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Title: Systematic targeting of management actions as a tool to enhance conservation of traditional rural biotopes

Year: 2017

Version:

Please cite the original version:

Raatikainen, K., Mussaari, M., Raatikainen, K. M., & Halme, P. (2017). Systematic targeting of management actions as a tool to enhance conservation of traditional rural biotopes. *Biological Conservation*, 207, 90-99.
<https://doi.org/10.1016/j.biocon.2017.01.019>

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1 **Systematic targeting of management actions as a tool to enhance conservation of**
2 **traditional rural biotopes**

3
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16

17 **Abstract**

18
19 Traditional rural biotopes (TRBs), which are biologically and culturally valuable habitats
20 maintained by low-intensity grazing and mowing, are a core element of biodiversity in
21 Europe. During the last decades, TRBs have faced severe habitat loss and fragmentation due
22 to agricultural modernization. Despite their well-known critical state, their conservation
23 remains inadequate, thus raising a need to advance TRB conservation via spatial land-use
24 planning. In this study we analyze a national GIS database on TRBs in order to examine how
25 the current TRB network can be complemented in terms of conservation value based on
26 known ecological characteristics. Given different target scenarios for the amount of managed
27 TRBs, we demonstrate where management should be directed to both on protected and
28 unprotected areas. We conclude that in current state, biodiversity depending on TRB
29 management is not efficiently sustained in Finland. Substantial amount of TRB habitats and
30 populations of threatened TRB species are left unmanaged. Based on our results, we suggest
31 that to advance TRB conservation in Finland, the cover of managed TRBs should be rapidly
32 extended to form ecologically functional networks. The expansion would prioritize additional
33 management to the Baltic Sea coast and smaller clusters within inland Finland, double the
34 cover of managed TRBs, and direct management subsidies in a more cost-effective way.
35

36 **Abbreviations**

37 AES, agri-environment scheme; TRB, traditional rural biotope

38
39 **Keywords**

40 Biodiversity conservation; Biodiversity management; Landscape management; Semi-natural
41 habitats; Spatial prioritization; Zonation software

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DOI: 10.1016/j.biocon.2017.01.019

42 1. Introduction

43
44 Although protection of biodiversity has been a fundamental tenet of conservation biology
45 since its early beginning (Soulé, 1985), tight coupling of social and natural systems escaped
46 conservation scientists' attention for a long time in many regions (Kareiva and Marvier,
47 2012). Recently, temporal changes in how conservation is perceived have raised global
48 attention to a social-ecological approach in conservation (Corlett, 2014; Mace, 2014). In
49 Europe, a significant proportion of biodiversity is situated in landscapes formed through a
50 sequential overlay of traditional rural land-use systems (Plieninger et al., 2006). This process
51 has continued for thousands of years, resulting in a rich diversity of cultural landscapes and
52 associated species which are sustained by human land use (Batáry et al., 2015; Plieninger et
53 al., 2006; Pullin et al., 2009).

54
55 Since low-intensity land use is important for existence of a lot of European biodiversity
56 (Halada et al., 2011; Pullin et al., 2009), much of nature conservation aims to halt the loss of
57 farmland biodiversity, and many protected areas are managed in ways that reflect traditional
58 agricultural practices (Batáry et al., 2015; Linnell et al., 2015). Challenges, however, are
59 substantial. Agricultural industrialization has caused a widespread decline in farmland
60 heterogeneity and biodiversity (Benton et al., 2003; Strijker, 2005). Modern socioeconomy
61 drives rural landscapes towards land abandonment and agricultural land-use intensification,
62 centralization, and specialization (Beilin et al., 2014; Fjellstad and Dramstad, 1999; Knickel,
63 1990; Lambin et al., 2001). Therefore some of the most critical conservation issues today
64 relate to the abandonment of traditional farming practices and the disappearance of biodiverse
65 habitats dependent on them (Halada et al., 2011; Henle et al., 2008).

66
67 Traditional rural biotopes (TRBs) are heterogeneous disturbance-dependent grasslands and
68 wood-pastures maintained through long-term grazing and mowing. The term "traditional rural
69 biotope" refers to culturally influenced natural habitat complexes that are part of a traditional
70 landscape formed through archaic rural livelihoods (Ministry of the Environment, 1992), and
71 although its usage is specific to Finland, similar habitats are found throughout Europe (e.g.
72 Bergmeier et al., 2010). Typical TRB habitats in Finland are grazed woodlands, sparsely
73 wooded pastures, and mesic to moist meadows (Raunio et al., 2008). Management of TRBs is
74 based on low-intensity raising of livestock on unfertilized vegetation growing on non-tilled
75 soils, a practice that is especially valuable for biodiversity conservation across Europe
76 (Beaufoy and Cooper, 2013). TRBs are among the most diverse and species-rich habitats of
77 rural landscapes (Cousins and Eriksson, 2002; Fjellstad and Dramstad, 1999; Luoto et al.,
78 2003), and they are mentioned as central elements of high-nature-value farmland (Heliölä et
79 al., 2009; Plieninger et al., 2015). As ecosystems, TRBs are highly variable and dynamic.
80 Their species assemblages depend on the interplay between active management, vegetation
81 succession, and metapopulation dynamics (Allan et al., 2014; Halada et al., 2011; Hanski,
82 2011).

83
84 Ongoing TRB loss and fragmentation has serious ecological effects. TRB species'
85 metapopulations lose their viability, because unoccupied habitat patches are not colonized at
86 the same rate as extant populations disappear, i.e. they reach their extinction threshold
87 (Hanski, 2011). Yet, some species – especially vascular plants – react slowly to land-use
88 changes and persist on abandoned TRBs for long time periods (Cousins, 2009; Eriksson et
89 al., 2002; Lindborg and Eriksson, 2004). Unless targeted habitat restoration and proper
90 management actions are secured, species specialized in TRBs continue to decline and their

91 populations face inevitable local extinctions (Cousins, 2009; Krauss et al., 2010; Kuussaari et
92 al., 2009).

93
94 Loss of farmland biodiversity has created a need for agri-environment measures, which are
95 incentives designed to encourage farmers to protect and enhance the environment on their
96 farmland (Anonymous, 2005). Countries within European Union are increasingly funding
97 habitat management and restoration actions through voluntary, contract-based subsidies
98 within national agri-environment schemes (AESs) (Batáry et al., 2015; Kleijn and Sutherland,
99 2003). The AES contracts are the main tool for encouraging management of TRBs. However,
100 the effectiveness of AESs has been questioned in TRB management and biodiversity
101 conservation in general (Arponen et al., 2013; Batáry et al., 2015; Kleijn and Sutherland,
102 2003). In Finland, during the 20th century, over 99 percent of TRB cover disappeared as a
103 consequence of agricultural modernization (Raunio et al., 2008; Salminen and Kekäläinen,
104 2000). Currently, TRBs are the most threatened of all Finnish habitat types (Raunio et al.,
105 2008) and provide habitat for a total of 1 807 red-listed species (Rassi et al., 2010). Despite
106 this, current conservation measures have been insufficient to tackle the situation.

107
108 Several reasons contribute to inefficient conservation of TRBs in Finland. These include
109 capacity, knowledge, institutional, and ideological obstacles (cf. Bennett et al., 2016). Firstly,
110 besides the AES, other funding sources for TRB management are scarce (Ministry of
111 Agriculture and Forestry, 2013). Secondly, management actions have not been efficiently
112 directed to biologically valuable sites (Arponen et al., 2013; Kemppainen and Lehtomaa,
113 2009), and thirdly, the dynamic and management-dependent character of TRBs challenges
114 Finnish environmental authorities, who have mostly relied on establishing permanent set-
115 asides to conserve natural habitats, aiming to exclude most or all human influence from them
116 (Vuorisalo and Laihonen, 2000). In this sense, Finnish nature conservation has not followed
117 the European tradition where nature and culture are intertwined, but rather a wilderness-
118 oriented approach that separates people from nature (Linnell et al., 2015). In this context, the
119 biological value of TRBs is deemed “semi-natural”, and the motivation for conserving these
120 “unnatural” habitats is undermined (Cronon, 1996; Mace, 2014).

121
122 As a result, TRBs are weakly represented in Finnish nature conservation policies. They have
123 often been excluded from conservation networks such as Natura 2000 (Ministry of the
124 Environment, 2015; Council of State, 1996; Vuorisalo and Laihonen, 2000). Although sole
125 establishment of protected areas is insufficient for TRB conservation (Arponen et al., 2013;
126 Bengtsson et al., 2003), there are valuable TRB sites on protected areas. However, the
127 majority of them are unmanaged, and protection status is regularly based on conservation of
128 other habitats (Pakkanen et al., 2015; Raatikainen and Raatikainen, 2015).

129
130 Several means to enhance the conservation of TRBs have been proposed. These include
131 establishing complementary management funding sources (Keränen et al., 2012), increasing
132 AES uptake (Grönroos et al., 2007), and targeting funding to manage locations with high
133 biodiversity (Arponen et al., 2013). Achieving a favorable TRB conservation status needs
134 increasing their cover under protection, restoration, and active management alike. Because
135 human influence essentially drives TRB ecology, TRB restoration requires reviving
136 traditional social-ecological interactions. Therefore we refer to it as bio-cultural restoration
137 (Egan et al., 2011).

138
139 In this paper we explore if and how conservation of TRBs could be improved by directing
140 restoration and management actions spatially on a national scale. We began by evaluating the

141 current management status of TRBs (Fig. 1). Then we explored how the current surveyed
142 network of valuable TRBs can be complemented, assuming that the most important aim of
143 network expansion is to secure the maintenance of threatened habitats and species dependent
144 on TRB management. We answered the questions via a spatial prioritization analysis, where
145 several layers of information contribute to the conservation value of a given habitat patch,
146 and yield an optimized management network solution.

147

148 The purpose of the analysis was to inform management allocation on large scale instead of
149 suggesting whether a specific site should be managed or not, and we did not aim to
150 exclusively point out the most valuable individual TRB sites in whole Finland. Rather, we
151 synthesized currently available spatial information. The quantified results provide a starting
152 point for developing a national implementation strategy for further conservation action
153 (Knight et al., 2006).

154

155 Given the national goal of securing management of all valuable surveyed TRBs and
156 increasing the total cover of managed TRBs to 60 000 hectares (Kemppainen and Lehtomaa,
157 2009; Kotiaho et al., 2015; Salminen and Kekäläinen, 2000), we formulated a spatial
158 prioritization solution for four nested management scenarios (A: surveyed TRBs, B–D:
159 surveyed TRBs with a progressive addition of managed area). In each consecutive scenario,
160 ca. 4 000 managed hectares were added, thus forming a realistic step-wise plan for expansion
161 of the management network. The most extensive scenario (D) yielded a spatial allocation of
162 nearly 45 000 hectares of managed TRBs.

163

164 **2. Materials and methods**

165

166 **2.1. Data sets**

167

168 We used existing GIS data derived from five different sources: (1) a national network of
169 surveyed TRBs, covering ca. 30 300 ha; (2) AES subsidy contracts on TRB management in
170 year 2014, ca. 19 200 ha; (3) habitat type inventories on protected and state-owned areas, ca.
171 4 620 200 ha; (4) database on protected private and state-owned TRBs, ca. 32 200 ha; and (5)
172 16 077 point occurrences of 133 TRB-specialized red-listed vascular plant species. The data
173 sets are further described in Electronic appendix A. The Åland islands were excluded because
174 of their self-governmental status. Without the Åland islands, the land area of Finland is
175 30 234 700 ha (National Land Survey of Finland, 2016).

176

177 We incorporated data on surveyed and protected TRBs in the analyses without modifications.
178 AES contract sites outside surveyed TRBs or protected areas were omitted from spatial
179 prioritization, as their biological value as TRBs has not been surveyed in the field, and
180 according to our personal experience their quality varies from good to very poor. Habitat type
181 inventory data is built on a nested structure, which was used to form GIS layers of different
182 TRB habitats on two levels. Firstly, we derived an upper-level TRB habitat classification
183 comparable to the assessed threatened habitat types (Raunio et al., 2008). Secondly, we
184 categorized more strictly defined Natura 2000 -habitats (listed in the Habitats Directive
185 Annex I: Council of Europe, 1992) as separate layers (Table 1). This allowed us to give
186 increased weight on sites having high conservation value at the European level. However, the
187 inventory did not cover all TRB sites. For these sites, a layer of undefined TRB habitat was
188 formed, as there were no data on specific habitat types available.

189

190 We included certain complementary habitat layers because they contribute to TRB
191 connectivity by sharing similar species communities. These were old traditional yards,
192 reindeer gathering grounds, Sami camp sites, managed esker habitats, and dry, sandy sunlit
193 dunes. In addition, occurrences of TRB specialist vascular plants may indicate undetected
194 TRBs and act as source populations for nearby known TRB sites.

195

196 In order to control for biogeographical bias in species richness, we pooled existing red-listed
197 species occurrences together according to their threat status. All species occurrences
198 categorized as potentially or certainly disappeared were merged to form one data layer that
199 reflected the historical range of TRB specialists.

200

201 2.2. Current management status

202

203 To estimate the amount of currently managed TRBs, we performed an overlay analysis by
204 unioning the data on AES subsidy contracts, surveyed TRBs, and protected TRBs. The latter
205 were divided according to landownership (either private or state-owned). Circa 2 500
206 hectares of managed TRBs are not subsidized (Kemppainen and Lehtomaa, 2009), but as
207 there are no inclusive GIS data available on these sites, we were forced to exclude them. All
208 GIS data handling were done with ArcGIS (ESRI[®] ArcMAP[™] version 10.3.1).

209

210 2.3. Management scenarios

211

212 We used conservation prioritization software Zonation (version 4; C-BIG Conservation
213 Biology Informatics Group, 2014) to produce spatial management scenarios. Starting from a
214 full landscape, Zonation iteratively removes locations (cells or planning units) of least
215 contribution to remaining biodiversity while minimizing marginal loss of overall
216 conservation value following from the removal (Moilanen et al., 2005). Zonation accounts for
217 connectivity measures and weights given for different biodiversity features, which are entered
218 into the analysis as separate raster data layers. During prioritization, Zonation aims to retain a
219 complementary-based balance across all features (Moilanen et al., 2011), and for each step, it
220 calculates conservation performance as the average proportion remaining over all features
221 within the analysis (Arponen et al., 2013).

222

223 Data layers and feature-specific weights used in the prioritization are listed in Table 1.
224 Original data were rasterized with a cell size of 25 m × 25 m, as TRB sites and habitat
225 patterns are small and highly fragmented. For computational reasons, initial cells were
226 aggregated to binary 50 m × 50 m resolution. Total number of grid cells within the analysis
227 was 307 072. We weighted habitat and species layers based on their red-list status (Rassi et
228 al., 2010; Raunio et al., 2008), by giving a higher weight to a more threatened type. Critically
229 endangered (CR), endangered (EN), vulnerable (VU), and near-threatened (NT) classes were
230 given weights of 4, 3, 2, and 1, respectively. Additively, Natura 2000 habitats were weighted
231 in respect to their importance according to the Habitats Directive (Council of Europe, 1992);
232 priority habitats within the European Union were given a weight of 3 whereas other Natura
233 2000 habitats received a weight of 2. There were few exceptions based on national emphases
234 on TRB management (Ministry of the Environment, 2013; Salminen and Kekäläinen, 2000):
235 the weights of slash-and-burn areas and semi-natural dry grasslands and scrubland facies on
236 calcareous substrates were raised by one unit; and the weight of boreal Baltic coastal
237 meadows was lowered by one unit. Since species layers were fewer, we balanced the sum of
238 their weights against the sum of weights of habitats (Lehtomäki and Moilanen, 2013). The
239 final weights for species layers were: 32.4 for CR species, 21.6 for EN species, 10.8 for VU

240 species, and 3.6 for NT species. We weighted remaining layers with the aim of producing
241 weights that were as balanced as possible with the previously determined weights.

242

243 We chose the additive benefit function as the location removal rule. It is suitable for cases in
244 which different co-occurring data layers are considered to provide additional value to each
245 other, and the data is interpreted as indicating general conservation value rather than specific
246 features (Moilanen, 2007). We assumed that TRBs with high heterogeneity (various TRB
247 habitats), several species occurrences, and possibly an AES subsidy contract are the most
248 important ones in conservational sense. Also, as we pooled the species data, it no longer
249 represented specific species occurrences but reflected a general distribution of red-listed
250 species dependent on TRBs.

251

252 Surveyed TRBs, protected unsurveyed TRBs, complementary habitat sites, and species
253 occurrence sites were used as distinct planning units, because it was more purposeful to
254 remove spatially separate sites rather than single cells from the landscape. We used a
255 hierarchical removal mask to force all surveyed TRBs to the top fraction of the prioritization,
256 thus forming management scenario A in our analysis. To determine subsequent management
257 scenarios we utilized Zonation's hierarchical landscape zoning in which the order of site
258 removal implies the conservational importance of different areas (Moilanen et al., 2011). We
259 identified top-ranked residual unsurveyed TRBs corresponding to area targets within
260 scenarios B–D to produce nested management networks.

261

262 We conducted separate analyses with and without landscape connectivity measures. While
263 other feature-specific parameters were kept the same, we added interaction connectivity
264 (Rayfield et al., 2009) by including a positive contribution of protected TRBs and
265 complementary habitats for surveyed TRBs. We ran two connectivity analyses utilizing
266 distribution smoothing with 2 km (according to Arponen et al., 2013) and 5 km mean
267 dispersal distances. To determine whether including connectivity significantly affected the
268 prioritization, we analyzed the rank orders of sites from the prioritizations with Wilcoxon
269 signed rank test in R 3.3.0 (R Core Team, 2015).

270

271 In ArcGIS, we extracted management scenarios from the prioritization rank map, and further
272 examined their spatial patterns with average nearest-neighbor analyses. As our main interest
273 was to locate the most optimal solution for the expansion of surveyed TRB network
274 regionally, we created generalized prioritization maps, in which each scenario was combined
275 and mapped with a resolution of 10 km × 10 km.

276

277 2.4. Assumptions and limitations

278

279 There are several assumptions related to our data and the analyses, which affect the
280 interpretation of the results:

281

1) Surveyed TRB sites are more valuable than unsurveyed ones.

282

2) Sites within habitat type inventory are more valuable than sites without habitat
283 information.

284

3) Sites with many TRB habitats are more valuable than sites with only one TRB habitat
285 type.

286

4) Unmanaged sites retain some value as TRBs despite the level of vegetational changes
287 after abandonment.

288

289 We acknowledge that the national data on surveyed TRBs are not up-to-date for each
290 individual site. Also, the AES subsidy contract data do not include all managed TRBs. The
291 database on protected TRBs was formed by merging several different data sets into a
292 collection of all sites with some value as TRBs (Pakkanen et al., 2015; Raatikainen and
293 Raatikainen, 2015). It includes sites where lack of management has launched successional
294 substitution of a TRB habitat by another habitat type, as disturbance-dependent vegetation
295 changes rapidly after management ceases. The database includes also fjell and shore
296 grasslands, where natural disturbances maintain populations of TRB specialists. As a result,
297 all sites within the prioritization may not be in need of active management. Species
298 occurrence data are dependent on sampling effort, and the habitat data are similarly spatially
299 restricted, as only protected TRB sites are covered by habitat type inventory. For the sake of
300 our research questions these assumptions and limitations are not major problems.

301

302 **3. Results**

303

304 3.1 Current management status

305

306 Subsidized TRB management spread over different TRB categories (Table 2). Altogether
307 19 225 hectares received AES subsidy for TRB management. Of the total subsidized area,
308 42.8 % comprised of unprotected and unsurveyed sites located on private land.

309

310 Protected TRBs covered 38.0 % of the subsidized area. Among them, surveyed sites were
311 more often managed than unsurveyed sites. Also, there were more managed private than
312 state-owned TRBs.

313

314 Despite their substantial total area, unprotected privately-owned surveyed TRBs were rarely
315 managed. They covered 19.2 % of the total subsidized area.

316

317 3.2 Spatial allocation of TRB management

318

319 Accounting for connectivity changed site ranking (Wilcoxon signed rank test, $n = 25\ 136$, $p <$
320 0.001 for both 2 km and 5 km scales). Also the connectivity analyses differed from each other
321 ($p = 0.04$). However, conservation performances of prioritization analyses were quite similar
322 (Table 3). We derived management scenarios from the analysis with 2 km connectivity,
323 which had the highest average performance. In each scenario, a fifth of the total area was
324 under AES-funded management. Site pattern in all scenarios was spatially significantly
325 clustered.

326

327 Scenario A, which consisted of surveyed TRBs, encompassed 52.4 % of the analysis
328 landscape and 0.1 % of the total land area of Finland. Area-wise the scenario centered on SW
329 Finland and the large river valley close to Swedish border (Fig. 2, A). There were surveyed
330 sites throughout the country, but in Lapland and near the Russian border the spatial
331 distribution was sparse. Protected sites comprised 24.0 % of scenario A (Table 3).

332

333 The prioritization analysis targeted TRB management especially to Baltic Sea coast, but also
334 other distinct clusters in parts of Southern, Central, and Northern Finland emerged in the
335 results (Fig. 2, B–D). When compared to the current extent of TRB management (Fig. 2, E),
336 the core areas along the western coast were strengthened, and management allocation within
337 Lapland and inland was increased. Along the western coastline the prioritized unsurveyed
338 TRBs were mostly located on protected areas (Fig. 2, F). Inland areas expressed a more

339 fragmented pattern where management was largely targeted according to TRB specialist
340 species occurrences (Fig. 2, G).

341

342 3.3 Red-listed vascular plant species specialized in TRBs

343

344 Most of the existing occurrences of TRB specialists within the analysis were located on
345 unprotected and unsurveyed sites. Only 3.8 % (501 out of 13 038 occurrences) were managed
346 through an AES contract (Table B.1). Surveyed TRBs (scenario A) hosted 1 123 occurrences
347 of 58 threatened and 33 near-threatened species. This included 68.4 % of all species in the
348 data, but only 8.6 % of their occurrences (Fig. 3). Targeting management actions according to
349 scenario B included a total of 122 red-listed species (with 8 422 existing occurrences), with a
350 focus on threatened species. Half of scenario B's additional management effort was allocated
351 to unprotected sites indicated by occurring specialist species (Table 3). Extending
352 management according to scenario C incorporated 127 species (11 668 occurrences). It
353 especially increased management of populations of near-threatened species. Scenario D did
354 not cover any additional species, and the rise in the amount of species occurrences was small
355 (168 additional occurrences).

356

357 3.4 TRB habitats on protected areas

358

359 The majority of scenario A consisted of sites without specific habitat information, including
360 all unprotected surveyed sites (Table C.1). On protected areas, different TRB habitats were
361 unevenly represented when compared to their total coverages (Fig. 4A). The pattern was
362 somewhat similar when Natura 2000 -habitats were explored (Fig. 4B). Areal summaries
363 (Tables C.1 and C.2) showed that the most frequent habitats on protected TRBs in scenario A
364 were moist to mesic meadows, wooded pastures, or grazed woodlands, whereas other TRB
365 types were rare.

366

367 Scenarios B–D hosted increasing proportions of different TRB habitats (Fig. 4A and 4B).
368 Scenario B emphasized habitat rarity and it included the scarcest TRB habitats, except for
369 heaths. Scenario C especially increased the total area of mesic and moist meadows, heaths,
370 and grazed woodlands. Considering Natura 2000 -habitats, scenario C included over 90 % of
371 all types other than wooded pastures, coastal meadows, and dry heaths. Scenario D covered
372 nearly all TRB habitats on protected areas. Only moist meadows were left to 68.8 %
373 representation. Similarly, coastal meadows were the only Natura 2000 -habitat left under 90
374 % representation within scenario D (exact coverage 87.8 %).

375

376 4. Discussion

377

378 Our results show that the conservational status of TRBs remains ecologically inadequate in
379 Finland. We demonstrated that the overall cover of TRBs managed through an AES contract
380 has decreased to less than 20 000 hectares in ten years (from ca. 24 500 ha in 2005–2007
381 according to Kemppainen and Lehtomaa, 2009). In 1950s, TRB cover was over 2.1 million
382 hectares (Raunio et al., 2008). Thus we conclude that after the collapse during late 20th
383 century, the total cover of managed TRBs is further declining. Although our data on the
384 general management status of TRBs were deficient, the change is clear and we doubt that
385 more accurate data would change the interpretation. With such prevalent habitat loss, both the
386 low amount of remaining habitat and the high degree of fragmentation will strongly reduce
387 remaining species richness (Rybicki and Hanski, 2013). In the long term, habitat loss and

388 fragmentation also lead to genetic and evolutionary changes in remnant populations of
389 specialized species, often reducing their viability (Hanski, 2011).

390

391 We prove that while a majority of remaining conservationally valuable TRBs is unmanaged,
392 over 40 % of area under AES management consists of sites whose biological value is not
393 documented. This finding confirms the earlier notion that Finnish authorities have been
394 unsuccessful in targeting TRB management according to the conservational value and
395 connectedness of the sites (Arponen et al., 2013; Kemppainen and Lehtomaa, 2009). AES
396 policies have compensated for management costs without accounting for effects on
397 biodiversity (Arponen et al., 2013). We suggest that these unsurveyed and unprotected sites
398 should be inspected by authorities in order to determine their value as TRBs.

399

400 Building a management network that best benefits biodiversity is challenging with limited
401 resources (Kotiaho et al., 2015). If appropriate, reallocation of management funding should
402 be considered. It is essential that future subsidies are systematically directed to sites that
403 either are biologically representative or will develop into such. Targeting management
404 funding spatially in a more optimal manner would increase the effectiveness of TRB
405 management both economically and ecologically (Arponen et al., 2013).

406

407 Our spatial prioritization produced management scenarios that reflect the distribution of
408 TRB-related conservation value. In all scenarios, the South-West–West coastal region
409 receives most of the prioritized management effort. Spatial coordination of management
410 actions promotes habitat connectivity and the associated ecological functions, such as
411 population densities, dispersal, and outbreeding (Arponen et al., 2013; Hanski, 2011).
412 Targeting additional TRB management and restoration primarily to the Baltic Sea coast
413 would promote the extent and connectedness of TRB habitats and support species
414 populations' viability. Within this core area, a 30 % cover of TRB habitat should be locally
415 pursued in order to maintain a large fraction of specialist species (Hanski, 2011). This target,
416 however, calls for large-scale bio-cultural restoration of abandoned TRBs. The success of
417 TRB restoration, in turn, is dependent on the successional vegetation changes following
418 management abandonment. Remnant species, interactions, and TRB structures compose an
419 ecological memory that makes ecosystem reorganization possible (Bengtsson et al., 2003).
420 Occurrence of TRB specialists makes it possible to discriminate restorable TRBs from sites
421 that are difficult to restore.

422

423 According to the prioritization, small clusters of inland sites with red-listed TRB specialist
424 species should be managed in a network-like manner. The observed spatial clustering of
425 prioritized TRBs serves as a good platform for strengthening species' metapopulations. It
426 counteracts the fragmentation effect and enables creation of new high-quality habitat patches
427 via restoration and management reinitiation, therefore relaxing populations' extinction
428 threshold (Eriksson and Kiviniemi, 1998; Rybicki and Hanski, 2013).

429

430 Management scenarios B and C would substantially improve the conservational status of
431 TRB-dependent species. Our analysis took into account 133 vascular plants, but it should be
432 noted that there are a vast number of TRB specialists also in other red-listed taxa (Rassi et al.,
433 2010). Majority of these are insects living on dry meadows, especially butterflies and beetles,
434 but unfortunately records on their populations are scattered (Rassi et al., 2010). In addition,
435 bird species breeding on coastal and alluvial meadows have faced population declines due to
436 habitat degradation, and many of them are categorized as threatened (Rassi et al., 2010).

437

438 Because of spatial segregation between species occurrences and TRB habitat sites and higher
439 weights given to species data, the prioritization process emphasized species over habitats.
440 However, different TRB habitats became well represented within the largest management
441 scenario (D). Scenario D encompasses nearly all protected sites with TRB habitats of
442 European level conservation interest (Halada et al., 2011). We conclude that the order of
443 scenarios A–D serves as an initiative and a guideline for prioritization of additional TRB
444 management in Finland. Realization of the national target of 60 000 managed hectares of
445 TRBs needs further increase in available resources and their purposeful allocation. Without
446 systematic targeting of field surveys, management planning, and restoration it is impossible
447 to achieve a two- to threefold increase in the total amount of managed area when compared to
448 the current situation.

449
450 Our work is the first nation-wide attempt to advance TRB conservation on the basis of
451 ecological functionality instead of administrative categorizations (see Fig. 1 and Table 2).
452 Although surveyed TRBs (scenario A) provided a basis for management network building,
453 we demonstrated the conservational potential of TRB management on unsurveyed sites.
454 Protected and unprotected TRBs, in turn, complement each other by forming habitat networks
455 within the landscape (Bengtsson et al., 2003).

456
457 Our suggestions for future work concern effective ways to advance TRB conservation. The
458 systematic assessment presented here is only one part of conservation planning, and its results
459 should be critically evaluated (Knight et al., 2006). Because conservation of TRBs is
460 dependent on collaboration between authorities, landowners, and managers, we propose
461 adoption of and research on modern systematic conservation strategies, which are based on
462 promoting resilience and cooperation. These include multi-use conservation landscapes
463 (Hanski, 2011), dynamic reserves (Bengtsson et al., 2003), contract-based temporary
464 conservation (Moilanen et al., 2014), and adaptive co-management (Berkes, 2007).

465
466 As a final note, we argue that current incoherent governance of TRB conservation hinders
467 promotion of TRB management and more efficient utilization of management funding. This
468 finding is based on an observation we gained through our data collection process. There are
469 several Finnish authorities involved in TRB-related decision-making, none of which carries a
470 clear responsibility on coordinating TRB conservation (Ministry of the Environment,
471 Ministry of Agriculture and Forestry, Finnish Environment Institute, Metsähallitus Parks &
472 Wildlife Finland, Agency for Rural Affairs, and 15 regional ELY centres). Also elsewhere in
473 Europe disintegration to static, isolated, and monosectoral conservation strategies has proven
474 to be inefficient in tackling the biodiversity loss in rural landscapes (Plieninger and Bieling,
475 2013). Individual organizations and structural institutions shape how the environment is
476 governed, and often impede integrative conservation practice (Bennett et al., 2016). This
477 should be taken into account while our results are implemented.

478 479 **5. Conclusions**

480
481 Throughout Europe, traditional rural biotopes and their species are declining. This has caused
482 substantial biodiversity loss. We noticed two main challenges in TRB conservation. On the
483 one hand, the total area under management is too small to safeguard TRB-dependent
484 biodiversity. On the other, management actions are not targeted to sites that are
485 conservationally most important. As a solution, we present a nation-wide and spatially
486 explicit management network optimization. It introduces ecological functionality into

487 systematic promotion of TRB management and targeting of management funding, and can be
488 implemented in a step-wise manner.

489

490 Allocating additional management and large-scale restoration actions to Baltic Sea coastal
491 region emerges as a strategic starting point. This would create a large, well-connected core
492 area for a Finnish TRB habitat network. In addition, reviving populations of red-listed TRB
493 species requires that smaller inland clusters of TRB sites are managed in order to promote
494 habitat connectivity. However, as current policies are failing in sustaining biodiversity
495 dependent on TRBs, we stress that implementation of targeted TRB management calls for
496 adopting new perspectives on their conservation and governance.

497

498 **Acknowledgments**

499

500 The authors wish to thank Santtu Kareksela (Metsähallitus, Parks and Wildlife Finland) for
501 offering guidance in the conduction of the Zonation analyses. Grassland Group of the Finnish
502 Board on Ecological Restoration kindly commented the study set up and the initial results of
503 the analyses. Janne Heliölä and Mikko Kuussaari (Finnish Environment Institute), and three
504 anonymous reviewers gave valuable comments on earlier versions of the manuscript. The
505 work within this study was funded by Maj and Tor Nessling Foundation (for KJR), Ministry
506 of the Environment and Metsähallitus, Parks and Wildlife Finland (for MM and KMR), and
507 Kone Foundation (for PH).

508

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702

703 **Table 1.** Analysis layers. “No.” refers to continuous numbering of data layers. For each layer,
704 also name, weight value, and distribution are listed. Base layers (1–3) included site-level
705 information on survey and management status. Habitat type inventory data was used to form
706 layers 4–14 and 16–28. TRB habitat layers 4–11 are comparable with the Finnish assessment
707 on threatened habitats (CR: critically endangered, EN: endangered, NE: not evaluated;
708 according to Raunio et al., 2008). Natura 2000 -layers are listed according to the TRB
709 habitats in directive 92/43/EEC on the conservation of natural habitats and of wild fauna and
710 flora (Council of Europe, 1992). Habitats marked with an asterisk (*) are classified as priority
711 habitats within the European Union. Undefined TRB habitat (layer 15) includes all area that
712 is not covered by habitat type inventory. Species layers include information on the occurrence
713 of red-listed vascular plant species specialized in TRB habitats. Transformed layers (34 and
714 35) were included only in the analyses with landscape connectivity measures. Weight sums
715 were balanced between layers 1–28 and 29–33. Cell size in the analysis was 0.25 ha (50 m ×
716 50 m).
717

	No.	Layer name	Weight	Distribution (cells)
Base layers:	1	Nationally and regionally surveyed traditional rural biotopes on private and state-owned land (corresponds to scenario A)	2	160 830
	2	Protected TRBs on private and state-owned land: extended network	1	166 457
	3	AES management contract areas (on layers 1 and 2)	2	65 745
Habitat layers:	4	Heaths (CR)	4	5 950
	5	Dry meadows (CR)	4	2 834
	6	Mesic meadows (CR)	4	7 625
	7	Moist meadows (CR)	4	35 640
	8	Wooded meadows (CR)	4	215
	9	Wooded pastures (CR)	4	3 630
	10	Grazed woodlands (EN)	3	7 364
	11	Slash-and-burn areas (NE)	4	188
	12	Old traditional reindeer gathering grounds	1	163
	13	Old traditional yards and Sami camp sites	1	1 204
	14	Dry sandy sunlit dunes and eskers	1	3 302
Natura 2000 layers:	15	Undefined TRB habitat	2	242 034
	16	Boreal Baltic coastal meadows (1630) *	2	19 502
	17	European dry heaths (4030)	2	4 207
	18	Semi-natural dry grasslands and scrubland facies on calcareous substrates (6210)	3	24
	19	Species-rich <i>Nardus</i> grasslands on siliceous substrates (6230)*	3	7
	20	Fennoscandian lowland species-rich dry to mesic grasslands (6270)*	3	1 792
	21	Nordic alvar and precambrian calcareous flatrock (6280)*	3	60
	22	<i>Molinia</i> meadows on calcareous, peaty or clayey-silt-laden soils (6410)	2	1
	23	Hydrophilous tall herb fringe communities (6430)	2	1 227
	24	Northern boreal alluvial meadows (6450)	2	3 905
	25	Lowland hay meadows (6510)	2	190
	26	Mountain hay meadows (6520)	2	93
	27	Fennoscandian wooded meadows (6530)*	3	146
	28	Fennoscandian wooded pastures (9070)	2	3 979

Species layers:	29	Critically endangered (CR) plant species inhabiting TRBs	32.4	34
	30	Endangered (EN) plant species inhabiting TRBs	21.6	1 816
	31	Vulnerable (VU) plant species inhabiting TRBs	10.8	5 213
	32	Near threatened (NT) plant species inhabiting TRBs	3.6	5 213
	33	NT, VU, EN, or CR plant species historically inhabiting TRBs; disappeared or potentially disappeared locations	3.6	2 936
Transformed layers:	34	Contribution of protected TRBs (layer 2) to connectivity of surveyed TRB network (layer 1)	5	166 457
	35	Contribution of dry sandy sunlit dunes and eskers (layer 17) to connectivity of surveyed TRB network (layer 1)	2	3 299

718

719 **Table 2.** Management status of traditional rural biotopes in Finland (in hectares and percents)
 720 in year 2014. Note that managed TRBs include only sites where management is funded
 721 through national agri-environment scheme. For unmanaged sites, private unprotected and
 722 unsurveyed sites are excluded, as there is no existing data on them. Original vector data were
 723 used in the analysis.
 724

		Managed (ha)	Unmanaged (ha)	Managed (%)
Protected:	State-owned surveyed	1 122.0	2 946.6	27.6
	State-owned unsurveyed	1 460.7	14 555.2	9.1
	Private surveyed	1 531.2	1 739.4	46.8
	Private unsurveyed	3 199.9	6 468.3	33.1
Unprotected:	Private surveyed	3 681.8	19 237.2	16.1
	Private unsurveyed	8 229.8	N.A.	N.A.
Total (protection status):	Protected	7 313.8	25 709.4	22.1
	Unprotected	11 911.5	N.A.	N.A.
Total (survey status):	Surveyed	6 335.0	23 923.2	20.9
	Unsurveyed	12 890.4	N.A.	N.A.
Grand total:		19 225.4	N.A.	N.A.

725

726 **Table 3.** A summary of spatial prioritization from Zonation analysis. Rows 1–3 give
727 conservation performances of different prioritization analyses in terms of average proportion
728 of conservation value remaining within the prioritized landscape of given size. Nested
729 management scenarios were further investigated only for connectivity analysis with 2 km
730 dispersal distance (rows 4–12). Original vector data were used in the calculations instead of
731 raster data from the analysis. However, the coverage of species point occurrences outside of
732 surveyed traditional rural biotopes or protected areas was estimated from rasterized data (cell
733 size 0.25 ha). Currently managed area is derived from agri-environment scheme contracts on
734 TRB management in year 2014. ANN refers to Average Nearest-Neighbor analysis
735 conducted for each scenario.
736

	Scenario A (surveyed TRBs)	Scenario B (A + 5 000 ha)	Scenario C (A + B + 5 000 ha)	Scenario D (A + B + C + 5 000 ha)
Conservation performance (without connectivity)	0.333	0.719	0.865	0.940
Conservation performance (with 5 km dispersal distance)	0.335	0.722	0.864	0.937
Conservation performance (with 2 km dispersal distance)	0.345	0.727	0.866	0.939
Additional area (ha)	0.0	4 362.6	8 256.5	12 133.1
Total area within scenario (ha)	30 258.1	34 620.7	38 514.6	42 391.2
Coverage on protected areas (ha)	7 258.8	9 194.4	12 280.6	16 150.1
Coverage on unprotected areas (ha)	22 999.3	25 426.4	26 234.0	26 241.1
Currently managed area (ha)	6 335.0	6 740.2	7 752.5	8 851.7
ANN: observed mean distance (m)	1 254.7	926.0	833.8	801.1
ANN: expected mean distance (m)	4 311.5	2 950.4	2 650.0	2 587.9
ANN: z-score	-122.2	-175.7	-196.6	-202.8
ANN: p-value	<0.001	<0.001	<0.001	<0.001

737

738 **Figure legends**

739

740 **Fig. 1.** A framework for categorizing traditional rural biotopes from a governance
741 perspective. Key determinants are management, protection, and survey statuses. Information
742 on management status is mainly available through AES contracts. Protected TRBs are located
743 both on private and state-owned land. A recognized network of valuable sites is based on
744 nationally and regionally conducted surveys on TRBs. The management and protection
745 statuses of surveyed TRBs are variable. Ecologically, TRBs are detected via distinct
746 structural features such as the occurrence of TRB habitat specialist species, whether the site is
747 managed or not. On national level, the data on TRBs vary in quality. The level of knowledge
748 positively correlates with the ability of Finnish environmental authorities to influence
749 management of TRBs belonging to different categories. Data sets utilized in detecting sites
750 belonging to each category are listed in *italic* (for detailed descriptions of data, see Electronic
751 appendix A).

752

753 **Fig. 2.** Distribution of surveyed traditional rural biotopes (management scenario A; panel A)
754 and allocation of cumulative TRB network expansion according to management scenarios B,
755 C, and D (panels B–D, respectively). For comparison, the distributions of currently managed
756 TRBs (according to AES contracts; panel E), protected TRBs (surveyed and unsurveyed;
757 panel F) and TRB-specialist vascular plant species occurrences (panel G) are also shown.
758 Note that the Åland islands were excluded from the analyses.

759

760 **Fig. 3.** The proportional increase in the number of specialist vascular plant species (A) and
761 their occurrences (B) according to nested management scenarios (A–D, on x-axis). Curves
762 are drawn according to red-list status: CR: critically endangered; EN: endangered; VU:
763 vulnerable, and NT: near-threatened. The numbers of occurrences per species are
764 summarized in Table B.1.

765

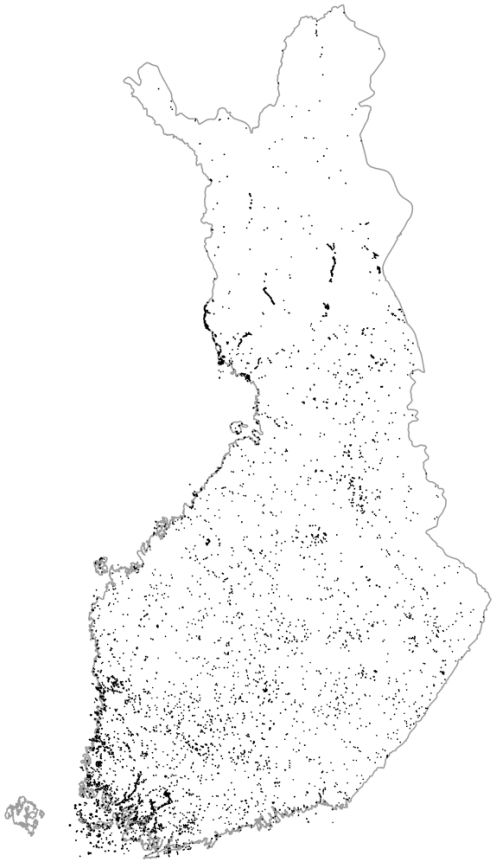
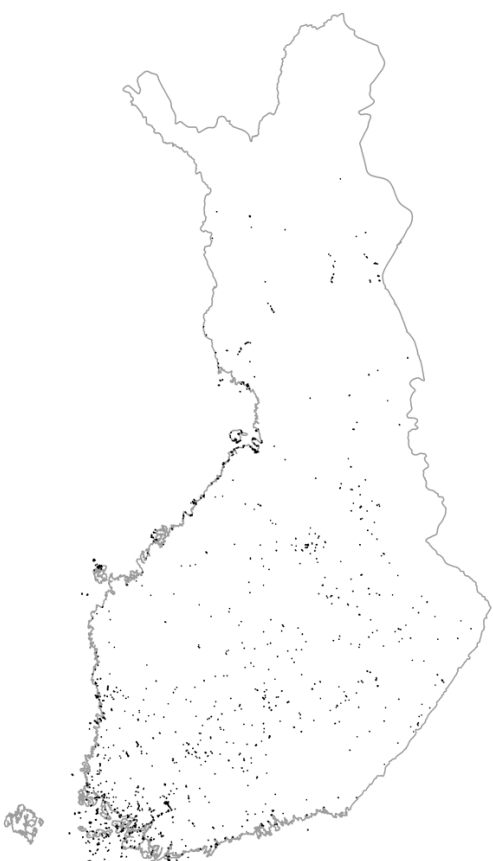
766 **Fig. 4.** The increase in the proportion of different habitat types included in the nested
767 management scenarios (A–D; represented in grayscale). Panel A shows upper-level habitat
768 type inventory classes. In panel B more specific Natura 2000 -habitats are depicted (codes in
769 brackets). The numeric data are provided in Tables C.1 and C.2. Only sites located on
770 protected areas are included.

771 ¹: complementary habitats

772 ²: sites without habitat information, including all unprotected TRBs

773 *: priority habitats within the European Union

Appendix A.

Original vector data sets used in the analysis:	Snapshot:
<p>1. Surveyed traditional rural biotopes</p> <p><i>Type:</i> Polygon</p> <p><i>Description:</i> Includes site-level geometries and attributes of TRBs detected in field surveys by environmental authorities (regional ELY Centres). Sites are classified as nationally, regionally, and locally valuable (with sub-classes). Also sites classified as restorable are included. Database is compiled and updated by the Finnish Environment Institute. Originally, the national survey on Finnish TRBs was conducted during 1992–1998. It covered 18 640 hectares of TRBs classified as biologically valuable. After that, additional surveys and follow-ups have been done regionally, and the database has been updated accordingly (latest update in summer 2014). The coverage of the data is 30 258 ha. Because the data is combined from several sources, it is heterogeneous and its accuracy varies spatially and temporally.</p> <p><i>Extent:</i> Nationwide data</p> <p><i>Date of acquisition:</i> November 4th 2014. Field data are collected during a time period 1992–2014.</p> <p><i>Source:</i> Finnish Environment Institute</p> <p><i>References:</i> (Kemppainen and Lehtomaa, 2009; Raatikainen, 2009; Vainio et al., 2001)</p>	 <p>0 100 200 400 km</p>
<p>2. Agri-environment scheme contract areas</p> <p><i>Type:</i> Polygon</p> <p><i>Description:</i> Plot-level geometries of five-year AES subsidy contracts on TRB management. Only contracts valid on year 2014 were included. The combined coverage of the data is 19 225 ha.</p> <p><i>Extent:</i> Nationwide data</p> <p><i>Date of acquisition:</i> June 19th 2014. Continuously updated.</p> <p><i>Source:</i> Ministry of Agriculture and Forestry</p>	 <p>0 100 200 400 km</p>

3. Habitat type inventory

Type: Polygon

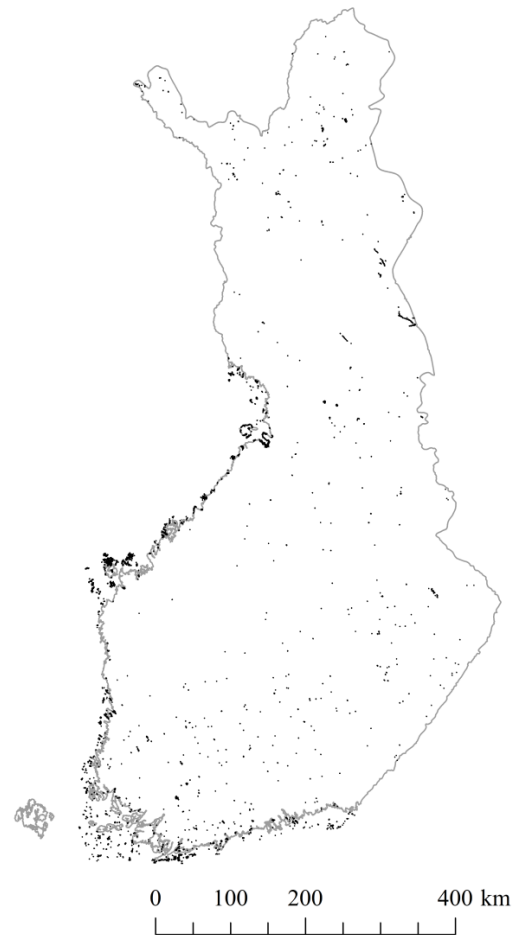
Description: Includes plot-level geometries and attributes on habitats located on private protected areas and all state-owned land. Geometries are formed with a high level of accuracy and habitat information is categorized within a multi-level database structure, where general habitat classes are further divided into more detailed Natura 2000 -habitat classes and/or vegetation classes. In total, the inventory covers 4 620 235 ha (including water bodies). For Zonation analysis, geometries without TRB-related attributes were discarded, leaving a data set covering 11 143 ha (depicted in the right-hand map).

Extent: Protected and state-owned areas

Date of acquisition: December 4th 2012 (privately-owned protected areas) and June 11th 2014 (state-owned areas). Inventories started in year 2001, and most of the field work was conducted during 2003–2006. The database is continuously updated.

Source: Metsähallitus, Parks & Wildlife Finland

References: Airaksinen and Karttunen, 2001; Metsähallitus, 2010; Pakkanen et al., 2015; Raatikainen and Raatikainen, 2015



4. Protected traditional rural biotopes

Type: Polygon

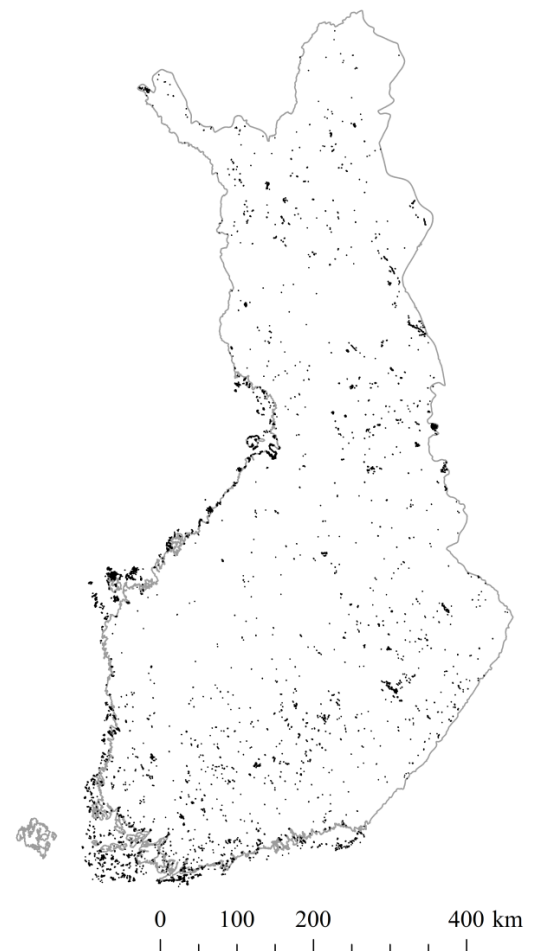
Description: Geometries and attributes of surveyed and unsurveyed TRB sites located on protected areas (either private or state-owned) and unprotected state-owned land. Database was compiled from the national survey on TRBs, existing and expired AES contracts on TRB, landscape, and biodiversity management, NTI data, and additional GIS data on managed and unmanaged TRBs on protected areas available during years 2012–2014. The information level of the database varies according to the original data source, and it includes sites whose value as TRBs is unsure. Total coverage of the data is 32 229 ha.

Extent: Protected private and all state-owned areas

Date of acquisition: September 17th 2014.

Source: Metsähallitus, Parks & Wildlife Finland

References: Pakkanen et al., 2015; Raatikainen and Raatikainen, 2015



5. Occurrences of vascular plant species specialized in traditional rural biotopes

Type: Point

Description: Includes existing and historical occurrences of red-listed TRB-dependent vascular plants derived from national Hertta database. Species are listed in table B.1. Species were selected according to their specialization in TRB habitats, and this information was based on the national survey guide for TRBs (Raatikainen, 2009) and the 2010 Red List of Finnish Species (Kalliovirta et al., 2010). Compilation of the data set is described in Pakkanen et al. (2015) and Raatikainen and Raatikainen (2015). Oldest observations of the data are from 19th century herbariums, and in recent years environmental authorities have recorded their red-listed vascular plant observations routinely to the database. Only occurrences with at least 100 meter accuracy were included. Number of currently existing occurrences within the data is 13 038. In addition, there are 3 039 historical occurrences that are categorized as potentially or certainly disappeared.

Extent: Nationwide data

Date of acquisition: June 2nd 2014. Continuously updated.

Source: Finnish Environment Institute

References: Kalliovirta et al., 2010; Rytteri et al., 2012



References:

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- Raatikainen, K.M., 2009. Perinnebiotooppien seurantaohje. In Finnish.
- Rytteri, T., Kalliovirta, M., Lampinen, R., 2012. Suomen uhanalaiset kasvit. Tammi, Helsinki.
- Vainio, M., Kekäläinen, H., Alanen, A., Pykälä, J., 2001. Traditional rural biotopes in Finland. Final report of the nationwide inventory. In Finnish. Finnish Environment Institute, Vammala.

Appendix B.

Table B.1. Red-listed vascular plant species specialized in traditional rural biotopes and a summary of their occurrence data. The red-list statuses are according to Kalliovirta et al. (2010) and the nomenclature follows Hämet-Ahti et al. (1998). Columns 3–5 present the number of existing occurrences of the species on different TRB sites, column 6 lists all occurrences within the data, and column 7 summarizes the number of occurrences located on TRB management subsidy contract areas. Note that surveyed TRBs are equivalent to scenario A in the prioritization analysis. Scenarios B–D, however, allocate additional management to unsurveyed TRB sites without accounting for protection status.

Red List status	Species	Occurrences on surveyed TRBs	on protected, unsurveyed TRBs	on unprotected, unsurveyed TRB habitats	Total n:o of existing occurrences	Managed through AES subsidy
CR	<i>Anthyllis vulneraria</i> subsp. <i>polyphylla</i>			9	9	
CR	<i>Armeria maritima</i> subsp. <i>intermedia</i>			7	7	
CR	<i>Asperula tinctoria</i>	2			2	
CR	<i>Botrychium simplex</i>	4		2	6	2
CR	<i>Pimpinella major</i>	4		3	7	
CR	<i>Thalictrum lucidum</i>			1	1	
CR	<i>Veratrum album</i> subsp. <i>lobelianum</i>			2	2	
EN	<i>Agrimonia pilosa</i>	12		27	39	
EN	<i>Anagallis minima</i>	1		4	5	
EN	<i>Androsace septentrionalis</i>			19	19	
EN	<i>Arctium nemorosum</i>	14	1	8	23	12
EN	<i>Armeria maritima</i> subsp. <i>elongata</i>	5	4	6	15	
EN	<i>Asplenium ruta-muraria</i>	1	3	88	92	
EN	<i>Botrychium matricariifolium</i>	12		18	30	2
EN	<i>Carex hartmanii</i>			1	1	
EN	<i>Carex hostiana</i>			1	1	
EN	<i>Carex vulpina</i>			2	2	
EN	<i>Carlina biebersteinii</i>	3	3	28	34	
EN	<i>Crepis praemorsa</i>			8	8	
EN	<i>Epilobium lamyi</i>	1		5	6	
EN	<i>Epipactis palustris</i>			18	18	
EN	<i>Euphrasia micrantha</i>			1	1	
EN	<i>Euphrasia rostkoviana</i> subsp. <i>fennica</i>	4		36	40	
EN	<i>Galium saxatile</i>	7		6	13	
EN	<i>Gentianella amarella</i>	12	2	149	163	9
EN	<i>Gentianella campestris</i>	28	2	56	86	9
EN	<i>Gentianella uliginosa</i>	4			4	3
EN	<i>Hippuris tetraphylla</i>	11	103	88	202	35
EN	<i>Lithospermum arvense</i>	7	1	26	34	
EN	<i>Lonicera caerulea</i>	1	19	38	58	
EN	<i>Malaxis monophyllos</i>	1	5	75	81	
EN	<i>Ophrys insectifera</i>			3	3	
EN	<i>Orchis militaris</i>			3	3	
EN	<i>Persicaria foliosa</i>	13	6	266	285	3
EN	<i>Potentilla anglica</i>	11	2	10	23	9
EN	<i>Potentilla tabernaemontani</i>			1	1	
EN	<i>Primula stricta</i>	1		189	190	
EN	<i>Pulsatilla patens</i>		2	262	264	
EN	<i>Rosa sherardii</i>	4			4	2
EN	<i>Sagina maritima</i>	4	1	6	11	1
EN	<i>Salicornia europaea</i>	3	18	6	27	18
EN	<i>Samolus valerandi</i>			27	27	
EN	<i>Saxifraga adscendens</i>	5	3	39	47	
EN	<i>Scleranthus perennis</i>			5	5	

Red List status	Species	Occurrences on surveyed TRBs	on protected, unsurveyed TRBs	on unprotected, unsurveyed TRB habitats	Total n:o of existing occurrences	Managed through AES subsidy
EN	<i>Stellaria crassifolia</i> var. <i>minor</i>	1		3	4	1
EN	<i>Vicia cassubica</i>			6	6	
EN	<i>Viola persicifolia</i>	2		29	31	1
EN	<i>Viola uliginosa</i>			5	5	
VU	<i>Alchemilla hirsuticaulis</i>	1		5	6	
VU	<i>Antennaria nordhageniana</i>			15	15	
VU	<i>Antennaria porsildii</i>		1	32	33	
VU	<i>Botrychium boreale</i>	29	21	200	250	12
VU	<i>Botrychium lanceolatum</i>	27	10	168	205	7
VU	<i>Campanula cervicaria</i>	14	17	487	518	3
VU	<i>Carex caryophyllea</i>	8		22	30	
VU	<i>Carex pulicaris</i>			1	1	
VU	<i>Carex viridula</i> var. <i>bergrothii</i>	1	1	108	110	
VU	<i>Carlina vulgaris</i>		1	1	2	
VU	<i>Cirsium oleraceum</i>			2	2	
VU	<i>Crassula aquatica</i>	5	9	144	158	4
VU	<i>Crataegus monogyna</i>	7	3	4	14	6
VU	<i>Crataegus rhipidophylla</i>	6	7	10	23	
VU	<i>Dactylorhiza incarnata</i> subsp. <i>cruenta</i>	13	30	318	361	11
VU	<i>Dactylorhiza incarnata</i> subsp. <i>incarnata</i>	5	17	1 241	1 263	3
VU	<i>Dactylorhiza traunsteineri</i>	1	4	395	400	
VU	<i>Drosera intermedia</i>			67	67	
VU	<i>Elymus fibrosus</i>	7	10	77	94	3
VU	<i>Epipactis atrorubens</i>		1	82	83	
VU	<i>Erigeron acris</i> subsp. <i>decoloratus</i>	3	6	32	41	
VU	<i>Eriophorum brachyantherum</i>	1		105	106	
VU	<i>Fragaria viridis</i>	6		1	7	6
VU	<i>Galium verum</i>	28	2	77	107	9
VU	<i>Gymnadenia conopsea</i> var. <i>conopsea</i>	43	4	136	183	12
VU	<i>Gypsophila muralis</i>			32	32	
VU	<i>Leersia oryzoides</i>	2		78	80	
VU	<i>Lythrum portula</i>			23	23	
VU	<i>Malus sylvestris</i>	34	12	65	111	19
VU	<i>Melampyrum arvense</i>	2	1	5	8	1
VU	<i>Melampyrum cristatum</i>	19		10	29	12
VU	<i>Ononis arvensis</i>		2	13	15	
VU	<i>Polygala amarella</i>	11		8	19	10
VU	<i>Polygala vulgaris</i>	7		10	17	1
VU	<i>Potentilla neumanniana</i>	26		2	28	23
VU	<i>Primula nutans</i> subsp. <i>finmarchica</i>	67	165	530	762	84
VU	<i>Sorbus intermedia</i>	3		2	5	2
VU	<i>Thalictrum simplex</i> subsp. <i>simplex</i>	26		39	65	8
VU	<i>Ulmus laevis</i>	5	2	292	299	1
NT	<i>Ajuga pyramidalis</i>	2		8	10	1
NT	<i>Alchemilla samuelssonii</i>			3	3	
NT	<i>Allium schoenoprasum</i> subsp. <i>alpinum</i>	3	1	5	9	
NT	<i>Allium ursinum</i>	1	4	7	12	
NT	<i>Anchusa officinalis</i>	3		7	10	
NT	<i>Antennaria dioica</i>	18	21	260	299	1
NT	<i>Antennaria villifera</i>			11	11	
NT	<i>Anthyllis vulneraria</i> subsp. <i>lapponica</i>			62	62	
NT	<i>Blysmus rufus</i>	7			7	2
NT	<i>Botrychium lunaria</i>	169	74	585	828	50
NT	<i>Botrychium multifidum</i>	103	26	485	614	26
NT	<i>Carex acutiformis</i>			15	15	

Red List status	Species	Occurrences on surveyed TRBs	on protected, unsurveyed TRBs	on unprotected, unsurveyed TRB habitats	Total n:o of existing occurrences	Managed through AES subsidy
NT	<i>Carex atherodes</i>	8	1	66	75	2
NT	<i>Carex glareosa</i>	5			5	2
NT	<i>Carex paleacea</i>		1	1	2	
NT	<i>Carex rhynchophysa</i>			14	14	
NT	<i>Carex riparia</i>		1	45	46	1
NT	<i>Catabrosa aquatica</i>	11	5	133	149	8
NT	<i>Cerastium glutinosum</i>	5		1	6	3
NT	<i>Cynoglossum officinale</i>			10	10	
NT	<i>Cypripedium calceolus</i>	1	17	1 565	1 583	1
NT	<i>Dactylorhiza fuchsii</i>	2	1	63	66	
NT	<i>Dactylorhiza sambucina</i>	14	4	25	43	3
NT	<i>Dianthus deltoides</i>	64	13	339	416	21
NT	<i>Draba muralis</i>	13		3	16	8
NT	<i>Euphrasia bottnica</i>	3	2	6	11	2
NT	<i>Geranium bohemicum</i>	2		19	21	
NT	<i>Helianthemum nummularium</i>	2		2	4	1
NT	<i>Leontodon hispidus</i>	3	1	17	21	
NT	<i>Melica picta</i>	1		1	2	
NT	<i>Mentha aquatica</i> var. <i>litoralis</i>	1		1	2	
NT	<i>Myosotis nemorosa</i>	26		55	81	3
NT	<i>Nardus stricta</i>	18	5	106	129	4
NT	<i>Orchis mascula</i>			2	2	
NT	<i>Phleum phleoides</i>			1	1	
NT	<i>Phleum pratense</i> subsp. <i>serotinum</i>	2		1	3	
NT	<i>Prunus spinosa</i>			3	3	
NT	<i>Sesleria caerulea</i>	5			5	5
NT	<i>Stellaria fennica</i>	4	1	118	123	
NT	<i>Thalictrum minus</i> subsp. <i>kemense</i>	6		24	30	
NT	<i>Thymus serpyllum</i> subsp. <i>serpyllum</i>		1	332	333	
NT	<i>Trifolium aureum</i>	5	3	118	126	1
NT	<i>Trifolium fragiferum</i>	4		1	5	4
NT	<i>Trifolium montanum</i>	2		1	3	
NT	<i>Trifolium spadiceum</i>	25		279	304	8
NT	<i>Valerianella locusta</i>			1	1	
Total:		1 123	683	11 232	13 038	501

References:

- Hämet-Ahti, L., Suominen, J., Ulvinen, T., Uotila, P., 1998. Retkeilykasvio. Yliopistopaino, Helsinki.
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Appendix C.

Table C.1. Cumulative cover of different habitat types located on prioritized sites included in the nested management scenarios (A–D). In addition, total coverage of each habitat type within the analysis is given. Note that areas are derived from rasterized data, which somewhat overestimates total coverages. Due to generalization into 50 × 50 m cell size, the covers of different habitat classes overlap. The data are represented proportionally in Fig. 4A. Habitat data were available only from protected sites covered by habitat type inventory. All sites without habitat information, including all unprotected sites, are classified as undefined TRB habitat.

	Scenario A (surveyed TRBs)	Scenario B (incl. A)	Scenario C (incl. A and B)	Scenario D (incl. A, B, and C)	Total coverage (ha)
Heaths	101.2	728.9	1 352.1	1 425.0	1 487.5
Dry meadows	139.6	497.4	651.8	690.8	708.5
Mesic meadows	549.0	1 031.3	1 551.7	1 763.3	1 906.3
Moist meadows	1 318.7	2 076.0	3 483.8	6 130.1	8 910.0
Wooded meadows	43.8	53.8	53.8	53.8	53.8
Wooded pastures	451.0	675.2	832.2	891.2	907.5
Grazed woodlands	629.6	784.3	1 259.2	1 741.6	1 841.0
Slash-and-burn areas	7.8	47.0	47.0	47.0	47.0
Old traditional reindeer gathering grounds	8.6	40.8	40.8	40.8	40.8
Old traditional yards and Sami camp sites	54.8	174.0	280.8	289.9	301.0
Dry sandy sunlit dunes and eskers	11.6	158.5	385.5	806.5	825.5
Undefined TRB habitat	11 920.2	21 541.0	34 429.3	48 527.8	60 508.5

Table C.2. Cumulative cover of Natura 2000 -habitats located on prioritized sites included in the nested management scenarios (A–D), and total coverage of each habitat type within the data. Note that areas are derived from rasterized data, which somewhat overestimates total coverages. Due to generalization into 50 × 50 m cell size, the covers of different habitat classes overlap. Habitats marked with an asterisk (*) are classified as priority habitats within the European Union. The data are represented in Fig. 4B. Only sites located on protected areas are included.

	Scenario A (surveyed TRBs)	Scenario B (incl. A)	Scenario C (incl. A and B)	Scenario D (incl. A, B, and C)	Total coverage (ha)
Boreal Baltic coastal meadows (1630) *	975.1	1 399.3	2 233.0	4 280.7	4 875.5
European dry heaths (4030)	43.1	670.0	935.0	992.9	1 051.8
Semi-natural dry grasslands and scrubland facies on calcareous substrates (6210)	3.3	6.0	6.0	6.0	6.0
Species-rich <i>Nardus</i> grasslands on siliceous substrates (6230)*	1.0	1.8	1.8	1.8	1.8
Fennoscandian lowland species-rich dry to mesic grasslands (6270)*	232.5	395.6	425.6	438.6	448.0
Nordic alvar and precambrian calcareous flatrock (6280)*	6.8	15.0	15.0	15.0	15.0
<i>Molinia</i> meadows on calcareous, peaty or clayey-silt-laden soils (6410)	0.0	0.3	0.3	0.3	0.3
Hydrophilous tall herb fringe communities (6430)	51.2	207.7	284.1	294.5	306.8
Northern boreal alluvial meadows (6450)	153.3	455.9	943.1	962.6	976.3
Lowland hay meadows (6510)	33.8	47.3	47.3	47.3	47.5
Mountain hay meadows (6520)	17.5	22.7	22.7	22.7	23.3
Fennoscandian wooded meadows (6530)*	29.5	36.5	36.5	36.5	36.5
Fennoscandian wooded pastures (9070)	483.4	700.3	879.4	956.0	994.8