

1 **Semantics about soil organic carbon storage: DATA4C+, a comprehensive**
2 **thesaurus and classification of management practices in agriculture and**
3 **forestry**

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36

37 **Abstract**

38 Identifying the drivers of soil organic carbon (SOC) stock changes is of utmost
39 importance to contribute to global challenges like climate change, land degradation,
40 biodiversity loss or food security. Evaluating the impacts of land-use and management
41 practices in agriculture and forestry on SOC is still challenging. Merging datasets or
42 making databases interoperable is a promising way but still with several semantic
43 challenges. So far, a comprehensive thesaurus and classification of management
44 practices in agriculture and forestry is lacking, especially while focussing on SOC
45 storage. Therefore, the aim of this paper is to present a first comprehensive thesaurus
46 for management practices driving SOC storage (DATA4C+). The DATA4C+ thesaurus
47 contains 224 classified and defined terms related to land management practices in
48 agriculture and forestry. It is organized as a hierarchical tree reflecting the drivers of
49 SOC storage. It is oriented to be used by scientists in agronomy, forestry and soil
50 sciences with the aim of uniformizing the description of practices influencing SOC in
51 their original research. It is accessible in Agroportal
52 (<http://agroportal.lirmm.fr/ontologies/DATA4CPLUS>) to enhance its findability,
53 accessibility, interoperability and re-use by scientists and others such as laboratories
54 or land managers. Future uses of the DATA4C+ thesaurus will be crucial to improve
55 and enrich it, but also to raise the quality of meta-analyses on SOC, and ultimately help
56 policy-makers to identify efficient agricultural and forest management practices to
57 enhance SOC storage.

58

59 **Keywords**

60 interoperability, data, FAIR movement, climate change, soil carbon sequestration

61 **1. Introduction**

62 Soil organic carbon (SOC) represents about 25% of the potential of natural climate
63 solutions (NCS) to mitigate climate change (Bossio et al., 2020). Maintaining or
64 increasing SOC stocks can play a significant role to tackle global challenges like
65 climate change, but also land degradation, biodiversity loss or food security (IPCC,
66 2019). Identifying and addressing the drivers of SOC stock changes is therefore crucial
67 to contribute to Sustainable Development Goals (e.g. SDGs 2, 13 and 15) adopted by
68 the United Nations in 2015 (UN General Assembly, 2015).

69 Wiesmeier et al. (2019) reported a large number of drivers at various scales, from
70 climate to soil physico-chemistry, including land-use and management practices. Land-
71 use and management practices shape carbon inputs and outputs at the plot scale,
72 quality of carbon inputs, and may modify the turnover of soil organic matter (SOM) and
73 SOC stocks (e.g. Fujisaki et al., 2018; Paustian et al., 2016; Poeplau et Don, 2015;
74 Powlson et al., 2016). Evaluating the efficiency of management practices (e.g. no
75 tillage, organic amendments) and improving our understanding of processes involved
76 in SOC storage is still challenging and discussed (Chenu et al., 2019; Erb et al., 2017).
77 Consequently, large datasets are necessary to make statistically robust analysis of
78 SOC storage and its drivers. In that perspective, the number of systematic reviews or
79 meta-analyses is growing (e.g. Beillouin et al., 2021; Bolinder et al. 2020; Cardinael et
80 al., 2018; Fujisaki et al. 2018). Data-driven soil research and the inference of soil
81 knowledge directly from data by using computational tools and modelling techniques,
82 are becoming more and more popular (Wadoux et al., 2020). Merging datasets or
83 making databases interoperable to have global datasets is another promising way (e.g.
84 Lawrence et al., 2020; Wieder et al., 2020). Open Science (OCDE, 2015) and the FAIR

85 – i.e. Findability, Accessibility, Interoperability, Reusability- guiding principles
86 (Wilkinson et al., 2016) offer opportunities to explore this path.

87 However, two conditions for drivers, such as land-use and management practices, are
88 compulsory for systematic reviews, meta-analyses or interoperability of databases on
89 SOC storage: 1) have standard definitions and 2) be homogeneously described.

90 Harden et al. (2018) highlighted the need for harmonized description of land-use and
91 management practices. Todd-Brown et al. (2022) emphasized the role that semantics
92 should play to overcome the challenges above. Indeed, there are currently two major
93 limitations for these drivers of SOC change: subjectivity of the semantics and limited
94 scope of the terms. Many global scale studies do not always clearly define the
95 management practices, and use subjective terms like “improved management”, or
96 “best management practices” (Batjes, 2019; Paustian et al., 2016; Smith et al., 2020).

97 Consequently, comparisons between studies might be impossible as improvement or
98 best management practices are highly context dependent (i.e. agronomic, climatic,
99 socioeconomic, or time context) (Rosenstock et al., 2016). Reversely, meta-analyses
100 or original studies that evaluate the effect of specific land management practices on
101 SOC storage provide detailed description of the land-use and management practices
102 but their scope is generally limited to one land cover type, one broad category of land
103 management practice, or focus on a climatic zone, a region or a country (Cardinael et
104 al., 2018; Corbeels et al., 2019; Li et al., 2018; Poeplau and Don, 2015; Maillard and
105 Angers, 2014).

106 Several standards are available for the description of land cover (e.g. FAO Land Cover
107 Classification System, System of Environmental-Economic Accounting (SEEA)) and
108 more recently of land-use (e.g. Intergovernmental Panel on Climate Change, SEEA)
109 (Jansen and DiGregorio, 2002; Pesce et al., 2018). Three standards for farming

110 practices are listed by the Agrisemantics map of data standards (Pesce et al., 2018):
111 a list of agricultural practices established by the FAO
112 (<https://vest.agrisemantics.org/node/20351>), the land-use categories in World Census
113 of Agriculture (<https://vest.agrisemantics.org/node/20353>), and the SEEA Land-use
114 Classification (<https://vest.agrisemantics.org/node/20352>). However, a comprehensive
115 thesaurus and classification of management practices is lacking, especially while
116 focussing on SOC storage. For instance, the standards for " farming practices " listed
117 in the Agrisemantics map (<https://vest.agrisemantics.org/by-theme/7705/7705/7713>)
118 are not exhaustive (e.g. empirical farmers' practices in Southern countries), nor
119 harmonized or/and specific to SOC storage. As far as we know, there has been no
120 attempt to deal with these shortcomings to be able to understand, quantify or
121 extrapolate processes and drivers of SOC storage in agriculture and forestry using
122 large databases. Therefore, the objectives of this study were: i) to compile a
123 comprehensive thesaurus, i.e. a list of standards and specifically defined terms, for
124 management practices driving SOC storage, ii) to keep such thesaurus easy to use for
125 non-scientists such as soil test laboratories or land managers, and iii) to define a
126 classification of these drivers to further enhance interoperability of databases on SOC.
127 The aim of this paper is to present a first comprehensive thesaurus and classification
128 of management practices in agriculture and forestry with a focus on soil organic carbon
129 called DATA4C+.

130

131 **2. Materials and Methods**

132 **2.1. Identification of SOC drivers related to land**
133 **management practices**

134 In the present work, land management practices covered croplands, grasslands and
135 forestry practices established at the field scale, without any change in land-use. We
136 identified land management practices which are recognized in scientific literature to
137 influence SOC change. The literature search was conducted based on expert
138 knowledge. A first list of meta-analyses was established by the authors, allowing the
139 identification of relevant land management practices (e.g. Cardinael et al., 2018; Mayer
140 et al., 2020; Smith et al., 2020, see Supplementary material 1 for some examples and
141 Supplementary material 2 for the full list). Focus was put on meta-analyses as
142 homogeneous definitions are a pre-requisite to conduct such analyses. Besides, the
143 list of land management practices gathered from the meta-analyses was completed
144 thanks to technical and institutional reports (e.g. Chotte et al., 2019; Pellerin et al.,
145 2020; Sanz et al., 2017; Smith et al., 2007), which are hardly referenced in search
146 engines like Scopus, Web of Science or Google Scholar. Finally, this list of practices
147 was extensively discussed among the group of authors resulting in the selection of
148 other practices than the initial ones.

149 Only land management practices explicitly described were retained. Therefore,
150 management practices labelled as “improved” were discarded. Agroforestry was
151 considered in this study as a land management practice, since it is defined as an
152 agroecosystem where “forest species of trees and other wooded plants are purposely

153 grown on the same land as agricultural crops or livestock, either concurrently or in
154 rotation” (FAO, 2015).

155

156 **2.2. Definition of drivers**

157 Definitions of land cover classes, land-use classes, and land management practices
158 were found in data standards (e.g. World Census of Agriculture, FAO, 2015), thesaurus
159 (e.g. Agrovoc) and scientific literature collected at the former step of driver
160 identification. In case a definition was lacking in the primary data source, it was
161 collected through thematic glossaries (e.g. IPCC, 2019; “Landmark Glossary”;
162 “WOCAT Glossary”).

163

164 **2.3. Classification of land management practices**

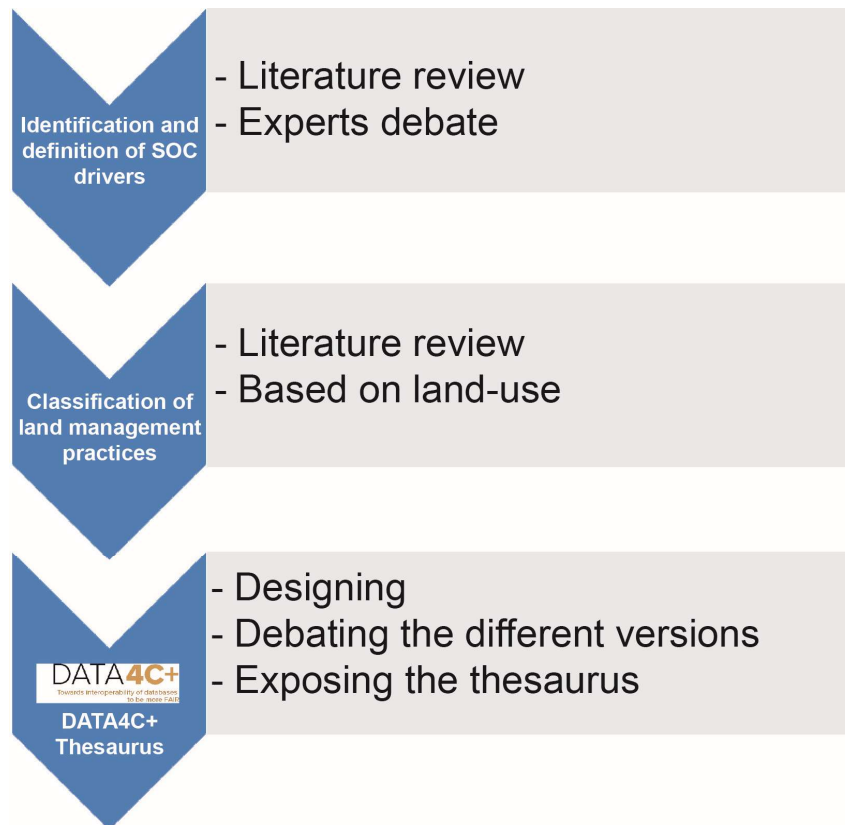
165 As there is currently no comprehensive thesaurus for land management practices
166 which directly or indirectly affect SOC dynamics, we classified the single management
167 practices gathered in the previous steps into a hierarchical tree. This hierarchical tree
168 was built thanks to existing classifications of land management practices found in
169 literature. These classifications usually rely on the manipulation of several components
170 of the agroecosystem which often affect C inputs and C outputs from soils, such as the
171 plant management, water management or soil tillage management for example
172 (Supplementary material 1). We considered, in the hierarchical tree, only single land
173 management practices. Integrated land management practices (e.g. conservation
174 agriculture, organic agriculture) were not included as a whole, but described by their

175 single components (e.g. conservation agriculture = no tillage, permanent soil cover,
176 rotation/crop diversification).

177

178 **2.4. Design and quality control of the thesaurus**

179 From October 2019 to October 2020, participants to the project DATA4C+
180 (<https://www.data4c-plus-project.fr/en>) carried out the editing phase of the thesaurus.
181 Participants were junior and senior scientists from 3 French research institutions (i.e.
182 Cirad, INRAE, IRD) that joined their expertise about organic carbon dynamics in
183 temperate and tropical soils. A first version of the thesaurus and classification was
184 shared and discussed among them in October 2020. The consolidation phase was
185 carried out from November 2020 to June 2021. A second version of the thesaurus and
186 classification was shared, discussed and validated among participants of the project in
187 July 2021. From July 2021 to September 2021, editors of the thesaurus checked its
188 consistency before its first available on-line version, as presented in this paper (see
189 Fig. 1).



190

191 **Figure 1 – Summary of the different steps to build the DATA4C+ thesaurus**

192 **3. Results**

193 **3.1. Land management practices**

194 Land management practices were classified in three main categories according to
 195 land-use: i) land management practices in annual and perennial croplands, ii) land
 196 management practices in grasslands, and iii) land management practices in forests
 197 and tree plantations. We chose to classify the land management practices inside large
 198 categories of land-use rather than land cover for several reasons. Land-use categories
 199 are well harmonized between different standards (FAO, IPCC, SEEA, World Census
 200 of Agriculture, see Gong et al., 2009), whereas the matching of land cover categories
 201 between the main standards is less straightforward (see, for instance, Herold et al.

202 (2009) and Yang et al. (2017) for the harmonization of FAO Land Cover Classification
203 System with other land cover standards). Land-use categories suit well with
204 greenhouse gas (GHG) balance accounting thanks to the IPCC framework (IPCC,
205 2006). Furthermore, some management practices may induce a change in land cover
206 without changing in land-use, such as management practices regarding plant
207 management like agroforestry practices.

208 In these categories, several sub-categories were created, regarding plant, biomass
209 (through grazing and animal management in grassland, residue management in
210 croplands, biomass fluxes in forests), and amendments management, but also erosion,
211 water, fire, and land clearing management in the case of agroecosystems implanted
212 after land clearing. These sub-categories are mainly inspired from Smith et al. (2020).
213 They rely on management techniques from the point of view of the land managers,
214 which is commonly used in literature for the classification of land management
215 practices that affect SOC dynamics (Supplementary material 1). Another classification
216 of land management practices could be specifically based on the mechanisms
217 affecting SOC dynamics, i.e. modification of carbon inputs and/or modification of SOM
218 turnover. However, this approach would be less handy for a non-scientific audience.
219 Furthermore, there are still knowledge gaps regarding the processes involved in SOC
220 sequestration after the establishment of several management practices (Chenu et al.,
221 2019).

222

223 **3.2. The DATA4C+ thesaurus: technology, content and browsing**

224 The DATA4C+ thesaurus is freely available at the following URL address:

225 <http://data4c-plus.net/admin/thesaurus/index>.

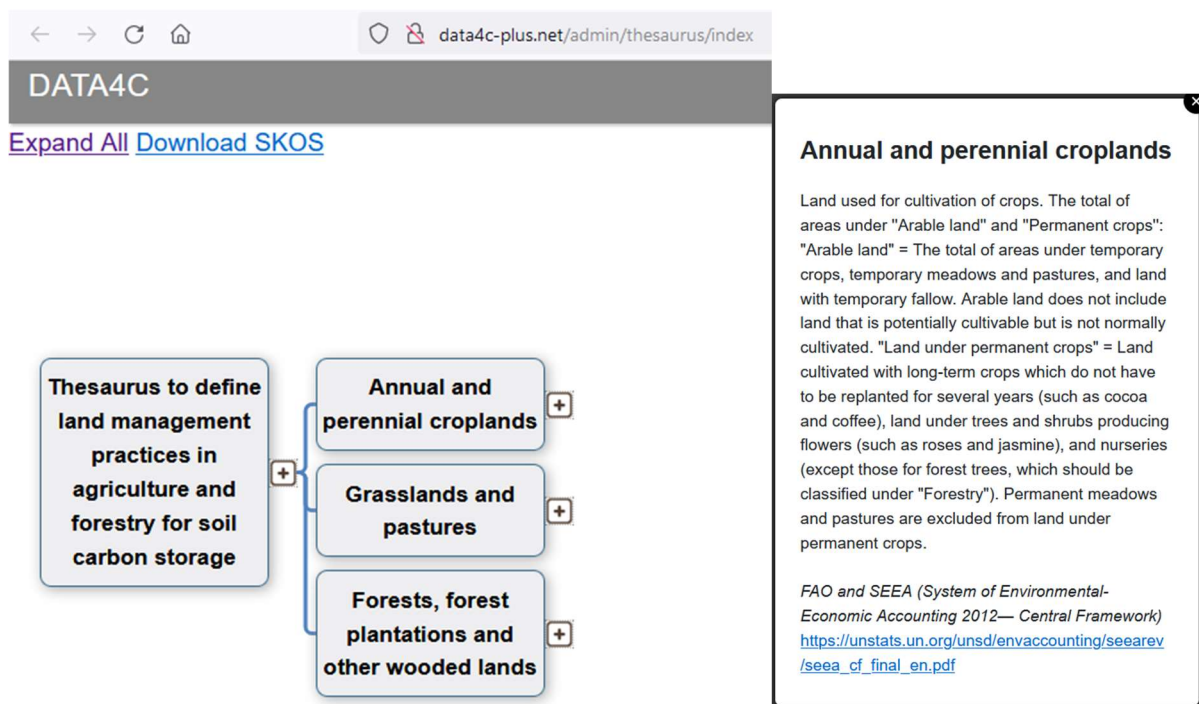
226 The DATA4C+ thesaurus is connected to a PostgreSQL® database. The intuitive web
227 interface uses the jsPlumbTree function of the jQuery library, which is a plugin that
228 renders a reducible and extensible tree structure representing the hierarchical
229 relationship between different nodes. In addition, the plugin uses the jsPlumb library to
230 draw connection lines using Bézier curves between nodes. The tree is drawn
231 dynamically from left to right and top to bottom when connecting to the database.

232 Each term of the database is defined by four nodes:

- 233 ● data-id: term identifier. Must be unique throughout the tree
- 234 ● data-parent: identifier of the parent node
- 235 ● data-first-child: identifier of the first child node
- 236 ● data-next-sibling: identifier of the next sibling node

237 The DATA4C+ thesaurus was developed by Cirad. All the source programs are
238 available on the forge <https://gitlab.com/ecosols> and can be freely accessed on request
239 under the [CC BY-SA 4.0 FR license](#). To facilitate re-use of the DATA4C+ thesaurus, it
240 can be downloaded as Simple Knowledge Organisation System ([SKOS](#)) format (W3C,
241 2009). The DATA4C+ thesaurus is accessible in Agroportal
242 (<http://agroportal.lirmm.fr/ontologies/DATA4CPLUS>) to enhance its findability,
243 accessibility, interoperability and reusability by scientists in agronomy, forestry and soil
244 sciences. It may also be used by other end-users such as soil test laboratories to
245 describe the soil samples analysed or by land managers to describe and report their

246 practices (e.g. for carbon farming programmes). Additionally, the Comma Separated
247 Values (CSV) file of DATA4C+ thesaurus is available on the data depository of Cirad
248 (<https://dataverse.cirad.fr>) under the CC-BY 4.0 FR license with the DOI:
249 <https://doi.org/10.18167/DVN1/HMCPMF>. The DATA4C+ thesaurus classifies 224
250 defined terms related to land management practices in agriculture and forestry. It is
251 organized as a hierarchical tree reflecting the drivers of SOC storage. To have access
252 to the definition of a given term, the user must find the term in the tree and click on it.
253 Then a “pop up” appears with the definition of the term and the source of the definition
254 (Fig. 2). A link to the source of the definition (URL or DOI) is given for each term. By
255 clicking on this link, a new web page appears.



256

257 **Figure 2 – Browsing hierarchical tree and definition in the DATA4C+ thesaurus**

258

(<http://data4c-plus.net/admin/thesaurus/index>)

259 **4. Discussion**

260 **4.1. Less subjectivity of land-use and management practices will** 261 **improve re-use of data and quality of meta-analyses**

262 The terms “improved management practice” or “conventional agricultural” are currently
263 used in the scientific literature despite their subjectivity (Sumberg & Giller, 2022). The
264 use of this term implicitly means comparing one practice to another practice and
265 describing the improved actions, which is hardly ever done. The DATA4C+ thesaurus
266 gives a framework to describe the practices. This is vital to produce robust meta-
267 analyses. For instance, the term “improved management of pastures” encompasses
268 diverse agronomic practices (e.g. introduction of leguminous species, switch from
269 mineral to organic fertilizers, no burning for land clearing, reduced grazing intensity).
270 The description of each of these agronomic practices is specific: species’ names and
271 plant density for the introduction of leguminous, type, amount and date of application
272 of fertilizers for the switch from mineral to organic fertilizers, amount of biomass left on
273 site for no burning for land clearing. Besides, their impacts on SOC stocks are highly
274 different as highlighted by Maia et al. (2009), Conant et al. (2017), or Fujisaki et al.
275 (2018).

276

277 **4.2. More genericity in the description of management practices** 278 **will improve re-use of data and quality of meta-analyses**

279 The DATA4C+ thesaurus intends to facilitate data sharing for the evaluation of soil
280 carbon storage through land management practices, thanks to the genericity of the
281 proposed terms. We evaluate the DATA4C+ thesaurus against land management
282 practices used in several meta-analyses (Table 1). In many situations, there is an

283 adequate matching between terms used in the meta-analyses and terms used in the
284 thesaurus.

285 However, some studies use levels of details uncovered in the thesaurus, such as the
286 species family of plants sown in the fields (Bai et al., 2019), or several tillage
287 techniques (Jian et al., 2020), that can be grouped into larger categories used in the
288 thesaurus (Intermediate intensity tillage or High intensity tillage). These very detailed
289 levels were not covered in the thesaurus because of the current lack of the evaluation
290 of their effect on SOC dynamics. Indeed, the effect of soil tillage on soil carbon storage
291 is still discussed by soil scientists (Chenu et al., 2019), and the use of numerous
292 categories of tillage practices may weaken the significance of the observed trends. We
293 used in the thesaurus classes of tillage intensity based on the study of Haddaway et
294 al. (2021), which distinguished High intensity tillage from Intermediate intensity tillage
295 depending on the inversion or not of the soil during tillage, and the performed depth of
296 the tillage practice. This offer in our opinion transparent criteria to characterize tillage
297 intensity.

298 On the other hand, several studies use broader categories than in the present
299 thesaurus, which may prevent re-use of the dataset. This is the case for land
300 management practices in grasslands studied by Conant et al. (2017), where categories
301 such as "grazing" and "fire" are not further detailed, despite the wide response range
302 of soil carbon stocks according to the intensity of grazing for instance (Abdalla et al.,
303 2018).

304 Concerning meta-analyses of SOC, Beillouin et al. (2022) identified issues of low
305 transparency, reproducibility, and updatability. Improving the quality and reliability of
306 synthesis papers is of utmost importance as they are increasingly used to inform policy
307 decisions with possibly large environmental and socioeconomic implications (Krupnik

308 et al., 2019). Nosek et al. (2015) noted that advances must be made to give full and
309 unbiased access to scientific data in line with open science practices. In that
310 perspective, the transparency and the genericity of the terms defined in the DATA4C+
311 thesaurus, mostly inventoried in original papers, technical and institutional reports, will
312 contribute to increase the quality of data and ultimately to merge and analyze data from
313 various sources.

314 Table 1. Matching evaluation of land management practices assessed in meta-analyses against land management practices in the
 315 DATA4C+ thesaurus.

Source	Land management category in paper	Land management practice evaluated	Land management practice or variable in the DATA4C+ thesaurus
Bai et al. (2019)	Climate Smart Agriculture practices	No-till	No-till
		Reduced tillage	Intermediate intensity tillage
		Cover crop	Cover crop
		Biochar	Biochar
	Crop residue	Return	Mulched residues OR Shredded residues OR Buried residues
		Remove	Exported residues
	Nitrogen fertilization	1-100	Partially covered: mineral fertilization practice is included but not the quantity supplied
		101-200	Partially covered: mineral fertilization practice is included but not the quantity supplied
		> 200	Partially covered: mineral fertilization practice is included but not the quantity supplied
	Water management	Irrigation	Irrigation
	Crop sequence	Rotational	Rotation of annual crops
		Continuous	Monoculture
	Cover crop species	<i>Poaceae</i>	Not covered in the thesaurus

		<i>Fabaceae</i>	Not covered in the thesaurus
		<i>Poaceae + Fabaceae</i>	Not covered in the thesaurus
Conant et al. (2017)	Grassland management	Fertilizer	Mineral fertilization
		Grazing	Several choices required in "Grazing management"
		Sowing improved grass species	Plant breeding
		Grass ley in rotation	Temporary grassland in crop rotation
		Fire	Several choices in required in "Fire management"
		Earthworms	Not covered in the thesaurus
		Irrigation	Irrigation
		Reclamation	Not covered in the thesaurus
		Silvopastoralism	Silvopastures
		Shi et al. (2018)	Agroforestry practices
Homegardens	Multistrata systems		
Silvopastures	Silvopastures		
Windbreaks	Hedgerows		
Han et al. (2016)	Crop fertilization	Unbalanced application of chemical fertilizers	Partially covered: mineral fertilization practice is included but not the appreciation of balanced vs unbalanced application
		Balanced chemical fertilization	Partially covered: mineral fertilization practice is included but not the appreciation of balanced vs unbalanced application
		Straw retention and	Mulched residues OR Shredded residues OR Buried residues AND

		application of chemical fertilizers	Mineral fertilization
		Application of manure and chemical fertilizers	Solid manure OR liquid manure AND Mineral fertilization
Jian et al. (2020)	Tillage group	Disk tillage	High or intermediate intensity tillage depending on the depth
		Sweep	High or intermediate intensity tillage depending on the depth
		Tandem disk	High or intermediate intensity tillage depending on the depth
		Full-tilled	High intensity tillage
		Mouldboard ploughing	High intensity tillage
		Harrowing	Intermediate intensity tillage
		Moldboard plowing	High intensity tillage
		Turnplow	High intensity tillage
		Plow-till	High intensity tillage
		Ridge-till	High or intermediate intensity tillage depending on the tools and the depth
		Mulch tillage	Intermediate intensity tillage
		Chisel	High or intermediate intensity tillage depending on the depth
		Slit tillage	High or intermediate intensity tillage depending on the depth
		Light tillage	Intermediate intensity tillage
		Strip-tiller tillage	Strip tillage
Deep-till	High intensity tillage		
No-tillage	No-till		

Jian et al. 2020	Conservation type	Agriculture forest system	Several choices required in the category Agroforestry
		Cover crop	Cover crop
		No tillage	No-till
		Reduced tillage	Intermediate intensity tillage
		Organic farm	Organic agriculture
		Straw return, mulching	Mulched residues
		Stubble	Not covered in the thesaurus
		Ridging	High or intermediate intensity tillage depending on the tools and the depth
		Rotation	Rotation of annual crops
		Plastic film mulching	Not covered in the thesaurus
		Interplanting	Intercropping
		Combination of two	Not covered in the thesaurus
		Organic farm with cover crop as green manure	Organic agriculture AND Cover crop
		Organic farm with no tillage	Organic agriculture AND No-till

4.3. Future development of the DATA4C+ thesaurus: uses and accrual

The DATA4C+ thesaurus is expected to be used by scientists in agronomy, forestry and soil sciences with the aim of uniformizing the description of practices influencing SOC in their original research. As it was developed to be simple and easy-to-use, the thesaurus may also be used by several end-users as land managers (e.g. to report their practices for carbon farming) or by laboratories to describe the soil samples analysed (e.g. metadata on the sample). The generated data will therefore be more easily to retrieve and to be integrated to perform meta-analyses in particular. Another perspective will be to mobilize the DATA4C+ thesaurus to feed models on SOC dynamics with more site-specific data. However, such perspective would need to enrich the DATA4C+ thesaurus with vocabulary related to annual carbon inputs to enhance carbon inputs to soil (e.g. Bolinder et al., 2007). Accrual of the DATA4C+ thesaurus could also be focused on emerging practices and empirical farmers' practices, which are poorly studied by researchers. Promotion and peer-reviewing of the updated versions of the DATA4C+ thesaurus will be performed by the Scientific and Technical Committee of the 4 per 1000 Initiative (<https://4p1000.org/>). Versioning of the DATA4C+ thesaurus will be done at the following URL address: <http://data4c-plus.net/admin/thesaurus/index>, in Agroportal (<http://agroportal.lirmm.fr/ontologies/DATA4CPLUS>) and on the data repository of Cirad (<https://doi.org/10.18167/DVN1/HMCPMF>). Suggestions of accrual could be sent to the corresponding author or at the following email address: data4c@cirad.fr.

339 **5. Conclusion**

340 The DATA4C+ thesaurus is the first attempt to compile and classify the land-use and
341 management practices in agriculture and forestry influencing SOC storage. Future
342 uses of the DATA4C+ thesaurus will be crucial to improve and enrich it, but also to
343 raise the quality of meta-analyses on SOC, and ultimately help policy-makers to identify
344 efficient agricultural and forest management practices to improve SOC storage. In that
345 sense, the DATA4C+ thesaurus is a contribution to SDG 17 “Partnerships for the goals”
346 (i.e. goals 17.6 and 17.7).

347

348 **Appendix**

349 Supplementary material: the full list of references, technical and institutional reports
350 used to identify the land management practices.

351

352 **Code availability**

353 The DATA4C+ thesaurus was developed by Cirad and Khaméos. All the source
354 programs are available on the forge <https://gitlab.com/ecosols> and can be freely
355 accessed on request under the CC BY-SA 4.0 FR license.

356

357 **Data availability**

358 The DATA4C+ thesaurus is accessible in Agroportal
359 (<http://agroportal.lirmm.fr/ontologies/DATA4CPLUS>). The CSV file of DATA4C+
360 thesaurus is available on the repository of Cirad in the Dataverse CIRAD

361 (<https://dataverse.cirad.fr>) under the CC-BY 4.0 FR license with the DOI:
362 <https://doi.org/10.18167/DVN1/HMCPMF>.

363

364 **Author contributions**

365 Kenji Fujisaki led the inventory and analyses of resources to build the thesaurus.
366 François Thévenin (Khaméos) and Jean-Baptiste Laurent did the informatic
367 development of the thesaurus. Antonio Bispo, Tiphaine Chevallier and Julien
368 Demenois supervised the conceptualization of the thesaurus. Kenji Fujisaki and Julien
369 Demenois prepared the manuscript with contributions from all the co-authors. All the
370 co-authors reviewed the thesaurus and the manuscript.

371

372 **Competing interest**

373 The authors declare that they have no conflict of interest.

374

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