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1 **Farming by the sea: a framework to capture the traits of coastal agriculture**

2

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18 **Highlights**

19 • Coastal farming is a relevant category of analysis of farming systems.

20 • A greater diversity of farming systems exists in coastal strip than inland at the regional scale.

21 • Four configurations of coastal farming were identified, which result from distinct dynamics and
22 combinations of urbanization and environmental pressures on agriculture

23 • Qualitative -quantitative analysis, with temporal depth, is essential to understand and fully
24 capture the complexity of coastal-farming configurations.

25

26 **Abstract**

27 The forms and presence itself of farming in coastal territories changed profoundly in the 20th century.
28 By contrast with other interface farming systems, such as mountain or peri-urban farming, coastal
29 farming has rarely been studied as such and has not, until now, been considered as a useful category
30 to describe and analyse production systems. The aim of this article is thus to address the relevance of
31 such a categorization, using empirical data collected in Brittany (France) as well as contextual
32 indicators, but also by carrying out a systemic qualitative-quantitative analysis, questioning the forms,
33 depth and continuity of marine influence on farming activities at the local scale. We show that specific
34 traits of coastal farming do indeed exist. A greater diversity of farming systems exists in coastal strip
35 than inland at the regional scale. Four configurations of coastal farming were identified, which result
36 from distinct dynamics and combinations of urbanization and environmental pressures on agriculture.
37 But these specific features cannot be revealed without a comprehensive and historicized approach of
38 its interactions with the coastal zone as a territory, rather than a biophysical milieu. These
39 configurations are characterized in the typical spatial extent of coastal farming and spatial patterns of
40 the transition to inland farming (gradient, discontinuities).

41

42 **Keywords**

43 coastal social-ecological system; farming system; interface; agroecosystem; landscape agronomy;
44 rural sociology

45 **1 Introduction**

46 Agriculture occupies a large percentage of coastal areas around the world. In France, 30% of the area
47 of municipalities located by the sea was used for agriculture in 2016 (Agreste, 2010). The continuation
48 of farming activities in these areas is remarkable, given these areas attractiveness and intensity of
49 pressures on agriculture. Coastal areas are indeed particularly attractive to a wide range of activities,
50 driven by the environment's biological capacities (e.g. fishing, aquaculture), amenities (e.g. tourism,
51 recreational activities, residential attractiveness); or their position at the interface with the sea (e.g.
52 transport, port industry). They have experienced profound changes over the last 100 years. In France,
53 although they were sparsely populated at the beginning of the 20th century, their residential
54 attractiveness has increased considerably since then. More recently, with the acceleration of global
55 changes, implementation of sustainable development principles to manage coastal areas has become
56 a major issue. Thus, besides being biophysically limited by the sea, agriculture is subject to at least
57 these two pressures. We assume that these pressures and their interactions may specifically shape the
58 importance and traits of agriculture in coastal areas. However, unlike mountain agriculture (Lopez-i-
59 Gelats et al., 2011) or agriculture at the rural-urban interface (Inwood and Sharp, 2012; Hiner, 2016),
60 coastal farming is discussed little in the scientific literature as a specific category of analysis. To date,
61 the literature has addressed coastal farming from two main angles.

62 In the first, coastal areas are considered as specific biophysical environments that farming activities
63 impact or that provide concrete support for farming activities. Thus, abundant literature discusses
64 agriculture through its positive or negative impacts on the integrity of coastal ecosystems. This
65 literature is published in environmental or ecological sciences and focuses on integrated coastal zone
66 management. The contribution of agriculture to an excessive input of phosphorus and nitrogen to the
67 aquatic compartment and its consequences on water quality (Jordan et al., 1997, Lee and Song, 2007,
68 Stuart, 2010, Soy-Massoni et al., 2016, Li et al., 2017) and on the biodiversity of marine ecosystems
69 (Perilla et al., 2012, Kroon et al., 2014, Petersen et al., 2018) have received much focus and are well-
70 documented worldwide, especially in coastal areas vulnerable to anthropogenic eutrophication (Pinay

71 et al., 2019). The literature also highlights the impact of agricultural intensification on habitat change
72 and subsequent biodiversity loss of species restricted to coastal marshes (Butet and Leroux, 2001), as
73 well as, conversely, the key role of specific agricultural practices, such as extensive grazing, in
74 preserving biodiversity in coastal wetlands (Yanez-Arancibia et al., 1999). In this literature, the coast is
75 regarded as a continuous space, whose spatial extent is defined by biophysical processes (e.g. coastal
76 catchments, ecological continuities), with an emphasis on biophysical features of the environment.
77 Agriculture is considered as an activity that puts pressure on the ecosystem. Some of this literature
78 however focuses on the influence of specific environmental conditions of coastal areas, such as climate
79 (Aggarwal and Kalra, 1994, Baguskas et al., 2018) and soil and water salinity (Yan et al., 2013), on
80 farming systems and their productivity, due to the proximity of the sea. This literature emphasises
81 farming activities themselves. Some characteristics of the biophysical environment of coastal areas are
82 considered as forcing pressures on agriculture. Often only one of these characteristics is considered at
83 a time, and its spatial extent determines the width of the coastal zone. The relationship between
84 agriculture and the coastal environment has changed over time with changes in agricultural
85 techniques, but also with climate change (Hadley, 2009). Agriculture is thus increasingly studied with
86 regard to its vulnerability to environmental conditions in a changing climate , such as rising sea level
87 (Kaniewski et al., 2016, Hasan et al., 2018), tidal storms (Durant et al., 2018), soil salinization (Helton
88 et al., 2014, Bless et al., 2018), and their effects on farm viability and food security. Recent studies also
89 address climate change and effects on coastal areas, which may offer new opportunities for
90 diversifying crop production by taking advantage of increasing regional temperature. For instance,
91 conditions in north-western France, considered limiting for viticulture in the past, could become
92 favourable for growing grapevine (Neethling et al. 2019) or help consolidate marginal systems (Bedrani
93 & Landré, 2020). The first planting initiatives are observed on the coasts, which not only have warmer
94 temperatures than before, allowing grapevine to grow, but also fewer frosts as compared to the inland
95 areas.

96

97 The literature's second angle is the competition between agriculture and other human activities (Wolf
98 et al., 2017), or between agriculture and nature in coastal-area management plans (Riguccio et al.,
99 2016). Agriculture is considered here as an activity that competes for land or natural resources (Gowing
100 et al., 2006, Hernandez et al., 2010). More than elsewhere, coasts are subject to residential and tourist
101 appeal that has led to a huge demand for land and heightened competition for access to farmland.
102 This line of research emphasizes non-reversible changes induced by land take, which tends to exclude
103 farming from coastal areas permanently. However, it also sheds light on emerging or enduring conflicts
104 involving farmers and farming activities (whether coastal or less so), whose legitimacy tends to be
105 challenged by socio-demographic changes and increasing environmental concerns in these areas
106 socially highly valued for their heritage (Levain et al., 2020). In this literature, the coast is regarded as
107 patches of activities interconnected with infrastructure, socio-economic networks and nature. The
108 inland extent of the coastal zone is related to the development of specific economic activities. By not
109 helping to maintain farming in coastal areas, these changes also challenge the perennity of small-scale
110 coast-specific farming systems, a phenomenon that is documented mainly by scattered case studies in
111 qualitative social sciences. This literature addresses the influence of land-sea socio-economic
112 interactions on the emergence, maintenance and adaptation of specific farming systems in coastal
113 areas. Studies generally emphasize the complementarity between marine activities (e.g. fishing,
114 harvesting, trade) and farming, at the individual, family or societal levels, as a structuring trait of
115 landscape, social hierarchies and organization in rural-coastal areas (Le Bouëdec et al., 2004; Dupé et
116 al., 2021). In particular, specific land tenures (common uses of marshes, rules of inheritance)
117 associated with these social systems have been documented in detail (Laligant, 2008, Charpentier,
118 2013; Beaudouin, 2016). The nature and availability of marine amendments, such as shells and/or
119 algae (*wrack*), has also been identified as a key component of local farming system orientations and
120 practices. Marine resources have helped improve the agronomic potential of poor land on coastal
121 marshes in the long term (Dumortier, 1992, Bourret, 1997), thus embedding marshes in larger
122 agricultural markets (Clout and Philips, 1972, Pereira and Cotas, 2019). The local importance of these

123 resources and the specific technical abilities, culture and heritage they are associated with, are
124 however, tending to decline on north-western coasts of the Atlantic, as the strong dependence of
125 agriculture on its environment weakens with the modernization of production techniques (e.g. use of
126 synthetic inputs, greenhouse cultivation).

127 This literature suggests that multiple interacting pressures may have challenged coastal farming and
128 shaped specific farming systems, agricultural dynamics and spatial organization over time. It also
129 suggests that multiple pressures are exerted at different spatial scales and over a variety of spatial
130 extent. Therefore the extent of coastal farming may vary depending on the local combination of
131 pressure. However, besides providing fragmented insights into coastal farming, the literature has
132 rarely reported how the unique combination of specific land-use mixture and biophysical
133 environments may have shaped farming activities and their evolution, at the sea-land interface of
134 coastal areas. According to Lampin-Maillet et al. (2010), interfaces are generally more diverse than
135 non-interfaced areas and must be considered as specific systems that have emergent properties and
136 not merely the sum of the properties of the two interfacing components. We argue that more detailed
137 systemic analysis is required of the specific traits of agriculture that result from the original
138 combination of drivers and legacies emerging in coastal areas. This analysis is necessary to investigate
139 (1) whether farming should be given more consideration in land use and sustainable development
140 policies in coastal areas and (2) the need to adapt how agriculture is considered when developing
141 coastal areas according to the local context.

142

143 In this paper, we analysed whether, as observed in other interface areas, farming by the sea is a special
144 system that shows similarities among all coastal areas and thus differentiates it from inland farming.
145 The specific objectives were (1) to identify the characteristics and diversity of farming types by the sea,
146 and (2) to capture their spatial patterns (e.g. continuity along the coastline, inland extent). We
147 performed the study in Brittany, a peninsula in western France that has 2730 km of coastline, and is
148 one of the leading agricultural production regions of France and the European Union (EU). We

149 developed a multi-scale approach: we provide a comprehensive view of farming systems by the sea
150 and pressures at the regional scale from easily available statistical information; and we developed site-
151 specific qualitative-quantitative approach to deeply investigate the spatio-temporal dynamics of
152 coastal farming in relation with the pressures it undergoes. Finally, we propose a typology of coastal
153 farming in Brittany.

154

155

156 **2 Materials and methods**

157

158 Addressing specific characteristics of farming at the land-sea interface implies questioning the
159 continuity of characteristics of coastal farming systems and assessing the width of the interface area.
160 Considering these questions and the multi-scale drivers and pressures that may influence or may have
161 influenced farming activities, we developed a multi-scale approach that combined readily available
162 quantitative databases with detailed qualitative survey data, and enabled longitudinal analysis of
163 agricultural patterns along the coastline and transversal analysis from the coastline inland. We worked
164 at two nested scales - a French administrative region, and study sites - the latter of which
165 corresponding to socio-geographical entities (i.e. the local scale).

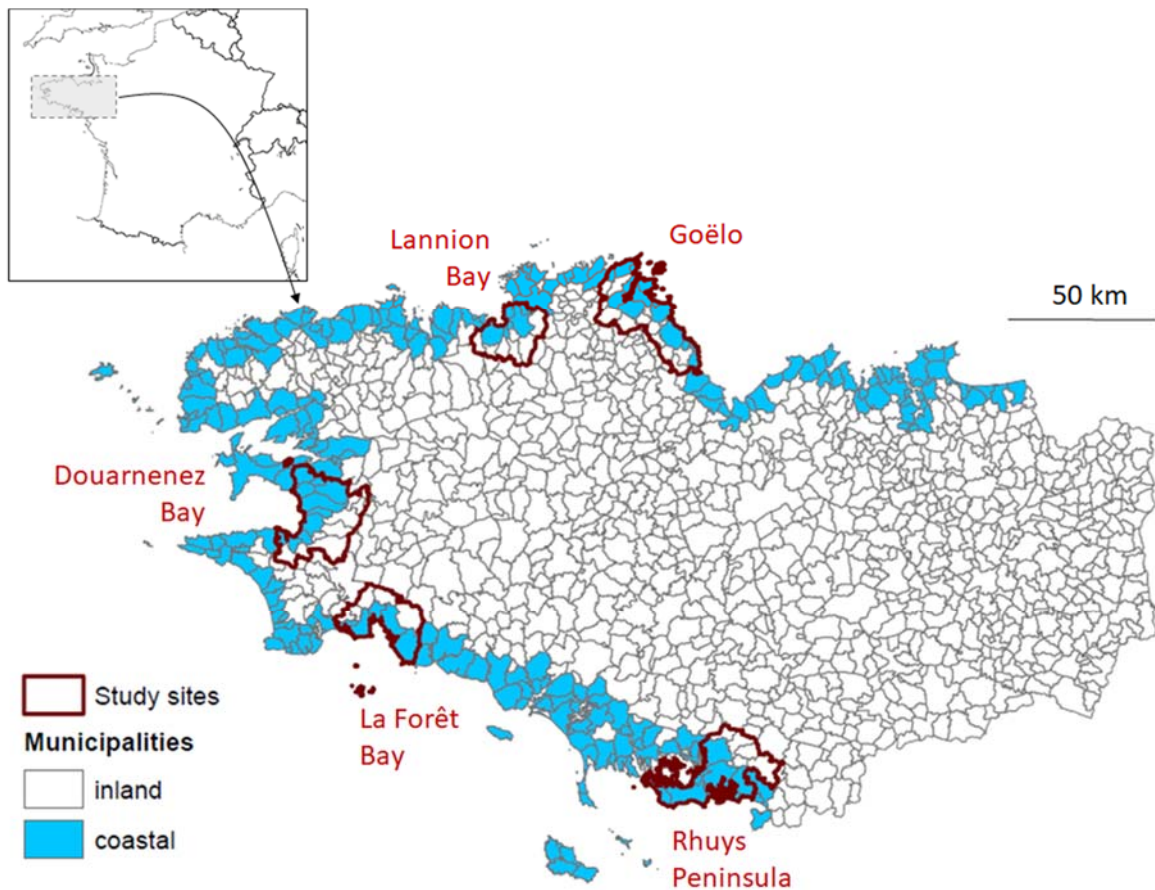
166 **2.1 Contrasting coastal farming to inland farming at the scale Brittany**

167 The scale of Brittany (27,208 km²) (Fig. 1) was relevant for several reasons. First, regions in France have
168 jurisdiction over transport, land-use planning and economic development. An administrative region is
169 therefore a critical organizational level at which to study coastal areas, which may be subject to
170 uniform policies. Second, French administrative regions also form units with relatively homogeneous
171 physiography and, especially in Brittany, a common and strong cultural, political and historical
172 background.

173 The breton coastline is heterogeneous, with cliffs and rocky coasts, sandy or sandy-silt accumulation
174 coasts, muddy coasts and polders. Since the 1950s, agriculture has been based on intensifying
175 livestock, forage and vegetable production, especially dairy cattle, with farming systems embedded in
176 industrial, globalized, and commodity-based food systems (Canevet, 1992; Rogers, 2000). It produces
177 the most livestock in France: 56% and 34% of the pig and broiler stocks respectively, and 23% of
178 national milk production (DRAAF Bretagne, 2018). Brittany is also the leading French agricultural region
179 for several vegetable crops: 83% and 25% of the national cauliflower and tomato production,
180 respectively (DRAAF Bretagne, 2018). Since the 1950s, the concentration of livestock production in
181 Brittany has resulted in strong economic and social development, but has also raised public concern
182 about human health hazards, food security, environmental issues and the uneven distribution of the
183 benefits of agricultural modernization and intensification.

184 We compared coastal areas and inland areas in Brittany (Fig. 1). Coastal areas were coastal
185 municipalities, as defined in the French Coastline Act (“Loi Littoral” - Act No. 86-2 of January 3, 1986):
186 “bordering seas and oceans, saltwater lakes and expanses of inland water of a surface area exceeding
187 1,000 hectares; or bordering estuaries and deltas when they are downstream from the saltwater
188 demarcation line and contribute to the economic and ecological balance of the coastal zone”. Inland
189 areas were all other municipalities in Brittany. Land use is regulated in coastal municipalities, where
190 buildings, installations and manure spreading are prohibited in the coastal strip that lies within 100 m
191 from the edge of the highest astronomical tide. Defining coastal areas as municipalities is commonly
192 accepted and used in socio-economic studies, and in national statistics. It has limitations, however,
193 because a municipality is considered to be coastal if any part of its territory, even a small one, lies next
194 to the coastline. Thus, the length of coastline among coastal municipalities ranges from 0.1 - 60 km ,
195 with a median of 9.8 km (Fig. S1).

196



197

198 **Fig. 1.** Identification of coastal municipalities in Brittany and locations of the study sites.

199

200 To characterize farming systems and their dynamics, we used readily available datasets from French
 201 national statistical databases at the municipal scale ([http://geowww.agrocampus-](http://geowww.agrocampus-ouest.fr/mviewer/?config=/apps/parchemins/parchemins.xml)
 202 [ouest.fr/mviewer/?config=/apps/parchemins/parchemins.xml](http://geowww.agrocampus-ouest.fr/mviewer/?config=/apps/parchemins/parchemins.xml)). We relied mainly on detailed data
 203 from the French National Service for Agricultural Statistics (Agreste). Statistical indicators of
 204 agricultural employment and the number and size of farms came from the national agricultural census
 205 now performed every 10 years. We used its data from 1988, 2000 and 2010. We compared mean
 206 values for coastal areas to those for inland areas using two-sample Student's *t*-tests, or when data did
 207 not meet the assumption of normality according to the Shapiro-Wilk test, two-samples Wilcoxon rank-
 208 sum tests. Differences were considered significant at $p < 0.05$. We mapped the spatial distribution of
 209 the indicators at the regional scale, and how they changed from 1988-2010. Types of farming systems

210 were defined using the French definition of the EU typology of economic configurations of farming
211 systems (OTEX) at the municipal scale, in 2000 and 2010. We compared the types of farming systems
212 in coastal and inland areas using chi-squared tests. In addition, to describe pressures placed on
213 agriculture in coastal and inland areas, we used quantitative demographic statistical indicators from
214 the French National Institute for Statistical and Economic Studies (INSEE). These were derived mainly
215 from the national general population census using data collected every 5-10 years since 1968 (Table
216 2). We also used regional datasets for land use (DREAL Bretagne, 2008), land take (DREAL Bretagne,
217 2017) and natural areas (<https://www.geoportail.gouv.fr/thematiques/developpement-durable-energie/espaces-protoges>).

219

220 **2.2 Investigating the diversity of farming and its dynamics at the local scale using a qualitative-** 221 **quantitative approach**

222 Due to the age and scales of the available statistics, however, not all specific features and emergent
223 dynamics of coastal farming could be detected using these indicators at the regional level. First, these
224 indicators were available mainly by municipality, which left many infra-municipal trends invisible. The
225 complex land-sea interactions in which agricultural trajectories are embedded remained largely
226 hidden, as did possible gradients along the land-sea continuum within municipalities. Indeed, many
227 coastal municipalities extend inland for more than 5-8 km from the coast. We assumed that a coastal
228 municipality includes a gradient of forcing pressures, which usually includes biophysical thresholds
229 (e.g. salinity, thermal amplitude, loess, precipitations) and social thresholds (e.g. seaside tourism,
230 urban and other artificial areas, sea-related industries and services, protected areas for nature
231 conservation). Second, most agricultural indicators dated to 2010, when the most recent agricultural
232 census had been performed. As drivers of the generally rapid decline in the number of coastal farms
233 and farmers had changed little since then, agriculture in these territories might have decreased to a
234 critical level. But the social visibility of such tipping points, the existence of individual and collective

235 adaptation strategies of farmers, or the contrasting ability of farming systems to withstand this general
236 trend had rarely been investigated. Previous surveys in France (ONML, 2013) and qualitative surveys
237 in Brittany (Levain, 2014), however, provided evidence that relatively similar biophysical contexts could
238 have very different development patterns and dominant farming types, which called for considering
239 farming systems in their specific local socio-historical contexts.

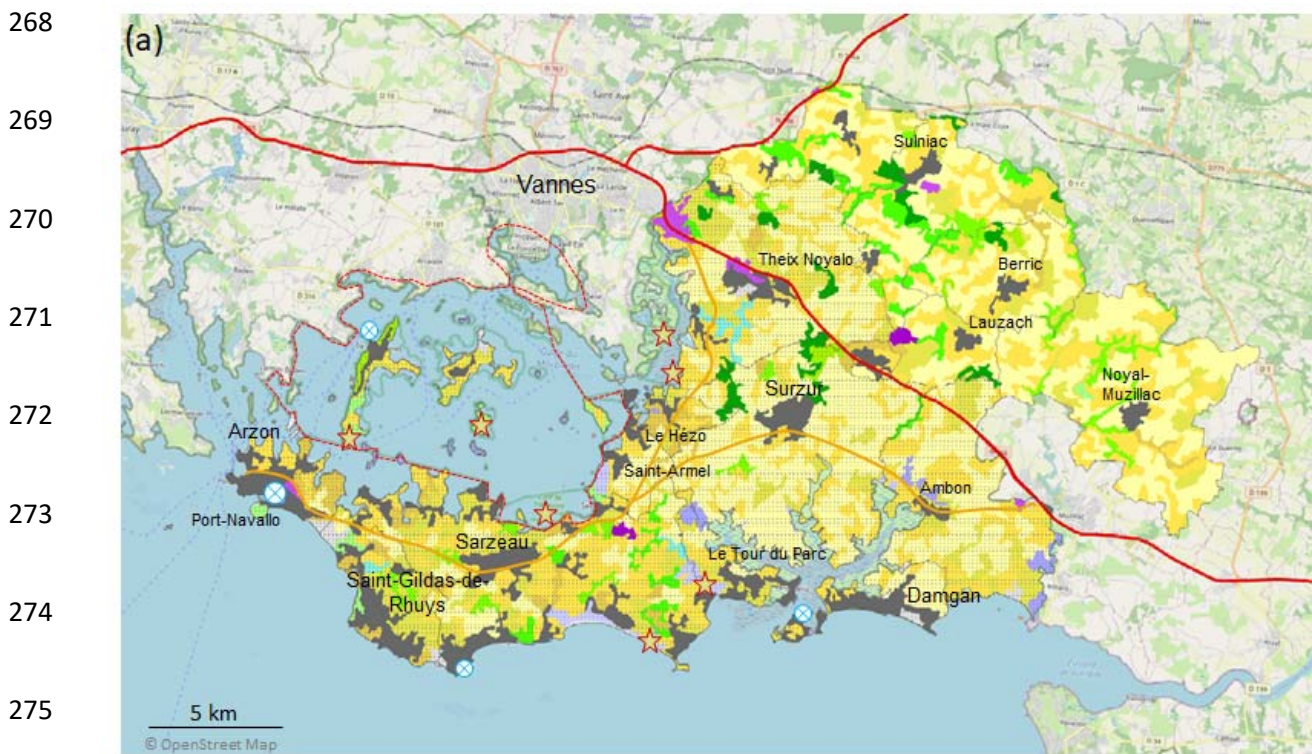
240 Dynamics of farming systems and activities were thus viewed through both the local expression of
241 indicators and qualitative social survey in five contrasting study sites of 1 to several hundred km²,
242 spread along the coast, that correspond to socio-geographical entities (e.g. bays, peninsulas, coastline
243 sections). The study sites included coastal municipalities and inland municipalities (i.e. that border
244 coastal municipalities) (Fig. 1). In this context, sites were chosen based on qualitative criteria, including
245 dominant farming types, the intensity of urban and tourism pressures, the intensity of public debates
246 about farming activities and historical, cultural and political consistency. We delineated them to
247 consider the land-sea continuum, especially from a hydrographic and water management perspective,
248 but also to include rural-coastal thresholds. We hypothesized that these sites would help identify and
249 cover the diversity of coastal-agricultural configurations. The quantitative indicators were analysed in
250 light of qualitative information collected at the sites through interdisciplinary social and agronomic
251 fieldwork and surveys. On this basis, we studied spatial patterns of coastal and inland farming at a
252 coarse and infra-municipality scale, and analysed gradients or discontinuities between them, as well
253 as their socio-geographical interactions. Within coastal municipalities, we emphasised the coastal
254 strip, where the land-sea interface influences farming, and areas inland of the coast, where it
255 influences farming less.

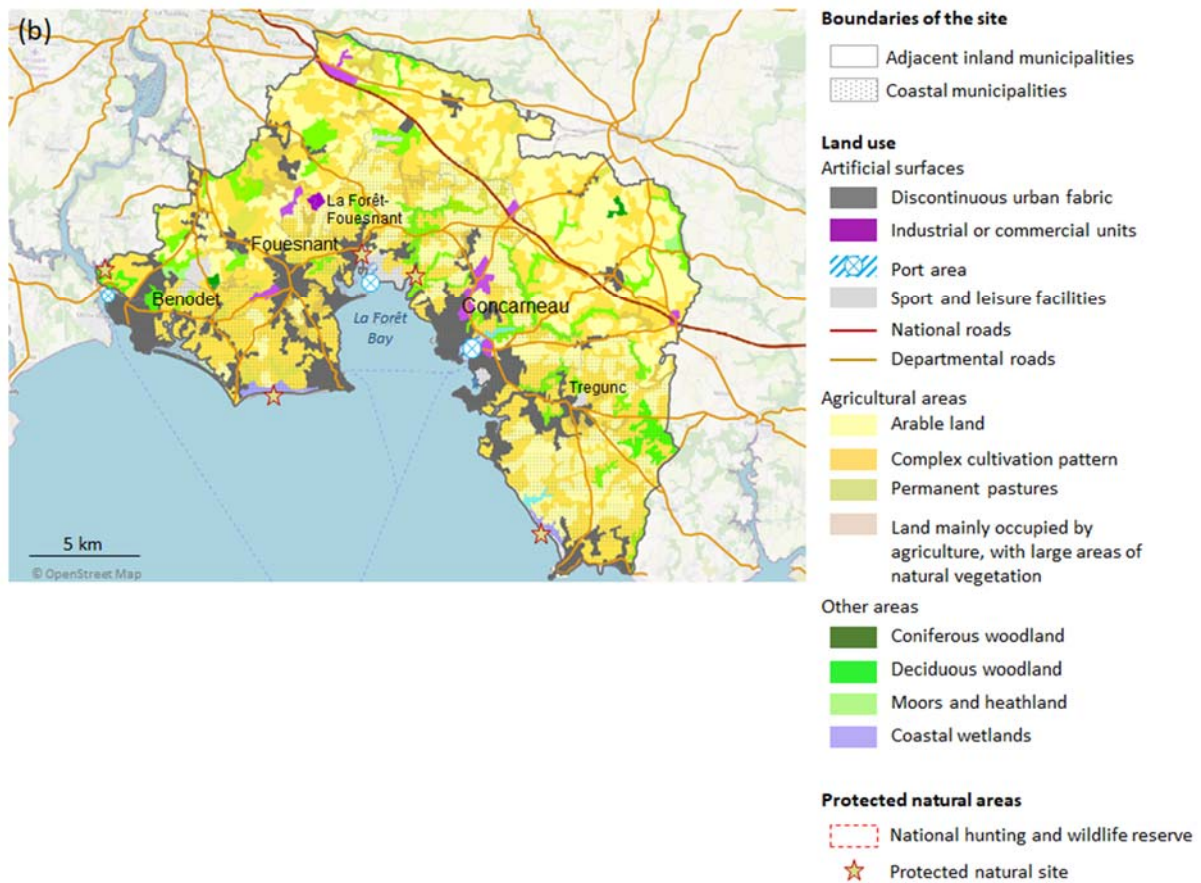
256 We deepened this approach for two of the five study sites (La Forêt Bay and Rhuys Peninsula, Fig.1)
257 using experiments that aimed to answering specific research questions: at La Forêt Bay, we organised
258 public workshops, to collect contrasting visions and concerns about changes in coastal farming, to
259 assess their social visibility and degree of legitimacy. At Rhuys Peninsula, we performed a quali-quantitative

260 agronomic survey of 25 farmers, to compare inland and coastal farming systems, changes, constraints
261 and opportunities in relation to farming modernization, residentialization and tourism (Parnaudeau et
262 al., 2020).

263 La Forêt Bay covers more than 283 km² and includes 10 municipalities, 5 of which are coastal (54% of
264 the site's area), while The Rhuys Peninsula covers 398 km² and includes 18 municipalities, 12 of which
265 are coastal (68% of the site's area), and 5 of which are on the peninsula itself. As touristic and peri-
266 urban areas, these two sites were those that experienced highest pressures on farming.

267 Finally, we developed a typology of coastal farming systems in Brittany, from this multi-scale research.





277

278 **Fig. 2.** Land use (Corine Land Cover classification), main roads and natural areas of the sites of (a) Rhuys
 279 Peninsula and (b) La Forêt Bay in Brittany

280

281

282 **3 Results**

283 **3.1 Farming characteristics in coastal and inland areas of Brittany**

284 *3.1.1. Overview of farming types and dynamics at the regional scale*

285 According to our definition, coastal areas cover 18% of Brittany, and include 244 of its 1,249
 286 municipalities. Agriculture has been a traditional activity in coastal areas, associated with specific land
 287 tenures and multiple activities (Laligant, 2008, Charpentier, 2013), and still holds an important place.

288 However the percentage of their area covered by agriculture is smaller than that inland (Table 1). In
289 2010, agriculture covered 45% and 62%, respectively, of coastal and inland municipalities in Brittany.
290 A similar pattern was observed at the national scale, at which agriculture covered 30% and 58% of
291 coastal and inland areas, respectively.

292 As generally observed at regional and national scales today, coastal areas in Brittany had less
293 agricultural area, lower farm density, and a lower percentage of employment in the agricultural sector
294 than inland areas from 1988-2010 (Table 1). In contrast, dynamics of coastal farming in Brittany
295 differed little from those of inland farming (Table 1): the density of farms decreased dramatically and
296 the percentage of area covered by farms also decreased. Farmland in coastal areas represented 14.5%
297 of the total agricultural area in Brittany in 1988 and 13.7% in 2010; on average, agricultural area on
298 the coast in Brittany did not decrease much faster than that inland. Some coastal municipalities,
299 however, gradually lost their agricultural aspect. Over the same period, mean farm size increased.
300 Employment in the agricultural sector has decreased in both coastal and inland areas since 1968, and
301 the decrease was greatest from 1975-2009 (Table 1).

302 Types of farming systems changed little from 2000-2010 in both coastal and inland areas of Brittany,
303 but they differed significantly between the areas ($p < 0.001$). The two dominant farm types in most
304 coastal areas were similar to those inland (Fig. 3) – “mixed granivore” (i.e. pigs and poultry) and
305 “mixed crop-livestock” – which together represented 47% and 87% of farms in coastal and inland
306 areas, respectively. However, the dominant farming types in coastal areas were more diverse than
307 those inland. Crop production, which represented 17% of farms in coastal areas but only 5% inland,
308 included farming types that were present only in coastal areas: flowers and horticulture, cereals and
309 field-grown vegetables. Moreover, fewer farms in coastal areas had livestock in 2010 than those
310 inland: 29% and 45%, respectively, had dairy cattle, and 11% and 16%, respectively, had pigs.

311

312 Table 1. Comparison of agricultural indicators of inland and coastal municipalities in Brittany in 1988, 2000 and 2010.

	1988			2000			2010		
	Inland	Coastal	P-value	Inland	Coastal	P-value	Inland	Coastal	P-value
Utilized agricultural area (%)	66	52	p<0.001 ^a	64	48	p<0.01 ^b	62	45	p<0.001 ^a
Farm size (ha)	20	16	p<0.001 ^a	34	29	p<0.001 ^a	49	41	p<0.001 ^a
Farm density (km ⁻²)	3.4	3.2	p<0.001 ^a	1.9	1.6	p<0.001 ^a	1.3	1.1	p<0.001 ^a
Employment in the agricultural sector (% of total employment)	44	27	p<0.001 ^a	34	20	p<0.001 ^a	26	15	p<0.001 ^a
Density of agricultural employment (equivalent full time. km ⁻²)	4.7	5.2	p<0.001 ^a	2.7	2.9	p<0.001 ^a	2.0	2.4	p<0.001 ^a
Proportion of farms with dairy cattle (%)	-	-	-	46	33	p<0.001 ^a	45	29	p<0.001 ^a

313 ^a Wilcoxon rank-sum test

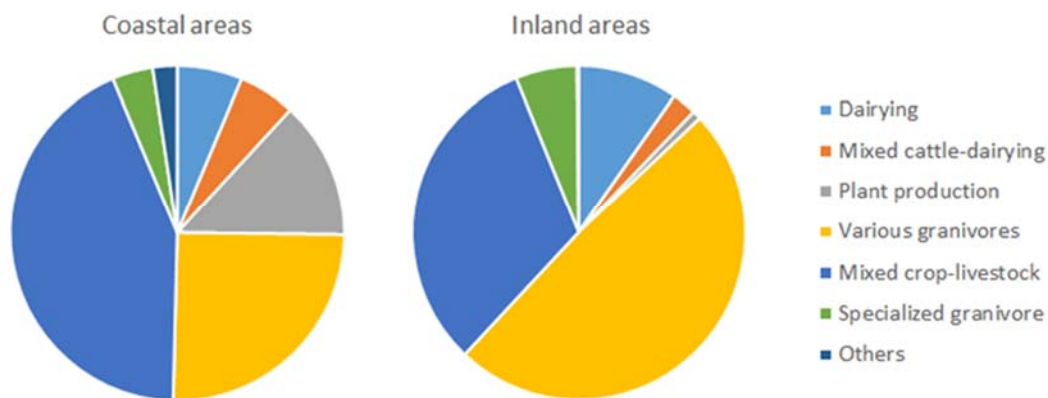
314 ^b Student's t-test

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319

320 **Fig. 3.** Distribution (%) of the dominant farming type in coastal and inland areas in Brittany in 2010.

321 Farming types were defined according to French definitions of the European Union farm typology
 322 (OTEX).

323

324

325 *3.1.2. Intense pressures on farming activities on the coast*

326 In Brittany, 36% of its inhabitants lived in coastal municipalities in 2014, twice the density of inland
 327 municipalities (256 inhabitants.km⁻²). The population has increased by 21% in coastal municipalities
 328 since 1968. Even in 1968, however, coastal municipalities had higher population density than those
 329 inland (Table 2). From 1968-2014, the population increased less in coastal municipalities than in inland
 330 municipalities, where some of the population growth was due to development of the Rennes
 331 metropolitan area, the capital and largest city of Brittany. From 1968-2014, the population of 28% of
 332 coastal municipalities even decreased. Coastal municipalities contributed 35% of Brittany's population
 333 growth from 1968-1975 but only 7.3% from 2009-2014. The population of coastal areas has aged, with
 334 a higher percentage of people over 60 than that of inland areas since the early 1990s: in 2014, 32% of
 335 inhabitants were over 60 in coastal areas vs. 24% in inland areas. On average, the natural change since
 336 2007 has been negative in coastal areas but positive in inland areas (adjacent or not). Population
 337 growth on the coast is now due to net migration.

338 In addition, the percentage of urban or other artificial area in coastal municipalities increased by 88%
339 over the past 40 years: from 10% in 1977 to 18% in 2000 (compared to 9.2% in inland municipalities in
340 2000) (DREAL, 2008; Chamseddine and Dupont, 2013). However, adjacent inland municipalities had
341 the largest increase in land take from 2011-2016: +0.93%, compared to +0.70% in coastal and other
342 inland municipalities (DREAL Bretagne, 2017).

343 Concerning the natural environment, the land-sea interface contains many natural or semi-natural
344 environments such as marshes, estuaries, wetlands and dunes. At the national scale, 45% of land in
345 coastal municipalities is classified as a natural area or wetland and 36% is classified as protected. In
346 Brittany, 10% of land in coastal municipalities is classified as protected, as is more than 75% of the
347 coastline. Many regulatory frameworks coexist for managing and conserving natural marine and
348 coastal areas (e.g. sensitive natural areas, listed and classified sites, acquisitions of the “Conservatoire
349 du Littoral” (coastal conservation agency), marine protected areas, regional natural parks), and they
350 involve many stakeholders.

351 Thus, given the dynamics of land take and the need to conserve natural areas, coastal areas have
352 limited space and strong pressure on land. According to CESER Bretagne (2017), mean prices of
353 developable land on the coast in Brittany’s departments of Ille-et-Vilaine and Morbihan are similar to
354 those in its city centres, which leads less wealthy and first-time buyers to reside in adjacent inland
355 areas. Finally, coastal areas are attractive for economic activities, especially tourism. The coast is now
356 the primary travel destination in France, and tourism represents 50% of the coastal economy (Gaspar
357 database, [https://www.data.gouv.fr/fr/datasets/base-nationale-de-gestion-assistee-des-procedures-
358 administratives-relatives-aux-risques-gaspar/](https://www.data.gouv.fr/fr/datasets/base-nationale-de-gestion-assistee-des-procedures-administratives-relatives-aux-risques-gaspar/)).

359

360 Table 2. Demographics of inland and coastal municipalities in Brittany from 1968-2014.

Year	Population		Population density		Natural change	
	(inhabitants)		(inhabitants.km-2)		(inhabitants. year ⁻¹)	
	Inland	Coastal	Inland	Coastal	Inland	Coastal
1968	1,460,028	969,872	89.7	235.1	-	-
1975	1,551,340	1,021,870	94.3	236.4	-	-
1982	1,643,320	1,042,368	99.1	236.2	-	-
1990	1,703,589	1,072,410	102.3	239.6	-	-
1999	1,778,187	1,110,442	106.9	242.9	-	-
2004	-	-	-	-	6865	185
2005	-	-	-	-	6605	-370
2006	-	-	116.3	253.4	8004	30
2007	-	-	117.8	254.3	7247	-512
2008	-	-	119.1	255.9	7660	-605
2009	1,990,647	1,162,001	120.5	255.8	7483	-1363
2010	-	-	121.8	255.3	7192	-1261
2011	-	-	122.9	255.1	7540	-1882
2012	-	-	123.9	255.3	5934	-2118
2013	-	-	124.7	255.4	5696	-2820
2014	2,103,380	1,170,875	125.7	255.8	5480	-2412

361

362

363

364 *3.1.3. Diversity of agricultural traits on the coast*

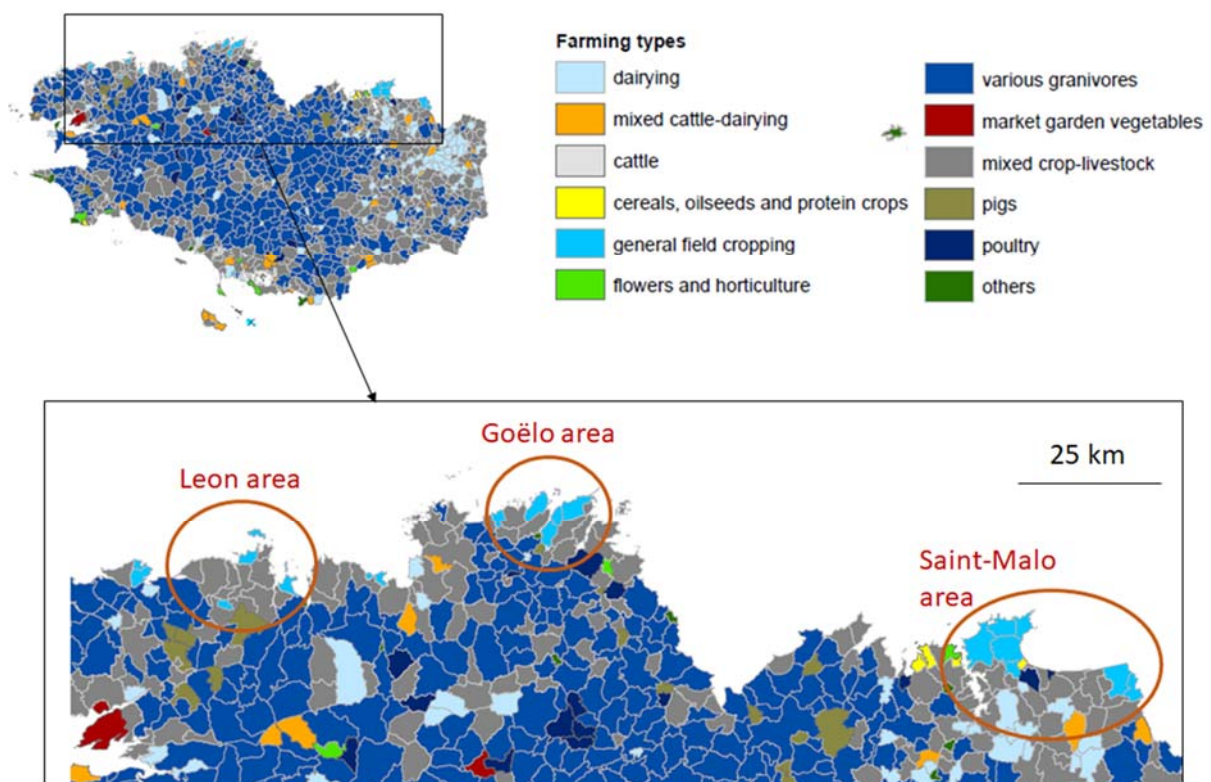
365 Based on the data at the municipality scale, the types and dynamics of agriculture varied along the
366 Breton coastline. A striking example appeared on the northern coast, where coastal municipalities with
367 a dominant farming type highly specific to the coastal environment alternated with coastal
368 municipalities with a dominant farming type similar to that of inland municipalities (Fig. 4). Specific
369 types of production are grouped into 'general field cropping' in the OTEX typology at the municipal
370 scale. They corresponded to field-grown vegetables, which are grown only in three areas of the
371 northern coast: (1) from Saint-Malo to the western edge of the Bay of Mont-Saint-Michel (lat. +48.67,
372 long. -1.88), (2) the Goëlo area between Plouha and Lannion (lat. +48.80, long. -3.07) and (3) the Léon
373 area around Roscoff (lat. +48.72, long. -3.98). These production areas are spatially distinct and extend
374 ca. 20-40 km along the coast and 10 km inland. Vegetable production in these areas benefits from the
375 local combination of favourable environmental conditions caused by the sea: mild weather with low
376 variability in temperature and no negative temperatures; deep, well-drained soils formed from aeolian
377 loess deposits; and available calcareous amendments from the coast. Vegetable production developed
378 and organized its professional sector after 1945 and remains dominant. Coastline sections with
379 dominant farming types similar to those inland include municipalities around Lieue de Grève Bay,
380 which lies midway between two vegetable-production areas, where the dominant farming type is dairy
381 production.

382 The Breton coast thus consists of alternating sections of farming types, some related to the coastal
383 context and some not. This high diversity results from three main factors, all of which depend on
384 coastal conditions, but in different ways. The first factor is the maintenance of historically coast-
385 specific systems, such as field-grown vegetable production, which took advantage of modernization in
386 the 1950s to transform favourable local environmental conditions into a set of socio-political resources
387 with leverage at key moments of negotiations at national and EU scales. This factor remains important
388 today, even though current production – strawberries and tomatoes around the city of Brest (lat.:
389 +48.3897, long: -4.48333 48) and early field-grown vegetables on the northern coast – is now largely
390 free from these local edaphic conditions. The second factor is the persistence of dairy cattle and

391 granivores in coastal areas where the development of tourism has been limited either by local
392 representatives and people or by the distance from urban centres and transport routes. The third
393 factor results from statistical uncertainty: a farm typology based on fewer farms in coastal
394 municipalities tends to vary and, on the coast, the residential economy favours ornamental crop
395 production. Thus, the diversity of coastal agriculture appears to depend greatly on socio-historical
396 processes, which implies considering demographic, organizational and local-development dimensions
397 when addressing the scales of description and analysis of current farming dynamics.

398

399



400

401 **Fig. 4.** Diversity of farming types along the northern coast of Brittany and location of field-grown
402 vegetable production areas (classified as "general field cropping").

403

404 **3.2 Beyond the regional scale: from local-scale spatial analysis to identification of emerging**
405 **coastal-agricultural configurations**

406

407 *3.2.1. Quantitative approach to farming dynamics at the research sites*

408 *3.2.1.1. La Forêt Bay*

409 The La Forêt Bay site is located in a peri-urban area: 7 municipalities west of the site are located in the
410 urban area of Quimper (127,500 inhabitants in 2015 in an area of 605 km²) and are classified as outer
411 suburbs of a large urban centre. Two municipalities of the site are located in the medium-sized urban
412 area of Concarneau (26,088 inhabitants in an area of 92 km²) (Fig. 2). According to the OTEX typology,
413 agricultural production was based on intensive livestock farming. In 2010, the site's dominant farming
414 types were 'mixed granivore' in inland areas and 'mixed crop-livestock' in coastal areas. These farming
415 systems are strongly connected to the food industry located inland of the site. Although the site's
416 coastal areas contained livestock, its inland areas had higher livestock density. Livestock density at the
417 site decreased from 1988-2010 from 114 to 59 livestock units.km⁻² in coastal areas and from 172 to 143
418 livestock units.km⁻² inland. It decreased mainly from 1988-2000 in coastal areas but from 2000-2010
419 inland. In 2010, farm density was 0.9 and 1.0 farms.km⁻² in coastal and inland areas, respectively. The
420 number of farms in the site's coastal and inland areas decreased by 52% and 41%, respectively, from
421 1988-2000, and by 28% and 33%, respectively, from 2000-2010. Mean farm size nearly doubled from
422 1988-2010, growing from 19 to 37 ha in coastal areas and from 21 to 54 ha inland. Employment in the
423 agricultural sector decreased strongly in coastal areas from 34% of total employment in 1968 to 7% in
424 2014.

425 The site's coast has a strong tourism and residential appeal. In 2014, its mean population density was
426 209 inhabitants.km⁻². Its population has increased almost constantly since 1968, with a mean increase
427 of 425 inhabitants.year⁻¹ from 1968-2014. Population growth was similar in coastal and inland
428 municipalities, with the latter having half the population density. The population has remained nearly

429 constant since 2006, has aged in all municipalities of the site, and is older in coastal municipalities,
430 which are highly touristic. They have long contained many second homes, whose density is still
431 increasing: from 20 km⁻² in 1968 to 75 km⁻² in 2014 in coastal areas, compared to from 1 to 5 km⁻²,
432 respectively, inland. Overall, 31% and 7% of residences were second homes on the coast and inland,
433 respectively. The site also has strong marine activities at three fishing and leisure ports. In addition to
434 these artificial areas, the site has a high concentration of outstanding natural sites within the 500 m
435 coastal strip (e.g. dunes, marshes, coastal wetlands, coves) that are subject to protective regulations
436 (Fig. 2).

437

438 3.2.1.2. *Rhuys Peninsula*

439 The Rhuys Peninsula is located in a peri-urban area: 9 municipalities west of the site are located in the
440 urban area of Vannes (150,860 inhabitants in 2015 in an area of 756 km²) and are classified as outer
441 suburbs of a large urban centre. Sarzeau (lat. +47.527°, long. -2.768°), the largest municipality of the
442 peninsula itself, is classified as a small urban centre (< 15,000 inhabitants). In 2010, the site's dominant
443 farming types were 'mixed granivore' in inland areas and 'mixed crop-livestock' in coastal areas. The
444 site's inland areas had higher livestock density. Livestock density decreased at the site from 2000-2010,
445 especially that of granivores (from 22% to 3% of farms for broilers, and from 10% to 4% of farms for
446 pigs). While cattle farming remained stable in the site's inland areas from 2000-2010, it decreased in
447 its coastal areas due to the closure of certain farms and the end of cattle farming on other farms
448 (Parnaudeau et al., 2020).

449 The site's inland municipalities had a slightly higher farm density than its coastal ones, and both
450 densities were close to the national average (1.1 and 0.8 farms km⁻², respectively). The number of
451 farms decreased from 1988-2010. In 2010, two municipalities no longer had any farms, and the lowest
452 densities were on the peninsula itself, where the remaining farms also had the smallest mean size

453 among the study sites (i.e. 41 ha (nearly a twofold increase since 1988), compared to 62 ha inland (a
454 threefold increase)).

455 Rhuys is a major site of coastal tourism in Brittany. Its population has increased constantly since 1968,
456 with coastal municipalities contributing 78% of population growth from 1975-1999 and 85% from
457 1999-2009. At the same time, its coastal population aged due to the peninsula's attractiveness for
458 retirement, while young households increasingly tended to settle inland due to the increasing price of
459 property on the coast. In 2014, second homes represented half of the residences in coastal
460 municipalities, which also contained most of the tourism facilities. The service sector has expanded
461 greatly and continuously since 1968. The coastal municipalities stand out by their low percentage of
462 agricultural and industrial employment (22% in 2014). All of the site's municipalities have been part of
463 a regional natural park since 2014, and a wide range of nature-conservation measures apply to the
464 coastal zone, which includes protected areas (Fig. 2). Overall, statistical indicators showed a classical
465 coast-inland gradient, with high demographic and land pressures, due to seasonal tourism and
466 rurbanization, that gradually decreased from the coast to inland areas. They also showed that because
467 most coastal areas are now devoted to marine activities, nature conservation and urban densification,
468 adjacent inland municipalities increasingly share these trends.

469

470

471

472 *3.2.2. Internal dynamics at the research sites: emergent dynamics of farming faced with a*
473 *combination of pressures in attractive coastal areas*

474 These two study sites were marked by the same historical trend: a significant decline in traditional
475 farming activities from 1980-2010. They share a history of early development of seaside tourism, which
476 led local authorities to focus on developing tourism infrastructure. However, during the Green

477 Revolution of the 1960s-1970s, their trajectories diverged. Most of the Rhuys Peninsula remained
478 excluded from the modernization of farming and massive land consolidation programmes of the 1970s-
479 1980s, due to problems of access and relatively poor soils. At the same time, La Forêt Bay was split up:
480 the urban-development plans implemented by coastal municipalities gradually relegated cultivated
481 land and pasture to their inland limits. However, as the site was located near the main regional roads
482 and strongly connected to inland areas, an agro-industrial nexus developed at the inland edge of its
483 coastal municipalities that covered all major regional production sectors (e.g. meat processing and
484 distribution, storage of fertilisers and livestock feed), along with a specific development of vegetable-
485 canning factories.

486 At both sites in the 1980s, rural families still performed marginal farming practices on salt marshes and
487 coastal wetlands, such as cattle grazing and harvesting of marine amendments. Nevertheless, small
488 coastal farms gradually closed, and their fields were purchased by larger farms. Since 2010, residential
489 attractiveness has continued to increase due to persistent tourism development and rurbanization, as
490 both sites lie close to a coastal urban centre. Consequently, farms have disappeared from
491 municipalities at both sites (or nearly so, $n < 5$) since then. Unlike the 2000-2010 period, however, this
492 phenomenon is not due mainly to continued land take, but rather to a change in the use of land and
493 buildings, which representatives at both sites highlighted during interviews as being characteristic of
494 2010-2020.

495 At the La Forêt Bay site, the spatial indicators showed that non-artificial areas (i.e. pasture on salt
496 marshes, immediately behind the dune belt, on overhanging cliffs and in estuaries) next to the coastal
497 strip (> 500 m) are now managed mainly in line with environmental objectives, under a variety of
498 property and contractual laws, such as ownership by the "Conservatoire du Littoral" and the signing of
499 farming protocols (11 out of 53 km of coastline). Social surveys allowed us to investigate dynamics of
500 this "first front" further. First, they showed that farming protocols were not very attractive to farmers.
501 Besides following the legal and contractual regulations, the remaining conventional dairy farmers

502 tended to adapt their practices on coastal fields in line with more general and cumulative public
503 pressures. For instance, they tended to remove cows from coastal pastures due to increasing difficulty
504 in accessing these pastures, but also out of fear of disturbance and complaints. Consequently, they
505 tended to manage coastal fields as mown grasslands where possible and highlighted their growing
506 dilemma about whether to grow maize or annual cash crops in the most fertile of these fields because
507 of a perceived criticism of fertilization practices and pesticide use in them.

508 Revegetation of the coast also results from the development of new farming systems, which, in
509 contrast, take advantage of a high degree of entanglement with coastal activities: the first front is
510 immediately followed by – and sometimes merged with – a movement towards establishing small and
511 diverse organic market-garden farms connected to local distribution networks (e.g. open-air markets,
512 smallholder associations). These farming systems often suffer from poor edaphic conditions but
513 benefit from favourable climatic ones, which demonstrates partial freedom from biophysical
514 constraints due to the attractiveness of the coastal zone to both new farmers and the general
515 population. Most of these farms are located in coastal municipalities on small (< 2 ha), intensively
516 cultivated fields that are often not adjacent to the farmer's home.

517 Adjacent inland and other inland municipalities now contain most family livestock farms, most of which
518 are dairy farms. These municipalities are located in catchments where specific measures to capture
519 non-point-source pollution apply: since La Forêt Bay experiences severe coastal eutrophication due to
520 nutrient inputs, its farmers are concerned by coastal dynamics, even though some of them stated that
521 they do 'not see much of the sea', due to family habits and the need to stay on the farm to take care
522 of cattle. Nonetheless, according to the dairy farmers interviewed, the observed difficulties and decline
523 in the number of farms were due more to the overall dynamics of the agricultural sector than to local
524 conditions. Indeed, the inland area of the site contains mainly larger conventional farms, which lie near
525 the main regional road and agro-industrial units. This road marks a virtual boundary beyond which

526 coastal influences tend to be less detectable from biophysical, agronomic, social-relation and
527 governance perspectives.

528

529

530 *3.2.3. Capturing diversity at the local scale: typology of coastal agricultural configurations*

531 The multi-scale analysis of agriculture and the analysis of pressures at the local scale, based on a
532 qualitative-quantitative approach, as illustrated for two study sites, allowed us to identify four distinct
533 coastal-agricultural configurations in Brittany (Table 3). These four configurations show the specific
534 spatial extent of coastal farming and shape the typical spatial patterns of the transition from coastal
535 to inland farming.

536 *Configuration 1 – Dynamic rural coasts, with specialized and speculative crop production*

537 This configuration includes the three vegetable-production areas on the northern coast of Brittany. As
538 mentioned, specific coastal climate and local pedological conditions are favourable for field-grown
539 vegetable production. Because this combination of environmental conditions exists only close to the
540 sea, field-grown vegetable production is concentrated in the first few km from the coastline, and
541 agricultural production differs greatly from that inland. In addition, agriculture has long been
542 specialized here, taking advantage of the combination of positive social-economic factors (e.g. export
543 of early vegetables to the southern coast of Britain) and a favourable balance of power. Indeed, the
544 vegetable sector was one of the first agro-food sectors to organize itself at the end of the 1950s, by
545 building simultaneously on the strong organization of unions, producers and the economy (auction
546 markets) to market the products efficiently (Canevet, 1992). These organizations enabled producers
547 to benefit from wide access to commercial markets early on and to position themselves at national
548 and international scales. This marketing also benefitted from the development of transportation
549 infrastructure in Brittany in the 1970s, especially the national road network and deep-water ports. The
550 sector's dynamism had a knock-on effect that contributed greatly to development of the economy and

551 the northern coast from the 1960s to the 1980s. These areas are subject to land take, urbanization and
552 tourism pressure, but these pressures are lower than those on the southern coast and are
553 concentrated in well-defined areas, next to ports and in the first few hundred metres from the
554 coastline. As observed more generally, the amount of agricultural land has decreased, but large areas
555 are still cropped with vegetables and, due to the increase in yields, production has remained constant.
556 To date, the sector has been able to rely on its strong organization to adapt to new production
557 constraints (e.g. markets, regulations) and to develop innovations for production systems (e.g.
558 development of organic systems, improvement in crop varieties) and the distribution network.

559 A smaller example of this configuration is Plougastel-Daoulas (lat. +48,371°, long. -4.371°), a coastal
560 peninsula and municipality to the south of Brest, whose cultivation of strawberries developed strongly
561 after a marine officer imported them there from Chile in the 18th century, providing evidence of the
562 multiple ways in which the proximity of harbours and coastal infrastructure can influence the
563 emergence and lasting establishment of new production systems (Le Bouëdec, 2009). Strawberry
564 production developed to such an extent that from the 1920s to 1950s, the municipality was the
565 second-largest area of strawberry production in France (Wilhelm, 1974), and it remains active today.
566 Located in a sheltered spot, it depends greatly on chemical inputs and most of it is integrated into
567 major agro-industrial firms and international markets.

568 This configuration also includes the coastal strip around Audierne Bay (lat. +47.841°, long. -4.341°),
569 where bulb-flower production developed in the 1980s. The bay's sandy deposits and the mild climate
570 are favourable to bulb growth and early harvesting. Agricultural production there is strongly related to
571 coastal environmental conditions, is highly specialized, depends on a speculative organized sector and
572 differs from the type of farming inland. In contrast to field-grown vegetable production, its historical
573 anchorage is weaker, and its environmental impacts are strongly criticized by local NGOs, as flowers
574 are produced directly in coastal marshes of high natural value.

575 *Configuration 2 – Dynamic rural coasts, with high and mixed pressures*

576 This configuration is found in the central-to-western section of the southern coast, in the Finistère
577 department. At the municipality scale, farming types are similar to those observed inland: 'mixed
578 granivore' or 'mixed crop-livestock'. However, gradients in the farming systems were observed at a
579 smaller spatial scale. The coastal zone is characterized by the abandonment of agricultural land and
580 the establishment of alternative farming systems, especially in the past 10 years. From the coast inland,
581 these alternative farming systems gradually transition to conventional systems that are typical of
582 inland farming and connected to the agro -food industry. Agricultural development started in these
583 areas before elsewhere in Brittany: from 1919-1939 , agriculture was already dynamic and relatively
584 intensive, and family farms produced livestock, forage crops and vegetables on the same farm. By the
585 sea, the existence of industrial infrastructure for fish canning supported early development of the agro-
586 food industry from 1930-1950, thus adding value to the local farm production (vegetables). In addition,
587 these areas have been attractive and have experienced high residential and tourism pressures since
588 the 1900s. This pressure, combined with the general agricultural crisis, has resulted in a gradual decline
589 in conventional coastal farming and drives the gradual transition in spatial pattern of farming types
590 observed recently.

591 *Configuration 3 - Rural coasts, with non-coast-specific farming types and strong environmental*
592 *pressures*

593 This configuration is found outside major seaside tourist sites and large coastal urban centres. It is
594 subject to low land take and tourism pressures. Its farming types are not driven by coastal climate or
595 edaphic conditions, even though farmers are used to considering them. The farming types, most of
596 them family farms, differ little from those inland in their main types of production: 'mixed crop-
597 livestock', 'mixed granivore' or 'mixed cattle-dairying'. Agricultural dynamics, such as the decrease in
598 agricultural area and number of farms, are similar to those observed inland. However, this
599 configuration is subject to strong environmental pressures related to the vulnerability of coastal
600 environments to non-point-source pollution and nutrient run-off. Environmental pressures have
601 intensified since the mid-1990s with the increased occurrence of green tides. They have led to changes

602 in and adaptation of farming practices designed to reduce nutrient loss from agricultural areas into the
603 river network (Gascuel et al., 2015). This pressure to decrease environmental impacts of agriculture is
604 exerted throughout coastal catchments, which are the units in which water quality is managed.
605 However, the pressure in catchments increases from inland to the sea (Levain et al., 2015), which
606 results in continuity between inland and coastal farming, with a similar increase in the greening of farm
607 practices from inland to the sea.

608 The extent to which farming practices can be adapted depends on the dominant farming types in
609 catchments. In the Lieue de Grève catchments on the northern coast (lat. +48.656°, long. -3.629°),
610 where agriculture historically specialized in dairy production in the 1950s, farming practices have been
611 adapted mainly to decrease fertilization of forage crops and convert areas of silage maize to grassland.
612 The same environmental pressures do not produce the same effects at sites dominated by confined
613 granivore production, such as around Douarnenez Bay (lat. +48.124°, long. -4.217°). The environmental
614 performance of such systems has long been and is still oriented towards technical performance,
615 upscaling of farming infrastructure and the avoidance of contact and neighbouring disamenities.
616 Maintaining such systems involves gaining and maintaining active political support and resources, so
617 that urban-planning decisions and tourism development do not interfere with the dominant techno-
618 economic orientations. In this context, environmental pressures tend to increase the potential for
619 social conflicts, and farming is often a polarizing issue in local political arenas.

620 *Configuration 4 - Post-rural dynamic coasts, with high and mixed pressures*

621 This configuration is observed mainly on the south-western coast of the Morbihan department on
622 touristic peninsulas, and on Breton islands. This configuration corresponds to coastal areas where
623 agriculture (livestock or mixed crop-livestock systems) modernized relatively late because they were
624 isolated and disconnected from the main transport networks. Multiple activities were also common in
625 these areas. In addition, they are attractive areas that have experienced high residential and tourism
626 pressures since the 1900s and have a high natural value. The landscapes can be composed of both
627 highly urbanized and semi-natural areas. Agriculture is therefore faced with strong competition for

628 land and declines strongly. It has disappeared completely in some locations, such as the Quiberon
629 Peninsula (lat. +47.486°, long. -3.119°). In other locations, such as the Rhuys Peninsula, a dynamic
630 towards the establishment of new farms has emerged, composed of alternative farming systems (e.g.
631 small-scale, sustainable, organic) associated with associative commitments and cultural activities.
632 Development of these multi-functional and local-market-oriented farming systems is aligned with local
633 policies regarding development of attractive coastal areas. In this configuration, agriculture either does
634 not exist or is marginal, but acquires a high heritage value, and in this way is closely related to the
635 coastal context. Its spatial extent inland is limited to the coastal strip and partly checked by the growth
636 of urban centres. It contrasts greatly to conventional inland farming.

637 **Table 3** Overview of the four types of coastal-farming configurations identified along the Breton coast.

Type of coastal-farming configuration	Coastal farming systems				Pressures		
	Dependence of production on the coastal environment	Dependence of agro-food sector on the coastal location	Current dynamics*	Spatial pattern of transition to inland farming	Residential attractiveness	Tourism attractiveness	Environment
Dynamic rural coast, with specialized and speculative crop production	High	High	Continuation	Sharp edge	Moderate	Moderate	Moderate
Dynamic rural coast, with high and mixed pressures	Low	High	Gradual decline and emergence of alternatives	Gradual change	High	High	High
Rural coast with non-coast-specific farming	Low	Low	Continuation	Gradual change	Moderate	Low	High

types, and strong
environmental pressures

Post-rural dynamic coast, with high and mixed pressures	Low	Low	Strong decline with emergence of alternatives	Sharp edge	High	High	High
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638 * Specific local dynamics, besides the general decline of agriculture observed at the national scale.

639

640

641 **4 Discussion**

642 **4.1 From coastal farming to coastal-interface farming**

643 Based on the qualitative-quantitative analysis of agricultural and pressure descriptors at the regional
644 scale of Brittany, it is clear that coastal farming exists as a category of its own, distinct from inland
645 farming. The macro-scale analysis, which considered coastal municipalities as a whole, enabled us to
646 identify and compare the main characteristics of coastal farming to those of inland farming: coastal
647 farming systems are more diverse, their decline is more apparent, and they are faced with highly
648 interacting pressures that challenge their activities, eventually leading to the end of many family farms
649 over the past 10 years. Yet, static analysis of the dominant farming types in a region as a function of
650 distance from the coastline is not sufficient to characterize coastal farming. Coastal areas must be
651 considered not only as an environment with specific biophysical conditions but also as a territory in
652 which multiple pressures interact. Considering multiple temporal and spatial scales is also necessary
653 to identify specific characteristics of coastal farming. The current configurations of coastal farming
654 indeed result not only from current pressures, but also from these pressures' long-term dynamics. A
655 similar variety of local and regional/global drivers and interactions among them has been described
656 for agriculture at the rural-urban interface (Soulard et al., 2018; Perez-Belmont et al., 2021).

657 Our analysis thus calls for considering coastal agricultural interactions as a specific form of hydro-social
658 spatial configuration, that is, a specific and situated assemblage “of people, institutions, water flows,
659 hydraulic technology and the biophysical environment that revolve around the control of water”
660 (Boelens et al., 2016). This concept, originally created to address freshwater systems, is expanded here
661 to coastal waters, considered as a scarce resource connected to the complex network of social-
662 environmental interactions that help shape agriculture's traits and trajectory.

663 The mixed method we applied was key to address complex and multi-scale rural coastal interactions
664 and interdependencies and to refine understanding of the specific dynamics of farming activities along

665 the coast-inland gradient. The typology of local-scale configurations ultimately reveals an appropriate
666 method for (1) considering the diversity of local assemblages and (2) improving the quality of
667 description by building on fine-scale analysis of social and ecological components of a dynamic system,
668 while developing the potential for generic description and further comparison. This research shows
669 that qualitative analysis not only compensated for limits of the temporal and/or spatial scales of the
670 statistical indicators, but also provided specific accounts, hypotheses and interpretation guidance
671 when designing exploratory research of an under-documented topic. We thus consider this
672 combination as a significant avenue for future improvement of transformative pressure analysis.

673 Relevant integrated approaches could be tested to further develop the analysis of coastal farming
674 systems and of their dynamics. These approaches include social-ecological frameworks (Ostrom 2009;
675 Collins et al., 2011), which offer a high level of conceptualization of coupled social-environmental
676 interactions and can support a multi-disciplinary analysis of the pressures at work. These frameworks
677 have already been applied to farming system analysis (e.g. Moraine et al. 2017). To our knowledge,
678 they have not been tested much against qualitative empirical data and little applied to farming in
679 interface areas (Piso et al., 2019), but they may have the potential to further capture the complexity
680 of the interactions involved in agricultural-coastal configurations and to structure the spatiotemporal
681 dynamics. In addition, integrated analysis of the farming systems such as agrarian diagnosis (Devienne
682 and Wybrecht, 2002) or biotechnical farming system analyses (Parnaudeau et al., 2020), could also be
683 applied to further analyse the internal logics of the farms and their drivers.

684

685 **4.2 Towards a typology of coastal-interface farming systems**

686 In this case study, we identified no farming system that depends only on biophysical conditions found
687 by the sea. Specific systems that often develop in lowland coastal areas (e.g. rice cultivation in coastal
688 marshes (Verhoeven and Setter, 2010), salt-meadow lamb breeding, machairs) can be found in other
689 areas and still exist locally in western France. Field-grown vegetable production and horticulture

690 benefit from favourable edaphic and climatic conditions near the sea but can be found in other
691 locations. Coastal farming consists mainly of farming systems that are not specific to the coast but that
692 are influenced by the combination of opportunities and tensions there. The temporal dynamics of
693 coastal farming thus appear to be essential criteria for differentiating coastal agricultural
694 configurations. The configurations we analysed were either inherited from old processes or resulted
695 from continual changes in long-lasting systems, associated or not with the emergence of new farming
696 systems.

697 Whether ancient, reinterpreted or recent, and whether specific to the coast or not, maintaining most
698 of these systems requires strong support from local policies, such as the creation of public land
699 reserves, access to housing and suitable farming infrastructure for farmers in highly attractive areas,
700 development of local food labels and policies, contractualization of food supplies, access to pasture on
701 coastal marshes, organizing the reception of visitors, as well as wetland and water management. The
702 timing and multiple constraints of such local agricultural policies decrease their effectiveness in a
703 context in which few farms can simultaneously claim historical legitimacy, long-term presence and the
704 production of social and environmental amenities, and in which the contribution of farming to local
705 economic development has become marginal due to the drastic decrease in the number of workers
706 and the local supply of goods and services.

707 Finally, in the four configurations we have identified, the same kind of pressures are involved: coastal
708 farming is confronted to urbanization and nature protection, i.e protection of the sea itself and/or
709 renaturation of the coastal strip. The four configurations of coastal farming identified today result
710 however from differential spatio-temporal dynamics of these two pressure fronts, with more or less
711 early progress of these fronts, and complex coupling / decoupling dynamics. Thus, the effects of such
712 pressures need to be addressed by fully considering complex interactions between agriculture, land
713 planning and the clear ecologization observed in coastal areas. The complex combination of pressures
714 eventually lead to the marginalization or even disappearance of agriculture in coastal territories,

715 making them “post-rural” in the sense that classical material typologies based on land use,
716 organization of social interactions and major development drivers are not as effective as that they
717 were previously (Gallent and Gkartzios, 2019). In these areas, maintaining farming activities by the sea
718 involves many social actors in reinventing new forms of rurality (Dupé et al. 2021).

719 In our analysis, we have considered that the boundary of the sea, i.e the third front, was fixed in space.
720 In the future, we may wonder about the need to take into account the possible mobility of this front,
721 with the rising of the sea level, and also in interaction with coastal risk management policies as a
722 balancing item. Indeed, in many depolderization or managed retreat plans (Goeldner-Gianella and
723 Imbert, 2005), rural areas and populations generally endorse the main consequences of renaturation
724 projects (see for instance, for the case of the Sundarbans: Jalais and Mukhopadhyay, 2020).

725

726

727 **4.3 Policy recommendations**

728 The four configurations defined, however, do not require or respond equally to the same types of
729 policy mechanisms. Local management of agricultural multi-functionality in high-stake areas, which is
730 often based on implementing environmental legislation of the EU, thus needs to address preservation
731 of local food production as a goal in itself. The main issue to address is the risk of stochastic shock,
732 which, given the still high rate of decline of small and medium-sized conventional family farms, can
733 lead to farm-free areas due to combined pressures, which can lead to a tipping point with no real
734 opportunity to relocate food production.

735 But, in urban planning in coastal and retro-coastal areas, the implementation of the net-zero-
736 urbanization principle, which should severely limit artificialization and land use changes, is far from
737 being achieved on the Atlantic coasts of France. Existing pressures still challenge farmland preservation
738 and relocation of food production areas within in coastal areas. Rather, effective implementation of
739 net-zero-urbanization could contribute to the development of small-scale farming systems in coastal

740 areas, where they can also benefit from short-chain markets and/or legacy from coast-specific systems
741 with a high heritage value. Combining net-zero-urbanisation with an active land-reserve policy is also
742 necessary to anchor family farms, especially cattle and dairy farms, in coastal municipalities to allow
743 for diversification strategies and avoid development of wasteland due to the complexity of managing
744 cattle in fragmented and distant fields. On this matter, as several case studies of this study show, the
745 boundary between natural protected areas and farm fields is instrumental to managing farmland
746 continuity and promoting multi-functional farming. In coastal areas, land planning policies should be
747 combined with specific support for the maintenance of light farm infrastructures, such as those
748 associated with market gardening and pastures. Finally, preserving and developing farming activity in
749 coastal areas also implies helping farmers that have no family connection to establish farms; more
750 generally, it involves a pro-active lodging policy to guarantee local housing for farmers and seasonal
751 workers.

752 Such recommendations largely concur with those suggested in rural-urban interfaces (e.g., Nixon and
753 Newman, 2016). However, the diversity of coastal configurations implies managing continuities and
754 porosities at a high spatial resolution. Thus, it requires adapting the articulation of policies and their
755 spatial declination to the specificities of local coastal configurations in terms of spatio-temporal
756 organization of farming activity and pressures. Additionally, the rapidly evolving land availability and
757 exposition to coastal hazards due to sea-level rise should support the emergence of flexible shoreline
758 management, eventually favourable to sustainable coastal farming emergence and maintenance.

759 Thus, our research calls for a mixture of land use and policy that addresses both food production and
760 coastal stewardship by working simultaneously on two spatial fronts. In this regard, emerging local
761 food plans provide unprecedented opportunities to help support farming in coastal areas.

762

763

764 **5. Conclusions**

765 We tested the hypothesis that coastal farming, at the land-sea interface, had specific traits. We
766 developed our research from a case study of Brittany, which has a strong land-sea interface as a
767 peninsula and is an EU leader in agricultural production. Coastal agriculture emerged as a relevant
768 category of analysis. Based on multi-scale analysis of pressures on agriculture and their coast-inland
769 gradient, we highlighted distinct coastal agricultural configurations along the Breton coast. These
770 configurations are characterized by the spatial extent of coastal farming and spatial patterns in the
771 transition to inland farming. Our study highlights the importance of combining qualitative and
772 quantitative data to address the complexity of coastal social-ecosystem configurations and the utility
773 of adding temporal depth to the analysis to more fully capture and understand the diversity of the
774 coastal agricultural configurations currently observed. This study lays the foundations for deeper study
775 of coastal agricultural social-ecosystems and ways of structuring public policies towards improved local
776 management of agricultural multi-functionality.

777

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785

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