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1 **Title: Diversity of farmland management practices (FMPs) and their nexus to environment:**
2 **A review**

3 **Abstract**

4 We examined the environmental impacts of farmland management practices (FMPs), considering
5 FMPs as frequent or single actions that change both land use AND use rights (land and property
6 relations). Based on a review of the international literature in both the social and life sciences and
7 using an analytical framework of landscape agronomy, we explored the links between FMPs and
8 changes in agricultural practices designed for the achievement of environmental goals. The Web of
9 Science (WOS) and SCOPUS bibliographic databases were used to identify references on FMP types
10 and their environmental effects based on the following search equations: 1- "*Farmland tenure OR*
11 *cropland tenure OR farm size and environment*" and 2- "*Farmland use rights OR farmland property*
12 *rights AND environment OR pollution OR biodiversity.*" Ninety references were selected from these
13 databases and read in depth. Google scholar enabled us to identify an additional 20 papers, using the
14 snowball approach. From this analysis, we present a typology of FMPs based on the distinction
15 between bottom-up strategies, which rely on local initiatives from farmers to improve the overall
16 functioning of their farms, and top-down strategies, which originate from public bodies or private
17 organizations. Our results also highlight the environmental impacts of FMPs considered in the
18 literature: tenure arrangements, whether rental or exchange of land parcels, may alter crop succession
19 and reduce phytosanitary pressure without changing cropping plans. Considering the direct agronomic
20 implications of farmers' land dynamics, we conclude that the area of FMPs is a potential tool for
21 reducing the environmental impacts of agricultural activities and protecting natural resources. This is
22 the subject of ongoing research that seeks to explore a particular FMP in greater depth, along with
23 temporary exchanges of plots between farmers as an agri-environmental tool to reduce agricultural
24 impacts on environment.

25 **Keywords: farmland management practice, environmental impact, farmland use rights, farmland**
26 **property rights**

28 **1. Introduction**

29 Preserving farmland and reducing the ecological footprint of agriculture is of global concern (Buskirk
30 and Willi 2004; Silva et al. 2010; Foley et al. 2011; Alavoine-Mornas and Girard 2016). For example, the
31 concern over degradation of agricultural soils led to the recent recognition of the importance of
32 farmland management in the preservation of biodiversity (Binot and Karsenty 2007; Bertrand and
33 Duvillard 2016). Another example is that European public policy has been gradually shifting toward
34 reducing the agricultural pressure on ecosystems (Jepsen et al. 2015). Also, scenarios designed to
35 preserve ecosystems focus on the protection of water resources and landscape management
36 (Millennium Ecosystem Assessment in Leemans and Groot 2003).

37 Much of the academic research into environmentally sound agricultural practices that is done from an
38 agronomic perspective focuses on the design of the cropping system (crop diversification, optimization
39 of agricultural practices, extension of crop rotation, and others) or on the management of pasture
40 (Steinmann and Dobers 2013; Davis et al. 2012; Foley et al. 2011; Ribeiro et al. 2016). These studies
41 are made at the scale of the agricultural plot or plot cluster, which are considered stable units.
42 However, studies conducted from the perspective of landscape agronomy highlight the dynamics of
43 permanent transformation of farm plots and farming landscapes; these dynamics result in successive
44 phases of growth, reduction, or reconfiguration (Wästfelt and Zhang 2018; Barbottin et al. 2018; Preux
45 2019). Such dynamics can alter the cropping system and affect the environment (Steinmann and
46 Dobers 2013). Better understanding of these effects on the cropping system and environment would
47 permit the identification of new tools to preserve the environment in agricultural systems. Any such
48 tools must take into account how the farmers' property rights affect the link between agricultural
49 production and environmental preservation (Beyene et al. 2006; Gueringer 2019).

50 In this study, we designate "farmland management practices" (FMPs) as farmers' decisions that are
51 based both on the dimensions of farming design and management of property rights (Sklenicka et al.
52 2015; Calo and Master 2016; Sklenicka 2016a). Indeed, upstream of technical concerns, farmers assess
53 the resources at their disposal, particularly land resources, and develop diversified strategies relating

54 to property rights (Holtslag-Broekhof et al. 2014). Depending on their investment capacity and
55 opportunities to access land, they arbitrate between farm tenancy, ownership, (Boinon 2013), illegal
56 land occupation (Lipscomb and Prabakaran 2020), or even plot exchanges (Lucas et al. 2015). Thus,
57 FMPs differ from one farmer to another according to the constraints each farmer faces.

58 Agriculture must be deeply concerned with biodiversity conservation (Jepsen et al. 2015). It is,
59 therefore, necessary to consider FMPs from an environmental perspective if one wishes to identify
60 perspectives for a sustainable management of natural resources in farming (Bertrand and Duvillard
61 2016). We propose to identify the mechanisms by which farmers manage their farmland in relation to
62 their land-use rights and how these mechanisms impact the environment.

63 Here, we have performed a literature review of FMPs and present an overview of diversity of the afore-
64 mentioned mechanisms. We also discuss the links between FMPs and changes in agricultural practices
65 that have been designed to meet environmental goals. We will address two questions. These are: **i)**
66 **what are the main types of FMPs in the literature?** and **ii) How are the environmental consequences**
67 **of FMPs considered in the literature about FMPs?** We hypothesized that the type of FMP will depend
68 on whether it originated from farmers' choices or from public or private policies. These FMPs are likely
69 to affect the environment.

70 We have adopted an interdisciplinary approach, interweaving agronomy and sociology to analyze the
71 diversity of FMPs.

72 We have organized the document into six sections. In Section 2, we briefly review the concept of FMPs
73 and explain our approach. In Section 3, we discuss the working methodology that we adopted. In
74 Section 4, we propose a typology of FMPs and illustrate it with examples taken from the literature. In
75 this section, we also discuss the possible environmental consequences of FMPs. In section 5, we
76 conclude by looking forward to new environmental research opportunities. Finally, we present some
77 limitation of the study.

78 **2. Conceptual framework**

79 **2.1. What is an FMP?**

80 A precise definition for FMPs is useful. In this study, we consider an **FMP as an action or frequent**
81 **actions that leads to changes in both land use and land-use rights.** These actions may be carried out
82 by a farmer, a group of farmers, or public authorities. Farmers may act independently or collectively--
83 the latter usually in the context of shared projects, and within the confines of the law. The actions may
84 be at the scale of an individual farm or of a group of farms and are likely to impact the organization
85 and implementation of technical systems.

86 The definition for FMP adopted above addresses the junction between property rights and actual land
87 use from the point of view of the actors involved (Gueringer 2019). Through an action, a farmer seeks
88 to ensure the nature, whether temporary or permanent, of agricultural uses on land (Le Roy 1991;
89 Deaton et al. 2018) and implement his technical operations. The way in which the farmland portfolio
90 is accessed and managed will therefore be a determining factor in carrying out technical operations
91 (Beyene et al. 2006).

92 The concept of FMP developed here is distinguished from agricultural practices by the fact that it
93 integrates both the social or even societal dimension and the agricultural dimension. The social
94 dimension refers to the strategies that farmers put in place to secure the right to use or own the land
95 they bring into production and the interactions that take place between the various actors involved
96 with it. The agricultural dimension refers to the agricultural use of the land, which is often the
97 implementation of agricultural techniques by the farmers.

98 Before production begins, farmers integrate their relationship with the land, particularly the
99 sustainability of access to it. They consider the future of their plots in the short-, medium-, and long
100 term and the measures to be taken to secure them. Depending on their investment capacity and the
101 opportunities to access land (e.g. to acquire land that was taken over following disposals), they may
102 arbitrate between different modalities such as leasing, acquisition, or taking stakes in companies
103 (Boinon 2013; Sklenicka 2016a). This may give rise to extension strategies, but also to internal

104 restructuring strategies that vary from one farm to another (Melot 2014). For instance, to reduce the
105 distances between the different plots, maintain crop rotation, or bring the plots closer to the farm's
106 headquarters, farmers may exchange plots with other farmers when the environment is favorable
107 (Gedefaw et al. 2019). A similar example is the expansion of farm surfaces by acquiring adjacent plots
108 and by leveling internal plot boundaries (Doré et al. 2006). The decision on the production mode,
109 whether low input or intensive, can also be influenced by the farmer's land-tenure situation, that is,
110 his degree of land-tenure insecurity (Sklenicka et al. 2015; Akram et al. 2019).

111 The insecurity of land tenure may be inherent in a land-lease contract when land tenure is precarious
112 and is also a factor in the willingness of farmers to invest in conservation (Reid et al. 2000; Gao et al.
113 2012; Sklenicka 2016). For example, a farmer who is operating without land ownership and holds a
114 precarious lease contract may not take measures to protect the soil, plant trees, or improve pastures
115 because there may not be enough time to ensure a return on investment (Xu et al. 2014; Choumert
116 and Phélinas 2015; Deaton et al. 2018). On the other hand, where the lease is long term and protected
117 by law, the farmer may be willing to make production-related investments in the leased land (Wästfelt
118 and Zhang 2018). Thus, a property system that favors land ownership by farmers should increase the
119 farmer's incentive to invest in his farm due to a low risk of expropriation (Lipscomb and Prabakaran
120 2020). Land ownership is also involved in the choice of equipment and the organization of work
121 through the dispersion and location of plots (Morardet 1995).

122 **2.2. What are the determinants of FMPs?**

123 As mentioned in Section 2.1, farmers acquire land use or ownership rights in different ways. Generally,
124 FMPs are determined by the structure and functioning of the farm, which are subject to different
125 constraints (Fig. 3) that we considered as internal or external.

126 Internal constraints are imposed by the structure of the farmland, which includes plot size, land
127 fragmentation, distance between plots, distance from the plots to the farm headquarters, accessibility,
128 and the feasibility of crop management, which includes breaking the weed cycle, respecting return

129 deadlines, and managing rotations. Such internal constraints can interfere with the implementation of
130 the farmer's farming practices (Fig. 3), resulting in a reorganization of the farm's territory through
131 farmland management.

132 External constraints represent environmental constraints, such as climatic variations and soil quality,
133 and socio-institutional constraints, such as public policies, land market, the land regulations imposed,
134 and the social environment. These constraints may lead the farmer to improve the characteristics of
135 his plots to meet his production requirements. Depending on his production goals, he may adopt
136 practices that enable him to reduce the impact of these constraints on his production. The choice of a
137 land-based tool will be based on the perceptions of the different land-use rights situations that arise.

138 3. Material and methods

139 4. Collection of secondary data and reviewed publications

140 We tested the hypothesis that the type of FMP depends on its origin: whether from farmers or from
141 public or private policies. We performed a literature review following the guidelines formalized by
142 Hagen-Zanker and Mallett (2013). Specifically, we asked what the options were for farmers to dispose
143 of temporary- or permanent-use rights on farmland and the environmental consequences of these
144 options.

145 We used Web of Science (WOS) and SCOPUS databases to identify articles relating to FMPs and the
146 environment. We chose these databases as they contain a wide range of references in different
147 disciplines, including agronomy, sociology, and ecology. We conducted two bibliographic searches at
148 different time periods. The first bibliographic searches were carried out from November 20 to
149 December 6, 2019, in SCOPUS and from December 7–13, 2019, in WOS.

150 Queries were performed in English using a series of keywords and combinations of keywords defined
151 in advance. The following search equation: "*Farmland tenure OR cropland tenure OR farm size and*
152 *environment*" was used to query the WOS and SCOPUS databases for items. With this first selection,
153 we obtained 8,879 papers. We considered this a source of raw data and next refined it by manually

154 screening each title and abstract. Papers that we selected met the following criteria: (1) the title of the
155 paper had at least one of the keywords and (2) the abstract of the paper included keywords and
156 discussion of “FMPs” or “farmland and environment.” Papers that were in both databases, that is,
157 duplicated, were identified and one duplicate was removed from the collection. No date restrictions
158 were applied to searches. After applying the first criterion, 820 papers were selected, and after
159 applying the second selection criterion, we obtained 75 papers from the two databases.

160 The second bibliographic searches were carried out from July 26–30, 2021, in SCOPUS and from August
161 10–15, 2021, in WOS. A new search equation: "*Farmland use rights OR farmland property rights AND*
162 *environment OR pollution OR biodiversity*" was used to query the WOS and SCOPUS databases. We
163 obtained a corpus of 624,951 papers. By applying the same approach as in the first search and after
164 completing all the sorting steps, 15 papers were retained and added to the first 75 papers, yielding a
165 final selection of 90 papers from the two databases.

166 In addition to WOS and SCOPUS, we drew on other sources for relevant papers. We used the snowball
167 approach with Google scholar to identify an additional 20 papers. The snowball approach consists of
168 reading a paper and searching its references for other relevant publications (Hagen-Zanker and Mallett
169 2013). Personal knowledge, discussions with colleagues and experts in the field, and the reading of
170 others’ literature (reports and unpublished studies) allowed us to broaden our thinking and identify
171 other relevant papers.

172 **3.2. Data analysis**

173 The selected papers were then subject to an in-depth reading and content analysis. We developed a
174 thematic analysis grid based on the main elements emerging from a careful reading of the corpus of
175 papers. Our goal was to classify FMPs according to their types, creating a typology. We identified the
176 theme of each paper: FMPs based on farmers' initiatives (38 articles), FMPs related to the
177 implementation of public policies (63 articles), and others (9 articles). These papers can be found in an
178 Additional file. Figure 1 describes the various stages of the literature search and data analysis.

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180
181

Step1: Bibliographic search in SCOPUS and WOS

Search equation1: «Farmland and environment OR cropland tenure OR farmland tenure OR farm size and land consolidation»

References found = 8,879 papers

Search equation 2: «Farmland use rights OR farmland property rights AND environment OR pollution OR biodiversity»

References found = 624,951 papers

First sort: selection factor = presence of at least one keyword of the equation in the title.

Papers selected after title reading = 1,050

Step 2: Abstract reading

Second Sorting :

- *selection factor = presence of keywords in the abstract and/or abstract not relevant to the theme*

Exclusion of duplicates (87 papers were duplicated, that is, present in both WOS and SCOPUS)

Papers selected for further reading = 90

Step 3: In-depth reading papers from WOS and SCOPUS (90 papers)

Search papers in Google Scholar by "snowball approach"

Additional papers = 20

Total papers selected for reading = 110

Step 4 : Thematic analysis of papers and grouping of papers by theme

- FMPs based on farmers' initiatives (38 papers)
- FMPs related to the implementation of public policies (63 papers)
- Other aspects of FMPs (9 papers)
- Agri-environmental impact of FMPs (25 papers)

Figure 1. Chronological description of the literature review and analysis of the papers.

182 **5. RESULTS AND DISCUSSION**

183 **4.1. Overview of the distribution of FMPs in the selected papers**

184 The topics addressed in the 110 papers that we consulted and classified are presented in Table 1.
 185 Papers dealing with policy instruments that impact user rights through regulation were the most
 186 numerous, with 43 papers referenced, and the next most numerous were papers dealing with FMPs
 187 initiated by individual farmers, with 28 papers referenced. Environmental issues related to FMPs were
 188 addressed for three out of four categories of agricultural land practices. No papers dealing with
 189 environmental impacts of FMPs initiated by farmers collectively were included in the list of selected
 190 papers.

191 Table 1: Classification of the 110 papers consulted by FMP category and environmental issues addressed.

Topic covered in the paper	No. papers in which environmental issues were addressed		Total papers per topic covered
	NO	Yes	
Policies instruments that change the structure of the land tenure	13	7	20
Policy instruments that impact user rights through regulation	38	5	43
FMPs initiated by individual farmers	22	6	28
FMPs initiated by farmers collectively	10	0	10
Others	2	7	9
Total paper per environmental issues addressed	85	25	110

192
 193 The papers we consulted originated from 40 different countries on all continents (Fig. 2). Twenty-six
 194 papers were from China, the most from a single country. Twenty-two papers were from France, nine
 195 from the USA, five from Poland, and two each from the Czech Republic and Canada.

196 More than 75% of the papers were published less than 10 years ago, which may be evidence of growing
 197 interest in agri-environmental aspect of FMP.

198

199

Table 2: Distribution of reviewed articles by field of study and keys issues addressed

Field of study	Did not include environmental issues	Included environmental issues	Total articles
Geography	17	3	20
Economics	13	5	18
Sociology	9		9
Agroeconomy	6	1	7
interdisciplinary	6	1	7
Agronomy	5	5	10
Social sciences	5	1	6
Rural landscape management	3		3
Urban planning	3		3
Ecology		2	2
Environmental science	2	4	6
Political science	2	1	3
Socioeconomy	2		2
Landscape agronomy	1		1
Management sciences	1		1
Mathematics	1		1
Others	9	2	11
Total	85	25	110

200

201 The table2 above shows the main scientific disciplines to which the papers in the corpus of literature

202 consulted are related. About 7 disciplines account for 75% of the articles dealing with the

203 environmental aspects of FMPs and 60% of all the articles consulted. Biodiversity is the main

204 environmental issue most often addressed. Geography, economics and sociology are the first three

205 disciplines most representative of the corpus of literature consulted. The environmental science

206 disciplines seem to be less interested in the environmental aspects of agricultural land tenure

207 practices, with only four articles.

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Table 3: Main data sources used in the different articles in the corpus of articles consulted.

Methodological features	Total	Pourcentage
General data bases analysis (Land register; Geographic Information System; socio economic data)	34	30.9
Interviews	15	13.6
Modelisation	13	11.8
Literature review	8	7.3
Field surveys	9	8.2
Policy analysis	6	5.5
Position paper	6	5.5
Case study	2	1.8
Data surveys	1	0.9
Archives.field surveys	1	0.9
Landscape observation	1	0.9
Life cycle assessment	1	0.9
Mail survey	1	0.9
Media info and web data	1	0.9
Spatial analysis of landscape	1	0.9
Others	10	9.1
Total	110	100

215

216 Table 3 above details the main data sources used in the articles. Researches are mostly undertaking
 217 modelling of GIS data or general databases (land register or agricultural census). This highlights the
 218 need for more field data collection (interviews, surveys, on-site observations).

219



220

221 Figure 2. Geographical distribution of papers related to FMPs.

222

223 The overview of this literature review helped us to establish the typology of FMPs. Particularly, we
 224 distinguish here between bottom-up strategies, which originate from local initiatives from farmers,
 225 and top-down or implementation strategies, which originate from public bodies or private
 226 organizations. This FMP typology is presented in Section 4.2 below.

227 **4.2. Typology of FMPs**

228 In this section, we present a typology of FMPs. The type of FMP is defined based on whether it is (i) a
 229 bottom-up strategy based on local farmers' initiatives to improve the overall functioning of their farms
 230 or (ii) implementation of top-down strategies that are imposed by public bodies or private
 231 organizations. The first category of FMP is divided into subcategories according to whether the action
 232 is collective or individual. Within each sub-category, we distinguished types that differ by the strategies
 233 used to tackle the constraints hindering the operation of the farm. The second category (top-down
 234 strategies) is also divided into subcategories according to the effects of the strategies on property and
 235 land-use rights.

236

237 **4.2.1. FMPs based on bottom-up strategies from local farmers' initiatives**

238 **4.2.1.1. FMPs initiated by individual farmers**

239 **a) Purchase of land-use rights to improve the farming technical system or the land structure**
240 **of the farm**

241 In this situation, the farmer faces difficulties related to the internal functioning of his farm. He seeks
242 to improve his production system or to improve the topology¹ of his farm through such strategies as
243 enlargement, maintenance, or reduction.

244 According to several authors, when the farmer faces logistical constraints, he may be tempted to
245 reconfigure his farmland holding² in space and time. He may re-arrange his parcels in one of several
246 ways. He could enlarge them, by linking the parcels together to form large islands in a single block, by
247 merging the parcels and removing their physical boundaries such as hedges, or by purchasing new
248 plots that might become available from neighboring farmers. He could also reduce the number of
249 parcels by selling some. Another option for re-arrangement of his parcels would be to agree with his
250 neighbor to exchange or rent the parcels. Reconfiguring the farmland resolves a structural constraint,
251 and the solution that is provided is generally long term or even definitive. In the literature, the practices
252 of grouping parcels with parcels that are close to the farm's headquarters or of exchanging plots
253 between farmers have been highlighted in Rwanda (Nilsson 2019), France (Francart et Pivot 1998 ;
254 Marie et al., 2009; Saint-Cyr et al. 2019), and the Czech Republic (Janovska et al. 2017).

255 When the farmer faces phytosanitary issues or must break the cycle of weeds, he may seek to
256 temporarily move his crops to other land, leaving his land fallow to resolve the problem. He may rent
257 land temporarily, perhaps with a yearly lease, or exchange parcels to avoid the overuse of certain crops

¹ For the farmer, the topology represents the relative position of the parcels in relation to each other and in particular in relation to the seat of the holding and other buildings of the holding, the relative size and shape of the parcels, as well as the structure of the access roads to his parcels.

² I consider "farmlandholding" as all cultivated plots of land for which a farmer has the right of use or ownership.

258 in the same location, which becomes problematic due to lower efficiency of chemical inputs.
259 Temporary rental of plots by farmers to meet agronomic constraints has been documented by Amblard
260 and Colin (2009) in Romania; Lucas et al. (2015) and Marie et al.,(2009) in France, and Choumert and
261 Phélinas (2015) in Argentina.

262 When the farmer's objective is to reduce operating overhead costs, he may choose to regroup his
263 parcels if they are dispersed or rent land. The latter seems to be the most accessible option, although
264 it does not always guarantee a high degree of security on the land (Ciaian et al. 2012). Also, the distance
265 between dispersed plots and the tractor travel necessary to reach them may prohibit their acquisition
266 (Preux 2019).

267 **b) Purchase of land-use and property rights to adapt to external constraints**

268 The farmer seeks above all to minimize external risks, such variations in the climate that are likely to
269 impact the operation of his farm. He uses the farmland as a lever or tool to adapt his production system
270 to the external environment.

271 To cope with constraints due to climate, the farmer will seek to have plots of land in different
272 environments to spread out production and minimize rainfall hazards. He will seek to acquire plots
273 scattered over different zones to benefit from the variation in microclimates and soils within these
274 zones, thereby reducing the constraints on crops. Some examples will serve to illustrate. Ethiopian
275 farmers (Gedefaw et al. 2019) and French farmers in mountainous regions (Mottet et al. 2006) seek to
276 own plots in both valleys and hills to take advantage of the ecological differences, to be able to allow
277 for complementary production (e.g. crops and meadows for breeding). In the states of Oregon and
278 Idaho, in the USA, Zhang al. (2018) suggest that climate change leads to larger and dispersed farms,
279 which are more likely to address irregular crop yields

280 When the external constraint is competition for land from urban pressure, the farmer may try to make
281 his land more secure. In some cases, he may invent new relationships with the land. An example in
282 Sweden is described by Wästfelt and Zhang (2018). In this example, the farmers developed novel land

283 leases called "side leases," in which they rented the land annually and re-negotiated the lease yearly.
284 Similarly in France, Jarrige and Napoleone (2003) note that large agricultural companies in peri-urban
285 areas address urban pressure for their land by extending and moving their plots frequently through
286 short-term leases.

287 **c) Accessing rights to land use through conquest or clearing land**

288 This discussion generally applies to young farmers who seek access to land or to increase the size of a
289 farm. This is a situation of land insecurity, in which the potential farmer does not have title deeds to
290 the land he attempts to acquire (Lipscomb and Prabakaran 2020). In response, he develops strategies
291 that enable him to occupy land and assert his right to farm it. An example of access to land-use rights
292 by young farmers is described in northern Cameroon by Dounias (1998). In this case, the strategy
293 adopted was to plow vacant land and plant it with cotton.

294 **4.2.1.2. FMPs initiated by farmers collectively**

295 **a) Sharing land-use rights between farmers**

296 This situation exists when there is no change of land ownership but rather direct interactions between
297 either farmers or social organizations with collective or community management.

298 In the case of direct interaction, rights are reciprocally shared: the farmer who owns land joins forces
299 with a second person, who manages it. For instance, an owner might authorize a herder to graze
300 animals on the owner's plots after harvest or during inter-cropping. In return, the animals will keep
301 the plot clean and the herds will deposit enriching manure on the land (Poinsot and Faure 2000). The
302 owner may also be required to produce fodder (in this case, alfalfa-type protein fodder) so that the
303 herder does not lack fodder, and in return, the herder is expected to regenerate the soil, specifically,
304 controlling weeds, improving soil structure, and enhancing its fertility.

305 Situations also occur in which an owner grants the right to use land to another farmer under a verbal
306 or written arrangement (Horst 2019). The delegation of use rights usually do not entail an intrinsic

307 right of access to the land (Colin and Tarouth 2017) and are usually between farmers who know each
308 other or who share the same social network (Clément et al. 2019; Keeley et al. 2019a). The owner may
309 be remunerated with a share of the harvest (sharecropping) or by receiving a lump sum (tenant
310 farming). He may also reserve the right to use certain parts, such as hedges or an irrigation network,
311 in his own operations. We found this practice in the USA (Horst 2019; Keeley et al. 2019a), Canada
312 (Magnan 2015; Rotz et al. 2019), and France (Poinsot and Faure 2000; Clément et al. 2019).

313 If we consider collective forms of land management, the community is the owner and ensures each
314 member of the community the right to use the land. Rules are established to resolve conflicts. An
315 example is a grazing reserve, called a “vain pasture” in France and "jiindo de pasto" in the semi-arid
316 Nordeste region in the northern part of the Brazilian State of Bahia. This reserve is an open space for
317 the collective use of natural resources that is used for communal grazing and is a resource for all
318 members of the community, not only for fodder, but also for wood and gathering (Sabourin et al.,
319 1995). Another example is the commonage in Ireland. A commonage is land held in common
320 ownership on which two or more farmers have grazing rights (Van Rensburg et al. 2009). In West Africa,
321 this mode of land management is present in complex ecosystems such as the Inner Niger Delta, where
322 land is often alternately flooded and cleared. Different users share land-use rights, sometimes at
323 different times (Binot and Karsenty 2007). When land management is community based as well as in
324 China, the community that holds the property rights grants farmers temporary land-use rights (W. Hu
325 1997; Yang et al. 2020).

326 **b) Pooling of land-use rights to meet a common goal**

327 In this scenario, there is no change of ownership, but rather a mutual commitment of resources, such
328 as land, supplies, or equipment, to meet a common goal. An example of a common goal might be to
329 reduce fixed costs. How temporary the project is will determine the farmer's level of investment and
330 his contribution of land-use rights. In a joint project of relatively short duration, investments will likely
331 be limited to exchanges of materials, group purchases of supplies and their storage, or sale of crops.
332 These will probably result in temporary pooling of land-use rights. If the joint project is of longer

333 duration, the farmers may invest in the purchase of equipment, and in this case, the pooling of land-
334 use rights may be more long term or permanent. In France, joint crop rotation results in plots of land
335 being considered as a single unit, but the farms involved are not merged. As mentioned by Gabriel et
336 al. (2019), this kind of cooperation can increase productivity because farmers can cultivate several
337 contiguous plots of land in one block and save time and work. It is possible for them to set up farming
338 areas where they can bring work sites closer together and significantly reduce mechanization costs
339 (Gabriel et al. 2019).

340 c) **Delegation of land-use rights to agricultural management companies**

341 Farmers, whether landowners or tenants, may entrust the management of their farm to agricultural
342 contractors. These service providers may control all or only part of the production process, allocating
343 crops to plots and overseeing cultivation. When the service provider has a sufficiently large customer
344 portfolio, he can set up an organization that enables him to manage all the farms he is responsible for
345 in a homogeneous manner. Each farm ultimately represents only one element of a much larger farm,
346 entirely managed by the contractor. Farm work companies are particularly appealing to farmers in
347 certain situations, such as farmers nearing retirement or not wishing to renew equipment.

348 According to Nguyen and Purseigle (2012), the use of agricultural contractors is a consequence of
349 families with a long history of farming who are unable to continue farming themselves but are unwilling
350 give up their farm. The increasing use of contractors is a contentious issue, as it may create barriers
351 for the entry of interested parties into agriculture: contractors and young farmers hoping to start their
352 farms may be in competition for land (Anzalone and Purseigle 2014). Management of farms by
353 contractors has been described in the USA (Horst 2019; Keeley et al. 2019a), the Czech Republic
354 (Sklenicka et al. 2014), Canada (Magan 2015), Africa (Colin and Tarouth 2017), and France (Cochet
355 2008; Anzalone and Purseigle 2014).

356 **4.2.2. FMPs based top-down strategies from public bodies or private organizations**

357 This discussion relates to policies that are implemented by public bodies, including local authorities,
358 public or semi-public agencies, or private agencies, such as non-governmental organizations. These

359 policies may consist of voluntary or mandatory regulations on farming activities, and they may directly
360 or indirectly impact land use and land-use rights.

361 There are many public policy instruments that affect land use. Gerber et al (2018) identified four types
362 of instruments of land policy, categorized by the nature of their regulation and effects on property and
363 land-use rights. These are:

- 364 i) Type 1: policies with no impact on the content of use or disposal rights,
- 365 ii) Type 2: policies with an impact on the scope and content of use or disposal rights,
- 366 iii) Type 3: re-definition of property rights with an impact on the scope and content of use or
367 disposal rights, for example, tradable development rights, and
- 368 iv) Type 4: re-definition of the structure of the distribution of property titles.

369 According to this typology of policy instruments, Type 1 refers to voluntary regulations and incentives
370 that are limited to changes in farming practices (Legras et al 2016). Instruments of this type include
371 agri-environmental measures, tax schemes, and common agricultural policy incentives. The
372 implementation process of these instruments is well documented in the literature, particularly when
373 economics are considered. Although these regulations may impact land values, they do not have a
374 direct impact on property rights and, for that reason, we have not included papers that refer to this
375 type of research here. Rather, we focused our survey on instruments of Type 2 and 3, which have an
376 impact on use rights through regulation, and Type 4, which change the structure of the land-tenure
377 system.

378 **4.2.2.1. Policy instruments that impact user rights through regulation**

379 These instruments consist of public policies implemented through Type 2 or 3 regulations [following
380 the Gerber et al (2018) typology of land-use policy instruments]. Both sets of regulations affect
381 property rights, and Type 3 regulations may have a major impact on property rights, even re-defining
382 them.

383 Among these policy instruments, we concluded that land consolidation was the most documented in
384 the literature we consulted. Many researchers consider land consolidation as a tool for simplifying
385 landscape management (Grammatikopoulou and Pouta 2013; Latruffe and Piet 2014; Luis OREA, et al.,
386 2015; Nilsson 2019). It has been widely used in various contexts to reduce the fragmentation of land
387 ownership (Luis OREA et al. 2015 ; Strek 2018) and to foster land exchanges as a tool for farm
388 restructuring, especially when a large number of willing owners participate (Teijeiro et al. 2020;
389 Gedefaw et al. 2019). In Poland and France, public policies promoting land consolidation have been
390 implemented to expand farms and address the problems often associated with land fragmentation
391 (small, irregularly shaped, or dispersed plots) (Gedefaw et al. 2019) and thus increase agricultural
392 production (Latruffe and Piet 2014). In China, too, the policy of land consolidation on fragmented land
393 has been widely promoted by the government (Yang et al. 2019).

394 Policy instruments may combine regulation and acquisition tools to impose constraints on agricultural
395 activities in vulnerable natural areas. In France, zoning imposed by the government serves to protect
396 environmentally sensitive areas, and land use is restricted and controlled. In these areas, building and
397 industrial activities are prohibited, and farming activities are markedly constrained. Zoning regulations
398 are sometimes combined with land acquisition by private estates to ensure the protection of the estate
399 (Legras et al 2016).

400 In the USA, the "land-trust movement" is an example of a private initiative that affects land use, in this
401 case, with an environmental objective. Land trusts acquire land to protect it and the local ecosystem
402 (Parker 2004). In France, community land trusts acquire farmland to preserve its value for agricultural
403 production in the long term and, in turn, lease them to farmers. Stipulations requiring organic and
404 environmentally sound practices may be part of the contract (Léger-Bosch 2019).

405 Rather than an agency acquiring full ownership, it may attempt to conciliate farming activities and
406 environmental protection by focusing on certain components in the bundle of rights held by the
407 landowner (development of rights or right of use). For example, land trusts may acquire "conservation

408 easements,” which are contracts between a landowner and an easement holder that impose
409 restrictions on all or certain plots held by the owner (Merenlender et al. 2004; Daniels 2020). In the
410 US, programs for ecological conservation concentrate on the purchase of conservation easements.
411 According to Stoms et al. (2009), these programs have enabled the US government and public sector
412 to preserve approximately 730,000 ha of agricultural land. In France, agreements that are equivalents
413 to conservation easements in common-law countries were introduced into national law in 2016. “Real
414 Environmental Obligations” (REOs) are land-based tools that can be used in environmental
415 preservation programs. They are contractual instruments that link permanent obligations to a
416 property. They are intended to protect the environment and are binding into the future, and to future
417 landowners. This contractual mechanism helps to maintain, conserve, manage, or restore biodiversity
418 elements or ecological functions.

419 Conservation easements are often part of ecological compensation policies. Ecological compensation
420 consists of securing land by means of sustainable acquisitions or agreements and restoring it through
421 ecological actions, with the goal of increasing its value (Etrillard and Pech 2015). This tool is still being
422 tested in various countries, although it seems to be well developed in the USA.

423 Another policy instrument often used by different states is expropriation. This concerns the transfer
424 of property rights of the original parcel from the landowner to a state (Gerber et al 2018). In France,
425 as part of the process of restoring water catchments that are most threatened by diffuse pollution of
426 agricultural origin, policies on property management allow local authorities to purchase agricultural
427 land by expropriation or by mutual agreement. The original use of the land may change, and it will be
428 used for agri-environmental purposes (Barataud et Hellec 2015 ; Lamoureux 2016).

429 **4.2.2.2. Policies instruments that change the structure of the land tenure**

430 These policy instruments are Type 4 in the Gerber et al (2018) typology. They can radically re-define
431 the structure of the distribution of property titles and are usually part of major reforms. They may
432 operate at different territorial scales.

433 Land reform can be a major public policy instrument with considerable impact on property rights. For
434 example, in China, Hu (1997) considered that the post-Mao rural reform of the early 1980s had taken
435 over the collective management rights of land by giving the farmers the right to use the land but failed
436 to provide a clear property regime for both owners and users of the farmland. According to this author,
437 despite the growth of Chinese's agriculture, the country's agri-environment has been widely degraded
438 since the implementation of the reform due to short-sighted decisions and the irresponsible use of
439 land resources. Land reform in Albania was done by redistributing the land on a per capita basis,
440 according to Sallaku et al. (2016). Each family received equal amounts of arable and non-arable land,
441 fruit trees, vineyards, and olive trees.

442 Table 4 below summarizes the types and characteristics of the FMPs identified in the literature we
443 consulted.

Table 4: Farmland management practices (FMPs) identified in the literature.

Determinants of FMPs	Type of FMP	Examples of FMPs
Agronomic constraints	Purchase of land-use rights to improve the farming technical system or the land structure of the farm	Grouping of plots with leveling of hedges or purchase of neighboring plots
		Temporary exchanges of plots
Environmental constraints + Constraints linked to the farm topology	Purchase of land-use and property rights to adapt to external constraints (climatic, urban pressure with competition on land)	Plot leasing
		Plot fragmentation (acquisition of dispersed plots)
		Purchase or sale of plots
Environmental constraints	Accessing rights to land use through conquest or clearing land	Dynamics of occupation of still vacant land (pioneer front in Africa and the Amazon)
	Sharing land-use rights between farmers	Extensive pasturing
Socio-institutional constraints		Community land-use rights (communal property)
		Land-use agreements between landowners and farmers
Environmental constraints + Constraints linked to the farm topology	Pooling of land-use rights to meet a common goal	Voluntary pooling of land use (collective land use)
Economic constraints	Delegation of land-use rights to agricultural management companies	Use of agricultural contractors
Measures or arrangements proposed to farmers from a given perspective and that directly or indirectly impact land use and land-use rights	Policy instruments that impact user rights through regulation	Environmental zonings
		Real Environmental Obligations (REOs)
		Rural Environmental Leases / land trust)
		Ecological compensation through supply
	Policies instruments that change the structure of the land tenure organizations	Land consolidation
		Land reform/expropriation

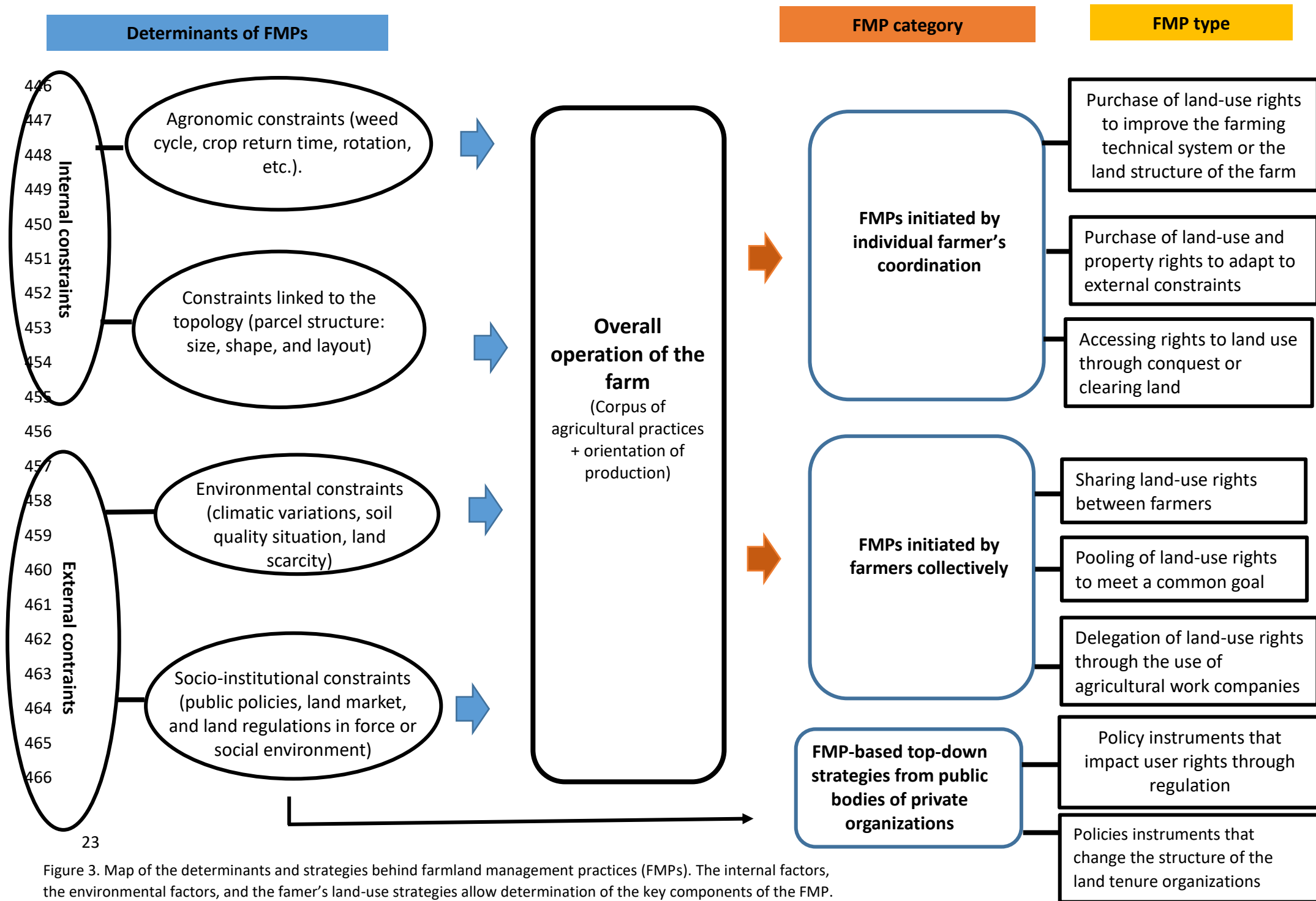


Figure 3. Map of the determinants and strategies behind farmland management practices (FMPs). The internal factors, the environmental factors, and the farmer's land-use strategies allow determination of the key components of the FMP.

467 **4.3. There are possible environmental consequences of FMPs but in-depth studies are needed**

468 The FMP typology that we presented in Section 4.2 highlights its diversity and accounts for the
469 reasoning, based on the agronomic realities, of the choices made of actors involved in FMPs. Questions
470 arise about the environmental impacts that may be associated with these choices. In this section, we
471 discuss the general environmental impacts of FMPs.

472 **4.3.1. The major environmental consequences of FMPs identified in our literature search**

473 Only 25 papers out of 110 that we included referred to the environmental consequences of agricultural
474 FMPs. Although this is not a substantial number of papers, we conclude from our study of them that
475 FMPs may have considerable impacts on biodiversity, landscape, soil resources and water quality on a
476 regional scale, both positive and negative.

477 **a) Environmental consequences of FMPs related to bottom-up strategies (local farmers'**
478 **initiatives)**

479 Bottom-up FMPs are based on local farmers' choices, and these may modify the structure of the
480 landscape and affect the environment. Particularly important factors in the agricultural pressure
481 imposed on the environment by FMPs are strategies that modify the organization of plots and the
482 cropping systems implemented (Leteinturier et al. 2006; Tschardt et al. 2005; Chopin et al. 2017).
483 For instance, Latruffe and Piet (2014), and Di Falco et al. (2010) noted that plot dispersal used by some
484 farmers to address climate uncertainties appears to have positive environmental impacts as it allows
485 a better match between crops and micro-local climatic conditions. Lipscomb and Prabakaran (2020)
486 point out that colonization of the Amazon rainforest for agriculture by farmers who do not have land
487 security is responsible for the destruction of forests and air pollution related to burning.

488
489 When the farmer strategizes to develop the topology of his farmland, he is likely to use such tools as
490 grouping, exchanging, or temporarily renting plots. These allow him to modify the plot structure so
491 that the plots become more homogenous. If the types of FMPs he chooses include structural
492 modification of the farmstead, there may be significant modification of his crop rotation schedule

493 (Barbottin et al. 2018). It may also result in the destruction of hedges (Saint-Cyr et al. 2019; Preux
494 2019), which can be problematic as hedges, along with bunches of trees, groves, copses, and forest
495 edges, are structuring and important elements of the rural landscape (Husson and Marochini 1997).
496 Enlargement of plots can also favor devoting a much larger plot to a single crop than before the
497 enlargement, which may lead to a decrease in crop diversity and increased vulnerability to pests and
498 epidemics. At the landscape scale, this can result in loss of biodiversity, increased runoff, pollution of
499 surface and ground water, and, in some cases, replacement of permanent grassland with plowed land
500 (Preux 2019).

501 We also consider land-tenure insecurity, which is inherent in precarious land-tenure contracts.
502 Although not a type of FMP, it is relevant here as it is proving to be a factor limiting farmers' willingness
503 to invest in conservation of natural resources (Reid et al. 2000; Gao et al. 2012; P. Sklenicka 2016b;
504 Hua Lu et al. 2019). For instance, unregulated changes in the property rights system may endanger the
505 sustainability of the soil resources and favor overexploitation. A case study on extensive cattle
506 breeding in Inner Mongolia (China) revealed that the privatization of pastures, which were previously
507 collectively managed, could result in the depletion of natural and soil resources. As fencing expenses
508 could not be implemented by all breeders, grassland in areas which remained open were overused (Li
509 et al. 2007).

510 Land-tenure insecurity also influences and differentiates farming operations. If farmers' plots are small
511 and irregularly shaped, farmers are reluctant to adopt modern technologies or invest in soil
512 improvement (Lucas et al. 2015). According to Keeley et al. (2019), the short duration of most leases
513 in the US, coupled with the failure of institutional instruments to regulate leases, constitute a major
514 constraint to the application of environmentally sound agricultural practices, such as agroforestry. In
515 the same vein, Choumert and Phélinas (2015) estimate that in Argentina, farmers with precarious land
516 leases are less inclined to adopt long-term land conservation and improvement practices than land
517 owners. The latter, presumably due to their greater security, are more willing to practice soil
518 conservation.

519 b) **Environmental consequences of FMPs related to top-down strategies from public bodies or**
520 **private organizations**

521 The consequences of FMPs initiated by public policy or private organizations on the environment were
522 discussed more than the bottom-up strategies in the papers we examined.

523 The most common issue addressed in this group of papers was the environmental impacts of the type
524 of FMP related to policy instruments that impact user rights through regulation. Land consolidation is
525 one such policy. To summarize the opinions of several authors in general terms, it appears that land
526 consolidation operations are intended to improve the spatial structure of agricultural areas and
527 preserve the environment (Yu, Zeng, and Yu 2014; OREA et al. 2015; Streck 2018; Nilsson 2019). In China
528 for instance, Li et al. (2017) studied the effects of a land transfer policy that was intended to regroup
529 small private structures into larger ones, thereby facilitating mechanization in Jiangsu using a model.
530 These researchers highlighted the fact that more pollution was caused by the increase from 13% to
531 51% use of diesel and the emission of engine exhaust. Yang et al. (2019) argue that changing the
532 farmland structure from scattered small farms to large farms with consolidated parcels of land could
533 reduce the environmental impacts of agricultural activities by reducing resource consumption. In the
534 same vein, Zhang et al (2010) concluded that in Gaolong, China, land consolidation improved the agro-
535 ecosystem services value, with the largest increase in nutrient cycling and the smallest in soil
536 conservation. However, Lu et al. (2018) point out that land consolidation is of interest only at the level
537 of plots, as it increases plot size without necessarily increasing the total area of the farm.

538 Researchers who are critical of these policies point out that the expansion of plots through land
539 consolidation results in decreased in crop diversity, making the farm more vulnerable to epidemics and
540 at increased risk for crop failure due to local natural disasters, such as heavy rains, hail, and floods
541 (Husson and Marochini 1997; Kurylo et al. 2017; Gedefaw et al. 2019). In addition, changes in parcel
542 structures may influence the choice of production systems (Pauchard et al. 2016).

543 Other public policy instruments that impact user rights through regulations that may have
544 environmental consequences are agri-environment programs, such as those implemented in many
545 European countries. In Switzerland, farmers were required to maintain 7% of their useful agricultural
546 area as biodiversity promotion areas (BPA). This requirement increased butterfly species richness
547 (Zingg et al. 2019) .

548 The environmental footprint of land is also important in the policy instruments that change the
549 structure of the land-tenure organizations. Sallaku et al. (2016) suggested that the decision of the
550 Albanian government to redistribute land to each inhabitant was the cause of the environmental
551 changes and loss of biodiversity that was observed subsequently. Reid et al. (2000) point out that the
552 major changes observed in land use across Ethiopia were the result of the succession of land reforms
553 imposed between 1975 and 1985. Similarly, it has been argued that post-Mao land reform in China led
554 to irresponsible use of land resources, specifically, private financial investment in agriculture and
555 intensification of agriculture (Hu 1997). Subsequent overall degradation of the agro-ecological
556 environment was considered to be the result. Also in China, in the Yellow River Delta, Xu et al. (2014)
557 studied the factors that caused farmers to adopt organic fertilizers to reduce land salinization; they
558 also concluded that land tenure was closely linked to farmers' decisions. According to Liu et al. (2019),
559 the opportunity granted to Chinese farmers to rent land, allowing them to enlarge their plots, has
560 resulted in the application of some new farming technologies that permit them to use less fertilizer
561 and pesticide use in wheat and maize production. This should result in reduction in heavy metal
562 contamination of food and drinking water as well as fewer pesticide residues in food and the
563 environment.

564 4.3.2. **The need for in-depth studies on the environmental consequences of FMPs**

565 Among the 25 papers identified in the literature that referred to the environmental consequences of
566 agricultural FMPs, there is an uneven distribution of papers that dealt explicitly with the environmental
567 impacts of FMPs in relation to our typology, as detailed in Table 1.

568 Various studies use environmental modeling to evaluate the impact of changes in farmland on non-
569 point water pollution and to assess the contribution of best management practices (BMPs) on
570 reduction of the environmental impact of agriculture. For instance, in a study conducted in the Three-
571 Gorges area in China, the authors identify BMPs favorable to water quality, such as contour farming
572 and conservation tillage (Liu et al. 2015). In another study on the land-cover changes in the province
573 of Shandong in China, Liu et al. found that increased grassland area had a positive impact on water
574 quality (Liu et al. 2013). Sith et al. applied a watershed model in a study of the Southern Islands of the
575 Japanese coral reef. They concluded that diversification of farmland use toward more pasture lowered
576 water pollution by nitrate considerably (Sith et al. 2019). In these various studies of BMPS, the value
577 of initiatives for collective action among farmers and advocacy for innovative local public policies is
578 apparent. However, they do not empirically investigate the FMPs connected to the changes in
579 agricultural systems.

580 We also note that the available papers provide a weak basis at best for methodology designed to
581 analyze the environmental impact of FMPs. Indeed, none of the papers related to local farmers'
582 initiatives specify the methodology used to assess the environmental impacts of land practices, and
583 conclusions seem to be based more on the authors' opinions than on a methodology designed for this
584 purpose. This weakness is accompanied by a certain risk of bias. We argue, therefore, that
585 methodological developments are needed to assess the environmental impact of FMPs based on local
586 farmers' choices. Such a methodology may help identify FMPs that have higher environmental value
587 and also help identify candidate FMPs that are likely to reduce the impact of agriculture on the
588 environment. Future research should investigate these aspects.

589 **5. Conclusion**

590 Our purpose here was to review the relevant literature concerning the relationship between FMPs and
591 the environment. We have focused on research that would help us develop a typology of FMPs and
592 inform us on their environmental consequences. We hoped that by using references from both social
593 and life sciences fields we could distinguish two main categories of FMP: bottom-up practices, which

594 are based on local farmers' initiatives to improve the functioning of their farms, and top-down
595 practices, which are policies implemented by public bodies or private stakeholders.

596 Our survey highlights the fact that some FMPs may be innovative tools that reduce the pressure of
597 agricultural activity on the environment. In contrast, others appear to have the undesired effects of
598 increasing the pressure of agricultural activity on natural and semi-natural habitats, thereby
599 threatening biodiversity and ecosystems. Additionally, some FMPs aim primarily to describe what is
600 done rather than how it could be done best or have an environmental purpose, as is the case with
601 BMPs.

602 Overall, our study underscores the need to consider both property rights and technical decision making
603 in assessing FMPs. Exploring the environmental aspects of FMPs may be an interesting and valuable
604 area for research as part of the current movement to reduce the environmental impacts of agricultural
605 activities.

606 **6. Limits of this study**

607 Our definition of FMP allows us to focus on the relationship between property rights and
608 environmental impact. However, because of this narrow definition, we have excluded studies related
609 to land use without a change in rights, even though there is considerable literature that addresses the
610 environmental consequences of changes in agricultural land use. Thus, research dealing with the link
611 between land abandonment and the environment was excluded from our study.

612 Another limitation of the study is the lack of in-depth statistical analysis. The exploratory nature of the
613 article led us to work with complex data in terms of the objectives pursued and the different questions
614 asked in each paper consulted. However, this article opens up interesting perspectives for future
615 research insofar as it positions environmental aspects of FMP as a potential research object.

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