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1 The golf ball method for rapid assessment of grassland structure

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14 method: Parks Victoria, North Central Catchment Management Authority, the Australian
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19 Monitoring program.

20 **Byline**

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26 3000 Australia). Claire Moxham and Brad Farmilo are ecologists at the Arthur Rylah Institute for
27 Environmental Research (Department of Environment, Land, Water and Planning, 123 Brown St,
28 Heidelberg, VIC 3084, Australia). John Morgan is part of the Department of Ecology,
29 Environment and Evolution, La Trobe University (Bundoora VIC 3086, Australia). This project
30 arose from our mutual interest in monitoring and managing grassy ecosystems for biodiversity
31 conservation.

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The golf ball method for rapid assessment of grassland structure

Summary

A key task for native grassland managers is to assess when biomass reduction is necessary to maintain plant and animal diversity. This requires managers to monitor grassland structure. Parks Victoria and La Trobe University developed a method for rapid assessment of grassland structure using golf balls. Baker-Gabb et al. (2016) provide an example of where the method has been used to manage grassland structure to favour an endangered bird, the Plains-wanderer (*Pedionomus torquatus*). In this paper, we provide further critical analysis of the method using three datasets collected across different parts of Victoria that relate golf ball scores to various habitat attributes. We demonstrate how the golf ball score provides a good surrogate for key aspects of grassland structure. We show that the method does not provide a reliable surrogate for aboveground biomass or vegetation cover, though we discuss how biomass and cover are not particularly good indicators of grassland structure. We argue that elements of grassland structure may be better correlated with desired conservation outcomes (e.g. plant species diversity, or the presence of a particular species) than biomass or cover alone. We discuss examples of how the golf ball method has been used, and how it can be improved. The method will be particularly useful where a link can be demonstrated between golf ball scores and desired conservation outcomes, such as in the case of the Plains-wanderer.

Keywords: Grassland, monitoring and evaluation, conservation management, disturbance, faunal habitat

30 **Introduction**

31 A major challenge for native grassland management in south-eastern Australia relates to the necessity
32 to manage disturbance regimes (by burning, grazing or slashing) that reduce biomass to alter
33 vegetation structure. Without disturbance to the vegetation, biomass may accumulate and smother
34 intertussock flora, preventing seedling recruitment and reducing plant species diversity (Morgan
35 1998). In extreme cases, biomass accumulation smothers dominant tussock grasses, leading to their
36 decline and replacement with annual exotic species (Morgan & Lunt 1999). Fauna, too, may prefer
37 particular grassland structures. For example, the grassland bird Plains-wanderer (*Pedionomus*
38 *torquatus*) is sensitive to grassland structure, which can either be too dense or too open (Baker-Gabb
39 et al. 2016). Striped legless lizard (*Delma impar*) is thought to be suited to complex grassland
40 structure (Howland et al. 2016), and populations may decline with an increase in the proportion of
41 short grass and bare ground (Dorrough & Ash 1999). In addition, Howland et al. (2014) showed that
42 in Australian grasslands and grassy woodlands, reptile abundance, species richness and species
43 diversity is highest with low grazing intensity, suggesting these measures respond positively to grass
44 cover.

45 The rate that biomass accumulates varies with grassland productivity in south-eastern Australia, and
46 hence so too does the required frequency of disturbance (Schultz et al. 2011). Productive grasslands in
47 wetter regions—such as Themeda grasslands in the Victorian Volcanic Plains (VVP)—quickly
48 accumulate dead grass (Morgan & Lunt 1999), which decomposes very slowly, and may require
49 frequent disturbance (around once every three years; Lunt & Morgan 1999) to negate the threat of
50 smothering. By contrast, dead grass in less productive and drier grasslands—such as those dominated
51 by *Austrostipa* spp. and *Rytidosperma* spp. in the Victorian Riverina—does not appear to accumulate
52 over long periods (Schultz et al. 2011), but instead may decay (or blow away) relatively quickly,
53 negating the need for frequent disturbance. Figure 1 shows the main areas of plains grassland in
54 Victoria, including the VVP and Victorian Riverina.

55 For grassland managers, disturbance interventions might be used to negate high grass cover, grass
56 height and litter levels that can compromise native plant and animal diversity (Morgan 2015).
57 However, choosing appropriate disturbance regimes for native grasslands is difficult as biomass
58 accumulation varies not only among grasslands in different geographic regions, but also within
59 grasslands due to climate variability (White et al. 2014). To date, grassland ecologists have generally
60 focussed on biomass accumulation as a driver of grassland dynamics, and indeed it is the
61 accumulation of biomass over time that changes grassland structure. However, biomass itself
62 (generally measured as $\text{g}\cdot\text{m}^{-2}$ or $\text{tonnes}\cdot\text{ha}^{-1}$) can be a poor indicator of structure (Morgan 2015), and
63 might not be particularly useful to grassland managers. For instance, Figure 2 depicts two
64 hypothetical grasslands with equal biomass, but very different structure. Other aspects of grassland

65 structure—such as how open a grassland is, or how much light is available for establishing plants—
66 are more likely to be directly related to conservation outcomes, such as maintaining plant species
67 diversity or providing habitat for fauna.

68 To meet the challenges of grassland management, a method for the assessment of grassland structure
69 is necessary. Techniques for measuring grassland structure vary from being rapid and coarse (e.g.
70 plant cover estimates by eye), to time-consuming and detailed (e.g. point quadrats); however, in order
71 for a technique to be useful to grassland managers it needs to be quantitative, repeatable, rapid and
72 simple (Gibbons et al. 2009). This should allow managers to confidently respond to changes in
73 vegetation condition (e.g. in response to rainfall or management). Seddon et al. (2011) also
74 acknowledge the challenge of achieving a balance between simple techniques and adequate
75 discrimination of condition between sites.

76 In an attempt to provide a grassland assessment method that meets these challenges, the ‘golf ball
77 method’ was developed by La Trobe University, in conjunction with Parks Victoria (Schultz 2007,
78 Schultz & Morgan 2010). It is based on the idea that golf balls lying in grassland vegetation will be
79 obscured from a bird’s-eye-view to varying degrees, depending on the amount and structure of
80 vegetation. Hence, the visibility of golf balls can be used to evaluate the current structure (or ‘state’)
81 of a grassland. Box 1 provides a description of the method. The method has gained wide use by
82 grassland managers in Victoria, in part due to its promotion by Parks Victoria and Trust for Nature.
83 Here, we examine the robustness of the scoring method and the relationship of golf ball scores to
84 various measures of grassland structure and plant diversity. We also discuss current applications of
85 the method, and how it can be improved.

Author

Box 1. Instructions provided to users of the golf ball method

Instructions are provided at www.bit.ly/GrassMonitoring, or email the authors for a copy. These ask the operator to place a 1-m² frame in grassland vegetation. This should be done at randomised locations, as specified by the project's monitoring design. Eighteen golf balls are then dropped, one at a time, into the vegetation within the frame, at different points around the 1m² area. The balls should fall through the vegetation to ground level. If the balls rest on top of grass tussocks, some gentle shaking of tussocks may be required to allow the balls to fall to ground level. Disturbance within the frame should be kept to a minimum. A digital camera should be held above the frame (around 160-170 cm) to capture the entire frame in a bird's-eye-view photo, which will be used to assign a visibility score. Scoring can also be done in the field without a camera. Photos are scored as such: a ball is scored as 1 if more than 90% of the ball is visible; a ball is scored as 0 if less than 33% is visible. All other balls are scored as 0.5. Hence, a low total score in a frame suggests a closed grassland structure, and high vegetation cover, whereas an open structure and low vegetation cover will give a high golf ball score. In some grasslands with high vegetation cover, golf balls may rest on top of dense tussocks or saltbushes and will not fall through to ground level with gentle shaking. In these situations, if the average height of the vegetation is ≥ 8 cm, these balls should be scored as zero. Figure 3 shows a scored photograph. Further details about conducting the method, including advice for monitoring design, and establishing conservation targets and management objectives, are provided in Parks Victoria (2014) and Antos (2016).

86

87 Applications of the method

88 Three studies in Victorian grassy ecosystems demonstrate the application of the golf ball method to
89 conservation management. Baker-Gabb et al. (2016) used the golf ball method to monitor Plains-
90 wanderer habitat and population size. The authors assert that grassland vegetation should be
91 maintained in the 13.5-17.5 golf ball score range to maintain suitable Plains-wanderer habitat. Golf
92 ball scores are now used to help guide management decisions to implement or remove disturbance
93 regimes (grazing and fire) to grasslands being managed for Plains-wanderer conservation.

94 Brown and Scroggie (2012) used the golf ball method to help discern the preferred habitat of the
95 threatened Hooded Scaly-foot (*Pygopus schraderi*, a legless lizard) in the Victoria Riverina
96 grasslands. They found no significant difference in golf ball score between Hooded Scaly-foot sites

97 and random sites in similar vegetation, and showed that the cover of cryptogams and the incidence of
98 spider holes and soil cracks were greater determinants of Hooded Scaly-foot habitat. In this way, the
99 golf ball scores helped to rule out grassland structure as a determinant of Hooded Scaly-foot habitat.

100 Golf ball scores were also used in an attempt to determine structural preferences of Golden Sun Moth
101 (*Synemon plana*) at Derrimut Grassland Reserve in the VVP (Griffith & Nano 2011). This was
102 important work, as previous research on the Golden Sun Moth has focussed on the species of tussock
103 grasses preferred by the moth (Braby & Dunford 2006, Richter et al. 2013), but not grassland
104 structure. Although the study suggested that Golden Sun Moth prefer slashed paddocks with an open
105 grassland structure, the golf ball score was not able to discern structural differences between slashed
106 and unslashed paddocks. This may be due to uniformly-low grassland biomass at the time of
107 monitoring (2008, a dry period). Hence, moth habitat preferences might be more evident during
108 periods of greater biomass production, when there is greater differentiation between sites with high
109 biomass and those for which biomass is experimentally reduced.

110

111 **Repeatability of assigning golf ball scores**

112 Any rapid assessment technique must be repeatable and reliable if it is to be widely adopted. To
113 determine how much observer variation occurs when assigning golf ball scores, we used 21
114 independent observers, including 13 post-graduate students from the Department of Botany, La Trobe
115 University, and eight staff members at Parks Victoria. The observers had no prior knowledge of the
116 method but were trained in biological observation. Each observer was introduced to the method of
117 scoring golf balls and an example dataset was scored as a demonstration. Observers were then asked
118 to independently score 12 standard photographs provided by Parks Victoria. The photographs spanned
119 a range of golf ball scores (0.5–18), and responses were compared to a ‘benchmark’ score agreed
120 upon by two experts (J. Morgan and M. Keatley).

121 There was some variation in the scoring of golf ball visibility by independent observers (Figure 4),
122 and observers tended to underestimate the golf ball scores compared to the benchmark scores.

123 Relative to the benchmark scores, observers correctly identified high scores (>16) and low scores
124 (<3), but identified intermediate scores with less accuracy and consistency. Importantly, all observers
125 correctly identified the differences between grasslands with an open structure (high ball scores: 15–
126 18) and those with a closed structure (low ball score: 0–5). Small departures in golf ball score of the
127 observers from the benchmark are unlikely to negate the ability of the method to be indicative of
128 grassland structure. Furthermore, this was the first attempt by the observers at scoring photos, and
129 they may become more consistent with greater experience. Overall, we believe the data show that the
130 method has performed quite well in the trial, and suggest that estimation of grassland structure using
131 the method is fairly robust against observer variation.

132 **Relationship of golf ball scores to grassland attributes**

133 The golf ball scores are an integrative measure of things we (as grassland ecologists and managers)
134 intuitively understand, such as the structure, density and patchiness of the grassland. Nevertheless, we
135 need to analyse the relationship of golf ball scores to grassland attributes to help understand what we
136 are measuring. To achieve this we analysed three datasets based on extensive monitoring of golf ball
137 scores and associated vegetation attributes: (1) the La Trobe University (LTU) dataset, collected in
138 2010 and spanning the range of grasslands and grassy woodlands occurring across Victoria; (2) the
139 Parks Victoria (PV) dataset, collected between 2009 and 2015 in the plains grasslands of the Victorian
140 Riverina (typically drier and less productive grasslands); and (3) the Arthur Rylah Institute (ARI)
141 dataset, collected in 2015 in the grasslands of the VVP (typically wetter and more productive
142 grasslands). The ARI dataset incorporated sites from both private paddocks (largely maintained by
143 grazing) and public roadsides (largely maintained by fire). Figure 1 shows the location of sites at
144 which data was collected for each dataset. The supporting information provides details of the data
145 collection for each dataset.

146 **LTU dataset**

147 The LTU data includes measures of golf ball scores, vegetation cover, biomass and species richness.
148 The correlation between golf ball score and vegetation cover was highly significant ($p < 0.001$, $R^2 =$
149 0.453 ; Figure 5a). Likewise, the correlation of golf ball scores to biomass was highly significant ($p <$
150 0.001) but weaker ($R^2 = 0.308$), particularly when the golf ball score is less than 10 (Figure 5b). This
151 weak correlation is expected; as demonstrated in the hypothetical grassland structures in Figure 2,
152 grasslands with very different structures may have similar biomass, negating any potential
153 relationship between biomass and the golf ball scores, particularly when data is collected from a range
154 of grassy vegetation types across a broad biogeographical range.

155 There was no correlation between golf ball scores and total species richness (Figure 5c). Despite the
156 conventional wisdom that an open grassland structure allows greater coexistence of species, this is
157 also not surprising, particularly given the range of different sites sampled. Grasslands and grassy
158 woodlands exist in a wide range of condition states, and differences in management history create a
159 large degree of variability in species richness which may override the impact of current grassland
160 state. For example, we assume that a relatively open grassland state is required to maintain plant
161 species diversity – however, a grassland might be open due to factors that do not favour species
162 diversity (e.g. heavy sheep grazing, recent cultivation). As such, the golf ball scores are more likely to
163 be correlated with species richness (1) over time at a single site, or (2) among sites in similar
164 ecological condition or with similar ecological histories. This needs to be tested.

165 **PV dataset**

166 The PV dataset measured the cover and height of different vegetation components, such as native and
167 exotic grasses, native and exotic forbs, bare ground, litter and cryptogams. We present four
168 correlations of golf ball scores with vegetation attributes (Figure 6), all of which are highly significant
169 ($P < 0.001$). The correlations of golf ball scores with vegetation cover and bare ground, whilst
170 significant, do not explain a high proportion of variability in the data ($R^2 = 0.44$ and 0.28 ,
171 respectively; Figure 6a and 6b), and show only that there are no low golf ball scores at high bare
172 ground or low vegetation cover—all other combinations of golf ball scores with bare ground or
173 vegetation cover are possible. For example, plots with vegetation cover of 80-100% can demonstrate
174 the full range of golf ball scores (0–18; see Figure 6a). We interpret this data to support our claim that
175 vegetation cover (and bare ground) can be poor predictors of grassland structure or openness. For
176 instance, the space between tall perennial grass tussocks in an ‘open’ grassland structure could be bare
177 ground, or it could be a low (say, <3 cm) cover of forbs or grasses.

178 There are other vegetation attributes, however, that are better correlated with golf ball scores than
179 vegetation cover and bare ground. The attribute ‘grass cover \times grass height’ (Figure 6c) represents an
180 approximation of the volume of grass in a 1-m^2 plot, and explains a higher proportion of the
181 variability in the data ($R^2 = 0.70$). This relationship shows that golf ball scores generally increase
182 (become more open) with decreasing grass volume. Figure 6d shows the cover of all grassland
183 components (bare ground, litter, cryptogam and vegetation cover) that are less than 12 cm in height,
184 and this also explains a higher proportion of variability in the data ($R^2 = 0.72$). This relationship
185 provides an estimation of the space available between large perennial tussocks, and golf ball scores
186 generally increase as this measure increases. These correlations support the idea that golf ball scores
187 provide a measure of grassland openness, and may be more informative about grassland structure than
188 measures such as vegetation cover or biomass.

189 **ARI dataset**

190 Correlations between golf ball scores and grassland attributes demonstrated a variety of responses,
191 with none of the correlations explaining as much variation as the LTU and PV datasets. Vegetation
192 cover had a negative and highly significant relationship with golf ball score in sites managed with fire
193 (i.e. public grasslands; Figure 7a), but was not significant in sites managed by grazing (i.e. private
194 grasslands; Figure 7b). A significant negative relationship between golf ball scores and ‘grass cover \times
195 grass height’ was also observed (Figure 7d); however the correlation explained substantially less
196 variation than the PV dataset (PV $R^2 = 0.719$ cf. ARI $R^2 = 0.221$). Unlike the PV dataset, there was no
197 significant relationship between golf ball score and bare ground cover (Figure 7c). We propose that
198 the differences observed may be related to the higher productivity of the VVP (compared to the
199 Victorian Riverina), and suspect a different relationship between grassland structure and bare ground
200 exists in the VVP. In lower productivity grasslands, like those investigated in the PV dataset, inter-

201 tussock spaces are likely to be comprised of bare ground and cryptogamic crust, whereas in VVP
202 grasslands, bareground is less likely. In addition, grazing is likely to exacerbate this trend by
203 promoting lateral growth (Noy-Meir 1993, Andreasen et al. 2002), leading to grassland structure that
204 resembles a lawn, and creating a situation in which both golf ball scores and vegetation cover can be
205 high. The PV data set demonstrated the potentially poor correlation between vegetation cover and golf
206 ball scores, though we believe the higher productivity in the VVP further diminishes this relationship.
207 The correlation between vegetation cover and golf ball scores was poorer on private land (which is
208 predominantly managed by grazing) than on public land (which is predominantly managed by fire).
209 This supports the idea that grazing promotes lawn-type growth, which would further diminish the
210 correlation between golf ball scores and vegetation cover. As such, we see the purpose of using the
211 golf ball method in the VVP as to provide a useful measure of grassland openness, not biomass or
212 cover. There may be more useful vegetation components to measure in conjunction with golf ball
213 scores to help test for the openness of grassland vegetation. For example, a separate estimate of the
214 cover of low vegetation (< 3 cm) might help to discern lawn-like vegetation from tussock grass cover
215 that has larger influence on grassland openness and structure. We predict that such measurements
216 would provide a strong correlation with golf ball scores.

217 **Discussion**

218 The findings from these three datasets demonstrate the need for a nuanced approach when applying
219 the golf ball method that is dependent on the productivity and disturbance history of a site. Hence, the
220 method should continue to be employed across a range of grasslands, but the way the golf ball scores
221 are interpreted will require careful consideration. We propose that because the method is a strong
222 indicator of 'openness' in the Victorian Riverina. As the measure has been shown to be a good
223 surrogate for Plains-wanderer population densities, this method can continue to be used by
224 practitioners with confidence for this purpose. However, in other landscapes, particularly more
225 productive landscapes such as the VVP, it is only through continued monitoring using more sensitive
226 measures of cover within the ground stratum that we will be able to identify how golf ball scores
227 relate to measures of grassland quality and habitat for fauna.

228 We advocate that other structural data, including cover of vegetation that is <3 cm in height, be
229 collected in conjunction with golf ball data – at least in the development stages of any management
230 regime – to help highlight and understand the grassland attributes that the method is revealing. The
231 method should not be used as an accurate surrogate for biomass or vegetation cover.

232 The examples we have illustrated demonstrate a demand for simple tools for monitoring grassland
233 structure, such as the golf ball method. We believe the golf ball method is a useful technique,
234 particularly as a measure of grassland openness. Nevertheless, we urge caution in how it is applied,
235 and how the data it provides are interpreted. The method is particularly useful for testing for

236 correlations between grassland structure (as represented by golf ball scores) and particular
237 management targets, such as plant or animal diversity, or the presence and relative abundance of
238 particular species. If such a correlation can be demonstrated, as is has been for the Plains-Wanderer,
239 the method may provide a useful and cost-effective ongoing tool to help support management
240 interventions. A further caution is to consider the rate of change of grassland states when using golf
241 balls as a trigger for management interventions. Biomass can increase rapidly in wetter years, and
242 grasslands can quickly change from an open to a closed grassland structure.

243 The golf ball method also provides a tool for community engagement and communication between
244 land managers as it is rapid, easy and intuitive. The method provides a common language about
245 grassland structure that can be adopted by practitioners of any level of ecological understanding. In
246 this regard, it can assist the adaptive management of grassland ecosystems across Victoria.

247 Finally, the application of the golf ball method to a wide-range of grassland ecosystems provides a
248 good example of a collaborative, cross-institutional approach to addressing important management
249 issues. Stakeholders from different government agencies, not-for-profit organisations and research
250 institutions have engaged in the method, and communicated openly about the results. This unified
251 approach has allowed us to generate and share large datasets for testing the ability of the golf ball
252 method to inform grassland management at a state-wide level, and demonstrated collaborative
253 approach to addressing natural resource management issues.

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324 The golf ball method for rapid assessment of grassland structure

325 Figure captions

326 **Figure 1. Areas of plains grassland in Victoria.** The two major areas are the plains grasslands of the Victorian
327 Riverina (A) and the Victorian Volcanic Plain (B). Plains grasslands also occur in the Wimmera Plain (C) and
328 the Gippsland Plain (D). The grey shaded areas show the modelled 1750 distribution of the Plains Grassland
329 ecological vegetation class. Data source: DELWP (2008) NV1750_EVCBCS [https://www.data.vic.gov.au/data](https://www.data.vic.gov.au/data/dataset/native-vegetation-modelled-1750-ecological-vegetation-classes)
330 [/dataset/native-vegetation-modelled-1750-ecological-vegetation-classes](https://www.data.vic.gov.au/data/dataset/native-vegetation-modelled-1750-ecological-vegetation-classes)

331 **Figure 2.** Two hypothetical grassland structures with equal biomass, but very different structure.

332 **Figure 3.** A scored photograph. The total visibility score is 15. The golf balls in the blue circles have been
333 scored as 1, the golf balls in the green circles have been scored as 0.5, and the golf balls in the pink circles have
334 been scored as 0.

335 **Figure 4.** Range of golf ball scores assigned by 21 independent observers, compared to benchmark golf ball
336 score assigned by an expert. The diagonal black line represents a 1:1 relationship between observer and expert
337 scores.

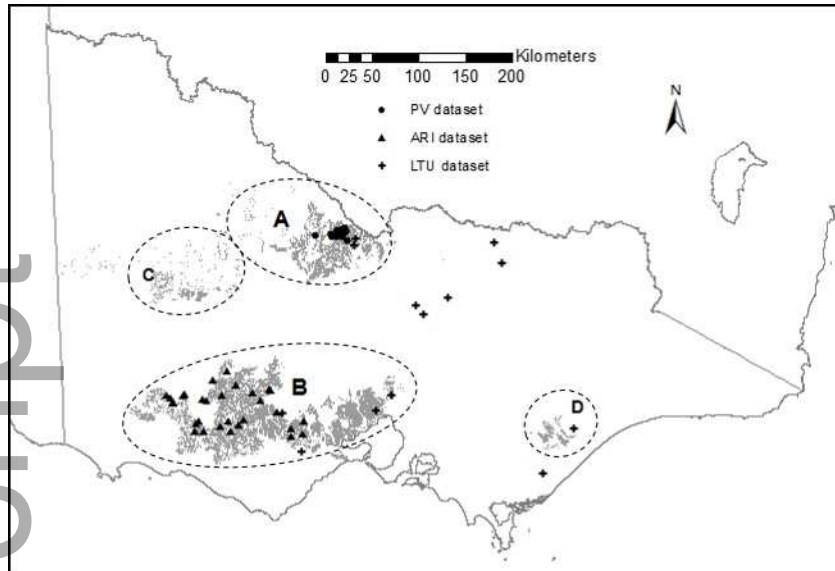
338 **Figure 5.** Correlations between golf ball scores vegetation attributes based on evaluations by La Trobe
339 University in a range of grasslands across Victoria. Correlations with golf ball scores are presented for (a)

340 vegetation cover ($n = 139$, $P < 0.001$), **(b)** Aboveground biomass ($n = 139$, $P < 0.001$), and **(c)** species richness
341 ($n = 139$, $P = 0.090$).

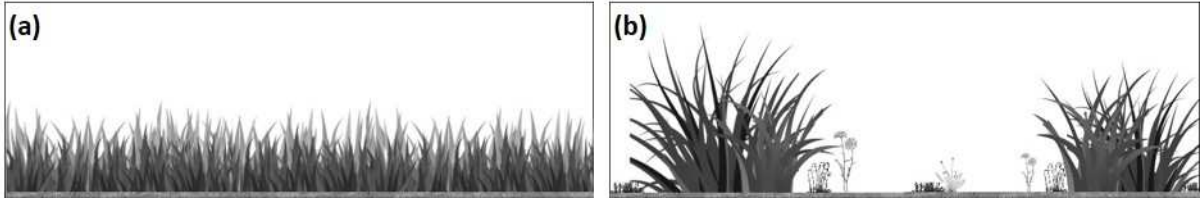
342 **Figure 6.** Correlations between golf ball scores and vegetation attributes based on monitoring by Parks Victoria
343 in plains grasslands of the Victorian Riverina. Correlations with golf ball scores are presented for (a) vegetation
344 cover, (b) bare ground, (c) Grass cover \times grass height, and (d) percentage of plot cover that is less than 12 cm in
345 height. All correlations are highly significant simple linear regression models (For each, $n = 2157$, $P < 0.001$).

346 **Figure 7.** Correlations between golf ball scores and vegetation attributes based on monitoring in Victorian
347 Volcanic Plains grasslands (ARI dataset). Correlations with golf ball scores are presented for (a) vegetation
348 cover on public land maintained by burning ($n = 120$, $P < 0.001$), (b) vegetation cover on private land
349 maintained by grazing ($n = 150$, $P=0.051$), (c) bare ground ($n = 270$, $P = 0.109$), and (d) grass cover \times grass
350 height ($n = 270$, $P < 0.001$).

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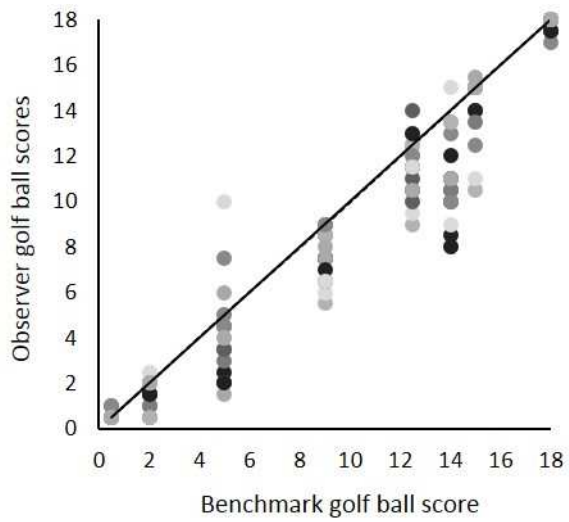


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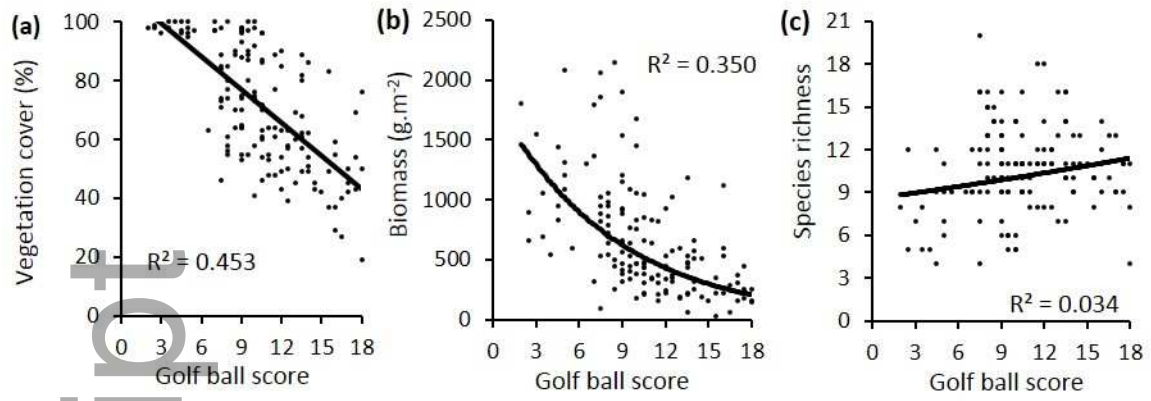
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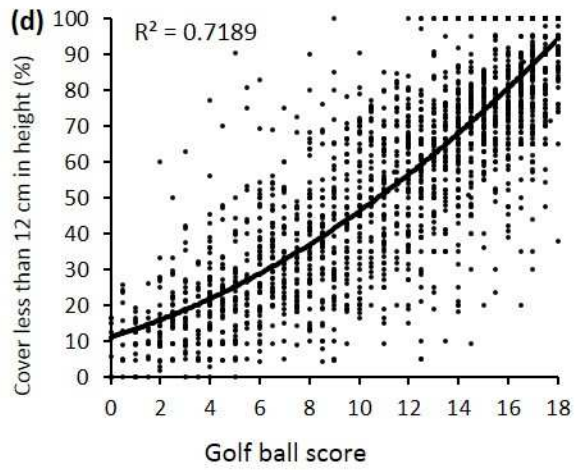
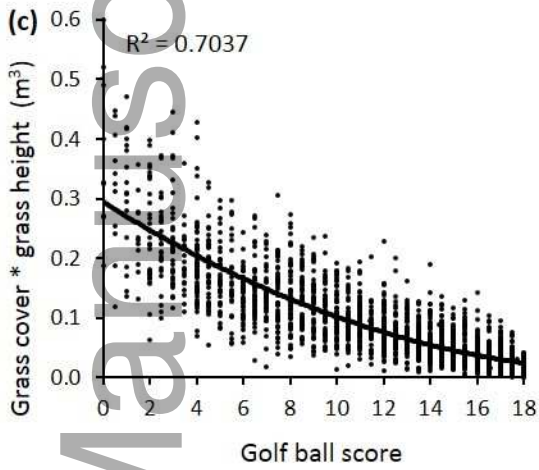
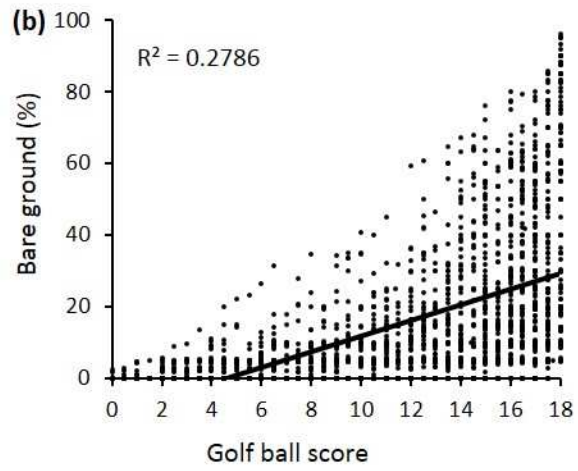
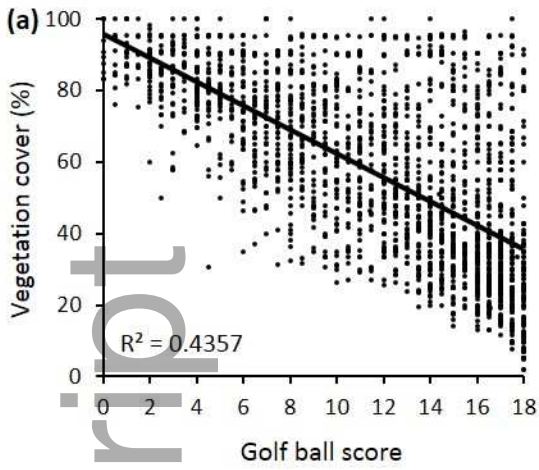


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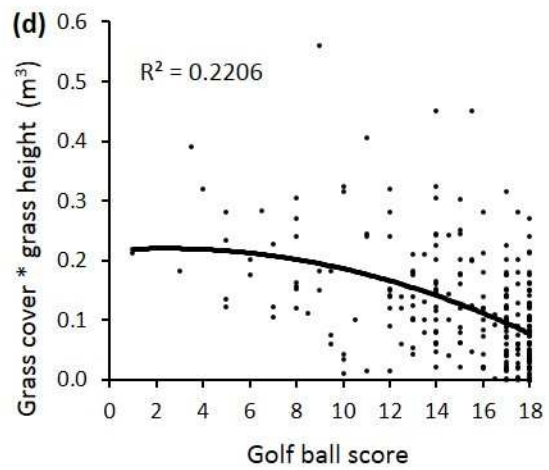
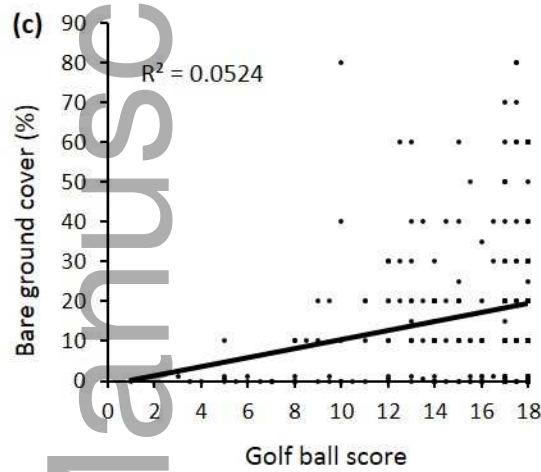
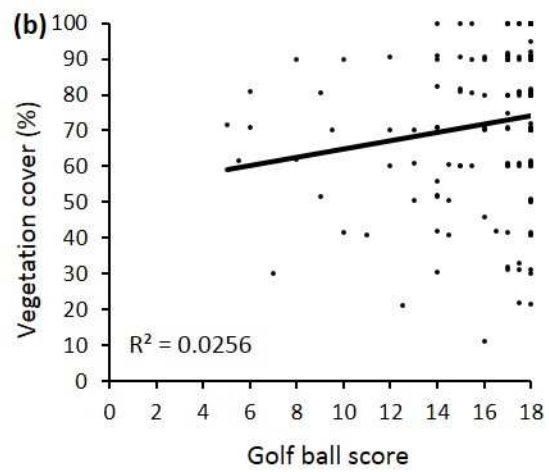
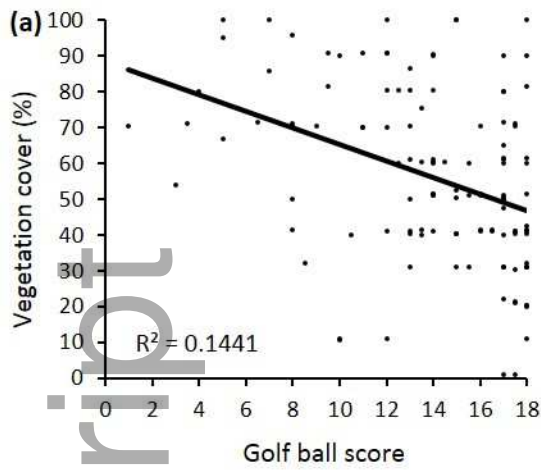


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