrialised countries  
153 from the Global North (8,9). We lack empirical studies that simultaneously consider factors  
154 related to the observed decrease in human-nature connectedness with age among countries  
155 differing in opportunities for physical contact with nature and biodiversity (i.e., species  
156 richness). Therefore, there is a gap in knowledge as to whether (1) human-nature  
157 connectedness is also linked to sustainability in developing countries, (2) how this  
158 relationship develops over a person's lifetime, and (3) whether human-nature connectedness  
159 relates to environmental degradation in these countries.

160

161 As a first step, in the present study we conducted a *cross-sectional survey* examining human-  
162 nature connectedness across different age groups in two countries that differ both in  
163 biodiversity and in contact with nature. We examined the relationship between age and pro-  
164 environmental behaviours, human well-being and opportunities to experience nature in  
165 participants that ranged in ages from three-to-87-years, in France and Colombia (N=1858  
166 total). These two countries differ notably in our metrics concerning nature (36). The

167 Colombian sample also included participants from Native populations (N=62) to explore the  
168 potential role of cultural worldviews and lifestyle on human-nature connectedness. This  
169 design allowed us to investigate how human-nature connectedness and its relationships with  
170 sustainable outcomes vary at different age stages, and across cultural groups.

171

172 The current study addresses the following research questions (RQ) : RQ1) Is human-nature  
173 connectedness linked to sustainable outcomes in both a country from the Global South  
174 (Colombia) and a country from the Global North (France)? RQ2) Does human-nature  
175 connectedness and its variations across different age groups, differ between France and  
176 Colombia? RQ3) Is the state of the environment (degree of urbanisation and forest cover)  
177 linked to human-nature connectedness in both countries?

178

179 We predicted that human-nature connectedness would be related to sustainable outcomes  
180 (well-being and pro-nature behaviours) in the two countries which would support human-  
181 nature connectedness-enhancement as a potential lever to reach sustainability at a global scale  
182 (RQ1). The biophilia hypothesis<sup>1</sup> refers to the spontaneous tendency of humans to  
183 demonstrate attraction and connection with the natural world and other living beings. Prior  
184 studies showing a higher human-nature connectedness in children than adults suggest that  
185 biophilia may decline with age (24,27,40,42,41,43). If this is generally true, then we should  
186 find that young children, whatever their country of origin, will show a higher human-nature  
187 connectedness than adults in our study (RQ2). Since France is similar to the UK in terms of  
188 nature-contact opportunities (average distance between home and low-impact area is 14 km in  
189 the UK, and 16 km in France, (36)), we predicted that France would show a human-nature-

---

<sup>1</sup> The term "biophilia" was introduced independently by the German psychologist Fromm (39) and the American biologist Wilson (40,41). Fromm used the term biophilia to describe "the psychological orientation of being attracted to all living things", thus adopting an ontogenetic perspective, whereas Wilson used the term biophilia to describe "the adaptive traits that enable us to develop a bond with the living world and nature", adopting an evolutionary perspective.

190 connectedness-age-related pattern similar to previous cross-sectional UK studies (27,28). We  
191 hypothesised that Colombians, especially Native populations (32,34), would show a higher  
192 connection than the French (RQ2), since they have greater opportunity for nature contact with  
193 an average distance of only 6 km between home and low-impact areas (36), and with highly  
194 biodiverse natural spaces (see the National Biodiversity Index-  
195 <https://www.cbd.int/gbo1/annex.shtml> of the Convention on Biological Diversity (2022)).  
196 Finally, we predicted that urbanisation would be negatively related to human-nature  
197 connectedness, and that forest cover (44) would be positively correlated with human-nature  
198 connectedness in both countries and at all ages (RQ3). In doing so, our study fills important  
199 scientific gaps in improving understanding of human-nature relationships, and the factors that  
200 help maintain human-nature connectedness and promote sustainable outcomes globally.

201

## 202 **Materials and methods**

203 We conducted a structured survey study which included 76 closed-ended questions and one  
204 open question. For the purpose of the current study we included and analysed the first 21  
205 closed-ended questions that assess well-being, pro-environmental behaviour and human-  
206 nature connectedness, in addition to socio-demographic and environmental information (age,  
207 municipality of residence, sex). All questions were presented in the same order to all  
208 participants and were administered to French and Colombian participants from different age  
209 groups: children, adolescents, adults and elders.

210

211 The questionnaire was administered in a paper-and-pencil format or online, depending on the  
212 most pragmatic method for each subpopulation. Face-to-face surveys were conducted with  
213 children and adolescents in schools in France and Colombia, and in Native Colombian  
214 nations. For French adults and elders, we used a Google Form. For Colombian adults and

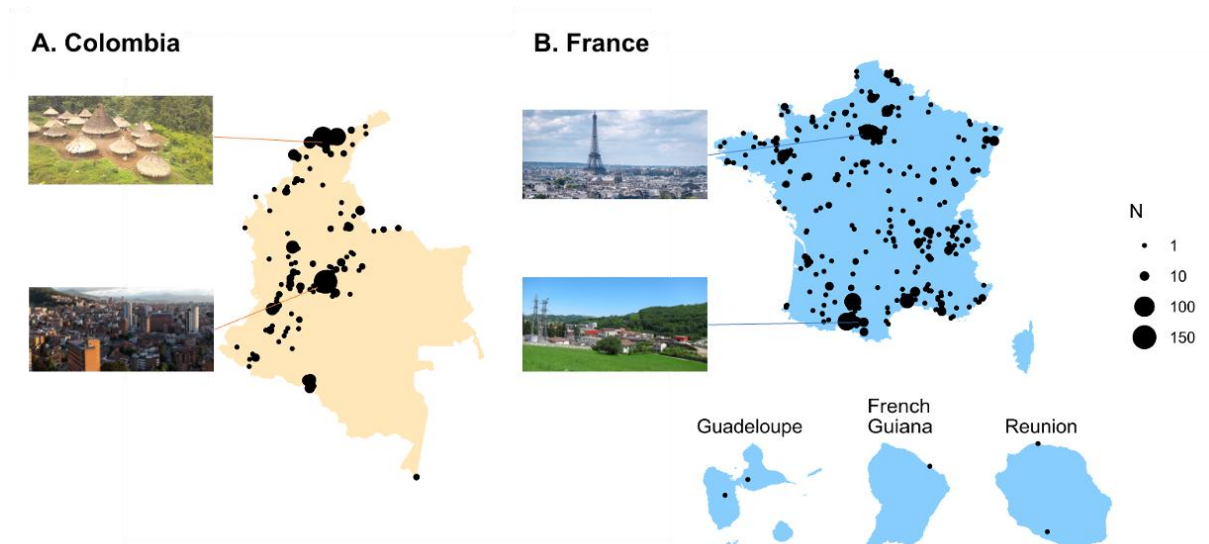
215 elders, we used a Google Form, then completed data collection with the YouGov panels  
216 ([yougov.co.uk/about/panel](https://yougov.co.uk/about/panel)).

217 Participants were informed that they would be participating in a survey about health. To  
218 mitigate sampling bias, the specific aim of the study was not disclosed in France or Colombia.  
219 We also employed targeted recruitment methods through diverse channels including national  
220 mailing lists and individual email. Individuals from various backgrounds were targeted, such  
221 as scientists, students, and professionals in various fields including cognitive sciences, health,  
222 ecology, psychology, economics, and education. The Colombian participants tested by  
223 YouGov were stratified by gender, age and location to enhance representativeness. Children  
224 and adolescents were surveyed in various public schools across urban and rural areas in  
225 France and Colombia (Fig. 1). Data was collected between April 2022 and June 2023.

226

227 One thousand eight hundred and sixty-nine individuals participated in the study. Eleven  
228 participants were excluded for the following reasons: (a) survey incomplete ( $N = 5$ ), (b)  
229 experimenter error in administration ( $N = 3$ ) and (c) the participant did not understand the  
230 questions ( $N = 3$ ). All excluded participants were young children, under age seven.

231



232  
 233 *Figure 1. Number of participants by municipality of residence in Colombia in A and France*  
 234 *its associated overseas departments in B. The size of the dots reflects the sample size N in*  
 235 *each municipality. Two photographs of cities of residence are presented for each country*  
 236 *(Kogi village in the Sierra Nevada de Santa Marta and Bogota in Colombia and Ledar and*  
 237 *Paris in France).*

238

239 The study was approved by the Ethics committee Université Paul Valéry - Montpellier III  
 240 (France) with the following IRB number: IRB00013686- 2023-19-CER UPVM. Every  
 241 interviewee gave their informed consent before participating. For participants under 18, we  
 242 also obtained signed informed consent from the parents in France, and oral consent from the  
 243 Directors of schools or the local authorities in Native populations in Colombia.

244

245 ***Participants***

246 Overall, a total of 1858 individuals (1072 females, 769 males (16 unspecified)) were included  
 247 in the study (Table 1). We included 1059 French and 799 Colombian participants (Table 1  
 248 and Fig. 1). Five French participants were from the French tropical areas (Guiana, Reunion  
 249 and Guadeloupe). One Colombian participant lived on a Colombian island (San Andres). Five  
 250 Colombian participants lived in France when completing the survey. Sixty-two Colombian  
 251 participants were from Native populations (Male = 31; Female = 31; mean age = 15; SD =

252 11). The seven cultural groups were Murui 17, Iku/Aruhaco 9, Kankuamo 2, Kichwa 25, Kogi  
 253 7, Wayu 2, Wiwa 1 (Annex 1 in Supplementary Information (SI)).

254

255 Table 1. Description of participants by country and age groups. Sample sizes (Ns) are  
 256 provided with the number of females in brackets. Standard deviations (SD) are indicated in  
 257 brackets, and age range in square brackets for each group category.

258

	France		Colombia	
	N (Female)	Mean age (SD)	N (Female)	Mean age (SD)
<b>Overall [3-87]</b>	1059 (649)	23 (16)	799 (423)	31 (18)
<b>Young Children [3-6]</b>	87 (40)	5 (1)	11 (3)	5 (1)
<b>Children [7-9]</b>	157 (72)	8 (1)	67 (36)	8 (1)
<b>Adolescents [10-17]</b>	268 (142)	12 (2)	201 (115)	12 (3)
<b>Adults [18-49]</b>	440 (332)	29 (8)	359 (185)	33 (9)
<b>Elders [50-87]</b>	107 (63)	60 (8)	161 (84)	59 (7)

259

260 ***Description of the survey***

261 ***Human well-being***

262 At the core of our assessment of human wellbeing was the concept of quality of life. This  
 263 concept has been widely studied and assessed cross-culturally in health. Subjective quality of  
 264 life is defined by the World Health Organisation as: “*An individual’s perceptions of their*  
 265 *position in life, in the context of the culture and value systems in which they live and in*”

266 *relation to their goals, expectations, standards and concerns*” (45). Quality of life was  
267 assessed by a profile of dimensions drawn from WHOQOL instruments that were designed by  
268 an international collaboration – the WHOQOL Group - for use by adults living in many  
269 diverse cultures worldwide. It has been adapted for young children in the C-QOL (45–49).  
270 The WHOQOL and the C-QOL questionnaires were developed following an ‘emic plus etic’  
271 approach, where items common to different cultures are first translated (etic) and culturally  
272 adapted, then items specific to a culture (emic) are targeted for later inclusion (49,48,47).  
273 Following instrument standardisation including validation, adult WHOQOL-Bref versions are  
274 now available in around 120 language versions, including French and Colombian Spanish.  
275 There is an adolescent version in English (47). The C-QOL for children is available in English  
276 and Thai (45). To develop a French and a Colombian version of the C-QOL for children, we  
277 followed the WHOQOL Group protocol by conducting cultural and contextual adaptations  
278 and translations during focus group interviews with French and Colombian children and  
279 adults (see Annexes 2 and 3 in SI). The aim was to clarify concepts in targeted audiences,  
280 modify them as needed, and select items to be included in the survey (49,48,47).

281 Since our survey included dimensions other than quality of life and well-being (see the  
282 following paragraphs), we shortened the Quality of Life questionnaires from 25 to 10 items by  
283 choosing the items that showed the highest discrimination index. This index reflects the  
284 quality of an item in terms of assessing how well a particular item differentiates between  
285 groups of individuals; in this case, children and adults (50,51). The discrimination index is  
286 considered high when its value exceeds 0.4 (45).

287 Focus groups were conducted in children and adults from the two countries on the 10 selected  
288 items that were refined or rephrased as necessary (Annexes 2 and 3). Ten items were included  
289 that tackle different facets of quality of life, namely (1) positive feelings, (2) difficulties for  
290 daily activities (*reversed score*), (3) self-esteem, (4) opportunities for acquiring new

291 information and skill, (5) negative feelings (*reversed score*), (6) family relationship, (7)  
292 friendship, (8) opportunities for leisure activities, (9) home environment, (10) physical health  
293 (Annexes 2 and 3). Responses to these items were rated as follows: 0 = never, 1 = almost  
294 never, 2 = sometimes, 3 = often, and 4 = almost always for adults.

295 Since pre-tests and focus groups revealed that children have difficulties when presented with  
296 more than four response categories, the "almost never" option was removed for children (see  
297 Annex 2). The rating scale for children was 0 = never, 2 = sometimes, 3 = often, and 4 =  
298 almost always. Participants' responses to the 10 items were averaged to produce a single well-  
299 being score for each participant. Since our data contain discrete items (i.e., Likert scale) that  
300 are non normally distributed, Cronbach's values and Omega total values with polychoric  
301 covariance matrix were calculated to estimate the scale reliability (52). Omega total values  
302 provide a reliability estimate similar to Cronbach's alpha for non normal, discrete data (52).  
303 Reliability values were acceptable in France (alpha = 0.74; omega\_total = 0.79) and  
304 acceptable to good in Colombia (alpha = 0.78; omega\_total = 0.83).

### 305 *Pro-environmental behaviour*

306 Pro-environmental behaviours were assessed from five typical behaviours: (1) influencing  
307 family and friends to act pro-environmentally, (2) saving energy in the household, (3) saving  
308 water in the household, (4) recycling, and (5) participating in activities to protect the natural  
309 environment (53). As these items were only available in English, we developed a French and  
310 Colombian version following the same WHOQOL Group procedure as before to clarify  
311 concepts and modify/remove them if needed (Annexes 2 and 3). Responses were rated as  
312 follows: 0 = never, 1 = almost never, 2 = sometimes, 3 = often, and 4 = almost always for  
313 adults. Again, for children, the rating scale was 0 = never, 2 = sometimes, 3 = often, and 4 =  
314 almost always. Participants' responses to the five items were averaged, resulting in a single

315 pro-environmental score for each individual and, Cronbach's values and Omega total values  
316 were calculated to estimate the reliability of the pro-environmental scale (52). The reliability  
317 was acceptable to good in both countries (France\_alpha = 0.75 ; France\_omega\_total = 0.80;  
318 Colombia\_alpha = 0.79; Colombia\_omega\_total = 0.84).

### 319 *Human-nature connectedness*

320 Human-nature connectedness was evaluated using an illustrated version of the Inclusion of  
321 Nature in Self (INS) scale (11,54,55), known for its parsimony (56), and validated in 18  
322 countries from the Global North (57). The illustrated version has been developed for German  
323 children (55). To adapt the illustrated version to French and Colombian Spanish, we  
324 performed focus group interviews with French and Colombian children and adults to verify  
325 that the translated scale was appropriate (see Annexes 2 and 3 in SI). The focus group  
326 participants report a very good understanding of the INS. We also asked participants to rate  
327 how much they "feel calm in nature"; an item extracted from the Connection to Nature Index  
328 (CNI; item 4), another validated human-nature connectedness scale (58). The INS and CNI  
329 scores were slightly and significantly correlated in both countries (Spearman rho France =  
330 0.34;  $p < .0001$ ; Spearman rho Colombia = 0.17;  $p < .0001$ ; see additional results in Annex 4).

331

### 332 *Landscape indices*

333 We used ESA-Climate change Initiative global land-cover maps (44) to compute two indices  
334 of opportunities to experience nature around each sampling locality: forest cover (proportion  
335 of buffer cells with forest: codes 50-100, 160, 170) and urbanisation (proportion of buffer  
336 cells with urban cover: code 190). Buffers of 20 km were applied around each locality.

337

### 338 *Statistical analyses*

339 All analyses were done using R version 4.3.0 (2023-04-21; R CoreTeam 2017). Since human-  
340 nature connectedness indices are constrained to 1-7, we used Spearman's correlations,  
341 Wilcoxon tests and Kruskal Wallis tests when appropriate.

342 We also used generalised linear regressions to analyse the relationship between sustainable  
343 outcomes (well-being, pro-environment) and human-nature connectedness ('glm' function in  
344 R). Since we expected that human-nature-connectedness would influence well-being and pro-  
345 environmental behaviours, we performed two distinct models: (1) A first model with well-  
346 being items averaged by participant as the dependant variable and with human-nature  
347 connectedness and socio-demographic variables (age, sex, country) as independent variables  
348 and, (2) a second model with pro-environmental items averaged by participant and human-  
349 nature connectedness and socio-demographic variables (age, sex, country) as independent  
350 variables.

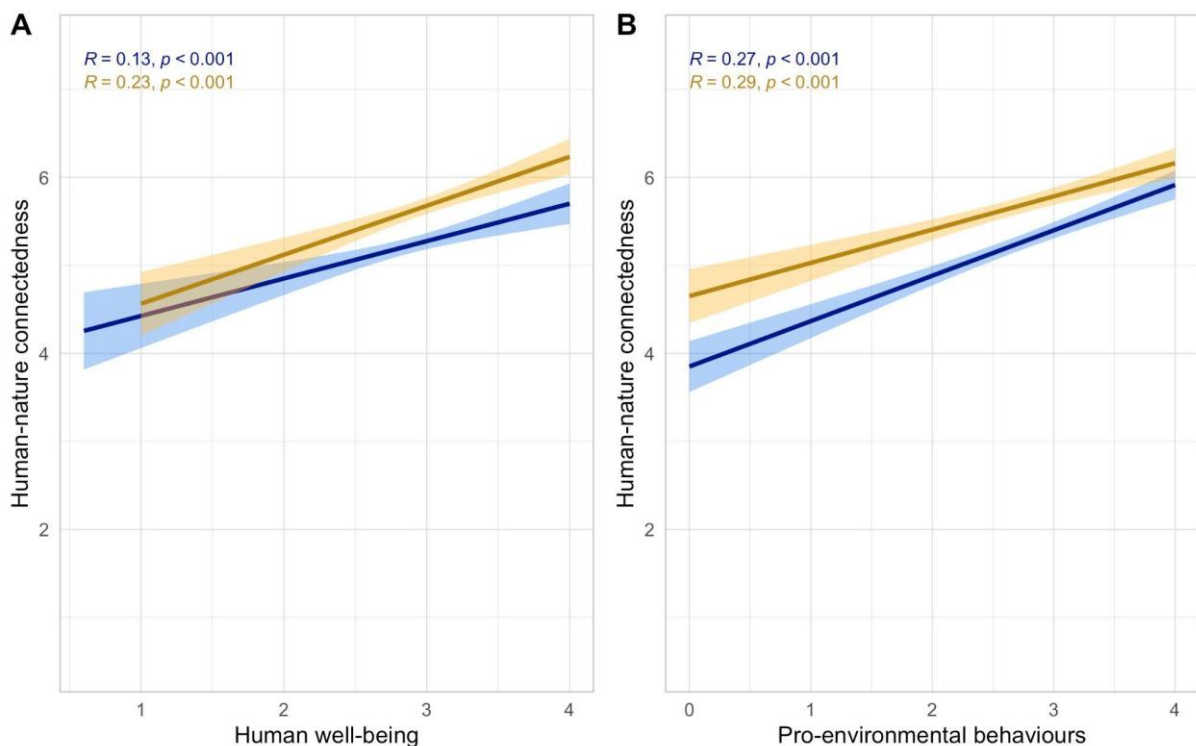
351 We also performed ordered logistic regressions ('polr' function in R) to analyse relationships  
352 between median well-being and median pro-environment and human-nature connectedness  
353 while controlling for socio-demographic variables (age, sex, country).

354 As we expected human-nature connectedness to be influenced by urbanisation and forest  
355 cover, we investigated the relations between human-nature connectedness (dependent  
356 variable) and opportunities to experience nature (independent variables) with urbanisation in a  
357 first model, and forest cover in a second model, using ordered logistic regressions.

358 To visualise human-nature connectedness across different age groups and countries, we fitted  
359 a smoothing curve using a non-parametric regression method (loess regression) using the R  
360 package "mgcv" (59), as we expected a non-linear relationship between human-nature  
361 connectedness and age (27,28).

362 **Results**

363 Human-nature connectedness in France was significantly lower than in Colombia (France:  
364 Median = 5, Mean = 5.22, SD = 1.5 ; Colombia: Median = 6, Mean = 5.7, SD = 1.4 ; *Odds*  
365 *Ratio* = 0.56,  $p < .001$ , Tables S1 and S2). Human-nature connectedness was significantly  
366 linked to well-being and pro-environmental behaviours in both France and Colombia (Fig. 2  
367 and Fig. S1 in SI). Native populations also showed a significant positive relationship between  
368 human-nature connectedness, pro-environment and well-being (Figure S2 in SI). All  
369 relationships remained significant after controlling for age, sex and effects of interaction  
370 between age and human-nature connectedness (Table S3). Since the sample size of Native  
371 populations was low (N=62), Native and non-native Colombian populations were pooled but  
372 additional analyses performed for the three populations separately are presented in Fig. S2.



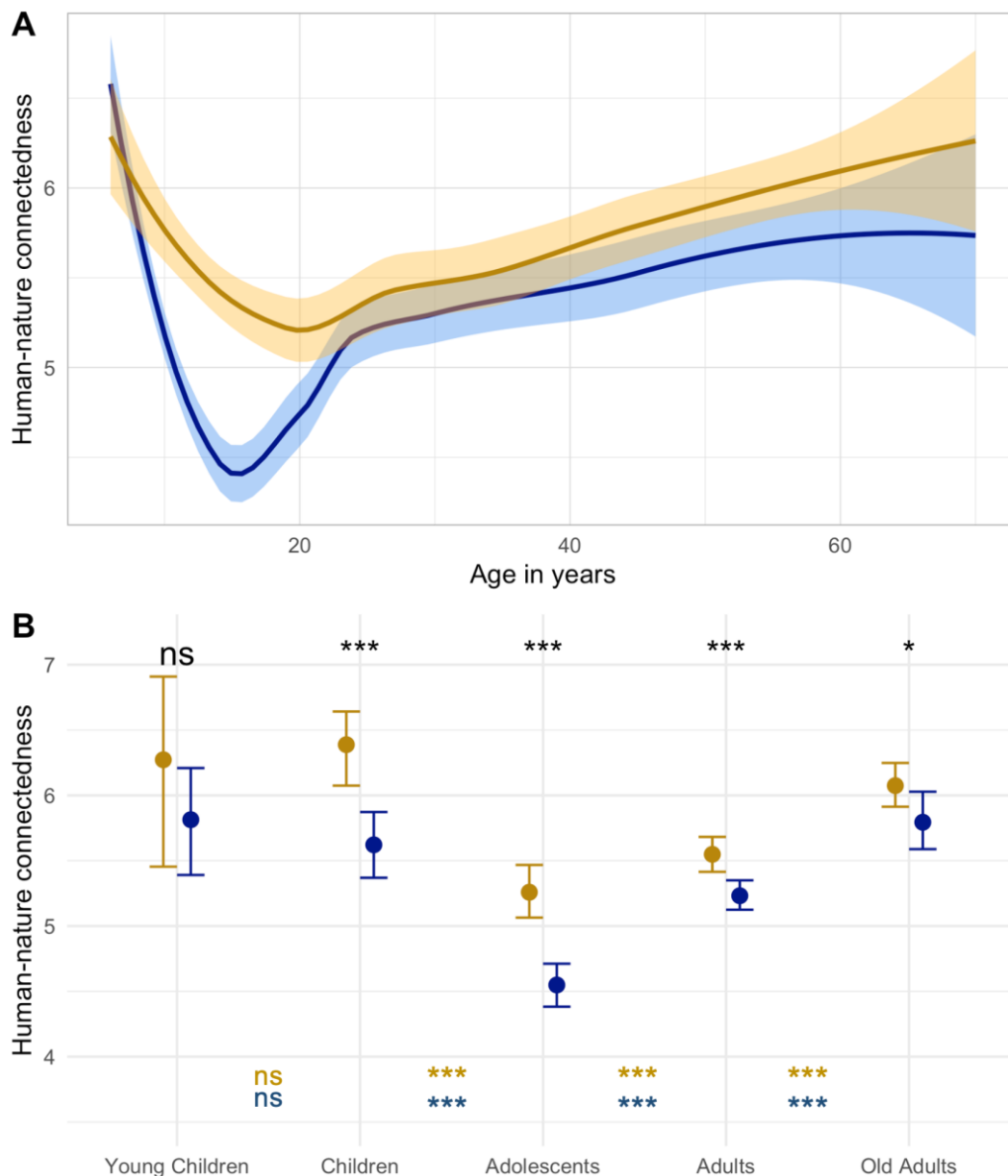
373

374 *Figure 2. Correlations between human-nature connectedness and sustainable outcomes from*  
375 *participants in France (blue) and Colombia (orange). Dark lines represent predicted means*  
376 *with 95% confidence intervals. R and p values correspond to Spearman's correlations. A)*  
377 *Correlations between human-nature connectedness and averaged well-being (10 items) in the*

378 *two populations. B) Correlations between human-nature connectedness and averaged pro-*  
379 *environmental behaviours (5 items) in the two populations.*

380

381 Overall, human-nature connectedness significantly decreased across adolescence (Fig. 3). A  
382 similar age-related pattern was observed in both countries with a high human-nature  
383 connectedness amongst children followed by a decrease for adolescents, but a supplementary  
384 increase for early adults that again increased in older adults (Fig. 3A). Post-hoc pairwise  
385 Wilcoxon tests show that human-nature connectedness scores were significantly lower for  
386 adolescents than other age groups (Fig. 3B). French participants were significantly more  
387 disconnected than Colombian at each time-period except during early childhood (Fig. 3B).  
388 Additional analysis of the age-related pattern of human-nature connectedness from Native  
389 populations shows a similar pattern (Fig. S3).



390

391 *Figure 3. Human-nature connectedness by ages with French participants in blue and*  
 392 *Colombian participants in orange. A) The time course of human-nature connectedness in 5–*  
 393 *70-year-olds from a nonparametric loess regression analysis ('stat\_smooth' function in R,*  
 394 *span = 0.75). Dark lines represent predicted means with 95% confidence intervals (light*  
 395 *orange and blue intervals). Human-nature connectedness scores ranged from 1 to 7. B) Mean*  
 396 *human-nature connectedness in Colombia and France for different life time periods. Error*  
 397 *bars indicate the 95% confidence intervals computed through a bootstrap method with*  
 398 *replacement with 1000 iterations. The lower and upper bounds of the 95% confidence*  
 399 *intervals are set at the 2.5th and 97.5th percentiles, respectively. P values were calculated*  
 400 *with Wilcoxon rank tests for country comparisons at each age period (black values on the*  
 401 *top). Post-hoc pairwise Wilcoxon comparisons contrasting age groups for each country was*  
 402 *performed and associated corrected p-values (Bonferroni) are presented on the bottom with*  
 403 *Colombia in orange and France in blue: ns= non-significant, \*  $p < 0.05$  \*\*\*  $p < 0.001$ .*

404

405 Human-nature connectedness indices varied significantly across countries, age, gender and  
 406 the opportunity to experience nature (urbanisation and forest cover of the participants'  
 407 municipality of residence, Table 2, Fig. 3). Overall, Colombian women participants, and  
 408 participants living in low-urbanised and high-forest-covered areas, have a higher human-  
 409 nature connectedness than others (Table 2, Fig. S4A and Fig. S4B in SI). While urbanisation  
 410 indices are negatively linked to human-nature connectedness in both countries, forest cover is  
 411 positively related to human-nature connectedness only in France, when controlling for age  
 412 and sex (Table S4, Fig. S4C and Fig. S4D in SI).

413 Table 2. Results from ordered logistic models showing the effect of the country, age, sex,  
 414 opportunity to experience nature (urbanisation and forest cover) on human-nature  
 415 connectedness. Since forest cover and urbanisation were anticorrelated, the first model (M1)  
 416 includes urbanisation as a proxy of the opportunity to experience nature while the second  
 417 model (M2) includes forest cover. No effect of interaction was found between age and the  
 418 state of the environment in the two models.

---

**Human-nature connectedness (1 to 7) – Ordered Logistic models**

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<i>Predictors</i>	<b>M1</b>		<b>M2</b>	
	<i>Odds Ratios</i>	<i>CI</i>	<i>Odds Ratios</i>	<i>CI</i>
Country [Colombia vs. France (REF)]	<b>0.69</b> ***	0.58 – 0.82	<b>0.70</b> ***	0.58 – 0.83
Age	<b>1.25</b> ***	1.15 – 1.36	<b>1.27</b> ***	1.16 – 1.39
Sex [Female vs. Male (REF)]	<b>0.81</b> *	0.68 – 0.96	<b>0.81</b> *	0.68 – 0.96
Urbanisation	<b>0.73</b> ***	0.67 – 0.79	-	-
Forest cover	-	-	<b>1.27</b> ***	1.15 – 1.39
Observations	1837		1837	
R <sup>2</sup> Nagelkerke	0.065		0.046	

AIC

5866.026

5901.101

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*\* p<0.05 \*\* p<0.01 \*\*\* p<0.001*

419

420 **Discussion**

421 Our study reveals that the relationship between human-nature connectedness and sustainable  
422 outcomes (well-being and pro-environmental behaviours) is not only specific to a Western  
423 industrialised country from the Global North like France, but is also observed in Colombia, a  
424 country of the Global South. We also found an age-related pattern of human-nature  
425 connectedness shared by the two countries, with a specific decrease in human-nature  
426 connectedness across adolescence. We further show that human-nature connectedness level  
427 and decreases, are modulated by the country of origin and the opportunities to experience  
428 nature.

429 We show a positive and significant relationship between human-nature connectedness, well-  
430 being and pro-environmental behaviours in Colombia and France, in line with findings in  
431 other countries of the Global North (8). The exploratory analysis of a subsample of Native  
432 participants in Colombia also shows this relationship (Fig. S3).

433 Overall, this body of research suggests that human-nature-connectedness enhancement could  
434 be *one important process lever* for reaching sustainable outcomes globally. By leverage point  
435 we mean that small interventions can have far-reaching effects for transformative change  
436 (17,19). Our results support the claim that human-nature connectedness can be such a lever  
437 for achieving sustainable targets as we show that human-nature connectedness is linked to  
438 pro-environmental behaviours, human health, and well-being in two countries that greatly  
439 differ in terms of opportunities to experience nature, and in culture (36).

440 While our study was not designed to analyse items independently, the exploration of single  
441 well-being and pro-environmental items revealed variations in effect sizes between items, and  
442 between countries (Figure S1, Tables S5 to S7). For instance, enhancing human-nature

443 connectedness could be particularly relevant for improving activities to protect nature (e.g.,  
444 garbage cleaning, Annex 2), and a willingness to communicate about environmental issues,  
445 although it might not be the case for energy saving (Fig. S1, Tables S5 to S7). Furthermore,  
446 human-nature connectedness is significantly and positively linked to recycling in Colombia  
447 but not in France, while the reverse pattern is observed for water saving. This result can be  
448 interpreted within a diverse range of human action theories including the Interdependent  
449 Metatheory. This theory focuses on understanding practices within communities and regions,  
450 emphasising the mutual dependency between factors and actions (see 3 for a systematic  
451 review). Future studies that include several items per concept (e.g., energy saving: turning off  
452 lights, phones and computers when not in use, restricting air conditioning), qualitative  
453 information about such behaviours, and investigate cultural and societal causes of  
454 discrepancies between countries, could help strengthen these exploratory findings.

455 Human-nature connectedness was higher amongst children compared to adolescents and  
456 adults. This result is concordant with the biophilia hypothesis which postulates that,  
457 throughout human history, the need for constant interaction with nature has favoured the  
458 survival of individuals with a curiosity, and attraction to the natural world (40). Children's  
459 high human-nature connectedness in France and Colombia aligns with previous studies from  
460 UK (27,28). Additional support comes from a study of children in the USA that showed  
461 children do not prioritise humans over other living beings in a moral game (60). In line with  
462 two previous studies that show a high degree of biophilia in elders (61,62), we also observed a  
463 high human-nature connectedness in older adults in both countries. This finding accords with  
464 previous study reported that the proportion of elders in a country is significantly correlated to  
465 the average human-nature connectedness of that country (10).

466 We also observed a similar “age-pattern” in human-nature connectedness in both France and  
467 Colombia with a decrease in human-nature connectedness among adolescents that matches

468 previous UK studies (27,28). This decrease could be due to several factors, such as  
469 socialisation with their peers, and other cultural factors that drive this drop among teenagers  
470 (27). Children who tend to be ostracised by their peers during childhood and adolescence tend  
471 to be more connected with nature than others (63). Teenage years are also associated with  
472 increasing pressure to perform in school, and are more strongly drawn to commercial and  
473 recreational attractions than to nature-based outdoor activities (29). People in their twenties  
474 are more likely to be leaving home; a change that might facilitate individual decisions toward  
475 personal activities, including those that are nature-based.

476 Lastly, the extent of the teen age disconnection varies between the two countries. French  
477 adolescents are significantly less connected than Colombian adolescents, and overall, French  
478 participants have a lower human-nature connectedness than Colombians. This might be  
479 explained by the greater opportunities that Colombians have to experience nature. Indeed,  
480 species richness in France is lower (National Biodiversity Index (NBI) = 0.320) than in  
481 Colombia (NBI = 0.935) and the NBI has been significantly and positively correlated to  
482 human-nature connectedness at country-level (10). Furthermore, birdsongs diversity has a  
483 positive causal influence on human-nature connectedness at an individual level (25). Our  
484 study accords with previous findings and further shows that within a country, people living in  
485 an area with less urbanisation and more forest cover, display a higher human-nature  
486 connectedness than others. Urbanisation seems to be a factor which plays a major role in  
487 human-nature disconnection in both countries.

488 The present study indicates that the teen period is critical for intervention, at least in  
489 Colombia, and France, and also UK (27,28). Teen years are an important life stage for  
490 decisions about the future in terms of the type of job desired, domain of training considered,  
491 etc. Children's contact with nature has been shown to be positively related to their level of  
492 biophilia, and their current and future willingness to support nature conservation, while a lack

493 of contact with nature is linked to a high biophobia and low concern for conservation  
494 (24,29,42,64). Maintaining a high connection with nature in teens and young adults would  
495 potentially increase individuals' choices that are more aligned with sustainable values and  
496 behaviours; one major lever mentioned in the last IPBES report to promote biodiversity  
497 conservation and well-being (65,66).

## 498 **Conclusions**

499 Our study shows that human-nature connectedness is modulated by age and environmental  
500 factors such as urbanisation, in both native and non-native populations in the Global South, as  
501 well as in Europe. This indicates that considering the age of the participant is important in  
502 efforts to “reconnect” individuals with nature, with teen age years being particularly critical  
503 (27). Our findings indicate that the promotion of practices that enhance human-nature  
504 connectedness increases both well-being and pro-environmental behaviours simultaneously. It  
505 individually empowers people in ways that help align societal values and actions towards  
506 reaching global sustainability targets (67).

507 Our study has important implications for conservation policies aimed at improving human  
508 well-being and nature conservation globally. Interventions to enhance opportunities to be in  
509 contact with nature should be recognized as a strategic environmental and public health  
510 measure (9,68–71). Such interventions include developing specific courses that are set in  
511 nature (outdoor education), and bringing nature into the classroom, schoolyard, workplace  
512 and urban centres. These measures would provide important, yet simple steps to fight against  
513 observed age-related human-nature connectedness decline (69). Limiting urban expansion and  
514 conducting restoration efforts that encourage local biodiversity is particularly recommended if  
515 we are to maximise the beneficial effects on human-nature connectedness and human well-

516 being (9,25,71). Promoting outdoor social events is particularly relevant since environmental  
517 education is more efficient when proposed in groups than individually (68).

518 Despite common patterns and qualitative evidence from focus groups indicating that the  
519 human-nature connectedness scale used in the current study was understood similarly across  
520 the two countries (Annex 3 and 4 and methods), a comprehensive psychometric  
521 standardisation of this scale in Colombia and France is still needed. Future research should  
522 focus on validating human-nature connectedness scales in diverse cultural contexts, to ensure  
523 its applicability and reliability. Such validation studies would clarify whether the scale is  
524 interpreted in the same way by people in different cultures, and would strengthen the  
525 interpretation of results in cross-cultural research on human-nature connectedness.

526 Numerous other factors that go beyond the scope of the present study, should be explored in  
527 the future (10,30). For instance, while the data collected suggest a potential shift in human-  
528 nature connectedness throughout a lifetime, this is not conclusive due to the cross-sectional  
529 nature of the study design. It is possible that adults and elders today may have possessed a  
530 greater degree of human-nature connectedness when they were younger (10). Conducting  
531 causal studies and longitudinal research combining different measures related to well-being,  
532 pro-environmental behaviours, qualitative and quantitative indices of opportunity to  
533 experience nature in other countries from the Global South, is warranted. This is particularly  
534 true especially in populations and in countries that might be primarily affected by climate  
535 change (72). Doing so should help us to understand the impact of global changes on human  
536 values, norms, and behaviours, and so to modify their trajectory by implementing concrete  
537 actions to maintain human-nature connectedness globally in the long term, for the sake of a  
538 desirable future.

539 **Author contributions**

540 Gladys Barragan-Jason and Camille Parmesan conceived the ideas and designed  
541 methodology; Gladys Barragan-Jason, Camille Parmesan, Suzanne Skevington, Maxime  
542 Cauchoix, Solène Hemet, Camilo Cardozo, Paula Diaz and Arielle Syssau-Vaccarella gave  
543 important feedback on the design; Gladys Barragan-Jason, Maxime Cauchoix, Solène Hemet  
544 and Arielle Syssau-Vaccarella collected the data; Philipp Heeb, Camilo Cardozo and Paula  
545 Diaz provided some early help collecting the data from Colombia; Gladys Barragan-Jason and  
546 Maxime Cauchoix analysed the data; Gladys Barragan-Jason wrote the draft and led the  
547 writing of the manuscript. All authors participated in the interpretation of data, contributed  
548 critically to the revision of the paper and gave final approval for publication.

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561 the study.

562

563 **Conflict of Interest**

564 We declare no conflict of interests.

565 **Data availability statement**

566 Data available upon request to corresponding author.

567 **Statement of inclusion**

568 Our study brings together authors from diverse countries (UK, US, France, Colombia),  
569 including scientists and research assistants based in the countries where the study was carried  
570 out. All authors were engaged early on with the research to ensure that the diverse sets of  
571 perspectives they represent was considered from the onset. Whenever relevant, literature  
572 published by scientists from the region was cited including work published in the local  
573 language.

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