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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**

4
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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 m².
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 m² 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 m² 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⁻¹) 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 τ 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 χ^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”) mowing regime carried out on arable field boundaries differently affected communities
347 depending on taxonomic group. In comparison with the standard mowing regime, the agro-environmental mowing regime increased the average number of inflorescences and flower-visiting insects within boundaries, but did not influence the average weed cover within arable fields and the average number of ground beetles within boundaries and arable fields.

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

364 Considering inflorescences and flower-visiting insects, the higher numbers observed in our study under the agro-environmental mowing regime appear in agreement with previous 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

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432

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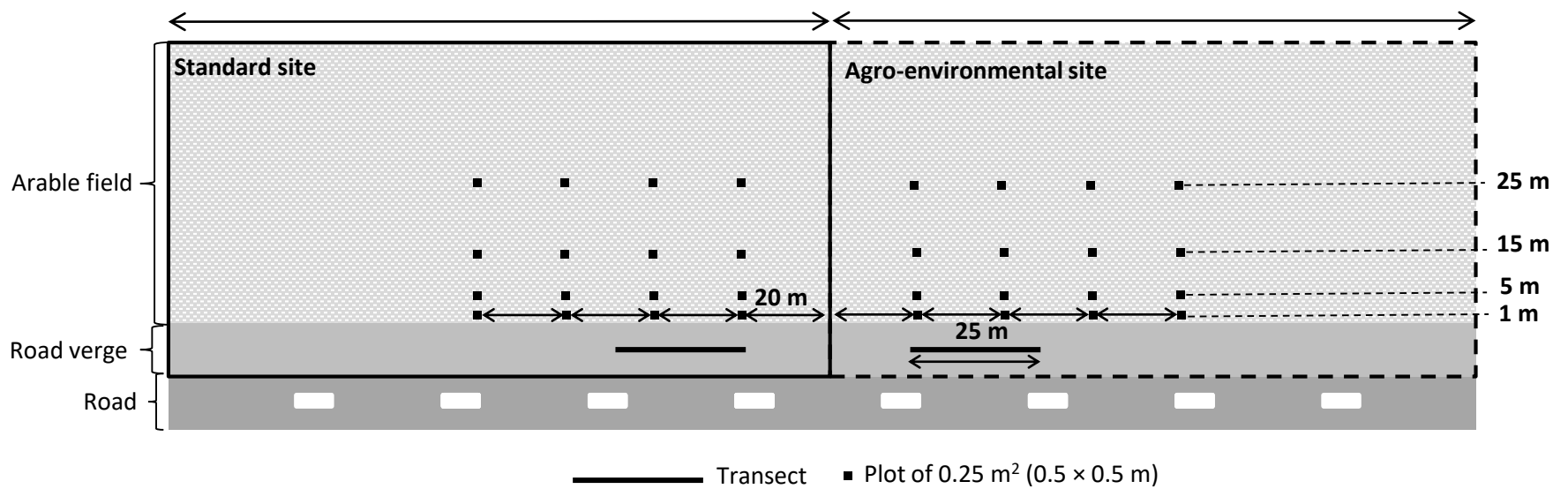
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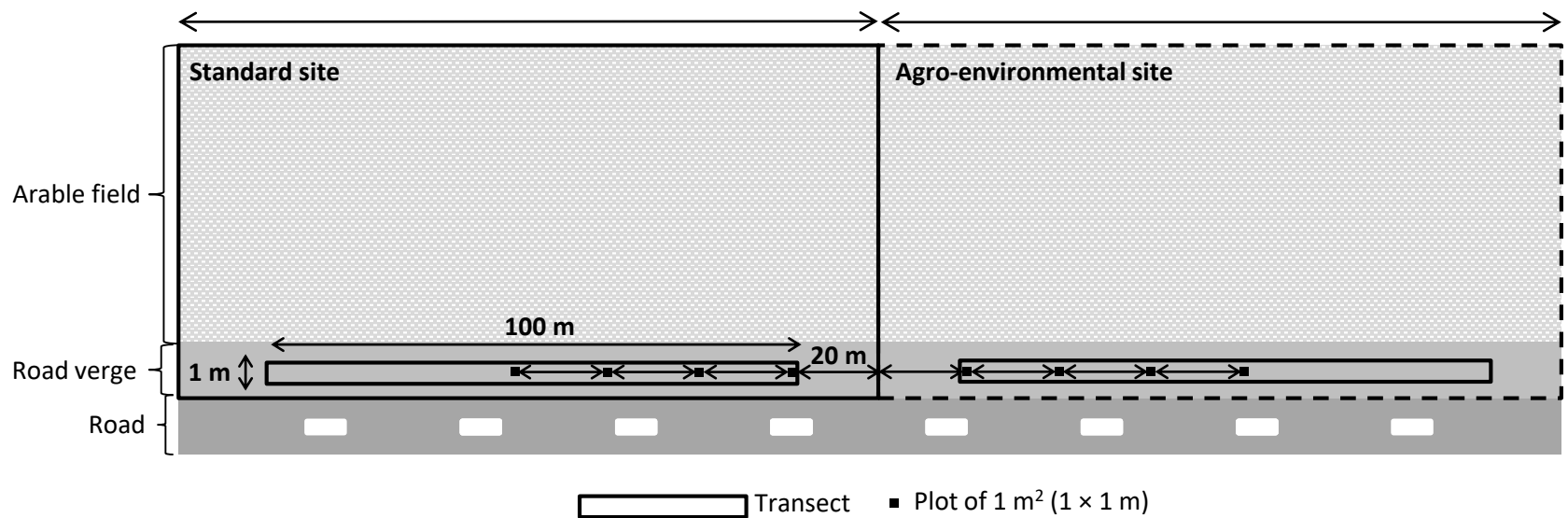
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633

(A) Vegetation



(B) Inflorescences and flower-visiting insects



(C) Ground beetles

