Farming by the sea: A qualitative-quantitative approach to capture the specific traits of coastal farming in Brittany, France

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Highlights

- Coastal farming is a relevant category of analysis of farming systems.
- A greater diversity of farming systems exists in coastal strip than inland at the regional scale.
- Four configurations of coastal farming were identified, which result from distinct dynamics and combinations of urbanization and environmental pressures on agriculture
- Qualitative -quantitative analysis, with temporal depth, is essential to understand and fully capture the complexity of coastal-farming configurations.

Abstract

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

Keywords

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

1 Introduction

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

In the first, coastal areas are considered as specific biophysical environments that farming activities impact or that provide concrete support for farming activities. Thus, abundant literature discusses agriculture through its positive or negative impacts on the integrity of coastal ecosystems. This literature is published in environmental or ecological sciences and focuses on integrated coastal zone management. The contribution of agriculture to an excessive input of phosphorus and nitrogen to the aquatic compartment and its consequences on water quality (Jordan et al., 1997, Lee and Song, 2007, Stuart, 2010, Soy-Massoni et al., 2016, Li et al., 2017) and on the biodiversity of marine ecosystems (Perilla et al., 2012, Kroon et al., 2014, Petersen et al., 2018) have received much focus and are well-documented worldwide, especially in coastal areas vulnerable to anthropogenic eutrophication (Pinay et al., 2019). The literature also highlights the impact of agricultural intensification on habitat change and subsequent biodiversity loss of species restricted to coastal marshes (Butet and Leroux, 2001), as well as, conversely, the key role of specific agricultural practices, such as extensive grazing, in preserving biodiversity in coastal wetlands (Yanez-Arancibia et al., 1999). In this literature, the coast is regarded as a continuous space, whose spatial extent is defined by biophysical processes (e.g. coastal catchments, ecological continuities), with an emphasis on biophysical features of the environment. Agriculture is considered as an activity that puts pressure on the ecosystem. Some of this literature however focuses on the influence of specific environmental conditions of coastal areas, such as climate (Aggarwal and Kalra, 1994, Baguskas et al., 2018) and soil and water salinity (Yan et al., 2013), on farming systems and their productivity, due to the proximity of the sea. This literature emphasises farming activities themselves. Some characteristics of the biophysical environment of coastal areas are considered as forcing pressures on agriculture. Often only one of these characteristics is considered at a time, and its spatial extent determines the width of the coastal zone. The relationship between agriculture and the coastal environment has changed over time with changes in agricultural techniques, but also with climate change (Hadley, 2009). Agriculture is thus increasingly studied with regard to its vulnerability to environmental conditions in a changing climate , such as rising sea level (Kaniewski et al., 2016, Hasan et al., 2018), tidal storms (Durant et al., 2018), soil salinization (Helton et al., 2014, Bless et al., 2018), and their effects on farm viability and food security. Recent studies also address climate change and effects on coastal areas, which may offer new opportunities for diversifying crop production by taking advantage of increasing regional temperature. For instance, conditions in north-western France, considered limiting for viticulture in the past, could become favourable for growing grapevine (Neethling et al. 2019) or help consolidate marginal systems (Bedrani & Landré, 2020). The first planting initiatives are observed on the coasts, which not only have warmer temperatures than before, allowing grapevine to grow, but also fewer frosts as compared to the inland areas.

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

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

In this paper, we analysed whether, as observed in other interface areas, farming by the sea is a special system that shows similarities among all coastal areas and thus differentiates it from inland farming. The specific objectives were (1) to identify the characteristics and diversity of farming types by the sea, and (2) to capture their spatial patterns (e.g. continuity along the coastline, inland extent). We performed the study in Brittany, a peninsula in western France that has 2730 km of coastline, and is one of the leading agricultural production regions of France and the European Union (EU). We developed a multi-scale approach: we provide a comprehensive view of farming systems by the sea and pressures at the regional scale from easily available statistical information; and we developed site-specific qualitative-quantitative approach to deeply investigate the spatio-temporal dynamics of coastal farming in relation with the pressures it undergoes. Finally, we propose a typology of coastal farming in Brittany.

2 Materials and methods

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

2.1 Contrasting coastal farming to inland farming at the scale Brittany

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

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

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

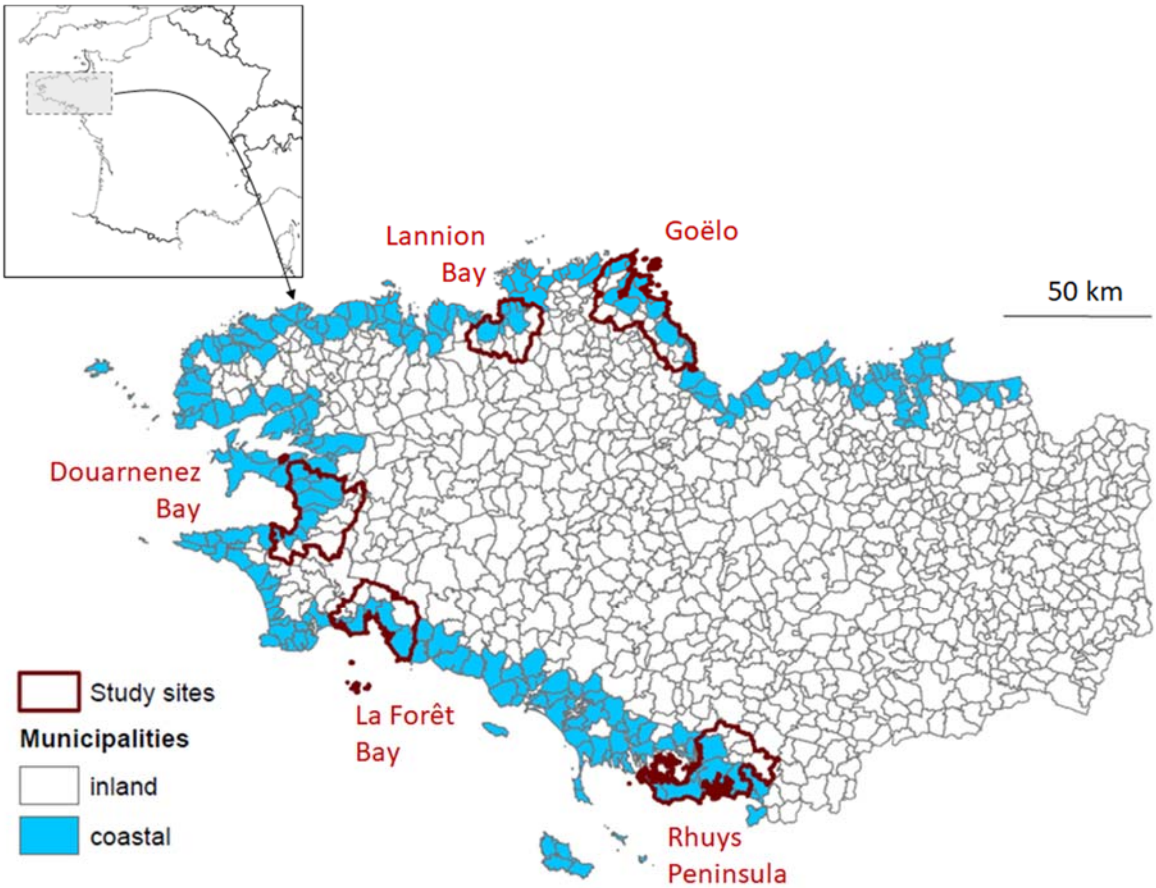


Fig. 1. Identification of coastal municipalities in Brittany and locations of the study sites.

To characterize farming systems and their dynamics, we used readily available datasets from French national statistical databases at the municipal scale (http://geowww.agrocampus-ouest.fr/mviewer/?config=/apps/parchemins/parchemins.xml). We relied mainly on detailed data from the French National Service for Agricultural Statistics (Agreste). Statistical indicators of agricultural employment and the number and size of farms came from the national agricultural census now performed every 10 years. We used its data from 1988, 2000 and 2010. We compared mean values for coastal areas to those for inland areas using two-sample Student's *t*-tests, or when data did not meet the assumption of normality according to the Shapiro-Wilk test, two-samples Wilcoxon rank-sum tests. Differences were considered significant at $p < 0.05$. We mapped the spatial distribution of the indicators at the regional scale, and how they changed from 1988-2010. Types of farming systems were defined using the French definition of the EU typology of economic configurations of farming systems (OTEX) at the municipal scale, in 2000 and 2010. We compared the types of farming systems in coastal and inland areas using chi-squared tests. In addition, to describe pressures placed on agriculture in coastal and inland areas, we used quantitative demographic statistical indicators from the French National Institute for Statistical and Economic Studies (INSEE). These were derived mainly from the national general population census using data collected every 5-10 years since 1968 (Table 2). We also used regional datasets for land use (DREAL Bretagne, 2008), land take (DREAL Bretagne, 2017) and natural areas (https://www.geoportail.gouv.fr/thematiques/developpement-durable-energie/espaces-proteges).

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

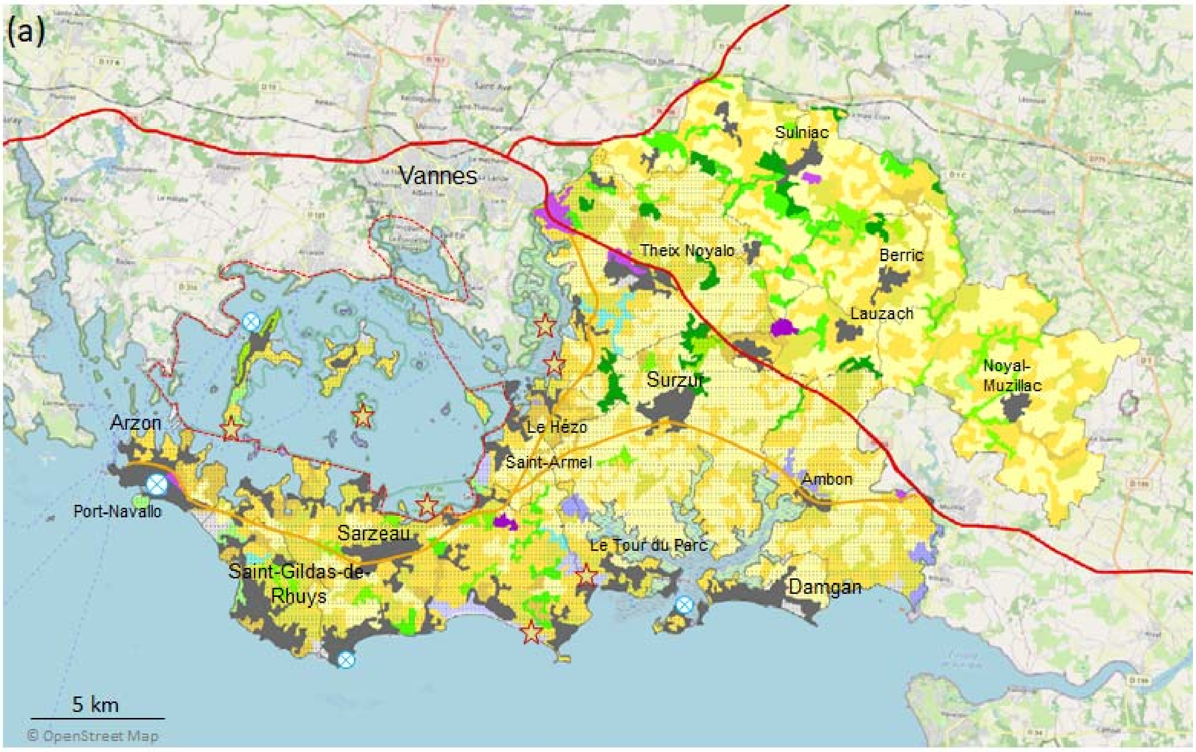
Due to the age and scales of the available statistics, however, not all specific features and emergent dynamics of coastal farming could be detected using these indicators at the regional level. First, these indicators were available mainly by municipality, which left many infra-municipal trends invisible. The complex land-sea interactions in which agricultural trajectories are embedded remained largely hidden, as did possible gradients along the land-sea continuum within municipalities. Indeed, many coastal municipalities extend inland for more than 5-8 km from the coast. We assumed that a coastal municipality includes a gradient of forcing pressures, which usually includes biophysical thresholds (e.g. salinity, thermal amplitude, loess, precipitations) and social thresholds (e.g. seaside tourism, urban and other artificial areas, sea-related industries and services, protected areas for nature conservation). Second, most agricultural indicators dated to 2010, when the most recent agricultural census had been performed. As drivers of the generally rapid decline in the number of coastal farms and farmers had changed little since then, agriculture in these territories might have decreased to a critical level. But the social visibility of such tipping points, the existence of individual and collective adaptation strategies of farmers, or the contrasting ability of farming systems to withstand this general trend had rarely been investigated. Previous surveys in France (ONML, 2013) and qualitative surveys in Brittany (Levain, 2014), however, provided evidence that relatively similar biophysical contexts could have very different development patterns and dominant farming types, which called for considering farming systems in their specific local socio-historical contexts.

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

We deepened this approach for two of the five study sites (La Forêt Bay and Rhuys Peninsula, Fig.1) using experiments that aimed to answering specific research questions: at La Forêt Bay, we organised public workshops, to collect contrasting visions and concerns about changes in coastal farming, to assess their social visibility and degree of legitimacy. At Rhuys Peninsula, we performed a quali-quanti agronomic survey of 25 farmers, to compare inland and coastal farming systems, changes, constraints and opportunities in relation to farming modernization, residentialization and tourism (Parnaudeau et al., 2020).

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

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



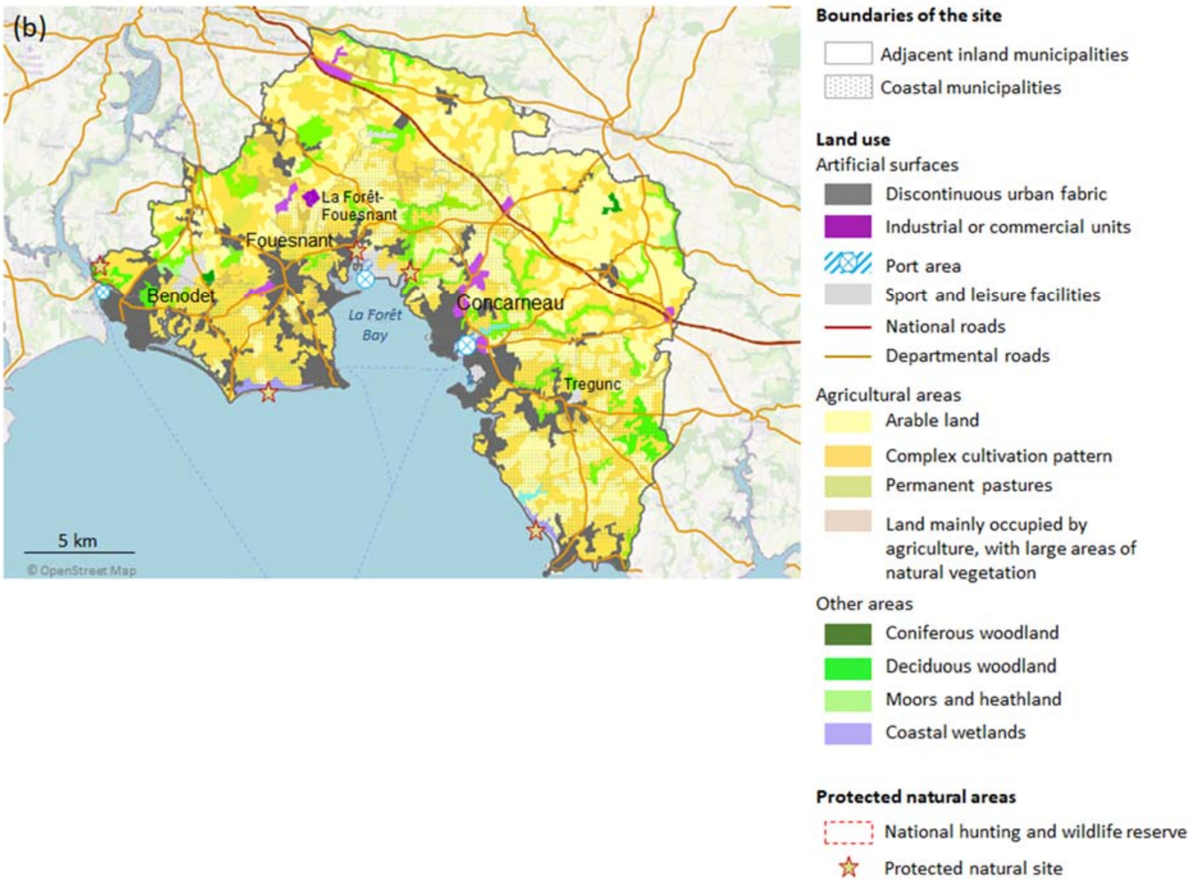


Fig. 2. Land use (Corine Land Cover classification), main roads and natural areas of the sites of (a) Rhuys Peninsula and (b) La Forêt Bay in Brittany

3 Results

3.1 Farming characteristics in coastal and inland areas of Brittany

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

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

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

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

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

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]

[a] Wilcoxon rank-sum test

[b] Student's t-test

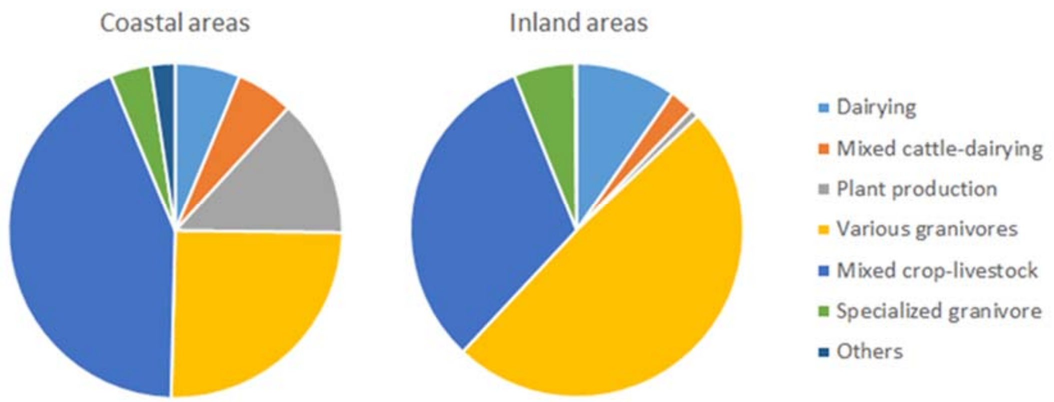


Fig. 3. Distribution (%) of the dominant farming type in coastal and inland areas in Brittany in 2010. Farming types were defined according to French definitions of the European Union farm typology (OTEX).

3.1.2. Intense pressures on farming activities on the coast

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

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

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

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

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

Year	Population (inhabitants)		Population density (inhabitants.km-2)		Natural change (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

3.1.3. Diversity of agricultural traits on the coast

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

The Breton coast thus consists of alternating sections of farming types, some related to the coastal context and some not. This high diversity results from three main factors, all of which depend on coastal conditions, but in different ways. The first factor is the maintenance of historically coast-specific systems, such as field-grown vegetable production, which took advantage of modernization in the 1950s to transform favourable local environmental conditions into a set of socio-political resources with leverage at key moments of negotiations at national and EU scales. This factor remains important today, even though current production – strawberries and tomatoes around the city of Brest (lat.: +48.3897, long: -4.48333 48) and early field-grown vegetables on the northern coast – is now largely free from these local edaphic conditions. The second factor is the persistence of dairy cattle and granivores in coastal areas where the development of tourism has been limited either by local representatives and people or by the distance from urban centres and transport routes. The third factor results from statistical uncertainty: a farm typology based on fewer farms in coastal municipalities tends to vary and, on the coast, the residential economy favours ornamental crop production. Thus, the diversity of coastal agriculture appears to depend greatly on socio-historical processes, which implies considering demographic, organizational and local-development dimensions when addressing the scales of description and analysis of current farming dynamics.

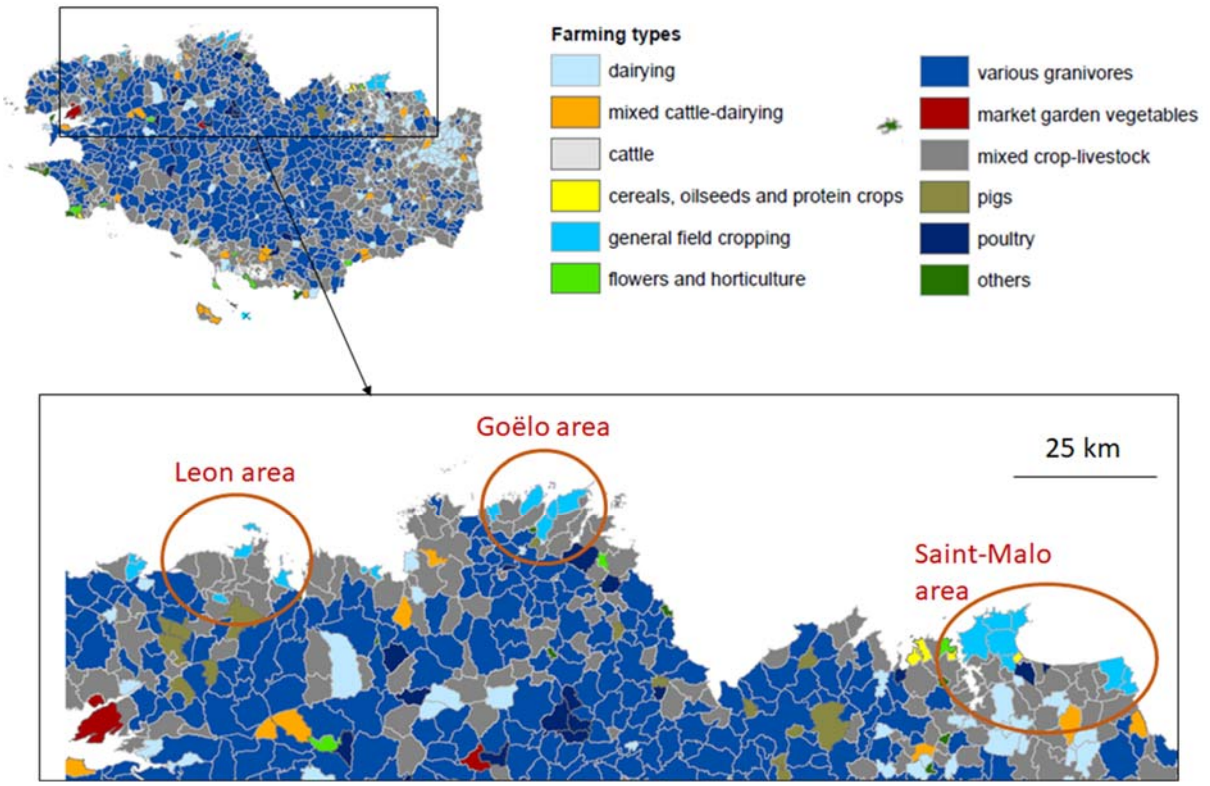


Fig. 4. Diversity of farming types along the northern coast of Brittany and location of field-gown vegetable production areas (classified as “general field cropping”).

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

3.2.1. Quantitative approach to farming dynamics at the research sites

3.2.1.1. La Forêt Bay

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

The site's coast has a strong tourism and residential appeal. In 2014, its mean population density was 209 inhabitants.km^{-2}. Its population has increased almost constantly since 1968, with a mean increase of 425 inhabitants.year^{-1} from 1968-2014. Population growth was similar in coastal and inland municipalities, with the latter having half the population density. The population has remained nearly constant since 2006, has aged in all municipalities of the site, and is older in coastal municipalities, which are highly touristic. They have long contained many second homes, whose density is still increasing: from 20 km^{-2} in 1968 to 75 km^{-2} in 2014 in coastal areas, compared to from 1 to 5 km^{-2}, respectively, inland. Overall, 31% and 7% of residences were second homes on the coast and inland, respectively. The site also has strong marine activities at three fishing and leisure ports. In addition to these artificial areas, the site has a high concentration of outstanding natural sites within the 500 m coastal strip (e.g. dunes, marshes, coastal wetlands, coves) that are subject to protective regulations (Fig. 2).

3.2.1.2. Rhuys Peninsula

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

The site's inland municipalities had a slightly higher farm density than its coastal ones, and both densities were close to the national average (1.1 and 0.8 farms km^{-2}, respectively). The number of farms decreased from 1988-2010. In 2010, two municipalities no longer had any farms, and the lowest densities were on the peninsula itself, where the remaining farms also had the smallest mean size among the study sites (i.e. 41 ha (nearly a twofold increase since 1988), compared to 62 ha inland (a threefold increase)).

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

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

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

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

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

At the La Forêt Bay site, the spatial indicators showed that non-artificial areas (i.e. pasture on salt marshes, immediately behind the dune belt, on overhanging cliffs and in estuaries) next to the coastal strip (> 500 m) are now managed mainly in line with environmental objectives, under a variety of property and contractual laws, such as ownership by the "Conservatoire du Littoral" and the signing of farming protocols (11 out of 53 km of coastline). Social surveys allowed us to investigate dynamics of this "first front" further. First, they showed that farming protocols were not very attractive to farmers. Besides following the legal and contractual regulations, the remaining conventional dairy farmers tended to adapt their practices on coastal fields in line with more general and cumulative public pressures. For instance, they tended to remove cows from coastal pastures due to increasing difficulty in accessing these pastures, but also out of fear of disturbance and complaints. Consequently, they tended to manage coastal fields as mown grasslands where possible and highlighted their growing dilemma about whether to grow maize or annual cash crops in the most fertile of these fields because of a perceived criticism of fertilization practices and pesticide use in them.

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

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

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

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

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

This configuration includes the three vegetable-production areas on the northern coast of Brittany. As mentioned, specific coastal climate and local pedological conditions are favourable for field-grown vegetable production. Because this combination of environmental conditions exists only close to the sea, field-grown vegetable production is concentrated in the first few km from the coastline, and agricultural production differs greatly from that inland. In addition, agriculture has long been specialized here, taking advantage of the combination of positive social-economic factors (e.g. export of early vegetables to the southern coast of Britain) and a favourable balance of power. Indeed, the vegetable sector was one of the first agro-food sectors to organize itself at the end of the 1950s, by building simultaneously on the strong organization of unions, producers and the economy (auction markets) to market the products efficiently (Canevet, 1992). These organizations enabled producers to benefit from wide access to commercial markets early on and to position themselves at national and international scales. This marketing also benefitted from the development of transportation infrastructure in Brittany in the 1970s, especially the national road network and deep-water ports. The sector’s dynamism had a knock-on effect that contributed greatly to development of the economy and the northern coast from the 1960s to the 1980s. These areas are subject to land take, urbanization and tourism pressure, but these pressures are lower than those on the southern coast and are concentrated in well-defined areas, next to ports and in the first few hundred metres from the coastline. As observed more generally, the amount of agricultural land has decreased, but large areas are still cropped with vegetables and, due to the increase in yields, production has remained constant. To date, the sector has been able to rely on its strong organization to adapt to new production constraints (e.g. markets, regulations) and to develop innovations for production systems (e.g. development of organic systems, improvement in crop varieties) and the distribution network.

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

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

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

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

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

This configuration is found outside major seaside tourist sites and large coastal urban centres. It is subject to low land take and tourism pressures. Its farming types are not driven by coastal climate or edaphic conditions, even though farmers are used to considering them. The farming types, most of them family farms, differ little from those inland in their main types of production: ‘mixed crop-livestock’, ‘mixed granivore’ or ‘mixed cattle-dairying’. Agricultural dynamics, such as the decrease in agricultural area and number of farms, are similar to those observed inland. However, this configuration is subject to strong environmental pressures related to the vulnerability of coastal environments to non-point-source pollution and nutrient run-off. Environmental pressures have intensified since the mid-1990s with the increased occurrence of green tides. They have led to changes in and adaptation of farming practices designed to reduce nutrient loss from agricultural areas into the river network (Gascuel et al., 2015). This pressure to decrease environmental impacts of agriculture is exerted throughout coastal catchments, which are the units in which water quality is managed. However, the pressure in catchments increases from inland to the sea (Levain et al., 2015), which results in continuity between inland and coastal farming, with a similar increase in the greening of farm practices from inland to the sea.

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

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

This configuration is observed mainly on the south-western coast of the Morbihan department on touristic peninsulas, and on Breton islands. This configuration corresponds to coastal areas where agriculture (livestock or mixed crop-livestock systems) modernized relatively late because they were isolated and disconnected from the main transport networks. Multiple activities were also common in these areas. In addition, they are attractive areas that have experienced high residential and tourism pressures since the 1900s and have a high natural value. The landscapes can be composed of both highly urbanized and semi-natural areas. Agriculture is therefore faced with strong competition for land and declines strongly. It has disappeared completely in some locations, such as the Quiberon Peninsula (lat. +47.486°, long. -3.119°). In other locations, such as the Rhuys Peninsula, a dynamic towards the establishment of new farms has emerged, composed of alternative farming systems (e.g. small-scale, sustainable, organic) associated with associative commitments and cultural activities. Development of these multi-functional and local-market-oriented farming systems is aligned with local policies regarding development of attractive coastal areas. In this configuration, agriculture either does not exist or is marginal, but acquires a high heritage value, and in this way is closely related to the coastal context. Its spatial extent inland is limited to the coastal strip and partly checked by the growth of urban centres. It contrasts greatly to conventional inland farming.

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

* Specific local dynamics, besides the general decline of agriculture observed at the national scale.

4 Discussion

4.1 From coastal farming to coastal-interface farming

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

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

The mixed method we applied was key to address complex and multi-scale rural coastal interactions and interdependencies and to refine understanding of the specific dynamics of farming activities along the coast-inland gradient. The typology of local-scale configurations ultimately reveals an appropriate method for (1) considering the diversity of local assemblages and (2) improving the quality of description by building on fine-scale analysis of social and ecological components of a dynamic system, while developing the potential for generic description and further comparison. This research shows that qualitative analysis not only compensated for limits of the temporal and/or spatial scales of the statistical indicators, but also provided specific accounts, hypotheses and interpretation guidance when designing exploratory research of an under-documented topic. We thus consider this combination as a significant avenue for future improvement of transformative pressure analysis.

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

4.2 Towards a typology of coastal-interface farming systems

In this case study, we identified no farming system that depends only on biophysical conditions found by the sea. Specific systems that often develop in lowland coastal areas (e.g. rice cultivation in coastal marshes (Verhoeven and Setter, 2010), salt-meadow lamb breeding, machairs) can be found in other areas and still exist locally in western France. Field-grown vegetable production and horticulture benefit from favourable edaphic and climatic conditions near the sea but can be found in other locations. Coastal farming consists mainly of farming systems that are not specific to the coast but that are influenced by the combination of opportunities and tensions there. The temporal dynamics of coastal farming thus appear to be essential criteria for differentiating coastal agricultural configurations. The configurations we analysed were either inherited from old processes or resulted from continual changes in long-lasting systems, associated or not with the emergence of new farming systems.

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

Finally, in the four configurations we have identified, the same kind of pressures are involved: coastal farming is confronted to urbanization and nature protection, i.e protection of the sea itself and/or renaturation of the coastal strip. The four configurations of coastal farming identified today result however from differential spatio-temporal dynamics of these two pressure fronts, with more or less early progress of these fronts, and complex coupling / decoupling dynamics. Thus, the effects of such pressures need to be addressed by fully considering complex interactions between agriculture, land planning and the clear ecologization observed in coastal areas. The complex combination of pressures eventually lead to the marginalization or even disappearance of agriculture in coastal territories, making them “post-rural” in the sense that classical material typologies based on land use, organization of social interactions and major development drivers are not as effective as that they were previously (Gallent and Gkartzios, 2019). In these areas, maintaining farming activities by the sea involves many social actors in reinventing new forms of rurality (Dupé et al. 2021).

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

4.3 Policy recommendations

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

But, in urban planning in coastal and retro-coastal areas, the implementation of the net-zero-urbanization principle, which should severely limit artificialization and land use changes, is far from being achieved on the Atlantic coasts of France. Existing pressures still challenge farmland preservation and relocation of food production areas within in coastal areas. Rather, effective implementation of net-zero-urbanization could contribute to the development of small-scale farming systems in coastal areas, where they can also benefit from short-chain markets and/or legacy from coast-specific systems with a high heritage value. Combining net-zero-urbanisation with an active land-reserve policy is also necessary to anchor family farms, especially cattle and dairy farms, in coastal municipalities to allow for diversification strategies and avoid development of wasteland due to the complexity of managing cattle in fragmented and distant fields. On this matter, as several case studies of this study show, the boundary between natural protected areas and farm fields is instrumental to managing farmland continuity and promoting multi-functional farming. In coastal areas, land planning policies should be combined with specific support for the maintenance of light farm infrastructures, such as those associated with market gardening and pastures. Finally, preserving and developing farming activity in coastal areas also implies helping farmers that have no family connection to establish farms; more generally, it involves a pro-active lodging policy to guarantee local housing for farmers and seasonal workers.

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

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

5. Conclusions

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

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