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# An agro-environmental mowing regime favors the number of inflorescences and flower-visiting insects but not ground beetles of herbaceous boundaries of arable fields

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## ► To cite this version:

Clémence Chaudron, Rémi Perronne, Pascal Bonnin, Thierry Rattier. An agro-environmental mowing regime favors the number of inflorescences and flower-visiting insects but not ground beetles of herbaceous boundaries of arable fields. *Basic and Applied Ecology*, 2020, 48, pp.1-10. 10.1016/j.baae.2020.06.002 . hal-03082515

**HAL Id: hal-03082515**

**<https://hal.science/hal-03082515>**

Submitted on 30 Aug 2022

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1 **Title: An agro-environmental mowing regime favors the number of**  
2 **inflorescences and flower-visiting insects but not ground beetles of**  
3 **herbaceous boundaries of arable fields**

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34 **Abstract**

35       Herbaceous boundaries adjacent to arable fields can deliver ecosystem services not  
36 sufficiently provided at the field scale, as well as disservices such as increased weed pressure.  
37 The levels of services and disservices depend on the management regime implemented in  
38 these boundaries. Our study was conducted in Western France, where herbaceous boundaries  
39 of many arable fields constitute the road verge, and various mowing regimes were tested for  
40 conservation purposes. Until now, most studies of the influence of mowing regimes focused  
41 on one taxonomic group and documented contrasting results depending on the environmental  
42 context. This study aimed to compare the influence of two mowing regimes on road verges by  
43 evaluating different taxonomic groups that could potentially deliver services or disservices to  
44 adjacent arable fields. The mowing regimes used were a standard and an agro-environmental  
45 regime, the latter being characterized by one late mowing, a high mowing height and biomass  
46 removal. We monitored, during two consecutive years, seven road verges and their adjacent  
47 arable fields. Each road verge was divided into two zones of equal length, characterized by a  
48 different mowing regime. Communities of plants, flower-visiting insects and ground beetles  
49 **were sampled in herbaceous boundaries and/or arable fields in the period between the mass-**  
50 **flowering of oilseed rape and sunflower crops. In zones where the agro-environmental**  
51 **mowing regime had been implemented, the average number of inflorescences and flower-**  
52 **visiting insects within boundaries were higher than under the standard mowing regime.**  
53 However, between the two mowing regimes, no differences in weed cover within arable fields  
54 and the average number of ground beetles within boundaries and arable fields were observed.  
55 To conclude, our study suggests that in our particular environmental context, an agro-  
56 environmental mowing regime could promote pollination in adjacent arable fields without  
57 increasing weed pressure within the field.

58

59 **Keywords:**

60 Road verge; Field boundary; Arable field; **Winter wheat**; Arable weeds; Flower-visiting  
61 insects; Ground beetles; Inflorescences; **France**

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## 67 **Introduction**

68           The intensive agricultural production model based on an increasing use of external  
69 chemical inputs is currently questioned because of issues concerning environment and public  
70 health, as well as agronomic and socio-economic relevance (Bourguet & Guillemaud, 2016;  
71 van der Werf, 1996). In order to reduce the reliance on external inputs, several alternative  
72 directions have been proposed, considering efficiency-based and biodiversity-based  
73 agricultures (Duru et al., 2015). The biodiversity-based direction, considering  
74 environmentally-friendly agroecological practices for pest management, aims for a reduction  
75 of external inputs by promoting both a spatial and a temporal diversification of  
76 agroecosystems (Duru et al., 2015). In particular, it would be possible to reduce pest pressure  
77 by managing semi-natural habitats at the landscape scale in specific ways rather than just  
78 focusing on pest management at the field scale (Gurr et al., 2017; Holland et al., 2016).

79           These semi-natural habitats, and especially herbaceous boundaries, are indeed able to  
80 deliver ecosystem services that may be no longer sufficiently provided at the field scale,  
81 including crop pollination and pest control (Knapp et al., 2019; Persson & Smith, 2013;  
82 Stanley & Stout, 2014; Tschumi et al., 2015). Concerning pollination, boundaries can provide  
83 nesting sites as well as food for pollinators between periods of mass-flowering of different  
84 crops (Stanley & Stout, 2014), thus potentially avoiding a sharp decline of the number of  
85 pollinators due to limiting resources provided by arable fields after these flowering periods.  
86 Concerning pest control, boundaries can provide shelter for natural enemies, such as ground  
87 beetles, after crop harvest or during winter (Ganser et al., 2019; Labruyere et al., 2016), thus  
88 increasing the abundance of natural enemies **and/or** predation intensity in adjacent arable  
89 fields (Hof & Bright, 2010; Mansion-Vaquié et al., 2017). Nevertheless, these boundaries are  
90 also habitats for weed species able to colonize arable fields. Thus, boundaries may also supply  
91 disservices to adjacent arable fields, by an increase in weed pressure (Chaudron, Perronne, et  
92 al., 2016; Smith et al., 1999). However, the level of ecosystem services and disservices  
93 delivered by herbaceous boundaries to adjacent arable fields should depend on the  
94 management regime of these boundaries. Indeed, changes in vegetation structure **and/or**  
95 phenology can affect the habitat quality of boundaries for pollinators and natural enemies. As  
96 an example, the mowing regime can influence the number of flowering shoots (Jantunen et  
97 al., 2007; Noordijk et al., 2010), and consequently the number of visits by flower-visiting  
98 insects (Noordijk et al., 2009; Pywell et al., 2011), as well as the abundance of ground-  
99 dwelling arthropods (Albrecht et al., 2010; Buri et al., 2016; Noordijk et al., 2010). The

100 timing of mowing can also influence the abundance of invertebrates in some environmental  
101 contexts (Humbert et al., 2012; van Klink et al., 2019) and change the quantity of propagules  
102 able to spread to adjacent arable fields and become problematic arable weeds (Chaudron,  
103 Chauvel, et al., 2016; Leng et al., 2011).

104 Our study was conducted in Western France, where herbaceous boundaries of many  
105 arable fields correspond to the road verge and are usually managed by mowing. Since 1986, in  
106 the French metropolitan territory, changes in mowing regimes have been tested, including an  
107 increased height of mowing, a decrease in mowing frequency, a delayed first date of mowing  
108 and/or a removal of biomass. These changes have been recommended to allow seed  
109 production by annual plants, to avoid the increase of soil nutrient levels and therefore the  
110 proliferation of nitrophilous species, to increase the taxonomic diversity of plants in  
111 boundaries, to avoid direct invertebrate mortality due to low mowing height, and to provide  
112 refuges and food resources for invertebrates such as flower-visiting insects (Association  
113 Hommes et Territoires, 2011; Association Nord-Nature Chico Mendès, 2009). Beyond the  
114 French context, these changes in mowing regime have also been recommended in other  
115 European countries such as Belgium and the Netherlands (Godefroid et al., 2005; Sykora et  
116 al., 2002).

117 We were interested in road verges adjacent to arable fields in Western France as a case  
118 study in order to investigate the impact of changes in mowing regime carried out in these road  
119 verges on different taxonomic groups that could potentially deliver ecosystem services or  
120 disservices to adjacent arable fields. Until now, most studies that examined the influence of  
121 mowing regime on road verges focused on one taxonomic group and a few diversity metrics,  
122 especially species richness of plants on the boundary, and recorded contrasting effects  
123 depending on the frequency and timing of mowing and whether biomass was removed or not  
124 (Jakobsson et al., 2018). Moreover, invertebrates (e.g. arthropods, Hemiptera) have been  
125 much less studied (Jakobsson et al., 2018), and the influence of a particular management  
126 practice usually appears to affect the level of diversity differently depending on the taxonomic  
127 group. For instance, the number of mowings per year can have a marginally positive impact  
128 on flower abundance, which appears significantly positively related to the number of visits by  
129 flower-visiting insects (Noordijk et al., 2009). These responses to mowing regimes  
130 furthermore appear highly context-dependent. For instance, compared to a less intensive  
131 regime, a higher diversity of ground beetles after two cuts with biomass removal was shown  
132 in the Netherlands (Noordijk et al., 2010), while a higher diversity in uncut areas compared to  
133 mown areas was found in Scotland (Haysom et al., 2004). These context-dependent responses

134 have also been observed for road verge plant communities for which delaying the first date of  
135 mowing from early to late summer did not change plant species richness in Finland (Valtonen  
136 et al., 2006), but had a negative impact and could increase weed pressure in adjacent fields in  
137 France (Chaudron, Perronne, et al., 2016). In light of these considerations, assessing the  
138 relevance of changes in mowing regimes with the aim of maximizing ecosystem services  
139 while minimizing disservices delivered by boundaries to adjacent arable fields therefore  
140 requires to focus on a particular environmental context.

141 In our case study, two mowing regimes were compared: the standard mowing practice  
142 (one mowing in early summer, a short mowing height and without biomass removal), and an  
143 agro-environmental mowing practice (one late mowing between two and three months after  
144 the standard mowing date, a higher mowing height and biomass removal). Concerning  
145 herbicide treatments in arable fields adjacent to road verges, herbicides focusing on a broad  
146 spectrum of species were only applied before the sowing period; therefore, although weed  
147 pressure from road verges is underestimated, it gives us an idea of potential disservices  
148 delivered by boundaries to adjacent arable fields. In addition, although we did not directly  
149 measure ecosystem services, we adopted abundance-based metrics that are commonly used as  
150 proxies of these services (Noriega et al., 2018), and we assessed whether the implementation  
151 of the agro-environmental mowing regime changed (i) the weed cover in adjacent arable  
152 fields, (ii) the number of inflorescences and flower-visiting insects within boundaries and (iii)  
153 the number of ground beetles in boundaries and adjacent arable fields. In particular, we  
154 hypothesized that the agro-environmental mowing regime should increase (i) weed cover in  
155 the first meters from the boundary into the arable field, (ii) the number of inflorescences and  
156 flower-visiting insects within boundaries and (iii) the number of ground beetles within the  
157 boundary and in the first meters from the boundary into the arable field.

158

## 159 **Materials and methods**

### 160 *Study area*

161 The survey was carried out in an agricultural area dominated by cereal production  
162 located in Western France, Pays de la Loire region, Vendée department, France (46°29'N,  
163 0°58'W). Seven arable fields under conventional farming (Appendix A) and their boundaries  
164 were monitored. The herbaceous boundary of each arable field was divided into two zones of  
165 equal length. In one part, the vegetation was mown in early summer at 5 cm above the ground  
166 level and the mown biomass was left on site (**hereinafter** standard mowing regime). This

167 boundary zone and the adjacent arable field part constitute the standard site (Fig. 1). On the  
168 other part, the vegetation was mown in late summer at 25 cm above ground level and the  
169 biomass was removed (**hereinafter** agro-environmental mowing regime). This zone and the  
170 adjacent arable field part constitute the agro-environmental site (Fig. 1). The agro-  
171 environmental mowing regime has been operating for three consecutive years (2015, 2016  
172 and 2017). **In 2015, the mowing regimes were randomly allocated to the left and right halves**  
173 **of the field margin and then kept for the next two years (see Appendix B for details about**  
174 **standard and late mowing periods).** Vegetation and flower-visiting insect surveys were  
175 performed in all field margins in both the years 2016 and 2017, while the sampling of ground  
176 beetles occurred in 3 winter wheat fields in 2016 and 3 winter wheat fields in 2017 (no field  
177 sampled twice during these consecutive years).

178

## 179 *Data collection*

### 180 *Environmental data*

181 **The years 2016 and 2017 were characterized by distinct meteorological conditions**  
182 **(Appendix C), which influenced phenological stages of plants and thus associated insects.**  
183 **Therefore, to compare surveys between sampling periods, we expressed days in terms of**  
184 **accumulated growing degree-days (thereafter GDD) which were calculated following the**  
185 **method by McMaster and Wilhelm (1997) assuming a base temperature of 0 °C.**

186

### 187 *Vegetation surveys*

188 In the boundary zone of each site, the vegetation was sampled along one transect  
189 (**length: 25 m**) positioned in the center of the relevant boundary section (14 transects in total,  
190 i.e. 7 boundaries × 2 mowing regimes). The two transects per boundary (i.e. one transect per  
191 mowing regime) were placed 40 m apart, each being positioned at 20 m from the center of the  
192 boundary section (**Fig. 1A**). All vascular plant species of all boundaries were recorded **before**  
193 **mowing in the summers 2016 and 2017.** The abundance of each species was estimated  
194 following the Braun-Blanquet species abundance-dominance codes (Braun-Blanquet, 1964)  
195 and then converted into relative percentage of cover.

196 In the arable field part of each site, three or four transects were positioned  
197 perpendicular to the boundary and at various distances into the field (**Fig. 1A**). These transects  
198 were placed 20 m apart from each other, while the distance between the first transect of the  
199 standard site and the first transect of the agro-environmental site was 40 m (**Fig. 1A**). On each

200 transect, the cover of each arable weed species was estimated within four quadrats of 0.25 m<sup>2</sup>.  
201 Following Gaba et al. (2017), arable weeds are defined as “the set of wild plants found in  
202 agro-ecosystems that are well adapted to disturbed environments and have been associated  
203 with crop production since the origin of agriculture”. Weed cover was always estimated after  
204 a similar weed management program conducted in the whole field, usually including soil  
205 tillage **and/or** pre- and post-emergence herbicide application depending on the crop (see  
206 Appendix A for weed management information in wheat). The quadrats were positioned at 1  
207 m, 5 m, 15 m and 25 m from the boundary into the field. For each site, the average cover of  
208 each species per distance was computed.

209

### 210 *Inflorescence and flower-visiting insect surveys*

211 On each boundary zone, the number of inflorescences of dicotyledonous species was  
212 counted within three or four quadrats of 1 m<sup>2</sup> positioned 20 m apart from each other (**Fig. 1B**).  
213 The mean **number** of inflorescences of each species per boundary zone was computed.  
214 Flower-visiting insects on each boundary zone were studied in one plot of 100 m length × 1 m  
215 width positioned in the center of the zone. The two 100 m<sup>2</sup> plots per boundary (i.e. one plot  
216 per mowing regime) were placed 40 m apart, each being positioned at 20 m from the center of  
217 the boundary length (**Fig. 1B**).

218 Butterflies (Lepidoptera), honeybees and solitary bees (Hymenoptera), bumblebees  
219 (Hymenoptera), and hoverflies (Diptera) were recorded during 10 minutes every two weeks  
220 between June and July of both 2016 and 2017, resulting in 3 counts per year, 42 counts per  
221 mowing regime (3 counts × 7 boundary zones × 2 years). Flower-visiting insect counts were  
222 coincident with inflorescence surveys. Walks were carried out between 9.00 am and 17.00 pm  
223 when weather conditions were sunny and calm. **In order to ensure that the sampling of**  
224 **inflorescences and flower-visiting insects is done each year at similar GDDs, we took into**  
225 **account the sowing date of the crop of the different fields.**

226

### 227 *Ground beetle sampling*

228 Ground beetles were sampled in 3 winter wheat fields in 2016 and 3 winter wheat  
229 fields in 2017 (no field sampled **twice**). On each site, two transects were positioned  
230 perpendicular to the boundary and at various distances into the field (**Fig. 1C**). These transects  
231 were placed 20 m apart from each other, while the distance between the first transect of the  
232 standard site and the first transect of the agro-environmental site was 40 m. Along each  
233 transect, three sample points were positioned at different distances from the boundary: 0 m



234 (within the boundary), 2.5 m and 25 m (Fig. 1C). Ground beetles (Coleoptera: Carabidae)  
235 were sampled with one pitfall trap partly filled with a soap mixture (5% soap, 95% water) and  
236 salt (500 mg.L<sup>-1</sup>) to prevent the development of bacteria and fungi. Sampling occurred  
237 between May and June of each year, resulting in four (year 2017) or five (year 2016)  
238 sampling periods per year, each sampling period lasted one week. For each boundary zone  
239 and each year, the mean of ground beetles across the several sampling periods was computed  
240 to obtain a more complete measure of the ground beetle assemblage (see e.g. Noordijk et al.,  
241 2010).

242

### 243 *Statistical analyses*

#### 244 *Taxonomic composition of plant communities within boundaries*

245 Variations in taxonomic composition of plant communities due to differences in  
246 mowing regime were investigated using a Principal Component Analysis (PCA) performed on  
247 Hellinger-transformed species data based on relative cover (Legendre & Gallagher, 2001),  
248 and the statistical significance was assessed using a permutation test (Appendix D). We also  
249 used a partial Redundancy Analysis (RDAP) based on the same data to estimate the unbiased  
250 amount of explained variance due to mowing regime (see Appendix D for details).

251

#### 252 *Weed cover in arable fields*

253 We examined how the mowing regime affected the average weed cover at four  
254 different distances from the edge. To avoid a confounding effect related to the crop type  
255 sampled on weed composition and abundance, we used only sites located in winter wheat (i.e.  
256 three sites in 2016 and four in 2017, with no field sampled twice). These sites were subjected  
257 to soil tillage interventions and/or pre-emergence herbicide application before sampling. We  
258 implemented linear mixed models (LMMs) to assess the effect of mowing regime (a factor  
259 with two levels), year (a factor with two levels), distance (a quantitative variable) and all  
260 second-order interactions as fixed effects on weed cover, accounting for field identity as a  
261 random intercept effect. We chose to apply LMMs with Box-Cox transformation rather than  
262 binomial generalized linear mixed models (GLMMs) due to a strong asymmetry in the data  
263 distribution; requirements were met after the Box-Cox transformation (see Appendix E for  
264 details).

265

266

267 *Number of inflorescences and flower-visiting insects*

268 We examined how the mowing regime affected the average number of inflorescences  
269 of dicotyledonous species and the number of flower-visiting insects in all sites in 2016 and  
270 2017. We focused on the counts made at around 360 GDD in 2016 and 320 GDD in 2017  
271 after the standard mowing for both the average number of inflorescences and the number of  
272 flower-visiting insects to allow a comparison between years despite different meteorological  
273 conditions. This count was made between the flowering periods of the two mass-flowering  
274 crops in the area, i.e. oilseed rape and sunflower (see also Requier et al., 2015). We  
275 implemented quasi-Poisson generalized linear mixed models (thereafter GLMMs) to assess  
276 the effect of the mowing regime, the year and the interaction as fixed effects on the mean of  
277 inflorescences (or the number of flower-visiting insects), accounting for the field identity as a  
278 random intercept effect (see Appendix F1 for details). In addition, a Kendall rank correlation  
279 test was used to estimate the coefficient of correlation  $\tau$  between the average number of  
280 inflorescences of dicotyledonous species and the number of flower-visiting insects, assuming  
281 a positive correlation between these two variables ( $P < 0.05$ ).

282

283 *Number of ground beetles in boundaries and arable fields*

284 We examined how the mowing regime affected the average number of ground beetles,  
285 within the boundary and in the winter wheat field. We implemented quasi-Poisson GLMMs to  
286 assess the effect of mowing regime, year, distance and all second-order interactions as fixed  
287 effects on the average number of ground beetles trapped, accounting for field identity as a  
288 random intercept effect (see Appendix G1 for details).

289

290 For all LMMs and GLMMs tested, we checked for the homogeneity of variances,  
291 normality of the residuals, and applied a transformation when necessary. We applied sum to  
292 zero contrasts on fixed factors and Helmert contrasts on the random factor before fitting  
293 models, and a likelihood-ratio test based on the  $\chi^2$  distribution to evaluate the significance of  
294 the effect. The full model was compared with all models based on Akaike information  
295 criterion (AIC), and only the best model was presented, with both the lowest AIC and with all  
296 explanatory variables significant ( $P < 0.05$ ). Statistical analyses were performed using R 3.5.1  
297 (R Development Core Team, 2018) and its packages ‘vegan’ for PCA and RDAp (Oksanen et  
298 al., 2019), ‘forecast’ for Box-Cox transformation (Hyndman et al., 2019), ‘lme4’ for LMMs  
299 (Bates et al., 2015), ‘glmmTMB’ for quasi-Poisson GLMMs (Brooks et al., 2017) and ‘stats’  
300 for Kendall rank correlation test.

## 301 **Results**

### 302 *Taxonomic composition of plant communities within boundaries*

303 The PCA of Hellinger-transformed species abundance data based on relative cover  
304 showed significant compositional differences between plant communities in boundaries  
305 depending on the mowing regime (Appendix D). However, the partial RDA highlighted that  
306 the influence of the mowing regime explained only a small part of **the** compositional  
307 differences after accounting for field identity ( $R^2_{\text{adj}} = 14.8\%$ , Appendix D).

308

### 309 *Weed cover in arable fields*

310 A total of 21 arable weed species were recorded (Appendix E1). The average weed  
311 cover varied with the distance from the boundary, while the year and the mowing regime of  
312 the boundary appeared non-significant ( $\chi^2 = 32.82$ ,  $P < 0.001$ , **Fig. 2**, see Appendix E for  
313 details). The weed cover decreased from the first meter within the field to the field core (**Fig.**  
314 **2**). The weed cover appeared usually low in arable fields but varied between fields, which  
315 could explain that the mowing regime had no influence although the agro-environmental  
316 practice presented a mean weed cover lower than the standard practice at all distances from  
317 the boundary (**Fig. 2**).

318

### 319 *Number of inflorescence and flower-visiting insects*

320 Taking into account all sampling periods, a total of 1521 flower-visiting insects were  
321 observed, including 612 bees, 520 hoverflies, 216 butterflies and 173 bumblebees.  
322 Considering counts made at around 360 GDD in 2016 and 320 GDD in 2017 after the  
323 standard mowing, we observed that the average number of inflorescences of dicotyledonous  
324 species varied with mowing regime ( $\chi^2 = 32.14$ ,  $P < 0.001$ ), the year of the survey ( $\chi^2 = 13.11$ ,  
325  $P < 0.001$ ), and the ‘mowing regime  $\times$  year’ interaction ( $\chi^2 = 10.63$ ,  $P < 0.01$ ), **with a stronger**  
326 **negative effect of the standard compared to the agro-environmental practice in 2017 than in**  
327 **2016**. In addition, mowing regime showed a higher explanatory power than the other variables  
328 (**Fig. 3A**, see Appendix F for details). The number of flower-visiting insects also varied with  
329 mowing regime ( $\chi^2 = 27.79$ ,  $P < 0.001$ ) and year ( $\chi^2 = 10.61$ ,  $P < 0.01$ ), with mowing regime  
330 showing a higher explanatory power than year (**Fig. 3B**, see Appendix F). In addition, the  
331 average number of inflorescences and the number of flower-visiting insects were positively  
332 correlated, although the correlation coefficient was low ( $\tau = 0.23$ ,  $P < 0.05$ ).

333

334 *Number of ground beetles in boundaries and arable fields*

335 Taking into account all sampling periods, a total of 2270 ground beetles were trapped.  
336 Contrary to the number of inflorescences and flower-visiting insects, mowing regime did not  
337 influence the average number of ground beetles over the May-June sampling period, and year  
338 of the survey and distance into the arable field were also non-significant (see Appendix G2 for  
339 details). In addition, using data per sampling period rather than the average number of ground  
340 beetles over the May-June sampling period did not change the results (results not shown).  
341 However, within boundaries where the agro-environmental practice was used, the mean  
342 number of ground beetles was higher than within boundaries under the standard practice,  
343 although this difference was not significant (Appendix G).

344

345 **Discussion**

346 Our study showed that an environmentally-friendly (so-called “agro-environmental”)  
347 mowing regime carried out on arable field boundaries differently affected communities  
348 depending on taxonomic group. In comparison with the standard mowing regime, the agro-  
349 environmental mowing regime increased the average number of inflorescences and flower-  
350 visiting insects within boundaries, but did not influence the average weed cover within arable  
351 fields and the average number of ground beetles within boundaries and arable fields.

352 Considering plant communities, the mowing regime only slightly changed the  
353 taxonomic composition of boundaries and did not influence weed cover within arable fields,  
354 which was probably due to the short duration of the survey, which covered only the first three  
355 years after the change of the mowing regime. Moreover, the arable fields studied were  
356 intensively managed for weed control, which could have limited the development of weed  
357 populations from boundaries. However, in accordance with previous studies (e.g. Cordeau et  
358 al., 2011; Marshall, 1989; Romero et al., 2008), we found that weed cover was significantly  
359 higher near the boundary, < 1 m from the edge of the field, with than at distances further  
360 away. This could be explained by a less intensive management of field boundaries, resulting  
361 in a denser seedbank than in the field core (José-María & Sans, 2011), and a higher proportion  
362 of seed dispersed from the herbaceous boundary (Chaudron, Chauvel, et al., 2016; De Cauwer  
363 et al., 2008; Petit et al., 2013).

364 Considering inflorescences and flower-visiting insects, the higher numbers observed in  
365 our study under the agro-environmental mowing regime appear in agreement with previous  
366 studies conducted on field boundaries (Potts et al., 2009; Valtonen et al., 2006; Woodcock et

367 al., 2007), while other studies have highlighted different mowing regimes to promote floral  
368 resources and flower-visiting insects (Noordijk et al., 2009; Pywell et al., 2011). Moreover, in  
369 our study, the abundance of flower-visiting insects was positively correlated with the average  
370 number of inflorescences of dicotyledonous species, which is also in agreement with previous  
371 studies (Milberg et al., 2016; Noordijk et al., 2009). This positive effect of the agro-  
372 environmental mowing regime on the number of inflorescences and flower-visiting insects is  
373 likely due to the delay of the first mowing, allowing a longer flowering period for many  
374 species as well as seed production to provide the opportunity to produce seed for more  
375 species, therefore extending the availability of floral resources for flower-visiting insects,  
376 while an early mowing would cause a sudden decrease of resources which may potentially not  
377 be compensated later in the season (Jantunen et al., 2007). This important decrease in floral  
378 resources leads to a sharp decline in pollinator populations within agricultural landscapes  
379 (Persson & Smith, 2013). However, mowing twice a year or maintaining uncut refuges may  
380 also be recommended to increase floral resources and promote flower-visiting insects in other  
381 contexts (Buri et al., 2014; Noordijk et al., 2009). Moreover, biomass removal in agro-  
382 environmental mowing regimes could have also increased the cover and richness of  
383 dicotyledonous species at the expense of grasses (e.g. Pywell et al., 2011) due to the reduced  
384 competition and a higher light penetration to the ground (Tix & Charvat, 2005; Tognetti &  
385 Chaneton, 2015), which may benefit various groups of flower-visiting insects. However, the  
386 positive effect of the agro-environmental mowing regime may also be due to a temporal  
387 concentration effect (Kleijn et al., 2011). Indeed, although one mowing in late summer  
388 extends the availability of floral resources that attracts more flower-visiting insects, the  
389 advantage of the agro-environmental mowing regime may only be concentrated temporally,  
390 thus having a limited effect at the landscape scale (Johansen et al., 2019). However, this  
391 advantage allows greater availability of floral resources between the flowering periods of the  
392 oilseed rape and sunflower mass-flowering crops in our environmental context, which appears  
393 important to avoid the decline in pollinator populations between these two crops. **Finally, in**  
394 **both the number of flower-visiting insects and the number of inflorescences, we found a**  
395 **significant effect of study year, which could be due to the smaller cumulative precipitation in**  
396 **2017 compared to 2016, which may have constrained the regrowth of the vegetation after**  
397 **mowing.** This inter-annual variability was observed in other studies (Potts et al., 2009; Pywell  
398 et al., 2011).

399         Considering ground beetles in boundaries and arable fields, we did not find any  
400 influence of the mowing regime on their number in accordance with previous studies

401 (Haysom et al., 2004; Lafage & Petillon, 2014), this being potentially explained by the  
402 weaker influence of mowing on Coleoptera than on other arthropods (Morris, 2000).  
403 Moreover, it is possible that some functional groups respond to the mowing period and/or to  
404 the removal of the biomass, while others do not, as shown by Lafage and Petillon (2014) as  
405 regard to the mowing period.

406

## 407 **Conclusions**

408 Changing the mowing regime is a way to enhance some ecosystem services and  
409 reduce disservices delivered by boundaries adjacent to arable fields (Chaudron et al., 2018;  
410 Chaudron, Perronne, et al., 2016; Noordijk et al., 2009) as well as urban road verges  
411 (O'Sullivan et al., 2017). Based on a case study in Western France, we highlighted that one  
412 late mowing, with high mowing height and biomass removal could promote flower-visiting  
413 insects without increasing weed pressure in adjacent arable fields. However, long-term  
414 surveys are needed to confirm these results, as well as the lack of influence of the mowing  
415 regime on the abundance of ground beetles both in boundaries and adjacent arable fields.  
416 Moreover, in a context of changes in management practices carried out on road verges, our  
417 results encourage multi-taxon studies, to provide more comprehensive information for  
418 decision-makers. The kind of agro-environmental mowing regime studied here should be tried  
419 out in other environmental contexts, especially to allow the generalization of the observed  
420 results. This will help maximizing services while minimizing disservices delivered by  
421 herbaceous boundaries in a context of declining pollinator populations (Potts et al., 2010) and  
422 increasing weed resistance to herbicides (Délye et al., 2013; Heap, 2014).

423

## 424 **Acknowledgements**

425 This work was funded by a departmental programme (AGRIFAUNE 85) and supported  
426 by the departmental agricultural institute (Chambre d'Agriculture de la Vendée), the  
427 departmental hunting federation (Fédération Départemental des Chasseurs de Vendée) and the  
428 national hunting institute (Office National de la Chasse et de la Faune Sauvage). We thank R.  
429 Bodin, M. Leclercq and C. Basire for collecting the data. We are grateful to the editor and two  
430 anonymous reviewers who helped to improve the manuscript.

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432

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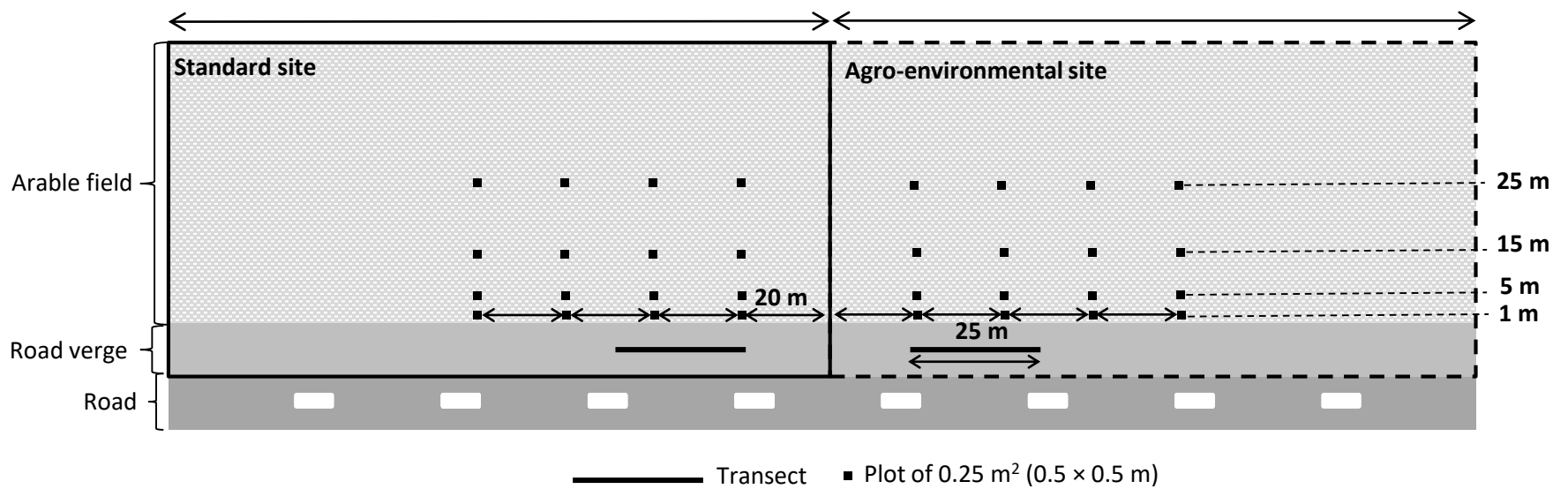
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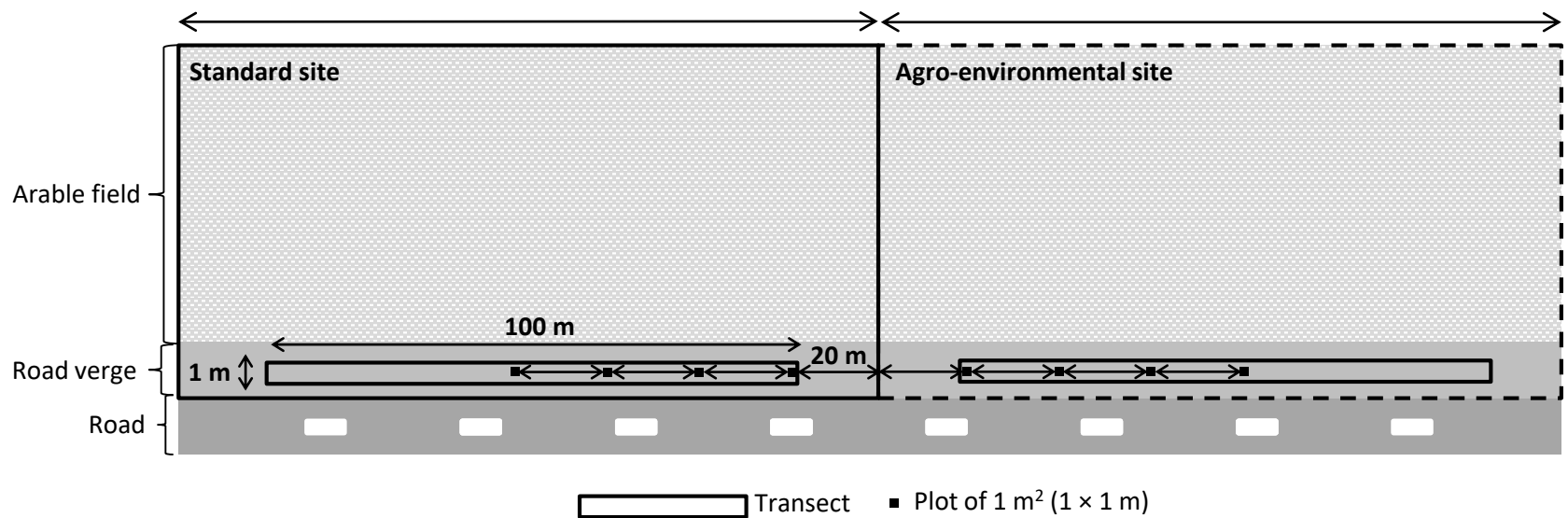
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## (A) Vegetation



## (B) Inflorescences and flower-visiting insects



## (C) Ground beetles

