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Spatio-temporal analysis of ecclesiastical constructions in the northern half of the Iberian Peninsula (10th-13th centuries)

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EDITOR'S NOTE

Historique
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1. Introduction : the Petrifying Wealth project and its database

1 The boom in construction with non-perishable materials that took place in Europe in the first centuries of the 2nd millennium is a well-documented fact, closely linked to the genesis and development of feudal society. The European Petrifying Wealth project addresses this phenomenon through a large-scale analysis, covering Iberia, Italy and the south of France, between 1050 and 1300[1]. This phenomenon implied a structural transformation of the entire society and led to the birth of a new and long-lasting panorama that entailed the creation of new individual, collective and regional identities[2]. Through the project's bibliography, it is possible to access multiple studies that analyze the various factors and actors that led this complex process[3].

2 Carrying out the project has involved handling different types of sources, from the construction remains themselves to geographical, bibliographical and documentary contextual data. Following the EU mandate to publish open access scientific data[4], a relational database that can be accessed through the project website has been

developed to integrate, manage and disseminate this information[5]. For this spatial database, a conceptual model has been built that allows integrating information from diverse datasets and disciplines, such as architecture, archaeology, epigraphy or documentary sources.

3 Several years of work on the design, implementation and filling of the database have resulted in an extensive and standardised dataset that, despite all the gaps that still remain to be solved, can be considered representative of the construction phenomenon over the 11th to 13th centuries. As of December 2022, the database contains 20 422 building records, of which 10 318 have been analysed, at least in terms of the required core data, including location, basic chronology, typology and fundamental parts. Gathering and handling the information has involved designing data management plans[6] that give a detailed description of both the sources used and the structure of the information itself[7].

4 This article deals with a specific part of this dataset, specifically all those buildings from which we have been able to extract the required information to address the analysis, resulting in a homogeneous list for the entire study area. This is the base for a large-scale analysis on the distribution of medieval buildings across the northern half of Iberia, within the Petrifying Wealth project.

5 This kind of research shares characteristics with others, such as the CARE [*Corpus Architecturae Religiosae Europae*] Project, focused on Catalonia and the Balearic Islands[8] or the Col&Mon Project, focused on France[9].

6 Like the aforementioned projects, Petrifiying Wealth has established a work model that seeks to be completed over time, completing the dataset and trying other research lines. For now, the architectural record and its formal analysis make up our basic knowledge source for a systematic and large-scale research about building activity. But there are other sources, such as written documents or archaeological data, with a promising contribution.

7 It is the case of some archaeological studies developed in the last decades, mainly in some specific areas of Iberia. For example, several excavations in Early Medieval sites in the of province of Álava, in the Basque Country[10], suggest that later building boom is not an « ex novo » process, but it develops upon a preceding village network. In fact, where there is archaeological evidence of early medieval churches, it is verified that these have been built within existing villages[11]. In addition, there are also some villages without a church and others with several. Therefore, although one can assume a certain relationship between demographic growth and building phenomenon – see for example Sánchez Pardo for the case of Galicia[12] –, this is not so straightforward.

8 In parallel, also in the Álava territory, archaeological analysis of architectural elements has revealed early chronologies in many buildings, between 9th and 11th centuries. This indicates that, at least in this area, the documented buildings would not always be new, but would have replaced earlier ones[13].

9 In the same way, documentary studies show a multitude of references about non-preserved buildings, with unknown characteristics and imprecise location in many cases. In the case of Galicia, Sánchez Pardo recovered 682 references prior to the year 1000[14]. This researcher and the Petrifying Wealth project have collaborated comparing these references against the database of preserved buildings, and we have

only registered 134 matches, of which uniquely 6 have fabrics that can be dated before year 1000.

10 Despite these cautions, we consider that the buildings dataset used in this article is representative enough. In this regard, it is worth mentioning the analyses carried out by Nicolas Perreaux[15], who, from the buildings collected in the work *La nuit des temps* from the Zodiaque editions, suggests the likely correlation between the density of buildings and the production of written documentation. The results obtained by this author are very close to the analysis of building density developed in the present study.

11 This work intends to address a long-term social process, in the same line as, for example, the study of the configuration of the parish network in Touraine (France) by Élisabeth Zadora-Rio[16], which is in turn framed within the « inecclesiamento » notion formulated by Michel Lauwers[17]. At the same time, local phenomena are also considered, such as the « sagreras » formation in Catalonia[18], the « Comunidades de Villa y Tierra » between the Duero river and the Central System[19], the formation of the Kingdom of Asturias[20] or the Carolingian Catalonia counties[21], or the development of the « Camino de Santiago » (Way of St James) in northern Iberia[22].

12 The aim of this study is analyzing the geographical distribution, and its chronological evolution, of High Middle Ages buildings in the northern half of the Iberian Peninsula[23], testing if it is a homogeneous phenomenon or, on the contrary, shows different patterns and trends depending on regions. By means of several spatial and statistical analyses, we intend to offer a first large-scale and long-term approximation to this historical process and, also, establish a framework in which more fine-grained approaches can be embedded, attending to local and short-term dynamics.

2. Objective and data

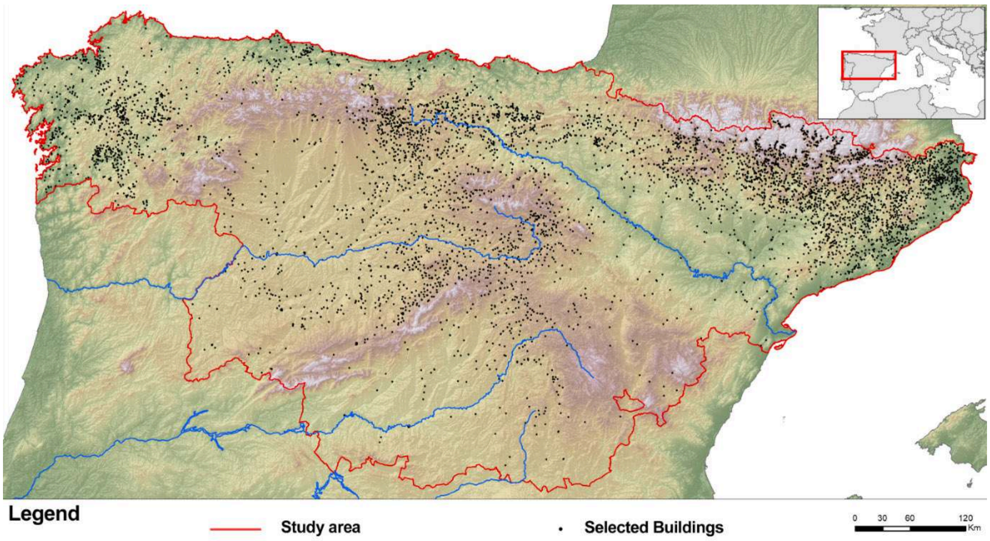
13 This article is the result of the collaboration between the Petrifying Wealth project and the Laboratory of Landscape Archaeology and Remote Sensing (LabTel) of the CSIC Institute of History. It aims to use information from the project's database to analyse the spatial distribution patterns and evolution over time of construction in non-perishable materials in the northern half of the Iberian Peninsula between the 10th and 13th centuries. In terms of the chronology project, the previous century is included to consider any buildings that are known to have already been standing, and which could therefore have influenced the construction process, mainly for the construction of new buildings.

14 For this purpose, a subset of buildings was selected according to the following criteria :

- They are only ecclesiastical buildings ;
- Only buildings that materially preserve, at least partially, the construction phase that can be assigned to the period of interest (900-1300) ;
- They belong to a specific area, which covers most of the northern half of the Iberian Peninsula (fig. 1) ;
- They can be chronologically assigned to the time of construction, with a precision that ranges between two intervals of 50 or 100 years. These intervals represent the most common way of assigning chronology in the sources consulted, given that in many cases they refer to buildings from the middle or end of, or at most, belonging to a specific century.

15 It should be added that all the buildings have a precise location, with an error of less than 10 m.

Fig. – Study area with the ecclesiastical buildings.



2.1. Ecclesiastical buildings

16 Even though the project and database consider all types of buildings in non-perishable materials, this analysis focuses exclusively on religious buildings (churches and monasteries) because they are the best documented, thanks to major encyclopaedic works such as the « Enciclopedia del Románico[24] » or « Catalunya Romànica[25] ». The first one, « Enciclopedia del Románico », has been developed by the Santa María la Real Foundation[26] and is the result of three decades of work to document all the Romanesque testimonies of the Iberian Peninsula and bring them together in a single collection, which already reaches 55 volumes. The data provided by the Santa María la Real Foundation is fundamental to geolocalize more than 9 000 patrimonial entities. The other one, « Catalunya Románica », is a website based on the 27 volumes published by « Enciclopèdia Catalana » between 1983 and 1998. It provides a general treatment of the Romanesque art that developed in the territories that make up what is now Catalonia, Andorra, eastern Aragon and southern France. It concentrates on the exhaustive description of the Romanesque monuments, organized by counties and municipalities, in a total of more than 4 000 monuments. Secular constructions – residential, defensive or productive – remain to be studied in the future. The aforementioned data management plans provide more specific definitions and figures on each of the typologies[27].

17 The ecclesiastical buildings considered include a wide variety of types of architecture, defined by size, construction techniques, representative or decorative elements, among other characteristics. However, for the purposes of our analysis, we have considered them all in the same way, leaving these aspects for the future.

18 The dataset of religious buildings includes 5 572 places of worship, 351 monasteries and 10 hospitals. In regards to size, we are not in a position to make a global assessment for the entire study area yet, but we can attest to its diversity, from small-sized buildings,

which are the majority in the study area, to urban buildings with a greater volume or particularly monumental constructions, such as large monasteries or urban cathedrals. In addition, we can differentiate the buildings according to the cost and the complexity of the construction processes. On the one hand, there are buildings made with expensive techniques, result of the aristocracy's investment income for the creation and strengthening of client networks. On the other hand, there are buildings that are a product of the initiative of rural communities, or more probably of local elites, with access to simpler constructive technologies and knowledge[28] – see, for example, the approach by Rocio Maira Vidal for Las Merindades region, in northern Castile[29].

2.2. Preservation criteria

19 We have only considered buildings with preserved material remains, specifically, those which at least keep structural parts, such as walls or foundations, and which, therefore, are tangible evidence of a building event on that site within a certain time range. Specific elements, such as baptismal fonts, columns, capitals, corbels or other decorative elements, whose presence may be due to reuse from buildings that have disappeared, have been discarded.

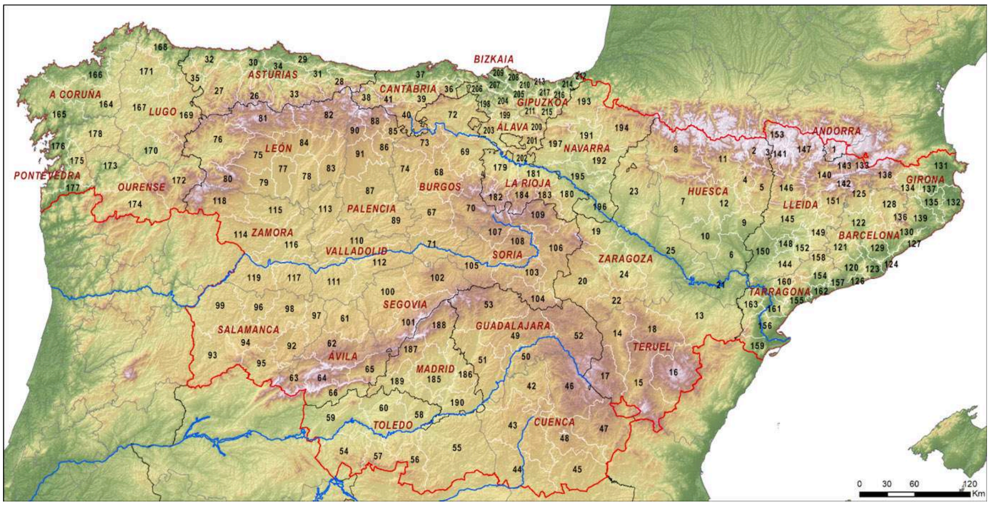
20 Applying this criterion implies the exclusion of any constructions for which there is evidence only from documentary sources. The absence of material remains from the period of interest, apart from the fact that in some areas the generally documented proliferation of buildings may never have existed, may be due to the fact that the building has disappeared or that all the visible work belongs to later times due to complete rebuilding, which was very common between the 16th and 18th centuries.

21 In this regard, the « Enciclopedia del Románico » collects multiple examples of buildings with modern interventions. For example, in the A Coruña province, in Galicia, where we have 175 buildings, of which only 52 can be considered almost complete, while of another 61, little more than the old medieval apse remains. In these cases, archaeological excavations should be carried out to verify the existence of remains prior to the modern fabric.

2.3. Analysis area

22 The area covers most of the northern half of the Iberian Peninsula, and only excludes the territory of Portugal and the Valencian Community (fig. 2 and tab. 1)[30].

Fig. 2 – Analysis area. Autonomous regions and agricultural districts of Spain.



Tab. 1 – Administrative divisions of the study area and the agricultural districts that comprise them, together with their extension.

Administrative divisions	Selected buildings	Total area	Useful surface area
Andorra	**22**		
Andorra	**22**		
1. Andorra	22	453.160613	96.786569
Aragón	**741**		
Huesca	**601**		
2. Alta Ribagorça Occidental	33	522.3584128	142.3201843
3. Alta Ribagorça Oriental	24	211.735806	77.33365992
4. Baja Ribagorça Occidental	54	674.6880772	588.9732898
5. Baja Ribagorça Oriental	121	1054.727365	994.7664056
6. Bajo Cinca	10	1397.848955	1397.848955
7. Hoya de Huesca	107	3011.838891	2966.788703
8. Jacetania	112	3006.794153	2228.254847
9. La Litera	19	1128.784161	1128.693486
10. Monegros	16	1344.64342	1344.64342
11. Sobrarbe	74	2117.697579	1267.266769
12. Somontano	31	1177.235039	1163.748686

Teruel	**17**		
13. Bajo Aragón	3	4025.31006	4023.379291
14. Cuenca del Jiloca	1	1767.957272	1767.611628
15. Hoya de Teruel	6	2781.593051	2558.107876
16. Maestrazgo	2	2399.941838	1647.260162
17. Serranía de Albarracín	1	1600.879093	1130.395529
18. Serranía de Montalbán	4	2234.963337	2223.633816
Zaragoza	**123**		
19. Borja	12	1183.966249	1158.804522
20. Calatayud	12	2539.522807	2537.843198
21. Caspe	5	1988.808771	1988.808771
22. Daroca	8	1246.89655	1246.89655
23. Egea de los Caballeros	65	3410.484059	3404.28676
24. La Almunia de Doña Godina	6	1942.842944	1941.256498
25. Zaragoza	15	4987.378104	4987.378104
Asturias	**146**		
Asturias	**146**		
26. Belmonte de Miranda	9	1008.913678	786.0062779
27. Cangas de Narcea	17	2129.965439	1949.513839
28. Cangas de Onís	9	1022.239698	781.6012907
29. Gijón	45	909.4744858	903.1704847
30. Grado	13	768.5551956	764.9830277
31. Llanes	17	793.5425646	766.4499448
32. Luarca	0	1109.281573	1101.943579
33. Mieres	10	1442.816772	1229.378289
34. Oviedo	23	891.268782	890.601725
35. Vegadeo	3	535.4762641	529.3344583

Cantabria	**104**		
Cantabria	**104**		
36. Asón	1	444.0152409	420.3723051
37. Costera	30	1728.53306	1720.183849
38. Liébana	18	574.6412652	430.9684152
39. Pas-Iguña	13	863.6921973	851.9905486
40. Reinosa	39	1011.495287	958.4346567
41. Tudanca-Cabuérniga	3	695.9440437	631.781719
Castilla - La Mancha	**215**		
Cuenca	**51**		
42. Alcarria	8	1899.964258	1899.507418
43. Mancha Alta	10	3422.839916	3422.839916
44. Mancha Baja	3	2390.279431	2390.279431
45. Manchuela	2	2140.606853	2140.606853
46. Serranía Alta	17	2917.978595	2500.282058
47. Serranía Baja	3	2519.110781	2508.467089
48. Serranía Media	8	1838.269733	1838.269733
Guadalajara	**137**		
49. Alcarria Alta	45	2411.620622	2411.462609
50. Alcarria Baja	15	1559.351096	1558.287787
51. Campiña	15	2403.538914	2403.538914
52. Molina de Aragón	11	2920.595635	2646.549244
53. Sierra	51	2906.517379	2669.644479
Toledo	**27**		
54. La Jara	0	1895.978023	1895.909594
55. La Mancha	3	4938.006985	4938.006985
56. Monte de los Yébenes	0	1218.770439	1218.770439

57. Montes de Navahermosa	2	833.7847365	833.7847365
58. Sagra-Toledo	19	1893.326417	1893.326417
59. Talavera	2	2664.888836	2664.888836
60. Torrijos	1	1917.433125	1917.433125
Castilla y León	**1674**		
Ávila	**39**		
61. Arévalo-Madrigal	21	1617.085811	1617.085811
62. Ávila	17	2238.162059	2092.796631
63. Barco Ávila-Piedrahita	0	1136.858584	808.9453525
64. Gredos	0	819.3535857	339.9698349
65. Valle Bajo Alberche	1	1079.087637	993.257074
66. Valle del Tiétar	0	1158.675682	1016.950044
Burgos	**547**		
67. Arlanza	43	1750.578089	1750.55528
68. Arlanzón	63	1755.70072	1751.927257
69. Bureba-Ebro	73	1986.126099	1982.657623
70. Demanda	55	2294.774543	2072.705836
71. La Ribera	34	1573.237006	1573.237006
72. Merindades	136	2337.183497	2321.885938
73. Paramos	61	1023.283282	1022.84179
74. Pisuerga	82	1550.49552	1550.49552
León	**74**		
75. Astorga	6	1398.582156	1389.69418
76. Bierzo	23	2828.372783	2592.664585
77. El Paramo	1	906.2583488	906.2583488
78. Esla-Campos	1	1392.45384	1392.45384
79. La Bañeza	4	654.272239	654.272239

80. La Cabrera	3	1278.41385	990.8661317
81. La Montaña de Luna	2	2033.965537	1270.995406
82. La Montaña de Riaño	16	2409.188537	1697.881447
83. Sahagún	8	935.8943548	935.8943548
84. Tierras de León	10	1753.038097	1751.880721
Palencia	**222**		
85. Aguilar	62	473.0496395	450.7877189
86. Boedo-Ojeda	33	585.1935172	585.1935172
87. Campos	50	3044.916753	3044.916753
88. Cervera	36	767.8086242	580.5304547
89. El Cerrato	20	1533.922098	1533.922098
90. Guardo	14	542.42552	430.8203271
91. Saldaña-Valdavia	7	1101.69115	1101.69115
Salamanca	**80**		
92. Alba de Tormes	11	1205.062993	1205.062993
93. Ciudad Rodrigo	5	2459.869849	2453.925337
94. Fuente de San Esteban	0	1427.745748	1427.745748
95. La Sierra	9	1484.492183	1437.397545
96. Ledesma	13	1079.716671	1079.716671
97. Peñaranda de Bracamonte	9	910.3198832	910.3198832
98. Salamanca	29	1464.633197	1464.633197
99. Vitigudino	4	2328.997065	2322.75442
Segovia	**253**		
100. Cuellar	70	2803.643961	2803.643961
101. Segovia	78	1978.622315	1687.907731
102. Sepúlveda	105	2147.095356	2114.650985
Soria	**273**		

103. Almazán	42	1304.1189	1304.1189
104. Arcos de Jalón	7	1046.369671	1046.369671
105. Burgo de Osma	51	1927.357173	1927.163308
106. Campo de Gomara	63	2402.357271	2364.331918
107. Pinares	6	898.1656953	768.5855857
108. Soria	66	1442.409687	1442.208359
109. Tierras Altas Y Valle del Tera	38	1277.96684	1117.264494
Valladolid	**81**		
110. Centro Valladolid	29	2473.377528	2473.377528
111. Sur	9	1916.561016	1916.561016
112. Sureste	36	1787.895924	1787.895924
113. Tierra de Campos	7	1931.113156	1931.113156
Zamora	**105**		
114. Aliste	8	1947.271451	1946.641031
115. Benavente Y los Valles	11	1447.24029	1447.24029
116. Campos-Pan	41	2177.400423	2177.400423
117. Duero Bajo	15	1512.671911	1512.671911
118. Sanabria	12	1998.759969	1655.210833
119. Sayago	18	1485.843821	1485.686273
Cataluña	**1859**		
Barcelona	**569**		
120. Alt Penedès	41	595.217044	595.217044
121. Anoia	47	870.0440899	869.9787656
122. Bages	122	1305.780679	1303.135872
123. Baix Llobregat	23	487.4785577	484.9774594
124. Barcelonès	13	144.19661	143.5454386
125. Berguedà	87	1188.911768	1036.240844

126. Garraf	1	185.1594882	184.5810444
127. Maresme	15	399.1048105	398.424492
128. Osona	101	1162.768161	1155.618529
129. Vallès Occidental	43	585.1577048	584.1544714
130. Vallès Oriental	76	855.1109853	849.6955672
Girona	**505**		
131. Alt Empordà	129	1365.604337	1359.33751
132. Baix Empordà	61	706.3704286	705.0255423
133. Cerdanya	24	248.810715	115.7851267
134. Garrotxa	84	737.0252986	724.4378627
135. Gironès	44	578.8840529	578.6975692
136. Osona	7	104.233198	103.5922886
137. Pla de L'Estany	56	264.6215052	264.5547274
138. Ripollès	64	958.2140639	653.500113
139. Selva	36	1001.053231	995.9630226
Lleida	**695**		
140. Alt Urgell	106	1450.521738	973.9298646
141. Alta Ribagorça Oriental	31	428.076002	156.3490115
142. Berguedà	2	56.025057	46.36744988
143. Cerdanya	26	295.956627	137.7246779
144. Garrigues	4	799.1731097	799.1731097
145. Noguera	130	1796.444919	1779.623717
146. Pallars Jussa	113	1346.462788	1123.966214
147. Pallars Sobirà	85	1384.917409	414.6513502
148. Pla D'Urgell	2	311.0107276	311.0107276
149. Segarra	58	724.3944617	724.3944617
150. Segrià	15	1390.866693	1390.866693

151. Solsonès	85	1006.703334	930.3805205
152. Urgell	16	573.7082747	573.7082747
153. Val d'Aran	22	633.7557927	118.3155069
Tarragona	**90**		
154. Alt Camp	13	539.0863551	539.0408822
155. Baix Camp	4	698.7238105	696.9859768
156. Baix Ebre	4	1000.867145	990.521706
157. Baix Penedès	10	296.1787472	295.9239588
158. Conca de Barbera	30	651.9005209	651.7545542
159. Montsià	2	738.9170078	730.8714209
160. Priorat	6	499.4247544	496.467906
161. Ribera D'Ebre	5	827.2765651	827.0082673
162. Tarragonès	9	318.2989701	317.4859091
163. Terra Alta	7	742.8901866	740.0939206
Galicia	**754**		
A Coruña	**175**		
164. Interior A Coruña	38	2640.487647	2639.884136
165. Occidental	74	2839.928612	2830.980427
166. Septentrional	63	2503.774237	2491.822051
Lugo	**261**		
167. Central Lugo	148	2572.444359	2571.494948
168. Mariña Lucense	6	1464.703486	1461.15928
169. Montaña de Lugo	29	1782.840006	1759.029554
170. Sur de Lugo	66	1985.845735	1970.938933
171. Terra Cha	12	2073.701222	2073.322575
Ourense	**171**		
172. El Barco de Valdeorras	17	2465.471505	2328.747851

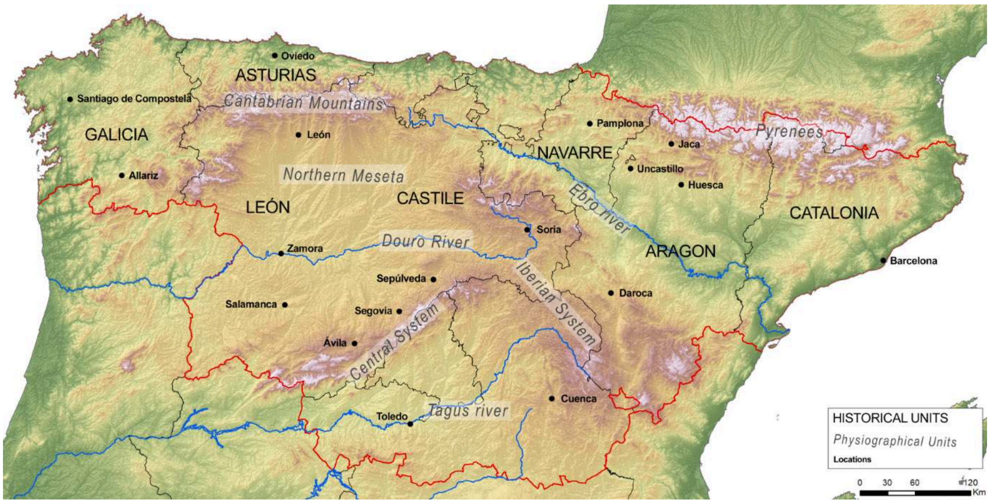
173. Orense	121	2156.951151	2154.836906
174. Verín	33	2671.194971	2665.731914
Pontevedra	**147**		
175. Interior Pontevedra	7	766.2239449	766.2011356
176. Litoral	54	1301.720157	1288.765404
177. Miño	14	803.7403773	802.291662
178. Montaña de Pontevedra	72	1641.713291	1641.713291
La Rioja	**77**		
La Rioja	**77**		
179. Rioja Alta	30	1139.59935	1132.747521
180. Rioja Baja	4	1006.664355	1006.664355
181. Rioja Media	16	786.3728312	785.2380889
182. Sierra Rioja Alta	9	892.7490395	649.0853683
183. Sierra Rioja Baja	8	410.2334167	407.7819455
184. Sierra Rioja Media	10	805.9193923	683.3092677
Madrid	**24**		
Madrid	**24**		
185. Área Metropolitana de Madrid	5	1737.740274	1737.740274
186. Campiña	8	1080.848644	1080.848644
187. Guadarrama	2	971.6581917	868.6407577
188. Lozoya Somosierra	4	1532.513582	1258.092782
189. Sur Occidental	5	1394.161094	1393.958597
190. Vegas	0	1307.014071	1307.014071
Navarra	**172**		
Navarra	**172**		
191. Cuenca Pamplona	33	778.1442093	776.3625687
192. Navarra Media	41	1273.989043	1272.568204

193. Nord Occidental	9	1901.586235	1875.728683
194. Pirineos	39	2310.107474	2230.992916
195. Ribera Alta Aragón	5	1224.922272	1224.922272
196. Ribera Baja	6	1328.530727	1328.530727
197. Tierra Estella	39	1541.843602	1537.618736
País Vasco / Euskal Herria	**145**		
Araba/Álava	**138**		
198. Cantábrica	5	331.9062269	326.7055783
199. Estribaciones Gorbea	15	403.8576742	403.1162772
200. Llanada Alavesa	60	833.571704	832.443176
201. Montaña Alavesa	21	484.1405416	481.6363267
202. Rioja Alavesa	6	315.5825419	312.5893694
203. Valles Alaveses	31	664.8555168	661.4961621
Bizkaia	**6**		
204. Arratia-Nervión	1	400.2299723	396.4830668
205. Duranguesado	0	316.7366679	308.6794958
206. Encartaciones	2	428.8768613	425.1534854
207. Gran Bilbao	1	372.8972258	371.5325139
208. Guernika-Bermeo	0	279.3678147	278.5989342
209. Munguia	2	211.8788577	211.286855
210. Ondarroa	0	205.5064172	203.6222614
Gipuzkoa	**1**		
211. Alto Deba	0	342.485365	338.8867442
212. Bajo Bidasoa	0	70.98478719	70.55144833
213. Bajo Deba	1	181.4389113	178.9479392
214. Donostia/San Sebastián	0	305.5156117	304.5529697
215. Goierri	0	386.4713642	381.8901764

216. Tolosa	0	365.9067661	360.8972996
217. Urola Costa	0	326.131786	322.2534248
Total general	**5933**		

23 Physiographically, the area analysed includes (fig. 3) : on the northern side, the Cantabrian coast and the southern slope of the Pyrenees ; in the northwest, the Galician coast and massif ; in the northeast, the Catalan Coastal System ; in the centre, the basins of the Duero (northern Meseta) and Ebro rivers, separated by the Iberian System ; and, in the south, the Central System and the central and upper basin of the Tagus river, in the southern Meseta.

Fig. 3 – Main elements discussed in the text.



24 The criterion for selecting the study area is determined exclusively by the completeness of the data. We only considered regions where, at the time of this analysis, all the preserved ecclesiastical buildings were documented. In the case of northern Portugal, this has not been possible due, to a large extent, to the absence of a reference work equivalent to the aforementioned « Enciclopedia del Románico » or « Catalunya Románica ». An approximate example could be the works linked to the « Rota do Romanico » website[31], although without the same completeness criteria.

25 Within the study area, to describe and analyse the data in detail, we did not resort to current delimitations, because these divisions respond to functional, but not historical, criteria. We have chosen the « agricultural districts » defined by the Spanish Ministry of Agriculture, Fisheries and Food[32] as the analysis territorial unit (see fig. 2). These districts are intermediate spatial units smaller than a province and bigger than a municipality – albeit without their own legal-administrative status –, which have a uniform character from an agrarian point of view. We have chosen them for two fundamental reasons. Firstly, their relative correspondence with the physiographic and historical configuration of the study area. Secondly, because of their size, which is large enough to reflect internal variability, and small enough to account for the general variability of the area as a whole.

2.4. Chronological criterion

26 The chronological assignment of each building is based on the earliest surviving building remains « in situ », which would indicate the earliest phase for which there is material evidence. The assignments are grouped in 50-year intervals (fig. 4).

Fig. 4 – Chronological allocation procedure for buildings, summarized for the entire study area.

Initial Chronology	Number of Buildings	Classified Chronology	Number of Buildings	Previous Assignment	Subsequent Assignment	Reallocated Total
700-750	11	700	11			0
700-800	1					
750-800	4	750	5	1	0	1
750-850	1					
800-850	9	800	11	1	1	2
800-900	11					
850-900	21	850	37	10	6	16
850-950	23					
900-950	32	900	68	17	19	36
900-1000	70					
950-1000	42	950	104	51	11	62
950-1050	45					
1000-1050	118	1000	243	34	91	125
1000-1100	289					
1050-1100	315	1050	641	198	128	326
1050-1150	221					
1100-1150	295	1100	665	93	277	370
1100-1200	709					
1150-1200	1122	1150	1964	432	410	842
1150-1250	807					
1200-1250	976	1200	1719	397	346	743
1200-1300	530					
1250-1300	246	1250	465	184	35	219
1250-1350	35					
TOTAL	**5933**		**5933**			**2742**

27 This is a chronological criterion conventionally used in medieval architecture studies, such as the reference sources consulted. On the other hand, it is a time range wide enough to deal with chronological uncertainty and precise enough to establish a detailed sequence.

28 The study sequence (900-1300) consists of eight intervals : 900-950, 950-1000, 1000-1050, 1050-1100, 1100-1150, 1150-1200, 1200-1250, 1250-1300. In this article, we have considered buildings that can be accurately assigned to one of these intervals (50-year accuracy) or to two consecutive ones (100-year accuracy). Buildings whose chronology cannot be accurately defined with 100 years have not been considered.

29 The rest of the buildings considered in this study, however, are not dated so accurately, and have been assigned to 100-year periods, either complete historical centuries (e.g. 1000-1100) or between two of them (e.g. 1050-1150). To avoid ambiguity and ensure a homogeneous analysis, each of these cases is reassigned to one of the two possible 50-year intervals, by « distributing » the buildings of each 100-year period between its two 50-year intervals. Buildings have been distributed on a weighted basis, in proportion to the number of buildings already in each 50-year interval. For example, for the Aguilar de Campoo district, the period 1150-1250 has 22 buildings, which have to be distributed between the periods 1150-1200 and 1200-1250, which already have 10 and 22 cases respectively. Buildings are distributed in line with the proportion of

these figures, so that seven cases from the period 1150-1250 will be assigned to the period 1150-1200 and the remaining 15 cases to the period 1200-1250.

30 Applying these criteria results in a set of 5 933 buildings (see fig. 1), which, despite the biases mentioned above, are considered a representative dataset for analysing the spatial distribution patterns of the construction phenomenon and its evolution over time. This analysis consists of two basic lines :

- Analysis of the surroundings of each and every building, quantifying the greater or lesser presence of other buildings in these surroundings, thereby defining dispersion and concentration patterns (section 3.1) ;
- Analysis of the density of buildings and its evolution in the different areas of the study zone, taking the agricultural district as the territorial unit of analysis (section 3.2-3.4).

31 GIS software (ArcGIS version 10.5) was used in the analysis to process the geographic data and, for the statistical analysis of the resulting data tables, Microsoft Excel and IBM SPSS Statistics (versions 2016 and 27 respectively).

3. Analysis

32 The general starting hypothesis is whether the density of buildings is homogeneous for the whole study area and whether it evolves regularly. The selected data for the described study area were analysed as follows to better understand the construction phenomenon and its spatial distribution :

- Analysis of the density of buildings, taking the immediate surroundings of the buildings themselves as the analysis unit ;
- Analysis of the density of buildings summarized in pre-defined units, such as agricultural districts ;
- Analysis of the relationship between the density of buildings and the roughness of the terrain in the agricultural districts ;
- Analysis of the density of buildings by agricultural districts using multivariate analysis techniques.

33 The first two analyses tackle the diachronic study of building density from different perspectives. The first, by means of defining a surrounding area around each building and counting the number of buildings inside. The second, using territorial entities – in this case, agricultural districts – as sampling units and calculating building density for each. We have worked with two density values : one considering the whole area of the district, and the other using only useful surface area according topographic criteria.

34 The third analysis explores the relationship between building density and terrain roughness. The starting hypothesis is that one should expect a higher building density in those areas whose topographic characteristics make mobility difficult and therefore require longer travel times for the same distances.

35 The last analysis tries to offer a general vision of the distribution of the building density and its temporal evolution, highlighting its main patterns and trends.

3.1. Analysis 1 : the immediate environment

3.1.1. Methodology

36 This analysis involves counting the number of buildings in the surroundings of each one of them and then identifying areas of concentration – surroundings with many buildings – and dispersion (isolated buildings). Each building environment is the basic analysis unit, and the number of buildings in that environment is the variable to be considered.

37 In this article, we define the environment of each building according to travel time, by means of isochrones, defined as « lines that indicate the same time value to be reached from a starting point, line or polygon[33] ». In other words, it would comprise the area accessible from a specific point – in our case, the building – within a given time interval. By means of GIS analysis, isochrones have been generated using topographic slope as the conditioning variable. The flatter the terrain, the wider the isochronous area ; on the contrary, the steeper the terrain, the smaller the area – further information in Appendix 1.

38 Isochronous areas will have different shapes and sizes, depending on the orography. In flat areas, due to the lower resistance to movement, the isochrones will be wider and with shapes tending to a circle. In mountainous areas, they will be smaller and irregularly shaped, being larger in the flatter sectors and smaller in the steeper sectors.

39 Two isochronous areas have been established for each building :

- 4-hour isochrones, representing a district or district scale. These are based on a round trip of 8 hours and would roughly define the area that can be covered in a day's journey ;
- 15-minute isochrones, representing a local level, and which would define the immediate environment. They are particularly useful for identifying high concentrations of buildings.

40 The number of buildings that each isochronous area comprises is counted, but only counting buildings which are contemporary to the central building, i.e. those already existing in the period when the latter appeared. This includes both buildings created in the same period and those built in earlier periods.

41 It should be emphasised that under no circumstances are isochronous areas intended to be effective reconstructions of historical or geographical territorial entities. Instead they are artificial spatial modules created strictly with topographic criteria and used exclusively for sampling purposes, for gathering relevant information for comparative analysis. They do not serve to reconstruct real geohistorical things, but they do serve to explore geohistorical processes, in a systematic and standardised way.

42 In any case, this clarification does not rule out the possibility of improving the modeling of mobility and the definition of areas of influence introducing other elements beyond topography, such as communication routes, visibility or buildings vicinity, to mention some of the criteria considered in spatial analyses performed in Medieval studies[34]. For this task, it is worth noting the reflections, proposals and applications about this issue in archaeological studies on landscape and territory[35].

3.1.2. Results

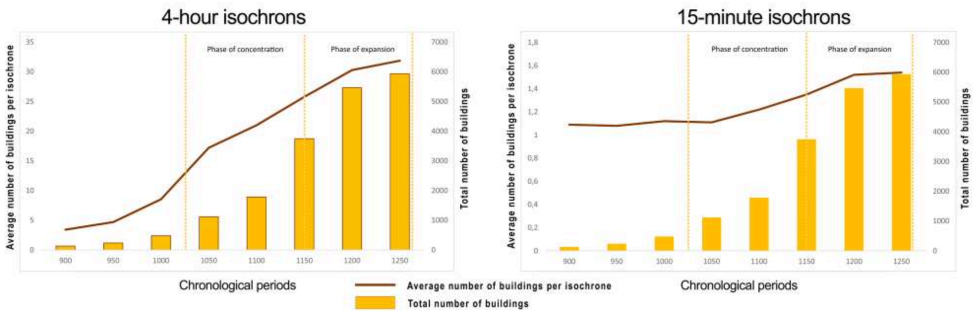
43 To make the results easier to interpret, first we represent them synthetically with bar and line graphs, where the total number of buildings and the average number of

buildings per isochrone are shown together, by periods[36], both for the study area as a whole and for a selection of six districts :

- Firstly, phases of « concentration » or « densification », of increasing building concentration, can be identified when the average number of buildings per isochrone increases compared to the total number of buildings in the study area. Densification is studied at two scales, district and local, corresponding, respectively, to the 4-hour and 15-minute isochrones ;
- Secondly, we have « expansion » periods, with a reverse process, as the total number of buildings within the area increases compared to the average per isochrone. This is indicative of building in new areas, which had no previous buildings.

44 This shows how, in general terms, building activity rose sharply from the year 1000 onwards, steadying around 1250 (fig. 5). At first, concentration prevailed over expansion, whereas from the 12th century onwards, the reverse was true.

Fig. 5 – Graphical result for the isochrone analysis for the whole of the study area.



45 These general results, however, should be qualified, given that they refer to the study area as a whole. As can be seen in the graphs for the six selected districts, the results vary greatly from one geographical area to another :

- In the Oviedo district (fig. 6), values are very high at the start of the sequence, both for total number of buildings and for concentration. Subsequently, the concentration values decrease and the expansion values increase significantly ;
- In the Alt Empordà (fig. 7), construction expanded heavily, continuously, from the mid-10th century onwards, but always maintaining the same concentration values. If we look at the nearby environment, we can see how 10th and mid-11th century are characterised by a strong concentration, while by the end of the sequence expansion predominates ;
- In the Baja Ribagorça Oriental (fig. 8), we have the same expansion trend at the end of the sequence, but not the concentration phase ;
- In the Sepúlveda, Aguilar and Lugo districts (fig. 9), however, construction boomed later, from the mid-12th century to the first half of the 13th century, and notably the Sepúlveda area first experienced a strong process of concentration, followed later by a process of expansion.

Fig. 6 – Graphical result for the analysis with isochrones in the Oviedo agricultural district.

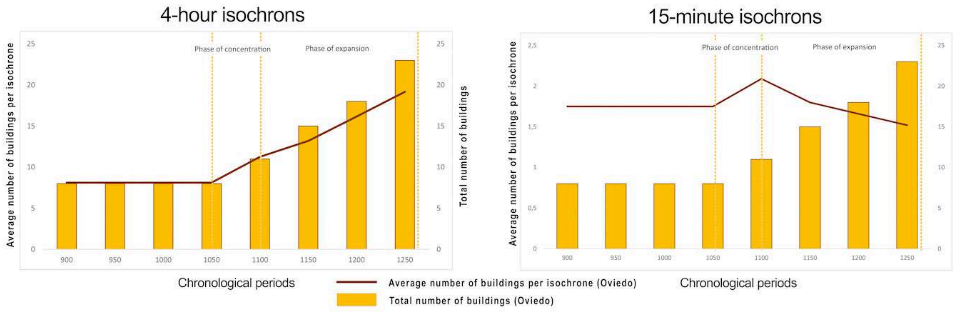


Fig. 7 – Graphical result for the analysis with isochrones in the Alt Empordà agricultural district.

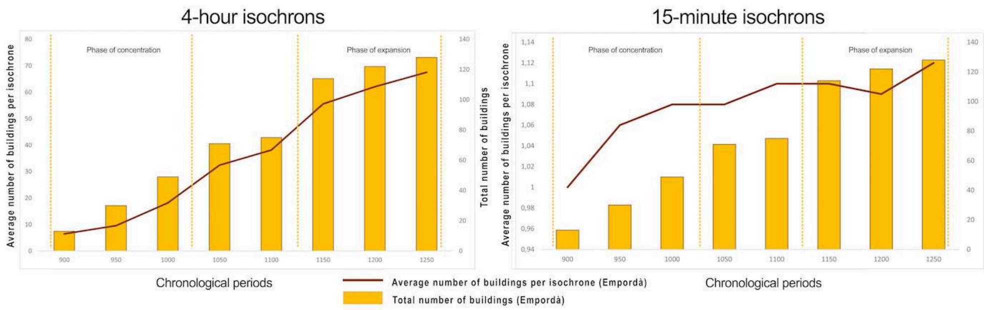


Fig. 8 – Graphical result for the analysis with isochrones in the Baja Ribagorça Oriental agricultural district.

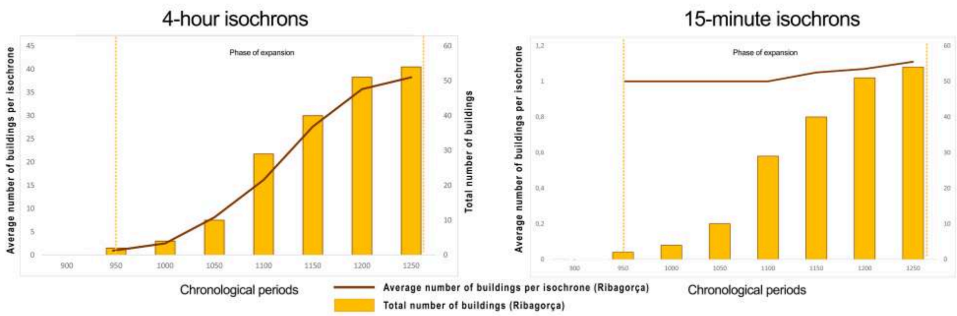
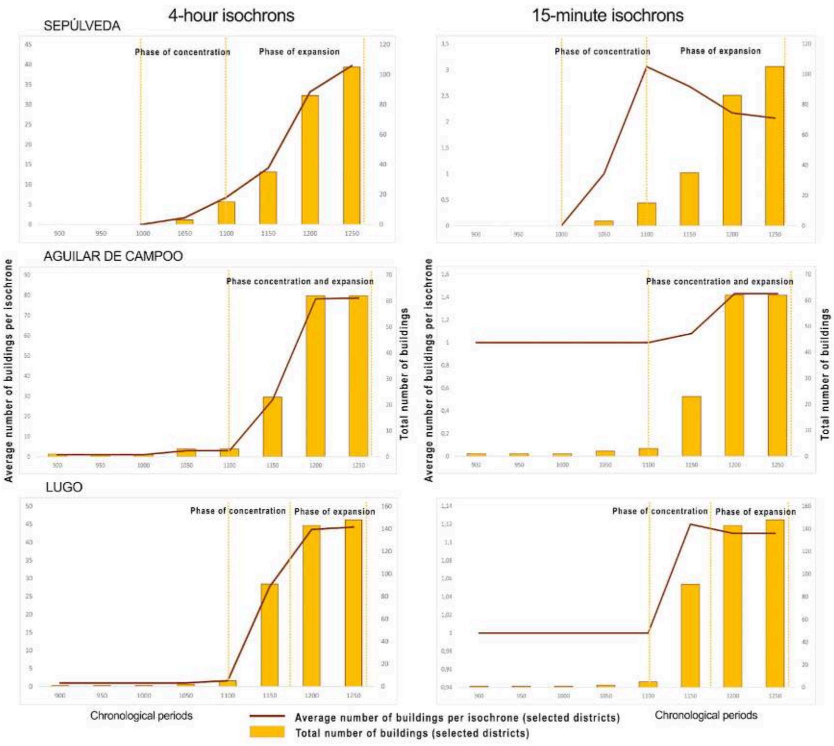
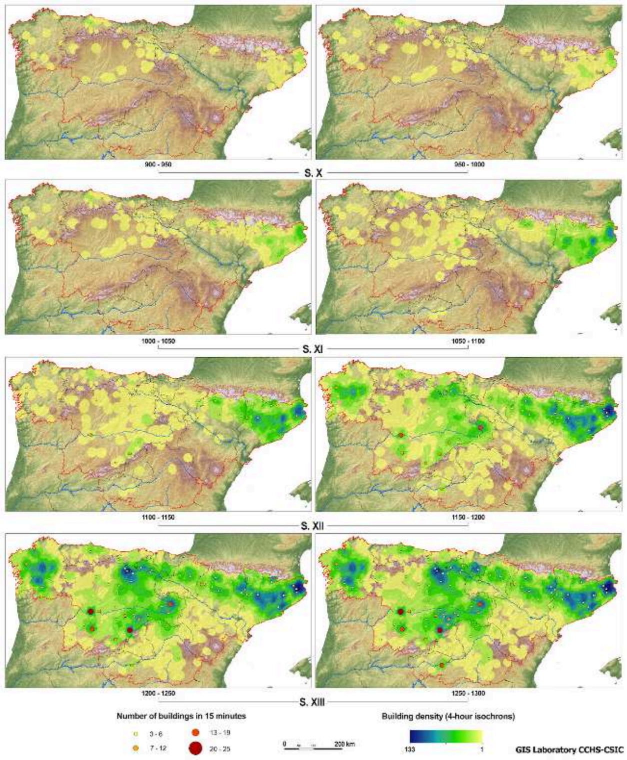


Fig. 9 – Graphical result for the analysis with isochrones in the Sepúlveda, Aguilar de Campoo and Lugo agricultural districts.



46 This shows the internal variability of the construction process in the study area. In order to analyse the data globally, we mapped them, superimposing the data obtained for the two types of isochrones –15 minutes and 4 hours (fig. 10) :

Fig. 10 – The 15-minute isochrones are represented by graduated dots and the 4-hour isochrones by a continuous surface, generated by interpolating density values.



- There is a remarkable scarcity of construction evidence between 900 and 950, and it mainly appears in two areas : Asturias, with Oviedo at the centre, where examples of construction from this period include the Cathedral of San Salvador, the church of San Julián de los Prados or the church of San Tirso ; and the north of Catalonia, specifically the Empordà. There are also other areas with a lower density of buildings, such as the north of Castile, the corridor between the Catalan Pyrenees and the coast of Barcelona, the middle Duero and scattered areas of Galicia ;
- The panorama between 950 and 1000 is similar, with a slight expansion in the aforementioned areas and a certain densification at district level in the Catalan area, mainly in the Empordà and Bages ;
- At the start of the 11th century, the values were highest in Catalonia, especially in the area of Barcelona and the Vallès, the districts of Osona, the north of Bages, the south of Berguedà and Solsonès ; and above all, in the Empordà, continuing the trend of the previous century. Next to Catalonia, construction was highly dense in the Aragonese Pyrenees, mainly in the Jaca area, the second most important after Oviedo, with outstanding examples of construction from this period in the Royal Monastery of Santa Cruz de Madres Benedictinas, the Church of Santo Domingo and the Church of San Pedro el Viejo ;
- Between 1050 and 1100, construction became denser in the aforementioned areas of Catalonia, notably in the Osona region and, for the first time, in the northeast of La Noguera. Worthy of note is the town of Tahüll, in Alta Ribargorça Oriental, which has more than three buildings in its immediate surroundings, namely the churches of Sant Climent, Santa María and Sant Martí. The trend towards regional densification can also be seen in the Aragonese Pyrenees, mainly in Jacetania and Ribagorça. Castile was marked by an expansion of building, especially in the Demanda district. During this period, the first constructions appeared to the south of the Duero River, specifically in the areas of Segovia and Toledo ;

- At the start of the 12th century, the proliferation of construction became more widespread and the trends seen at the end of the previous century became stronger. In Catalonia, regional densification continued in the aforementioned areas, with a predominance in the Empordà and, to a lesser extent, Osona, northeast Noguera and Vallès. New centres of local densification, such as Barcelona, Girona, Beders, la Torre de Rialb and Àger, began appearing. This same process spread to the east of Aragon (Ribagorça), in particular in the cities of Jaca, Huesca and Antenza. The widespread process of expansion continued throughout the rest of the study area, with the first constructions in the centre of the Ebro valley, and regional and local densification around certain towns and cities between the Duero and the Central System, such as Zamora, Segovia and Sepúlveda. Also noteworthy is the abrupt densification in the cities of Ávila, León and Santiago de Compostela. In the latter city, this period saw the Cathedral of Santiago being joined by buildings such as the Church of Santa Susana, the Church of San Miguel dos Agros, the Church of San Fiz de Solovio and the Collegiate Church of Santa María Maior e Real do Sar ;
- Major changes were observed in the mid-12th century, with strong and widespread growth in construction throughout the study area, either through expansion into new territories or through densification, both on a district and local scale, with a rise in the number of enclaves with more than three buildings.
  In the Catalan districts, there was further heavy densification and expansion, mainly southwards. A large number of new towns with a heavy concentration of buildings emerged, such as Tarragona – with the construction of the cathedral of Santa María Tecla and the church of Santa María del Miracle, among others –, Lleida, Terrassa, Besalú and Cornellà de Terri.
  A similar process occurred in Aragon, albeit on a smaller scale, with the densification in the aforementioned regions – Ribargorça, Jacetania, Hoya de Huesca – and the expansion to more southern areas, with the first constructions appearing to the south of the Ebro river. The phenomenon also spread to the Navarrese foothills, with densification in the town of Estella, with examples of buildings such as the Church of San Pedro de la Rúa or the Church of San Miguel, and in the regions of the upper Ebro and the Álava plains.
  Growth in construction was also heavy in Castile, where the phenomenon spread throughout the area and become regionally denser in the north – Aguilar de Campoo, Merindades, Demanda. In the Duero and to the south of the Duero basin, densification was stronger in certain urban areas – Ávila, Segovia, Sepúlveda, Soria – and, to a lesser extent, also in their regional areas. In the León area, the construction process was less intense in the northern half – bearing in mind that this study is based on preserved remains –, and stronger in León and Sahagún. However, the situation to the south of the Duero river seems to have resembled what was happening in Castile, with the densification of towns such as Ledesma, Alba de Tormes, Salamanca and, above all, Zamora, which currently has 19 documented buildings, including the Cathedral of San Salvador, the Church of Santa María de la Horta and the Church of Santiago del Burgo.
  Construction also expanded in the Cantabrian and Atlantic coastal areas, although to a lesser extent. Oviedo and its surroundings, where there had not been any new constructions since the 10th century, now seemed to be undergoing a new period of expansion. Galicia, however, is the area that stood out the most. Strong growth was seen in the regions of Central Lugo, the north of the southern region of Lugo and the mountains of Pontevedra. To the northwest of this area, construction became notably dense in the city of Santiago de Compostela, with more than seven buildings.
  It is interesting to note that, of all the areas where local density increased from the

mid-12th century onwards, most of those with more than seven buildings are in the area bounded by the Duero river to the north and the Central System to the south. Only Santiago de Compostela is outside this area ;

- The trend of the mid-12th century was consolidated at the beginning of the 13th century. Broadly speaking, in the Catalan and Aragonese areas, the process of regional densification and expansion continued towards the south, although on a lesser scale, compared with the strong growth that other areas, such as Castile, Galicia and Navarre, continued to experience. Most notable in Catalonia was the densification in the districts of Empordà and Pla de l'Estany, and to a lesser extent in Bages and Noguera. The number of buildings in the city of Barcelona also increased, with examples such as the convent of Santa Caterina, in addition to buildings from previous periods such as the Cathedral of Santa Creu and Santa Eulalia or the Church of Santa María del Pí. In Aragon, construction became denser in the regions of Ribagorça and Egea de los Caballeros and the towns of Uncastillo and Luesia, and expansion continued to the south of the Ebro, in particular in the town of Daroca. Navarre kept on experiencing strong growth, especially in the areas around Eristain and Roncesvalles.
  In Castile, there was further densification in the regions of Aguilar de Campoo, Merindades and Demanda, as well as in the towns of Soria, Segovia, Sepúlveda, Cuéllar, Ávila and Toledo. In the León region, growth was moderate in the north compared to the south, where construction was far denser in cities such as Zamora, Salamanca and Toro. In Galicia, there was further densification in the districts already mentioned in previous periods, which were joined by districts in the Orense area and the northern coast ;
- In the second half of the 13th century, the building process continued, although it seemed to slow down across the board. The greatest densification is documented as having occurred in the northern regions of Castile – between Aguilar de Campoo and the city of Burgos – and, especially, in the Llanada Alavesa district. Also worth noting is the densification in the city of Toledo, with examples such as the Church of Santiago del Arrabal, in addition to previous examples such as the Cathedral of Santa María or the Church of San Vicente, and in the regions of the Alto Tajo (Alcarria, Serranía), in the current provinces of Guadalajara and Cuenca.

47 In summary, the scant evidence that is preserved for the 10th century – without considering archaeological or documentary studies – is mainly concentrated in central Asturias and northeast and central Catalonia. During the 11th century there is a process of considerable densification, mainly in Catalonia, at the same time that the construction boom gradually spreads westwards. In the 12th century, building expansion extends to the entire study area, both to ancient Christian territories, standing out north Castile, Galicia and the northern part of the Ebro basin, and newly conquered areas from Muslim kingdoms, such as Soria, Toledo, Cuenca or Zaragoza. In parallel to this expansive process, there is a building densification in certain places, especially in the southern Duero basin, between this river and the Central System. This trend continues till the middle of the 13th century, when signs of deceleration are noted.

3.2. Analysis 2 : density of buildings by district – general inspection

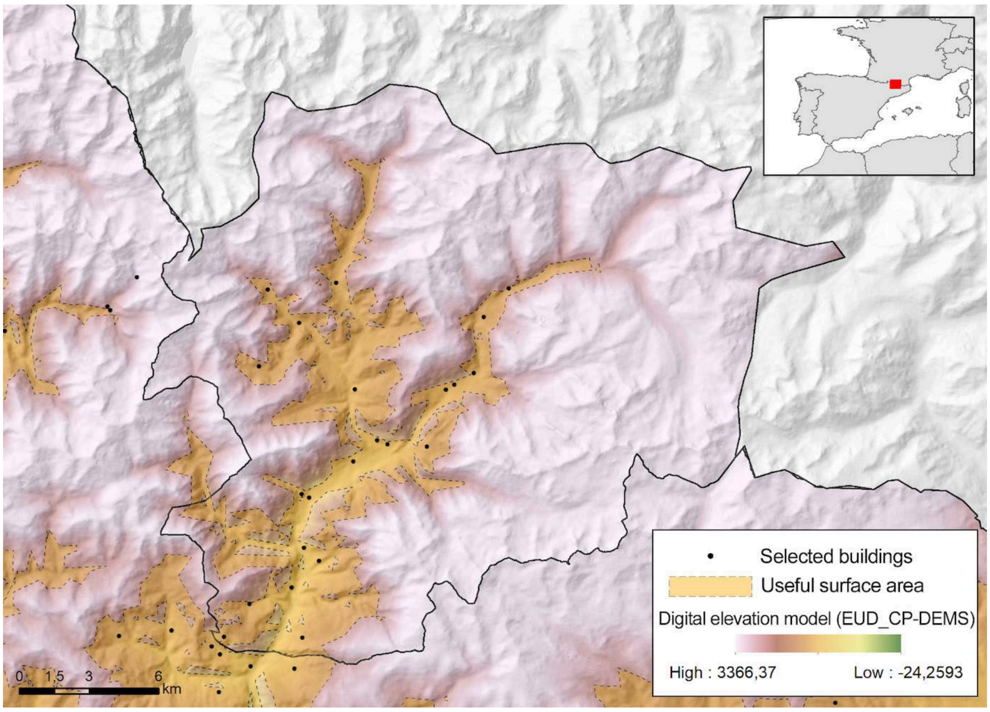
3.2.1. Methodology

48 The second line of analysis, to supplement the isochronous area analysis, studies the spatial variation of building density and its evolution, by calculating on the basis of territorial units, specifically the pre-defined agricultural districts.

49 The variable analysed is the density of buildings, specifically the number of buildings per 1 000 km². This variable has been calculated[37] for each of the aforementioned 50-year chronological intervals, within the period 900-1300.

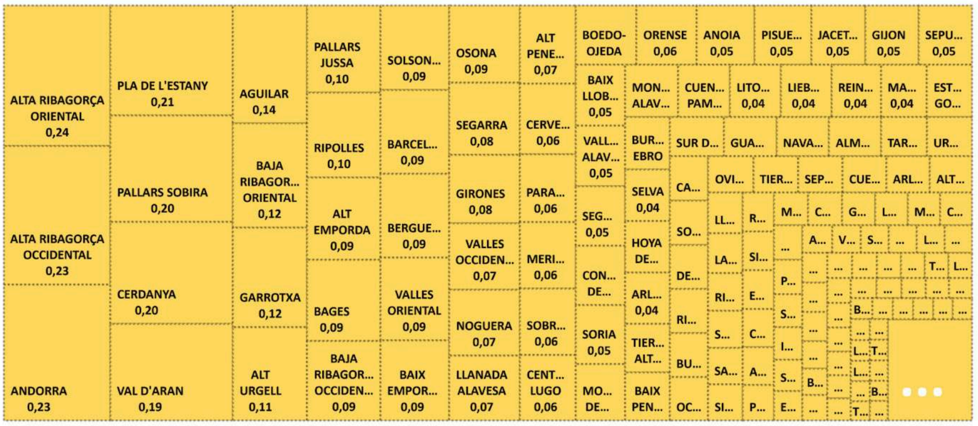
50 The building density was calculated on the topographically useful surface area, this value being considered to observe the topographical effect on building density in areas where it is a serious constraint on the landscape's habitability (fig. 11). The topographically useful surface area was defined by subtracting areas with altitudes higher than 1 700 m and/or slopes higher than 30 %, from the total surface area.

Fig. 11 – Example of selection of useful surface area (Andorra territory).



51 Figure 12 shows how, after applying this topographic discrimination criterion, most of the densest agricultural districts are to be found in the Catalan Pyrenees, in particular in the Alta Ribagorça (Huesca and Lleida) and Andorra. Other outstanding areas are the Pla de l'Estany district, in Girona and, outside the Catalan area, the Aguilar de Campoo district.

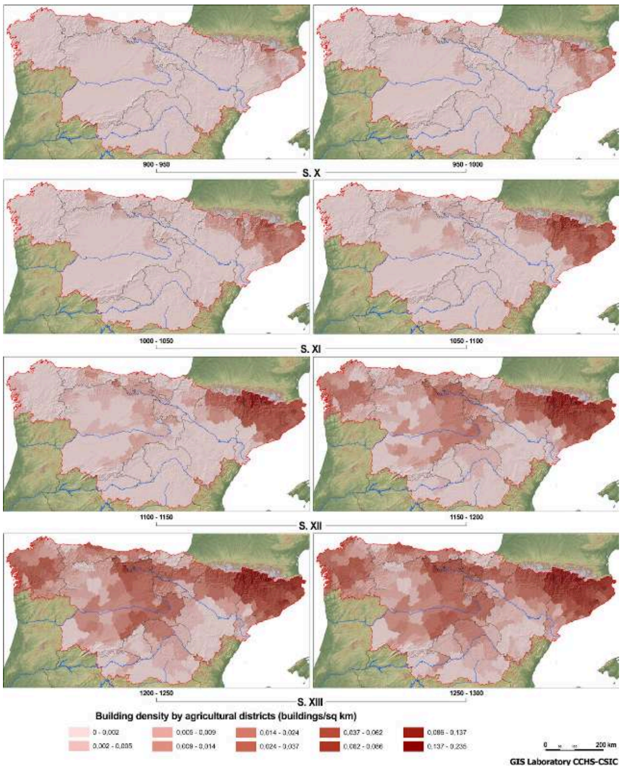
Fig. 12 – Agricultural districts categorised according to the density of buildings per useful surface area.



3.2.2. Results

52 If one observes the change in building density within each district, taking into account its usable area (fig. 13), the results obtained clearly follow the general pattern described in section 3.1.2, although the following aspects should be clarified :

Fig. 13 – Density by districts.



- When areas with high altitudes and steep slopes are removed from the analysis, the mountainous districts become particularly significant. For the 10th century, the Catalan area stands out from the rest, and within it, some Pyrenean districts, the Barcelona area and the strip of land that joins both of them ; also, worth noting are the Empordà districts, and in between both areas, others with a lower building density such as Osona, Selva or Gironès.

Outside the area of present-day Catalonia, there are isolated districts with a certain density of buildings, including Oviedo and its surroundings, as we have already seen, and also the Liébana district (Cantabria), a mountainous area that did not particularly stand out in the previous analysis ;

- During the 11th century, the general process is the same as described above, although the new method of analysis highlights the density of the Pyrenean districts, especially Ribagorça, Pallars Sobirà and Andorra. Similarly, outside the Catalan-Aragonese area, the mountainous area of Liébana stands out once again ;
- In the period from 1100 to 1150, there was further densification of the Catalan and Huesca districts, in particular in the Pyrenean districts as in the previous period, but the Pla de l'Estany district in Girona now stood out as an area of strong district densification. Outside this area, the process was the same as described above, a progressive generalised expansion, with the first examples to the south of the Duero river standing out ;
- In the second part of the 12th century, the process accelerated, especially in Galicia and Castile. There was widespread densification, with strong growth in Aguilar de Campoo, Merindades, Soria or Segovia in Castile, Salamanca or Campos-Pan (Zamora) in León, or Central Lugo or the Pontevedra Mountains in Galicia. In Catalonia and Aragon, there was further densification in certain districts – Ribagorça, Vall d'Aran, Alt Urgell, Ripollès and Solsonès, among others –, and further expansion towards the south – Priorat, Baix Camp and Bajo Cinca ;
- In the 13th century, the process of district densification continued in Castile and Galicia, and to a lesser extent in León, the Cantabrian Mountains and the upper Ebro. The expansion processes already described in section 3.2 have been corroborated, for example in the Tagus valley or south of the Duero river. The Llanada Alavesa district was once again the area with the strongest growth at the end of this century.

53 In summary, considering environmental conditions can introduce interesting nuances in the assessment of building density. There are some regions where the relief strongly conditions the settlement and consequently the useful surface area. After removing hardly habitable terrain according its topographic characteristics, some districts notably increase their building density, such as those in the Pyrenees or also Liébana, in the Cantabrian Mountains.

3.3. Analysis 3 : density of buildings by district – relationship with terrain roughness

3.3.1. Methodology

54 This section tests the hypothesis of whether the density of buildings is related to the roughness of the terrain. The basic assumption is that ecclesiastical buildings form a territorial network for controlling and assisting the local population and that their location responds, among other factors, to population mobility criteria which, in turn, could be conditioned by geographical and mainly topographical factors. If this assumption holds true, then the density of buildings should be higher in steep areas, where mobility is more complicated and, therefore, it would take longer to travel the same distances, than in flat areas.

55 This hypothesis has been tested by using regression analysis to examine the relationship between building density and travel cost, taking agricultural districts as units. The « cost » variable used is the same as explained and used before (see Appendix

1), and is expressed in time, more specifically in « slowness » values in seconds per metre. This analysis was carried out considering both the total surface area of the districts and the topographically useful surface area (see section 3.2.1).

56 The analysis procedure consisted of the following steps :

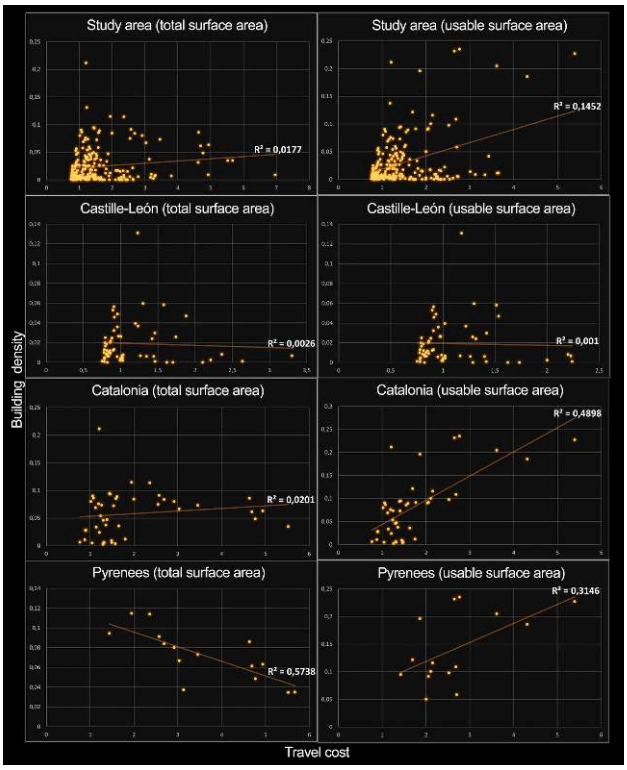
- Calculation of the average cost in each district – both for the total area and for the usable area[38];
- Statistical analysis : bivariate graph and regression analysis (SPSS).

3.3.2. Results

57 Overall, there is no correlation between building density and terrain roughness. Therefore, it seems that variations in density depend on other factors.

58 Examining specific geographical areas, this lack of correlation is again observed, except in the Catalan Pyrenees, where it does exist (fig. 14).

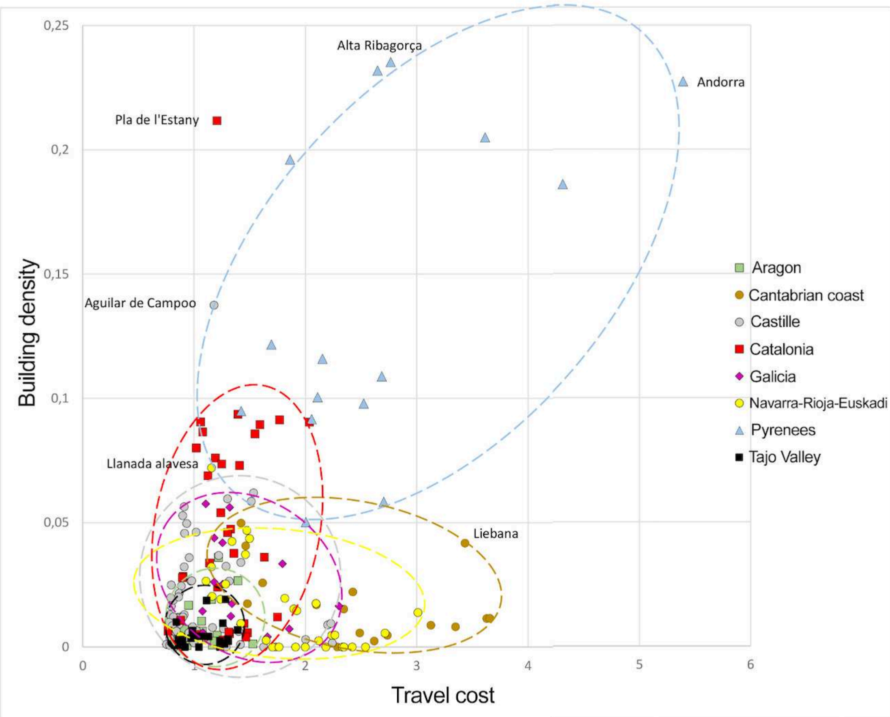
Fig. 14 – Relationship between density and travel cost in the whole study area and in representative areas[39].



59 If the total surface area of the district is used, the correlation is negative, indicating that the less rough it is, the higher the density tends to be, and vice versa ; this implies that an abrupt topography has a negative effect on the presence of buildings. On the contrary, if only the usable surface is used, the correlation is positive, i.e., the greater the roughness, the higher the density. This is also the case in the area of Catalonia analysed at a general level. This is the only case where the initial hypothesis would be met : the more abrupt the topography of the habitable areas, the denser the network of ecclesiastical buildings.

60 However, another aspect to highlight, if the bivariate graph formed by the density of buildings – taking the useful surface area – and the travel cost is analysed in detail, is that differences by zones can be seen, mainly in relation to the density of buildings (fig. 15).

Fig. 15 – Classification of agricultural districts by specific zones within the study area, showing similar patterns and groupings. Outstanding cases within each group are also represented. To facilitate the understanding of the graph, we have manually delimited each regional group by means of a dashed line with its corresponding color.



61 In the Cantabrian and Navarre-Basque-Riojan districts, the travel cost is high, but density values are similar. This group has similar characteristics to Castille-León and Galicia – if one excludes the exceptional case of the Aguilar de Campoo district –, although there are cases with higher building densities and in general their travel cost index is lower.

62 The Catalan districts – excluding those in the Pyrenees – also seem to form a group with similar characteristics, with high densities, but not very high travel costs. Finally, the districts that began the process later, such as those located to the south of the Central System, specifically in the middle valley – provinces of Madrid and Toledo – and upper valley of the Tagus river (Guadalajara and Cuenca) and the middle valley of the Ebro and the districts located to the south – current provinces of Zaragoza and Teruel –, have low values for both variables, but it is worth noting that they are grouped closely together, with similar characteristics.

63 Also worth noting is the grouped, although scattered pattern seen in the Pyrenean districts, with the highest density and travel cost values.

64 The bivariate graph shows certain cases of extreme behaviour, many of which have already been mentioned in the analysis in section 3.1. For example, Aguilar de Campoo stands out from the rest of the Castilian districts due to its much higher building

density value ; the Liébana district, with high travel costs, is among those with the highest building density in the Cantabrian area, together with Reinosa and Gijón ; the Llanada Alavesa district also has a very high density of buildings compared to the rest of the Navarre-Riojan group ; and the Pla de l'Estany district (Girona) has a higher density of buildings than the rest of the Catalan group, and also differs from the Pyrenean districts due to its lower travel cost.

65 The last feature of the graph is the proximity of districts such as Segovia, Sepúlveda or Soria, or also Toledo or Zaragoza, which shows that they are located in topographically similar environments, but at the same time it could be interpreted that similar historical and social processes were taking place in them, at least from the construction perspective.

66 In summary, in general terms there is no correlation between building density and terrain roughness, with the exception of the Pyrenean area. The combination of both variables shows four main groups : the Pyrenees – mainly in Catalonia and eastern Aragon –, with high building densities and high roughness ; Catalonia, with high densities and low roughness ; a wide strip formed by Galicia, the Cantabrian coast, Castile and the upper Ebro (Navarre and Rioja), with lower values in both variables in general terms ; and the Tagus and Ebro valleys, with the lowest values both for density and roughness.

3.4. Analysis 4 : building density by district – multivariate analysis

3.4.1. Methodology

67 A multivariate statistical analysis was applied to the density values to further study the spatial and temporal variations in building density and to obtain an overview of their structural features. This type of statistical analysis consists of the joint study of several variables in order to discover and describe potential relationships between them.

68 The following variables have been used in this analysis :

- The eight time-based variables, one for each 50-year period between 900 and 1300, each with the building density value per agricultural district ;
- Another seven variables regarding the increase in building density from one period to the next. These are obtained by calculating the difference between the density value of the most modern period and that of the oldest period.

69 Two multivariate analysis techniques were applied to these 15 variables :

- Principal Component Analysis (PCA), to see the basic dataset variability trends. PCA uses the original variables to generate new ones, called « principal components » which, in an orderly manner, summarize the internal variability – « variance », in statistical terms – of the dataset. The higher the percentage variance, the greater the explanatory power of the component. The first component is the one with the highest percentage variance, followed by the second, and so on, until the last ones, whose percentages of explained variance are usually very low. Therefore, it is the first components to which attention should be paid. Likewise, each component has a certain relationship with each of the original variables, the strength and sign of which is given by the « correlation coefficient ». The higher the absolute value of the coefficient, the stronger the relationship between the component and the original variable. If the sign is positive, it indicates that the relationship is direct : when the value of the component increases, so does that of the original variable, and, conversely, when one decreases, the other decreases. If the sign is negative, the relationship is inverse : when the value of the component increases, the value of the original variable decreases, and vice versa. The stronger the relationship of a component with each of the original variables, the greater its percentage variance and, therefore, the greater its explanatory power ;

- Cluster analysis, to define types of districts according to their similarities and differences in density values. Specifically, the k-means analysis was applied, due to its simplicity and ease of implementation, in our opinion. Cluster analysis consists of grouping the elements – in this case, the districts – on the basis of their values in the variables – in this case, the density values. The more similar the values of two elements are, the more likely they are to be assigned to the same group. The result is a set of groups (also called « clusters »), each of which contains a series of elements that are similar to each other and are different from the rest (tab. 2-7).

Tab. 2 – Principal component Analysis (PCA) : results. Total variance explained.

Component	**Eigenvalue**	**% variance**	**% accumulated**
1	9.747	64.979	64.979
2	2.158	14.389	79.367
3	1.209	8.058	87.425
4	0.797	5.315	92.740
5	0.406	2.706	95.446
6	0.302	2.015	97.461
7	0.222	1.481	98.942
8	0.159	1.058	100.000
9	6.732E-15	4.488E-14	100.000
10	1.105E-15	7.368E-15	100.000
11	2.298E-16	1.532E-15	100.000
12	1.038E-16	6.917E-16	100.000
13	5.217E-16	3.478E-15	100.000
14	2.828E-15	1.886E-14	100.000
15	7.367E-15	4.911E-14	100.000

Tab. 3 – Principal component Analysis (PCA) : results. Component matrix. From component 9 onwards all coefficients are near to zero.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
D0900_0950	0.675	-0.449	0.448	-0.132	-0.155	0.296	0.111	0.027
D0950_1000	0.801	-0.427	0.395	-0.026	-0.115	0.020	-0.040	0.062
D1000_1050	0.911	-0.353	0.134	0.016	0.031	-0.094	0.119	-0.061
D1050_1100	0.937	-0.253	-0.139	-0.020	0.169	0.072	-0.063	-0.032
D1100_1150	0.961	-0.048	-0.248	0.064	0.044	0.042	0.019	0.072
D1150_1200	0.959	0.185	-0.176	-0.057	-0.099	0.018	-0.025	-0.026
D1200_1250	0.916	0.377	0.003	-0.140	0.008	0.002	-0.003	0.008
D1250_1300	0.908	0.415	0.051	-0.028	0.013	0.017	-0.008	-0.005
D0950_1000_plus	0.807	-0.318	0.253	0.112	-0.044	-0.333	-0.224	0.094
D1000_1050_plus	0.883	-0.236	-0.122	0.052	0.160	-0.184	0.246	-0.164
D1050_1100_plus	0.847	-0.143	-0.339	-0.045	0.259	0.195	-0.200	-0.005
D1100_1150_plus	0.780	0.314	-0.378	0.193	-0.182	-0.019	0.157	0.235
D1150_1200_plus	0.714	0.533	-0.010	-0.248	-0.317	-0.028	-0.094	-0.186
D1200_1250_plus	0.232	0.696	0.514	-0.291	0.312	-0.044	0.061	0.101
D1250_1300_plus	0.346	0.436	0.344	0.742	0.038	0.109	-0.034	-0.087

Tab. 4 – K-means analysis : results. Initial cluster centers.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
D0900_0950	2.0514	0.0000	2.3678	0.0000	0.0000	0.3887	0.0000	0.0000	2.1139
D0950_1000	6.1541	0.0000	5.5249	1.3568	2.3993	0.3887	3.7790	1.3805	2.1139
D1000_1050	20.5137	0.0000	19.7316	5.4272	3.5990	0.3887	15.1159	4.1414	2.1139
D1050_1100	28.7192	0.0000	63.9305	14.9249	4.7986	0.7775	30.2319	24.8483	4.2279
D1100_1150	34.8733	0.0000	73.4017	47.4882	7.1979	1.9437	90.6956	41.4139	6.3418
D1150_1200	41.0274	0.0000	80.5050	107.1876	10.7969	35.3749	151.1593	71.7841	48.6207
D1200_1250	45.1302	0.0000	83.6621	111.2581	32.3907	55.5892	177.6122	77.3059	131.0645

D1250_1300	47.1816	0.0000	85.2406	113.9717	71.9794	57.5328	211.6230	80.0669	131.0645
D0950_1000_plus	4.1027	0.0000	3.1571	1.3568	2.3993	0.0000	3.7790	1.3805	0.0000
D1000_1050_plus	14.3596	0.0000	14.2068	4.0704	1.1997	0.0000	11.3369	2.7609	0.0000
D1050_1100_plus	8.2055	0.0000	44.1988	9.4976	1.1997	0.3887	15.1159	20.7070	2.1139
D1100_1150_plus	6.1541	0.0000	9.4712	32.5633	2.3993	1.1662	60.4637	16.5656	2.1139
D1150_1200_plus	6.1541	0.0000	7.1034	59.6994	3.5990	33.4312	60.4637	30.3702	42.2789
D1200_1250_plus	4.1027	0.0000	3.1571	4.0704	21.5938	20.2142	26.4529	5.5219	82.4438
D1250_1300_plus	2.0514	0.0000	1.5785	2.7136	39.5887	1.9437	34.0108	2.7609	0.0000

Tab. 5 – K-means analysis : results. Iterations.

Iteration									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	24.397	12.995	27.038	17.780	34.018	28.024	0.000	17.918	0.000
2	2.923	1.469	6.528	0.000	5.367	7.563	0.000	2.200	0.000
3	0.000	1.256	3.702	0.000	5.215	5.793	0.000	1.793	0.000
4	2.335	0.178	0.000	0.000	7.588	4.387	0.000	0.000	0.000
5	0.000	0.682	0.000	0.000	6.189	5.671	0.000	0.000	0.000
6	2.102	0.327	0.000	0.000	4.477	4.066	0.000	0.000	0.000
7	0.000	0.917	0.000	0.000	0.000	2.610	0.000	0.000	0.000
8	0.000	0.616	0.000	0.000	2.072	2.448	0.000	0.000	0.000
9	0.000	0.297	0.000	0.000	0.000	0.775	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	1.169	0.552	0.000	0.000	0.000

Tab. 6 – K-means analysis : results. Final cluster centers.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
D0900_0950	1.4139	0.0733	7.0090	0.0000	0.7035	0.5027	0.0000	2.1419	2.1139
D0950_1000	3.1768	0.1225	12.0123	1.1525	1.0796	0.6902	3.7790	4.6431	2.1139

D1000_1050	8.6660	0.1416	23.1642	7.9282	1.3542	0.8751	15.1159	11.7175	2.1139
D1050_1100	17.5750	0.3624	49.9470	24.5285	1.7985	1.7196	30.2319	30.1918	4.2279
D1100_1150	24.8166	0.6511	59.9750	50.7653	4.0106	3.5633	90.6956	48.1503	6.3418
D1150_1200	36.8985	2.0639	80.0891	102.4216	20.9879	13.1291	151.1593	67.7127	48.6207
D1200_1250	39.3158	4.1693	84.6486	111.0936	43.0200	21.7809	177.6122	73.7546	131.0645
D1250_1300	40.9985	4.9816	86.6150	114.3466	49.2737	24.0643	211.6230	76.9693	131.0645
D0950_1000_plus	1.7629	0.0493	5.0033	1.1525	0.3761	0.1874	3.7790	2.5012	0.0000
D1000_1050_plus	5.4891	0.0191	11.1519	6.7758	0.2746	0.1849	11.3369	7.0744	0.0000
D1050_1100_plus	8.9091	0.2208	26.7828	16.6002	0.4443	0.8445	15.1159	18.4743	2.1139
D1100_1150_plus	7.2416	0.2887	10.0280	26.2368	2.2121	1.8437	60.4637	17.9585	2.1139
D1150_1200_plus	12.0818	1.4128	20.1141	51.6563	16.9773	9.5658	60.4637	19.5624	42.2789
D1200_1250_plus	2.4173	2.1054	4.5596	8.6720	22.0322	8.6517	26.4529	6.0419	82.4438
D1250_1300_plus	1.6827	0.8123	1.9664	3.2530	6.2536	2.2834	34.0108	3.2147	0.0000

Tab. 7 – K-means analysis : results. Number of cases per cluster.

Cluster	**n**
1	10
2	117
3	6
4	2
5	19
6	41
7	1
8	15
9	1

3.4.2. Results

3.4.2.1. « Principal Component Analysis (PCA) »

70 PC1 explains a large part of the total variance of the dataset (64.98 %). This component shows the behaviour of almost all variables, as can be seen in its strong positive correlations with them : all the net density variables and the first five density increment variables, i.e. those covering the period from 900 to 1200. According to this and broadly speaking, PC1 would explain the overall density of buildings in the whole sequence from 900 to 1300 – high values indicate high densities and low values indicate low densities – and, in addition, the increase in densities in the interval 900-1200 – high values indicate notable increases and low values indicate low increases.

71 If one observes the distribution of PC1 by districts, the following progression is seen, from the highest to the lowest values :

- The highest values are in Catalonia, mainly in the northeast and centre, including Barcelona ;
- The rest of the districts in the north of Catalonia and, in the north of Castile, the district of Aguilar ;
- Alto Aragón, northern Castile – from Liébana to Álava –, central Asturias and central Galicia ;
- Upper Ebro, the rest of Castile (including Cantabria) and some regions of León, Asturias and Galicia ;
- The lowest values are found in most of the León area, Bizkaia and Gipuzkoa, southern Aragon and Catalonia and the Tagus valley.

72 PC2 explains an important part of the total variance (14.39 %) and has a remarkable correlation with two parts of the set of variables. First, a negative correlation with the densities of the initial intervals, mainly those corresponding to 900-1000. Second, a positive correlation with the density increases at the end of the sequence, from 1150 to 1300. In other words, it shows an inverse relationship between the presence of buildings in the 10th century and the increase of buildings at the end of the 12th century and during the 13th century : high PC2 values indicate low building densities in 900-1000 and high increases of these in 1150-1300, and low values indicate high densities in the early period and high increases in the late period.

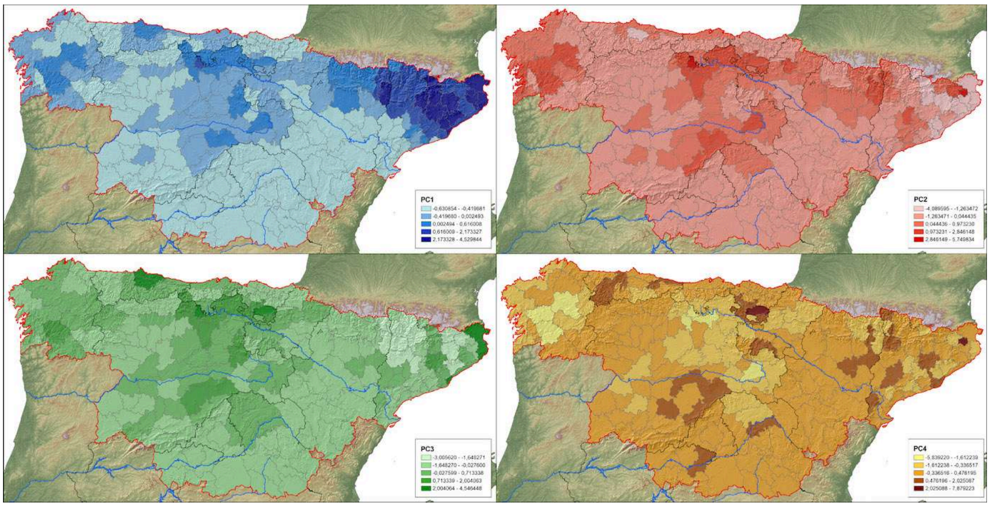
73 Represented by districts, the following progression is seen, from the highest to the lowest values :

- Three districts stand out : Pla de l’Estany and Garrotxa, in the northeast of Catalonia, and Aguilar, in the north of Castile ;
- A large part of Castile, especially the north, together with the areas of Soria and Segovia ; and the central and western districts of Galicia ;
- The coast of Asturias and Cantabria, the southern part of León (Zamora and Salamanca), the rest of Castile and large areas of the upper Ebro and Alto Aragón ;
- The North of León, Basque Cantabrian slope (Bizkaia and Gipuzkoa), Tagus valley, southern Aragon and western Catalonia ;
- The lowest values are in most of eastern Catalonia. It is striking that these same districts have very high PC1 values. That is, they present a very high density, but their growth slows down at the end of the study period.

74 PC3 explains 8.06 % of the total variance and correlates well with the net density variables of the first century of the sequence (900-1000), as well as with the increase in

density in the last century (1200-1300). Interpreting this component is more delicate, as the correlations with the original variables are weaker. Two specific and diametrically different phenomena can be deduced within it : growth in the 10th century in Asturias and a large part of eastern Catalonia, particularly in Barcelona and the Empordà, and growth in northern Castile, around Segovia and central Galicia in the 13th century (fig. 16).

Fig. 16 – Representation of the first four Principal Components.



75 PC4 explains 5.32 % of the total variance and presents a notable positive correlation with the increase in density in the interval 1250-1300, the last of the sequence. Its highest values are found in the Álava area and the Pla de l'Estany region, and its lowest in the Aguilar region (see fig. 16).

76 The other components are discarded due to their low explained percentage variance and their low correlation coefficients with the original variables – especially from PC9 onwards (see tab. 2-7).

3.4.2.2. « K-means analysis »

77 In the k-means analysis, nine groups were selected for the result, giving the ones explained below, with the following characteristics – the map and the group-based evolution graph is shown in figure 17, and also the bivariate graphs with principal components and the groups, shown in figure 18 :

Fig. 17 – Graphical and cartographic representation of the evolution of the nine groups resulting from the K-means analysis.

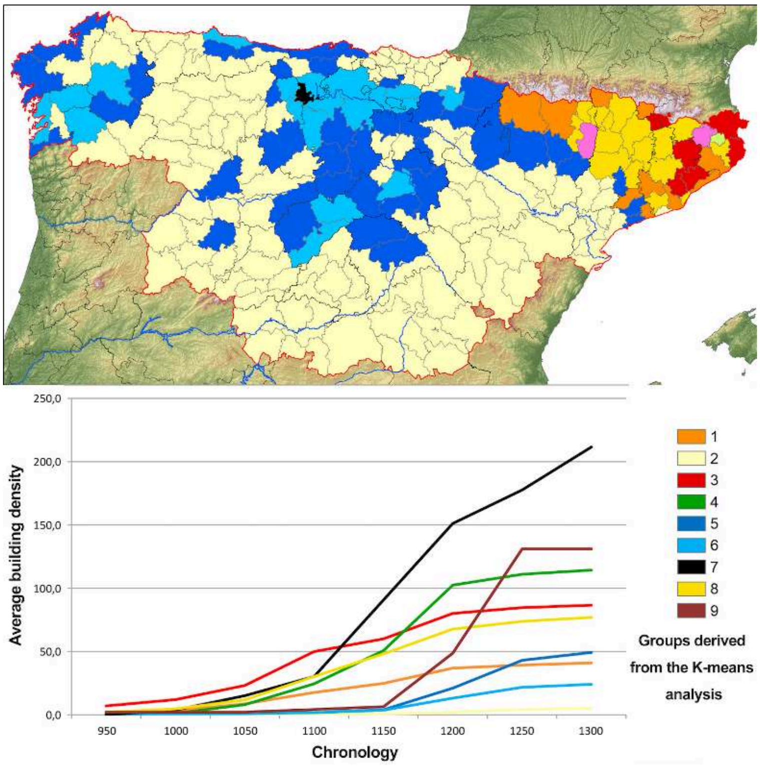
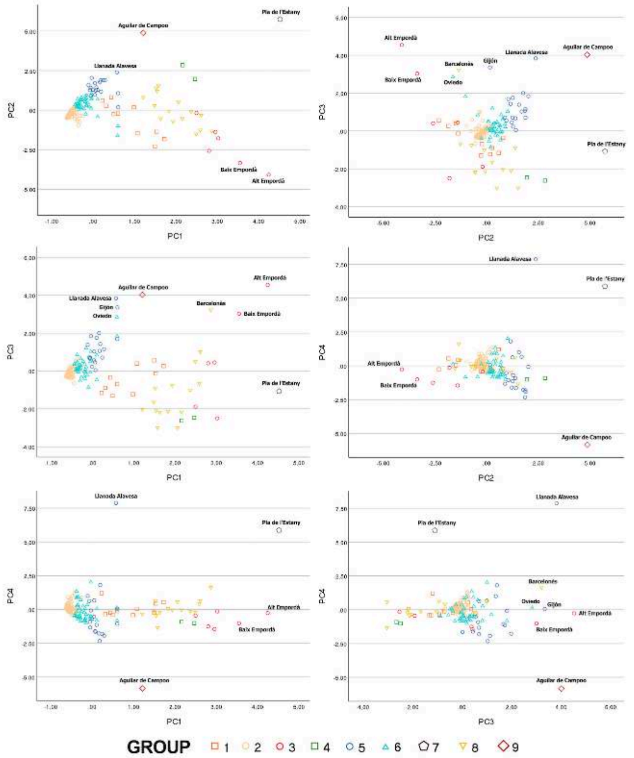


Fig. 18 – Bivariate graphs combining pairs of principal components (X and Y-axis) and k-means groups (dot symbols).



- Catalonia (groups 3, 4, 7 and 8) has the highest densities. Group 3, in the northeast of Catalonia, has the highest values in the first half of the sequence, from 900 to 1100, with a slower increase in the second half. Group 8, mainly in the northwest sector, shows a similar evolution to that of group 3, although with lower values. Group 7, with one single case (Pla de l'Estany), is different, with low values at the beginning and very strong increases afterwards, especially from 1100 onwards, notably exceeding all the other groups. The pattern in group 4, with two cases – Garrotxa and Baja Ribagorça Oriental –, is similar to that of group 7, although to a lesser extent ;
- The Aguilar district (group 9), in northern Castile, had a low density up to 1150 and experienced a very marked increase between 1150 and 1250, reaching very high density values, only lower than those of Pla de l'Estany ;
- Group 5 is limited to a strip that runs through northern Castile and Álava, and also includes some southern Castilian regions (Segovia and Soria), the centre and west of Galicia, the centre of Asturias and the Pamplona area. It has low density values, although with a sustained growth throughout the whole sequence ;
- Group 1 appears in eastern Catalonia and the central Pyrenees, mainly in Alto Aragón. It has very low values in the first centuries and significant increases from 1150 onwards ;
- Group 6 extends over most of Castile, the Zamora and Salamanca districts in the Leonese area, several Galician districts, especially coastal regions, Asturias and Cantabria, the upper Ebro and upper Aragon and some southern Catalonia districts ;
- Group 2 covers the largest area. It is distributed in the north and west of Galicia, the Basque Cantabrian slope (Bizkaia and Gipuzkoa), the León strip, the centre and south of Aragon, the south of Catalonia and the upper Tagus. It has very low density values and also low increases, somewhat higher from 1200 onwards.

78 Summarizing the results of the multivariate analysis, the first aspect to emphasise is a fairly stable distribution pattern of building density, with the same differences between areas at a comparative level throughout the entire sequence. Roughly, density values, from highest to lowest, are distributed in the following way :

- central and eastern Catalonia ;
- eastern and central Pyrenees ;
- Castile – mainly the northern zone and some nuclei in the south –, central and western Galicia and central Asturias ;
- upper Ebro, rest of Castile, the central part of the Cantabrian coast and the nuclei of Zamora and Salamanca, in the León region ;
- most of the León region, the Basque Cantabrian slope (Bizkaia and Gipuzkoa), central and southern Ebro basin and the Tagus valley.

79 Nevertheless, within this overall picture, there are some specific elements that must be noted. One is the very low density at the beginning of the sequence, with only a few nuclei with a certain concentration – mainly central Asturias and eastern Catalonia. Another aspect is the different rate of growth depending on the areas : Catalonia presents the highest increases till mid-12th century, but then slows down and other regions take over, such as central and western Galicia, northern and southern Castile, or the upper Ebro basin. Finally, we find some districts with a quite differentiated behaviour : such as Pla de l'Estany, in northeastern Catalonia, with very high growth rates, especially after 1100 ; Aguilar de Campoo, in northern Castile, with low density values till mid-11th century, a very strong increase between 1150 and 1250 and a marked slowdown in the second half of the 13th century ; or the Llanada Alavesa district (Basque Country), in the upper Ebro basin, with modest density values but a considerable growth since 1250, at the end of the sequence.

4. Discussion

80 Our research about the building phenomenon in the northern half of Iberia during the High Middle Ages points to a continuous, but complex and uneven process, with both spatial and chronological differences. This process cannot be constrained to physiographic factors, as we have seen in section 3.3, where it has been shown that topography plays a very limited role in relation to building density. On the contrary, we find a process whose characteristics can only be understood through social and political history. This process does not consist of a construction boom that arises in an empty space, but on a pre-existing population and settlement substrate. As Élisabeth Zadora-Rio points out[40], it is necessary to distinguish between the chronology of the habitat – with central places such as the cemetery –, the chronology of the church and the chronology of the parish. In our case, we are dealing with the second issue and trying to lay the foundations for further analysis of the third one.

81 The proliferation of religious buildings could respond to social changes, for example the gradual establishment of the parish network, which in turn entails a process of territorial organization and hierarchization. Directly related to the Gregorian Reform, that brought the triumph of the episcopal and parochial church[41], the parish spreads as an organizational model : the basic unit of the diocesan administration and the mainspring of ecclesiastical taxation[42]. The parish territory is the space where all the

social and religious practices at the local level were registered. It implies a spatial hierarchy determined both by the ritual of consecration of the church and the cemetery and by the distance that separates any point from the altar, the most sacred place[43]. At the same time, it is an active element in the configuration of complex social relationships which implies the attraction and fixation of the population around these sacred poles ; « las iglesias son instrumentos que evitan la dispersión del patrimonio familiar, son el lugar de enterramiento de las elites y sus familias, que de esta forma monumentalizan la memoria de sus antepasados, son centros de organización de la producción agraria y ganadera, son centros de dominio y de poder social, etc »[44]. As Michel Lauwers points out, more than a process of « incastillamento », as formulated by Pierre Toubert, it should consist of a slow and progressive « inecclesiamiento », that seems to have characterized land occupation and social organization during the Middle Ages[45].

82 These global processes have their particular expression in the various regions that make up our study area. It is the consideration of the social and political context and dynamics of each local scale, which can facilitate the historical interpretation of different patterns and trends in building density.

83 The results of our analyses present a scenario of an evident construction explosion. Even more, this evidence is in all probability only a part of the total number of ecclesiastical buildings that must have existed. Nevertheless, we can also presume that this « mantle of churches[46] » should not necessarily have a direct correlation with settlement or demography, as we have seen through some archaeological and documentary examples. For example, the Pyrenean Catalan valleys, traditionally considered as low population density areas, have very high building density values. On the other hand, Tagus and Ebro valleys, which must have been highly populated regions, we find extremely low building densities, as in Basque Country, Tarragona, or even the south of Navarre. Also, the kingdoms of León and Castile show marked differences in buildings density, which cannot be explained by equivalent differences in population density.

84 Documentary and archaeological studies should open new explanatory paths to these issues. For example, Nicolas Perreaux[47] through the quantitative study of the documentary collections collected in the work Codiphis for the Iberian Peninsula, and of the set of buildings collected in *La nuit des temps* from the Zodiaque editions, raises the hypothesis of correlation between buildings and documentary collections, with which for the case of León, we should have a higher number of buildings than the one we have, similar to what happens in Castilla.

85 The proliferation of buildings is to be seen in both expansion and densification phenomena, through the appearance of new constructions in previously empty territories or in the surroundings of pre-existing ones, respectively. Densification can occur both regionally, over a more or less broad territory, and locally scale, through the concentration of buildings in and around a town or city.

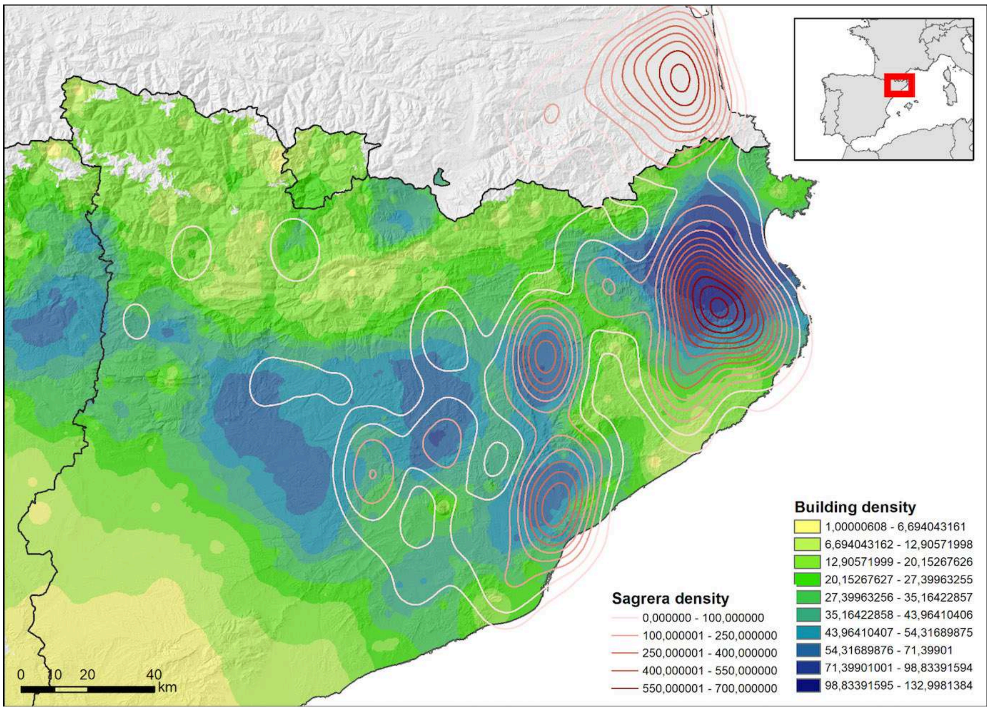
86 The initial scenario, at the start of the 10th century, was characterised by zero densities in most of the study area and low densities in the rest. The highest values are to be seen in the centre of Asturias, around the city of Oviedo, and Catalonia, mainly the Empordà districts and later the strip of land linking Barcelona with the Pyrenees through the inland districts. With a more scattered pattern, there were also examples of buildings

in the northern half of the Duero basin, the upper Ebro, the Aragonese Pyrenees and Galicia.

87 These early foci seem to be associated with the emergence and consolidation of political entities such as the Kingdom of Asturias or the Catalan counties, heirs to the Frankish Spanish March, also known as « Old Catalonia ». This last region shows the higher densities and the strongest growth till the end of the 10th century, particularly in the Empordà region and in the central Catalonia districts, such as Osona and Bages. This process seems closely related to the political organization introduced by the Carolingian conquest – from Girona in 785 to Barcelona in 801 –, or even with previous structures, as proposed by Jordi Bolòs[48], and favored the early stabilization of population in villages and the creation of churches, many of which have survived to this day[49]. In the case of Asturias, a royal power structure has been created. One expression of this is a group of buildings with a marked stylistic idiosyncrasy, known as « Asturian pre-Romanesque architecture », an artistic response to the consolidation of the political, social and territorial power of a monarchy that developed a calculated and invariable architectural programme, with typological norms and architectural models in accordance with the Christianisation of Asturias and the regularisation of a new liturgical space[50].

88 At the start of the 11th century, the building process spread throughout the Catalan districts and beyond, especially in the Empordà districts and the Aragonese Pyrenees, especially in Jaca. Between 1050 and 1150, it expanded to new areas, mainly to the south. In particular, the Northern Plateau – kingdoms of León and Castile –, with a proliferation of buildings south of the Duero, directly related to the conquest of Toledo (1085), or in the Ebro valley (kingdom of Aragon), after the conquest of Zaragoza (1118). Catalonia continued to lead the densification process, joined by the Aragonese Pyrenees, and later by Castile and the Ebro Valley. It is worth mentioning the « sagreras » phenomenon in Catalonia. These were the spaces around churches, considered as sacred and protected from feudal violence. Jordi Morelló[51], by means of an exhaustive documentary analysis, shows a long-term process with its climax since mid-11th till 12th century. It is interesting to check how the density of mentions to sagreras has a clear spatial correlation with the density of buildings calculated by us (fig. 19).

Fig. 19 – Superposition of sagreras density over the building's density calculated from 4-hour isochrons[52].



89 At the same time, certain population centers developed. Barcelona (County of Barcelona), Jaca and Huesca (Kingdom of Aragon) and León (Kingdom of León) became important as seats of power. Other towns and cities linked to the repopulation process, such as Zamora and Segovia, grew very fast at the end of this period, reflecting new forms of organization, such as the « Comunidades de Villa y Tierra ». These are political and territorial structures that developed in the southern Duero basin, between this river and the Central System mountains. They are under direct control of the counts of Castile, first, and of the kings of León and Castilla, later, and bring together pre-existing communities. The first documented case is Sepúlveda, near Segovia, with its « fuero » promulgation in 1076. Other examples are Segovia, Ávila, Salamanca or Cuéllar. This kind of political entity is directly linked to the frontier and the military requirements of Christian kingdoms against their Muslim neighbours – first the Taifa of Toledo and then the Almoravid and Almohad empires – and is characterized by a particular organization of space, nucleated around a town, which acts as the backbone of the entire territory[53]. These towns are formed by quarters or « colaciones », each one with its own parish church. Together with other nuclei such as Zamora and Soria, they present the highest concentrations of buildings in the entire study area.

90 Important changes took place in the 1150-1250 period. Densification slowed down in Catalonia, except in a few districts such as Pla de l'Estany, Garrotxa and Baja Ribagorça Oriental, where it continued at a marked pace. In other areas, however, such as the upper Ebro – in particular in the Pamplona area –, Galicia and, above all, Castile, the pace of densification increased. In this last region, high building densities are achieved in some of the aforementioned localities and also in certain northern districts, especially so in the Aguilar de Campoo area, with one of the sharpest density increases of the whole sequence. This construction boom in northern Castile, the upper Ebro and Galicia could be related to the development of the « Camino de Santiago » to Santiago

de Compostela as a means of structuring and bringing in new population. Nevertheless, as stated by P. Martínez Sopena[54], the development of towns and villages along the « Camino de Santiago » is not an isolated process, but a manifestation of a wider phenomenon that spread throughout the entire territory.

91 It also spread to new territories after the conquest of cities such as Lleida (1149), Cuenca (1177) or the restoration of cities such as Tarragona after its conquest at the end of the 11th century (1090), especially in the Tagus valley and the south of the Ebro basin – the present-day provinces of Toledo, Madrid, Guadalajara, Cuenca and Teruel. Construction also continued in various towns in the southern half of the Northern Plateau, between the Duero and the Central System, such as Zamora, Salamanca, Ávila, Segovia, Sepúlveda and Soria, the latter directly linked to the monarch Alfonso VIII (1158-1214), together with other centres of population like Uncastillo in the upper Ebro.

92 In the last phase (1250-1300), the densification process slowed down, with the exception of the Álava area, where it increased notably, joining the neighbouring districts of northern Castile and the upper Ebro. One reason for at least part of this apparent standstill could be a possible downward bias in the documentation of this final period, because even though the bibliography on Gothic buildings from this period has been reviewed, there are no encyclopaedic or systematic works for this artistic style, such as the « Enciclopedia del Románico » or « Catalunya Romànica ». Even so, it is worth mentioning that in autonomous regions such as Aragon or Catalonia, which have online architecture inventories, all the existing buildings, regardless of their artistic style, have been compared and the final result has hardly changed at all.

93 Therefore, purely historical reasons cannot be ruled out. One is the more urban character of Gothic art, with a greater tendency to construct fewer but larger buildings. Another is the strong expansion of the Christian kingdoms in the 13th century to more southern and eastern areas of the Peninsula – Extremadura, Andalusia, Murcia, Valencia –, with the consequent transfer of resources to these areas. Lastly, as stated by Michel Lauwers[55] and Élisabeth Zadora-Rio[56], in the middle of the 13th century we find a fully established parish network. A sign of this is the proliferation of conflicts of jurisdiction and boundary disputes between parishes. This seems to evidence the consolidation of a compact, continuous and articulated system of these territorial units.

94 Therefore, the process is complex. Chronologically, some areas took over from others in terms of building intensity. The most notable example is the leading role that Catalonia played in the early centuries, only to be overtaken by Castile, Galicia and Navarre from 1150 onwards. Moreover, the distribution varies in structure. For example, in Catalonia and northern Castile, it is very homogeneous and is markedly rural, with buildings distributed evenly throughout the territory ; while to the south of the Duero, buildings tend to be concentrated in urban areas and their surroundings.

95 To explain this process, several interrelated factors can be invoked : the genesis of the High Middle Ages society, the constitution of the parish network, social and political issues at the local level, and also the embodiment of power and identity representations through architecture. As stated by Ana Rodríguez, the speed, scale and dynamics of building activity confirms the hypothesis that it is precisely in the 12th and 13th centuries that a structural link between individual and collective wealth, on the one hand, and investment in stone or other durable materials on the other, became evident. From 1050 onwards, with a chronology staggered according to the different

regions, but coinciding in its great diffusion throughout the 12th century, the durable building in stone, brick or masonry is instituted as an instrument to manifest the identity of an ecclesiastical institution, of a noble lineage, of a council or a « Comunidad de Villa y Tierra », of a rural community or of the families that made up both, as well as the expression of the capacity for individual or collective action[57].

96 Also worth noting throughout the process is the low density of building remains in certain areas, such as the southeast sector – Tagus valley and south of the Ebro basin –, the eastern part of the Cantabrian coast – today's provinces of Bizkaia and Gipuzkoa – and, very strikingly, the western half of the Northern Plateau. The latter, corresponding to the historic Kingdom of León, has very low densities, except in specific nuclei, such as the cities of Zamora and Salamanca, and contrasts with neighbouring Castile, which has notably higher values. The question that remains is why there were so few new buildings, and we propose three possible, and not incompatible, reasons :

- One is low population density, as could be the case of the highlands of the Iberian System, in the current provinces of Teruel and Cuenca, where harsh climatic conditions have led to low population densities throughout history ;
- Another is the survival of the Mudejar population and, with it, of many of the pre-existing buildings, which could have discouraged new construction. There are many examples of mosques that were consecrated as churches after their conquest, but which were not reformed or rebuilt until much later, such as the cathedrals of Huesca or Toledo, or the Ferdinandine churches of Cordoba ;
- Finally, buildings may have disappeared completely or been replaced by more recent ones, in the late medieval and modern periods. This is particularly likely with less durable materials than stone, such as wood, adobe and even brick. One area where this possibility could be considered is the western half of the Northern Plateau, although a different pattern of occupation and building could be considered.

5. Conclusions

97 By way of conclusion, we would like to highlight the importance of this type of study for historical analysis on a regional and macroregional scale. The methodology we have just outlined has proven useful in the selected geographical area and can be extended to other areas, such as that covered by the European Petrifying Wealth project.

98 This is possible thanks to the design, implementation and feeding of the building spatial database. The data uploaded over several years has resulted in an extensive and standardised dataset which, despite all the shortcomings that still need to be addressed, can be considered representative of the construction phenomenon in the 11th to 13th centuries.

99 Correcting these shortcomings in the database, mainly the lack of documentary and archaeological information, should be one of future research lines. This would contribute to explore in greater depth and detail the spatial relationships between the constructive phenomenon and other realities, such as demography or settlement network.

100 We would also like to emphasise the fact that this type of study depends on a very broad empirical base that can always be updated. Therefore, the results shown,

although consistent, are not definitive and could be qualified and completed by adding new information.

101 On the other hand, the building database itself should be enriched to have a more complete overview, incorporating secular constructions, such as castles or fortified complexes. At the same time, in order to address a more weighted and hierarchical approach to ecclesiastical buildings, it would be necessary to consider certain characteristics, such as size, typology or architectural techniques.

102 It would also be interesting to work with all the construction phases of each building, not only with the date of its oldest preserved rests. From the social point of view, the construction of a new building would not have the same impact as the investment in modifications to existing ones. In the same way, reinvestment in pre-existing buildings provides information about the processes of legitimization and shaping of individual and collective identities within changing societies.

103 This presentation of a spatial analysis methodology based on the material remains of constructions will hopefully give rise in the near future to other studies in which the historical interpretation of the results given here will be explored in greater depth, as well as giving rise to other types of related studies and research.

6. Appendixes

N° 1 Methodology for the generation of isochrones

104 The isochronous areas were generated using GIS analysis tools, specifically through « cost surface analysis », also known as « friction surface analysis »[58]. Cost surface analysis models mobility by studying the geographical factors that condition it. The basic layer is the « cost surface » or « friction surface », which represents the spatial distribution of the cost variable, which quantifies the differential resistance to movement across the landscape. This variable is usually expressed in units of time or velocity and is calculated as a function of different variables regarding relevant travel-related dimensions of the landscape, such as topography, lithology or vegetation cover. The most frequently used of these variables to create the cost surface is the topographic slope, as is the case of this study, assuming it as a fundamental travel conditioning factor.

105 The cost layer was created as follows :

- Production of the digital elevation model (DEM) to be used to create the slope layer. This study used the SRTM DEM, created by NASA[59], specifically the version processed and distributed by the CGIAR Consortium for Spatial Information[60], with a spatial resolution of three sexagesimal seconds, which is equivalent to approximately 90 metres ;
- Creation of the slope layer, expressed as a percentage, from the DEM[61] ;
- Creation of the cost layer from the slope layer. The cost variable used in this work is the inverse of speed or, in other words, « slowness », and is based on the algorithm formulated by Gorenflo and Gale[62], which calculates walking velocity from the slope of the terrain.
  $v = 6\,e^{-3.5\,|s+0.05|}$

106 Where v is the velocity – in kilometres per hour –, s is the slope – expressed on a per unit basis, i.e. the tangent of the angle – and e is the base of the natural logarithm. The

velocity is calculated using the above formula and then converted to « slowness » values in seconds per metre.

107 The cost surface is used to generate the isochronous area of each location with the following procedure :

- Creation of a cost-distance (or « cumulative cost »)[63] layer. The cost-distance (or « cumulative cost ») is the distance. in cost units (in our case, time units), that separates one location from another. In other words, it is the minimum time required to get from one location to another ;
- The cost-distance layer is then used to define the isochronous area by selecting the area closest (in time) to the point of origin, below a given time threshold.

N° 2 Summary of buildings by agricultural districts

108 In this table we summarize the buildings by isochrones (both 15-minute and 4 hour), grouped by agricultural districts. The values shown in the cells are the averages of the counts per district and 50-year interval. We use color scales to highlight numerical values : green for 15-minute isochrons and blue for 4-hour ones. the higher the value, the darker the color. Agricultural districts are sorted by autonomous communities and provinces.

109 For example, Alt Penedès (with an average of 2 buildings for 15-minute isochrones) and Oviedo (with 1.75 and 8.13 for 15-minute and 4-hour isochrones, respectively) are the densest districts in the first half of the 10th century. On the contrary, in the second half of the 13th century, Pla de l’Estany shows the highest values (111.36 for 4-hour isochrones).

Tab. 8 – Average number of buildings for each agricultural district, grouped by administrative units and chronological periods

NOTES

1. This study has been carried out in the framework of the project « Petrifying Wealth. The Southern European Shift to Masonry as Collective Investment in Identity, c. 1050-1300 », financed by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (GA No 695515). PI. Ana Rodríguez (IH-CSIC). We would like to thank the members of the « Petrifiying Wealth » Project who have contributed to the creation and growth of the database. We also thank the encouragement and valuable suggestions by Juan Vicent and Pedro Díaz-del-Río, from the Research Group « Social and Economic Prehistory », in the CSIC Institute of History, being also the first the scientific manager of the Laboratory of Landscape Archaeology and Remote Sensing (LabTel), in the same Institution.

2. A. RODRÍGUEZ, « Construir para perdurar en la Edad Media : un panorama sobre materialidad, procesos constructivos y distribución espacial en la península ibérica (siglos XI-XIII) », *in* G. DE NAVARRA (ed.), *Construir para perdurar. Riqueza petrificada e identidad social. Siglos XI-XIV*, Navas de Tolosa, 2022, p. 27-50.

3. The bibliography of the Petrifying Wealth project is freely accessible through the CSIC institutional repository : https://digital.csic.es/cris/project/pj00207.

4. https://erc.europa.eu/managing-your-project/open-science.

5. For the spatial search of data, a cartographic viewer has been implemented : http://www.petrifyingwealth.cchs.csic.es/spatial/petri_spatial.html. For searching and downloading thematic information, there is a specific query form : http://www.petrifyingwealth.cchs.csic.es/spatial/consulta_bd.html.

6. The data management plans are openly accessible in the CSIC institutional repository, see : E. CAPDEVILA MONTES, L. RODRÍGUEZ DEL POZO and A. RODRÍGUEZ, *Petrifying Wealth. The Southern European Shift to Masonry as Collective Investment in Identity, c. 1050-1300*, Madrid, 2017 [https://digital.csic.es/handle/10261/155640] ; E. CAPDEVILA MONTES, A. PIÑEL BORDALLO and A. RODRÍGUEZ, *Petrifying Wealth. The Southern European Shift to Collective Investment in Masonry as Identity, c. 1050-1300. Horizon 2020 DMP (intermediate outline)*, Madrid, 2020 [https://digital.csic.es/handle/10261/239862.].

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11. J. A. QUIRÓS CASTILLO, « Arqueología del campesinado altomedieval : las aldeas y las granjas del País Vasco », *in* J. A. QUIRÓS CASTILLO (dir.), *The archaeology of early medieval villages in Europe,* ed. *Documentos de Arqueología e Historia*, 1 (2009), p. 385-404 [https://dialnet.unirioja.es/servlet/articulo?codigo=5226099].

12. J. C. SÁNCHEZ PARDO, « Análisis espacial de un territorio altomedieval : Nendos (A Coruña) », *Arqueología y territorio medieval*, 13-1 (2006), p. 7-48 [https://digital.csic.es/handle/10261/32909] ; *ID.*, *Territorio y poblamiento en Galicia entre la Antigüedad y la plena Edad Media*, Tesis Doctoral, Universidade de Santiago de Compostela (España), 2008 [https://minerva.usc.es/xmlui/handle/10347/2451]; J. C. SÁNCHEZ PARDO and A. RODRÍGUEZ RESINO, « Poblamiento rural altomedieval en Galicia : balance y perspectivas de trabajo », *in* J. A. QUIRÓS CASTILLO (dir.), *The archaeology..., op. cit.*, p. 137-148 [https://dialnet.unirioja.es/servlet/articulo?codigo=5225898].

13. L. SÁNCHEZ ZUFIAURRE, *Técnicas constructivas..., op. cit.*

14. A. RODRÍGUEZ, « Construir para perdurar... », *op. cit.*

15. N. PERREAUX, « Des structures inconciliables ? Cartographie comparée des chartes et des édifices « romans » (x^{e}-XIII^{e} siècle) », *Bulletin du Centre d'études médiévales d'Auxerre*, Hors-série n° 9 (2016) [http://journals.openedition.org/cem/13817].

16. É. ZADORA-RIO (dir.), *Des paroisses de Touraine aux communes d'Indre-et-Loire : la formation des territoires,* Tours, 2008.

17. M. LAUWERS, *Naissance du cimitière. Lieux sacrés et terres de morts dans l'Occident médéval*, Paris, 2005.

18. J. MORELLÓ BAGET, « Construir en espacios sacralizados : a propósito del surgimiento y expansión territorial de las sagreras catalanas, siglos XI-XIII », *in* G. DE NAVARRA (ed.), *Construir para perdurar..., op. cit.*, p. 301-339 [https://digital.csic.es/handle/10261/269011].

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22. VV. AA., *El Camino de Santiago y la articulación del espacio hispánico*, Navas de Tolosa, 1994.

23. GIS software (ArcGIS version 10.5) was used in the elaboration of maps and in the analysis to process the geographic data. The coordinate system used has been ETRS 89 / UTM zone 30N (EPSG : 25830).

24. VV. AA., *Enciclopedia del Románico*, Vols. 1-55, Palencia, Fundación Santa María la Real (Aguilar de Campóo), 1982-2002 [https://www.romanicodigital.com/el-romanico/enciclopedia-online].

25. J. VIGUÉ I VIÑAS and A. PLADEVALL I FONT, *Catalunya Romànica*, Vols. I-XXVII, Enciclopèdia Catalana, 1984-1998 [https://www.enciclopedia.cat/catalunya-romanica].

26. https://www.santamarialareal.org.

27. These large collections analyse exclusively Romanesque buildings, the predominant artistic style in our period of study. To complete the register, we have resorted to more specific bibliographical references that analyse pre-Romanesque, Mudejar or Gothic buildings, also developed within our chronology.

28. J. A. QUIRÓS CASTILLO, « Las iglesias altomedievales... », *op. cit.*, p. 197.

29. R. MAIRA VIDAL, « La construcción medieval en Las Merindades de Burgos entre los siglos XI y XIII. Costes, sistemas constructivos, recursos empleados y especialización de los talleres », *in* G. DE NAVARRA (ed.), *Construir para perdurar..., op. cit.*, p. 51-80 [https://digital.csic.es/handle/10261/269007].

30. Specifically, the area of analysis includes ten complete autonomous regions (Galicia, Castille-León, Principality of Asturias, Cantabria, Basque Country, La Rioja, Navarre, Aragon, Catalonia and Madrid), three provinces of the autonomous region of Castille-La Mancha (Guadalajara, Cuenca and Toledo), together with the Principality of Andorra. See tab. 1.

31. https://www.rotadoromanico.com/es/Monumentos/.

32. Agricultural Districts. Source : © Ministry of Agriculture, Fisheries and Food : https://www.mapa.gob.es/es/cartografia-y-sig/ide/descargas/agricultura/default.aspx.

33. L. GARCÍA SANJUÁN, D. W. WHEATLEY, P. MURRIETA FLORES and J. MÁRQUEZ PÉREZ, « Los SIG y el análisis espacial en arqueología : aplicaciones en la prehistoria reciente del sur de España », *in* M. Á CAU ONTIVEROS and F. X. NIETO PRIETO (ed.), *Arqueología náutica mediterránea*, Girona, 2009, p. 163-180, here p. 170 [https://idus.us.es/handle/11441/53295].

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36. The full results, summarized by agricultural districts, are given in Appendix 2.

37. Produced with ArcGIS 10.5, using the « Zonal Statistics as Table » tool.

38. Produced with ArcGIS 10.5, using the « Zonal Statistics as Table » tool.

39. An ascending line means a direct relationship between both variables ; a descending line means an inverse one. R-Squared value (R^2) indicates the intensity of the relationship between cost and density variables : less strong the closer to zero, stronger the closer to one. R-Squared values are only statistically significant (p-value < 0.05) in the following cases : general study area (usable area), Catalonia (usable area), Pyrenees (total and usable area). In the remaining cases, the relationship is not significant and therefore has no explanatory value.

40. É. ZADORA-RIO (dir.), *Des paroisses..., op. cit.*

41. L. M. VILLAR GARCÍA, « La formación... », *op. cit.*

42. É. ZADORA-RIO (dir.), *Des paroisses..., op. cit.*

43. M. LAUWERS, « Paroisse, paroissiens et territoire. Remarques sur *parochia* dans les textes latins du Moyen Âge », *Médiévales*, 49 (2005), p. 11-32.

44. J. A. QUIRÓS CASTILLO, « Las iglesias altomedievales... », *op. cit.*, p. 194.

45. M. LAUWERS, « Paroisse, paroissiens... », *op. cit.*

46. A. RODRÍGUEZ, « Construir para perdurar... », *op. cit.*, p. 28.

47. N. PERREAUX, « Des structures inconciliables... », *op. cit.*

48. J. BOLÒS, « La formación del hábitat... », *op. cit.*

49. G. RIPOLL LÓPEZ *et alii*, « La arquitectura religiosa... », *op. cit.*

50. L. ARIAS PÁRAMO, « Metrología y praxis constructiva en la arquitectura altomedieval hispana (siglos VIII-X) », *Madrider Mitteilungen*, 63 (2022), p. 446-511.

51. J. MORELLÓ BAGET, « Construir en espacios sacralizados... », *op. cit.*

52. J. MORELLÓ BAGET, « Construir en espacios sacralizados... », *ibid.* Sagreras density is represented as number of mentios per sq km and has been calculated through kernel density stimation :

https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-kernel-density-works.htm.

53. L. M. VILLAR GARCÍA, « La formación de las Comunidades... », *op. cit.*

54. VV. AA., *El Camino de Santiago..., op. cit.*

55. M. LAUWERS, « Paroisse, paroissiens... », *op. cit.*

56. É. ZADORA-RIO (dir.), *Des paroisses..., op. cit.*

57. A. RODRÍGUEZ, « Construir para perdurar... », *op. cit.*, p. 50.

58. For a summary of the cost analysis application, see D. WHEATLEY and M. GILLINGS, *Spatial technology and Archaeology : the archaeological applications of GIS*, London/New York, 2002, p. 151-159 ; J. CONOLLY and M. W. LAKE, *Geographical information systems in archaeology*, Cambridge, 2006, p. 252-256 ; I. GRAU MIRA, « Movimiento, circulación... », *op. cit.* ; P. FÁBREGA-ÁLVAREZ, « Un alto en el camino. Notas acerca del uso de SIG en los análisis de movilidad en arqueología », *in* M. D. C. MÍNGUEZ GARCÍA and E. CAPDEVILA MONTES (ed.), *Manual de tecnologías..., op. cit.*, p. 159-182. The procedure set out in this annex is drawn from the methodology applied in F. ACEITUNO BOCANEGRA and A. URIARTE GONZÁLEZ, « Conectando un territorio : simulación de rutas de movilidad entre cazadores-recolectores y primeros cultivadores. El caso del Cauca medio (Macizo Volcánico, Colombia) », *Trabajos de Prehistoria*, 76-2 (2019), p. 219-235.

59. Shuttle Radar Topography Mission : http://www2.jpl.nasa.gov/srtm/.

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61. ArcGIS ArcToolbox : Spatial Analyst Tools / Surface / Slope.

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ABSTRACTS

The *European Petrifying Wealth* project addresses the boom in construction that took place in Europe in the first centuries of the 2nd millennium and the social factors related to it. This task involves handling a large amount of information from different sources, for which a spatial relational database has been implemented. Through different spatial and statistical analyses, this article analyses the geographical distribution, and its chronological evolution, of ecclesiastical buildings in the northern half of the Iberian Peninsula between the 10th and 13th centuries. The results show a complex and varied scenario, which is interpreted in light of different historical phenomena, such as the emergence and development of political entities, the conquest and repopulation of new territories, or the formation of economic, territorial and cultural networks.

Le projet *European Petrifying Wealth* aborde l'essor de la construction en Europe au cours des premiers siècles du deuxième millénaire et des facteurs sociaux qui y sont liés. Cet objectif implique le traitement d'une grande quantité d'informations provenant de différentes sources, pour lesquelles une base de données relationnelle spatiale a été mise en place. Cet article analyse par le biais de différentes analyses spatiales et statistiques, la distribution géographique et l'évolution chronologique des bâtiments ecclésiastiques dans la moitié nord de la péninsule ibérique entre le Xᵉ et le XIIIᵉ siècle. Les résultats montrent un scénario complexe et varié, qui est interprété à la lumière de différents phénomènes historiques, tels que l'émergence et le développement d'entités politiques, la conquête et le repeuplement de nouveaux territoires, ou la formation de réseaux économiques, territoriaux et culturels.

INDEX

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