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THE FOUNDATION OF CISTERCIAN MONASTERIES IN FRANCE 1098-1789: AN HISTORICAL GIS EVALUATION

by

Jon Eric Klingenberg Rasmussen

A thesis submitted to the Graduate College
in partial fulfillment of the requirements
for the degree of Master of Arts
Geography
Western Michigan University
June 2015

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THE FOUNDATION OF CISTERCIAN MONASTERIES IN FRANCE 1098-1789: AN HISTORICAL GIS EVALUATION

Jon Eric Klingenberg Rasmussen, M.A.

Western Michigan University, 2015

Historical geography focuses upon those relationships which have shaped the evolution of place and landscape over time. One fundamental approach used to achieve this objective is the set of theories associated with spatial diffusion. This includes the spatial and chronological paths, the periodicities and rates of spread, as well as the identification of areas of void or avoidance. An emerging trend in historical geography is the use of Geographic Information Systems (GIS). A GIS provides the researcher with the necessary tools to re-evaluate and challenge long-standing interpretations of any given event, historical or otherwise, as well as develop new insights and formulate new research questions. The Center for Cistercian and Monastic Studies (CCMS) at Western Michigan University (WMU) is compiling a digital gazetteer database documenting Cistercian monasteries worldwide. This thesis project will utilize CCMS data and GIS software products from ESRI, Inc. to construct an historical GIS application which depicts and examines the foundation and expansion of Cistercian monasteries in France from their establishment in 1098 until their closure during the French Revolution. This investigation will examine spatial diffusion and attempt to reveal any patterns of clustering or avoidance that may exist. Results will be calculated with respect to the temporality of the data and will be presented using iterative maps and graphs.

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ACKNOWLEDGMENTS

Enrolling in grad school after a twenty-eight year hiatus has been a wonderful yet challenging experience. Of course this is partly due to age but there was also a wide technology gap to overcome. In 1980 during my senior year at Northern Michigan University I completed an Advanced Cartography course where the cutting-edge technology involved punching IBM cards. Obviously I now know just how much things have changed.

I would not have been able to complete this project or earn a degree without the patience, understanding and enthusiastic support of the faculty, staff and my fellow students in the Geography Department at Western Michigan University. I would like to extend special thanks and gratitude to the members of my thesis committee for their kindness, optimism, enthusiasm and especially for sharing their knowledge and expertise. This is one dinosaur who will never forget their kindness.

Finally, I would also like to thank my family and friends whose understanding and assistance during these past three years made it possible for me to accomplish my goal. I will always be in your debt.

Jon Eric Klingenberg Rasmussen

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TABLE OF CONTENTS

ACKNOWLEDGMENTS……..….ii

LIST OF TABLES……..….v

LIST OF FIGURES……..……..vi

INTRODUCTION…….....1

REVIEW OF LITERATURE……..……6

Geographic Information Systems (GIS)…….……....…6

Historical GIS……..…7

Spatial Data Analysis…….....10

Cartographic Visualization…….....12

Historic Route Mapping…….....14

Data Uncertainty……..…..16

Mapping Temporal Data……..…..18

METHODS…….....20

Software Platform……..…20

Input Data……..…21

Data Analysis…….....23

RESULTS……..28

Cartographic Methods..…….....28

Thematic Maps……...29

Choropleth Maps……36

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Table of Contents—Continued

Cartographic Methods

Density Map…..…37

Statistical Methods…..…40

Ripley's K-Function……..40

Euclidean Distance……43

Historical Route Reconstruction……....49

DISCUSSION……..…..55

APPENDICES

A. Input Data……..….64

B. The Foundation of Monasteries 1098-1789: Iterative Maps.……..…72

C. The Establishment of Cistercian Monasteries by Diocese…….…...90

D. Ripley's K-Function Test Results…..…….……96

E. Euclidean Distance Test Results…..……..…106

BIBLIOGRAPHY…….…...110

www.manaraa.com

LIST OF TABLES

1. Foundation Date Distribution……24

2. Ripley's K-Function Summary of Results by Filiation……42

3. The Number of Monasteries in the Buffer Region Before and After Bernard's 1145 Journey.....53

4. The Number of Monasteries by Decade in the Buffer Region of Bernard's 1145 Journey.....53

5. Monasteries per Square Kilometer.....54

www.manaraa.com

LIST OF FIGURES

1. French Diocese Basemap……...22

2. The Foundation of Monasteries Affiliated with Cîteaux by Decade…….30

3. The Foundation of Monasteries Affiliated with Clairvaux by Decade……..31

4. The Foundation of Monasteries Affiliated with La Ferté by Decade……32

5. The Foundation of Monasteries Affiliated with Morimond by Decade.....33

6. The Foundation of Monasteries Affiliated with Pontigny by Decade……...34

7. Density Map…….……..39

8. Ripley's K-Function Results 1098-1119……...41

9. Ripley's K-Function Results 1098-1129…….…….....41

10. Minimum Distance to Mother House by Decade.....…….……..44

11. Maximum Distance to Mother House by Decade…..……..45

12. Average Distance to Mother House by Decade……..…….45

13. Minimum Distance to House of Like Filiation by Decade……..……46

14. Maximum Distance to House of Like Filiation by Decade……..……...47

15. Average Distance to House of Like Filiation by Decade……..……..47

16. Minimum Distance to Another Cistercian House by Decade……..……...48

17. Maximum Distance to Another Cistercian House by Decade…..……..……48

18. Average Distance to Another Cistercian House by Decade……49

19. Map of Bernard's 1145 Languedoc Journey.....……51

www.manaraa.com

List of Figures—Continued

20. Detailed View of Bernard's 1145 Languedoc Journey……..……52

21. Number of Monasteries Founded by Decade (Cîteaux)…….……...75

22. Number of Monasteries Founded by Decade (Clairvaux)…….……78

23. Number of Monasteries Founded by Decade (La Ferté)…….……...80

24. Number of Monasteries Founded by Decade (Morimond)…..…….……..83

25. Number of Monasteries Founded by Decade (Pontigny)……..…….86

26. Number of Monasteries Founded by Decade (all Filiations)…...……89

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INTRODUCTION

Historical geography has been defined as "the study of geographies of past times" (Butlin, 1993, p. ix), whereby historical landscapes are reconstructed and studied. Even though interpretation of the past is unavoidably influenced by the present, historical geographers strive to achieve their goals with careful consideration being given toward developing an understanding of how individuals living in the past perceived their world.

Historical geography is a "complex, hybrid discipline, the product of differing fusions of geographical and historical traditions which themselves are illustrative of broader European intellectual, moral and political preoccupations" (Butlin, 1993, p. 2). During the seventeenth and early eighteenth centuries historical geography was focused on biblical geography. While the study of biblical subjects continued into later centuries, the focus of historical geography shifted to the study of ancient and classical civilizations during the nineteenth century. This process was closely linked to "studies of the history of geographical thought and the history of maps and mapping" (Butlin, 1993, p. 7). The direction of the discipline was the subject of much debate during the first three decades of the twentieth century. However by the 1920s the modern conception began to emerge. Today many scholars accept the paradigm that "historical geography…focuses upon those relationships which have shaped the evolution of place and landscape" (Butlin, 1993, p. 47). One fundamental approach used to achieve this objective is the study of spatial diffusion. This includes the spatial and chronological paths, the periodicities and rates of spread, as well as the identification of areas of void or avoidance (Butlin, 1993).

An emerging trend in historical geography is the use of Geographic Information Systems (GIS), referred to as historical GIS. A GIS allows for a wide variety of data

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types (numerical, textual, visual) "to be brought together in their appropriate location in time and space" (Gregory and Ell, 2007, p. 16) including data from different sources that would previously have been impossible or impractical to combine. This is a subtle but an important advantage for historical GIS research. GIS tools allow the scholar to re-evaluate familiar evidence in order to challenge long-standing interpretations as well as develop new insights and formulate new research questions. This is especially true in situations where data complexity has hindered progress in the past (Gregory and Ell, 2007).

The spatial diffusion of a phenomenon over a specific time period is the type of question frequently addressed by studies in historical geography (Butlin, 1993) and GIS supplies excellent tools and capabilities for conducting this type of research. The Center for Cistercian and Monastic Studies (CCMS) at Western Michigan University (WMU) is in the process of compiling a digital gazetteer database containing spatial and temporal data about Cistercian monasteries throughout the world, a data source that is appropriate for an historical GIS study (Steuer, 2013).

The CCMS and its predecessor the ICS (Institute of Cistercian Studies) has worked to promote Cistercian research for over 40 years through publications and annual conferences. One of the unique aspects of this Center has been its involvement with both the international scholarly community in Cistercian Studies and its ties to active Cistercian monastic foundations. Over the last decade the CCMS has been compiling a paper gazetteer containing data about Cistercian monasteries throughout the world. However the potential benefits of a searchable, digital version of this product has become apparent. Such a resource would "allow scholars to understand better the full scope of the

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Cistercian Order and to compare its development and inter-relationships in different cultural, linguistic, political and economic areas" (Steuer 2013, p. 6). Furthermore, the spatial analysis capabilities offered by GIS software could be used by scholars to analyze the geographic relationships within temporal data to raise new research questions, and discover new areas of research to enhance the current understanding of life in Cistercian monasteries.

The Cistercian Order was founded by men who desired a return to a simpler form of monastic observance. The Order followed the Rule of Benedict of Nursia (ca. 480 – 543), an Italian abbot who lived three years as a hermit before eventually establishing a monastery at *Monte Cassino* on a hilltop between Rome and Naples (Kinder 2002). The monastic lifestyle or Rule that he established required monks to forsake the ways of the world and follow in the footsteps of Jesus Christ. Benedict's followers were to practice strict obedience to their abbot and their Rule and perform daily the Opus Dei ("Work of God") consisting of eight liturgical offices. Between these offices, the monks spent their time working, reading, eating or sleeping. New aspirants promised stability, conversion of life and obedience.

The first Cistercian monastery *Cîteaux* in the duchy of Burgundy was founded in 1098 by a small group of monks who desired to follow the Rule of Saint Benedict to the letter (Burton & Kerr 2011). This new order was well-received within the Catholic Church and began to attract large numbers of new aspirants. In 1113 (Lekai, 1977; Williams, 1998) a group of young Burgundian nobleman, including Bernard (1090 – August 20, 1153) sought admission into the Cistercian order at *Cîteaux* (Williams, 1935). According to tradition, in 1115 Bernard was sent forth as abbot together with twelve

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monks to found a new monastery and on June 25 *Clairvaux* was established. Over the next several years Bernard's accomplishments and activities on behalf of the reformed Church won him great respect and admiration within both ecclesiastical and political circles. He "was a famed and sought-after crusading preacher, and the frank advisor of popes and monarchs" (Williams, 1998, p. 3). In 1130 with the Church in schism, he was selected to be the spokesman for one (the successful) of two rivals for pope at the council of Étampes. Bernard's reputation was further enhanced by his efforts to resolve this conflict. Included among Bernard's many other accomplishments were two journeys documented by Geoffrey, his biographer: one in 1145 to preach against heresy and the other an attempt to build support for a second Crusade. Bernard was canonized on January 18, 1174 (Williams, 1935).

From the beginning the *Charter of Charity* had served as the basic constitution of the Order (Williams, 1998). Among other things it sought unity within the Order while allowing each abbey a measure of autonomy. Within seventeen years of the founding of the first Cistercian house at *Cîteaux*, four daughter monasteries, or proto-abbeys, had been established: *La Ferté* (1113), *Pontigny* (1114), *Clairvaux* (1115) and *Morimond* (1115) (Kinder 2002). With the establishment of these daughter houses, a system of "filiation" was introduced as intended by the *Charter of Charity*. Filiation created a permanent relationship between all newly established monasteries originating from *Cîteaux* or one of the four daughter houses. While each new monastery was self-governing, it received an annual visit from the abbot of the founding mother house. In turn, each monastery was also required to send its abbot to an annual "General Chapter" meeting. "The first half of the twelfth century stands out . . . as a unique era of devotional

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enthusiasm, when monasticism turned into a mass movement of unparalleled proportions" (Lekai, 1977, p. 33). By the mid-twelfth century 350 Cistercian houses across Europe were in existence (Lekai, 1977).

While the monks strove to maintain self-sufficiency and follow the Rule of Saint Benedict to the letter, over time their roles in the wider local communities became more complex. Some monasteries evolved into centers of agricultural production and technological innovation and provided medical aid (Kinder, 2002) and sustenance to the local indigent population. In addition, the monasteries acquired vast property holdings, called granges, through donations, royal patronage, and bequests (Burton & Kerr 2011). The properties located near the abbey were typically considered the 'home grange.' In theory, more distant granges were to be within one day's journey or about thirty kilometers from the abbey. Some were, however, located as far away as eighty kilometers or three day's journey. Granges were used for agricultural and industrial purposes including mining and smelting and were sometimes located in urban centers. Any products surplus to the needs of the monastery were either sold in the local market economy or exchanged through the trade networks that formed during this period.

This thesis will utilize data extracted from the CCMS digital gazetteer database about the historical development of Cistercian culture and GIS software products from ESRI Inc. to construct an historical GIS application which examines and depicts the foundation and expansion of Cistercian monasteries in France from their establishment in 1098 until their closure during the French Revolution. The following objectives will attempt to demonstrate how GIS techniques may encourage the formation of new perspectives, questions, and ideas with respect to historical research:

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1. *Cartographic Methods. Examine and temporally portray spatial diffusion with iterative thematic maps, choropleth and density maps, and attempt to identify any patterns of clustering or avoidance that may exist both nationwide and by filiation.*
2. *Statistical Methods. Statistically test spatial patterns using measures of clustering and proximity at various scales within and across filiations. Apply GIS spatial data analysis techniques to a reconstruction of an historical route in order to answer a specific historical research question.*

REVIEW OF LITERATURE

The following seven subject areas applicable to this study are discussed in independent sections below: GIS, Historical GIS, Spatial Data Analysis, Cartographic Visualization, Historic Route Mapping, Data Uncertainty, and Mapping Temporal Data.

Geographic Information Systems (GIS)

A Geographic Information System (GIS) is defined as "a collection of computer hardware, software, and geographic data for capturing, storing, updating, manipulating, analyzing, and displaying all forms of geographically referenced information" (Knowles, 2002, p. 186). GIS technology has been transforming how spatial data is analyzed by providing "a framework for compiling and indexing information" (Knowles 2002, p. xv) since the 1990's when GIS was first released in a GUI desktop environment (ESRI.com).

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A GIS does not just identify locations on the earth, it links library catalogs, data sets, and distributed information (Lancaster and Bodenhamer, 2002).

A primary function of GIS software is the generation of maps which can be updated and re-generated as frequently as necessary. "GIS fundamentally redefines the role of the map in research … the map becomes a way into the data, and the researcher will constantly interact with the map as part of the process of exploring and analyzing the data" (Gregory and Ell, 2007, p. 68).

GIS spatial analysis capabilities are one of its most important strengths. By combining latitude/longitude or other geographical coordinate data with attribute data about environmental or cultural phenomena, research questions can be explored in an integrated manner (Gregory & Ell, 2005). The software has the ability to synthesize multiple layers of data, determine spatial interrelationships, and integrate text, images, maps and other digital data sources. Consequently "GIS can reveal patterns and relationships among data that are not readily apparent in spreadsheets or other statistical packages."(Padilla, 2008, p. 33).

GIS software offers the researcher many spatial tools. For example a buffer or zone of specified distance around a selected location (point, line or polygon) can be established in order to further examine the characteristics of distance or neighborhood. In addition the software provides the ability "to quantify distances, directions and attributes and then study their statistical characteristics" (Knowles, 2002, p. ix).

Historical GIS

During the past several years, interest in the application of GIS technology to historical research has increased among scholars. This led to the development in the late

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1990s of a sub-discipline called historical GIS (Gregory & Healey, 2007) or HGIS. The field is becoming increasingly important to historians, historical geographers, archaeologists, environmentalists and other scholars who reconstruct past places or environments (Knowles, 2005). Much of the early work of scholars focused on the development of databases with a shift of emphasis to processing techniques occurring more recently. Only in very recent years have finished papers utilizing an historical GIS analysis began to appear (Gregory and Ell, 2007).

The aim of historical GIS "is to attempt to recreate a study area that no longer exists" (Gregory and Ell, 2007, p. 87). Often this must be accomplished by using fragmentary and disparate extant sources which have been compiled by different organizations for different purposes.

Historical GIS can advance historical scholarship in three ways: by promoting revisionist ideas that challenge existing paradigms, by investigating unresolved questions, and by enabling researchers to formulate entirely new questions (Gregory & Healy, 2007). "The ability of GIS to integrate, analyze, and visually represent spatially referenced information is inspiring historians to combine sources in new ways" and promotes the re-examination of accepted historical interpretations (Knowles, 2002, p. xiii). GIS "redefines the role of the map in historical analysis" and "puts mapping at the core of research and data exploration" (Gregory & Southall, 2002, p. 129).

Additionally, three advantages to using GIS in historical research have been identified (Gregory & Healey, 2007). First, data values thought to be incompatible can be integrated through their location on the Earth's surface. Second, maps can be generated

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that portray the data visually (including animations and virtual landscapes). Finally, coordinate locations of the features become part of the spatial analysis.

Historical GIS projects often focus on the "relationships between localities and between one scale of human interaction and another, as between local, regional, and national conditions and events" (Knowles, 2002, p. xix). This allows historians to identify the level or scale at which a narrative or interpretation can correctly describe the known facts and when it cannot.

Some scholars believe that the strongest contributions of historical GIS projects are those which use the technology to reexamine historical sources and to map data which has heretofore been unmapped (Knowles, 2002).

Building historical GIS databases is a complex process since they are comprised of data obtained from multiple sources which are integrated for a specific use. In addition, they contain metadata and documentation concerning the data sources. Historical GIS databases are considered to be significant works of scholarship in their own right (Gregory & Healy, 2007).

There has been significant progress in historical GIS database development and several national historical GIS projects have been implemented (Padilla, 2008). The National Historical GIS (McMaster & Noble, 2005) contains census data and tract information for the period 1790-2000. This software can be used to display and analyze census data in map or report form. The China Historical GIS is a database of information about places and administrative units in China for the period 222 BC – 1911 AD (Bol & Ge, 2005). This software allows users to generate maps of historical units and perform spatial analysis and temporal statistics modeling. The Great Britain GIS or "Vision of

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Britain" displays temporal changes in the UK (Gregory, 2005). The database contains information from census reports, historical gazetteers, traveler's stories, and historic maps. The Belgian Historical GIS portrays administrative boundaries in Belgium since 1800 (Vanhaute, 2005). Database construction for these projects are data led, meaning that a large amount of data already exists. This data is analyzed to extract information contained within. This approach is different from efforts that require the collection and examination of new data to investigate a specific research question (Gregory & Healy, 2007).

Despite this considerable progress in the development of historical GIS databases, significant conceptual and technical issues remain. GIS databases are considered by some to be inadequate at handling the uncertainty, incompleteness, inaccuracy and ambiguity that are frequently associated with historical data (Gregory & Healy, 2007). In addition, GIS professionals and other scholars also struggle to develop and implement strategies for incorporating temporal data into GIS applications. Iterative mapping and time slider-bar techniques are two common approaches but scholars continue to search for other solutions.

Spatial Data Analysis

Point pattern analysis can be used to measure the spatial diffusion of a phenomenon over a specific time period. This type of analysis is the most basic form of spatial analysis and is frequently employed in historical geography (Butlin, 1993; Gregory and Ell, 2007). Usually this is necessary to identify and measure the presence of spatial dependence thereby allowing the researcher to adjust the statistical test being

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performed; or when there is interest in the patterns themselves (Rogerson, 2010). In the second case, the researcher generally attempts to determine whether or not such patterns occur due to a process of clustering or resulted by chance alone.

Statistical tests for spatial pattern analysis have been classified into three types. General tests are "designed to provide a single measure of overall pattern" (Rogerson, 2010, p. 274). Examples of these tests include the *Morans' I* statistic (Moran, 1950), *nearest neighbor* (Altman, 1992), *K-Function* analysis (Ripley, 1976), and the *quadrat* method. General tests are considered to be global tests because they require variable measurements from many geo-referenced points. An advantage is that individual level point data is maintained at actual georeferenced locations.

Focused tests are limited to smaller regions that have been pre-selected for a specific reason, for example the location of a power plant or toxic waste site (Rogerson, 2010).

Finally, local statistical tests are used to identify patterns when no foci of interest have been pre-selected (Rogerson, 2010). *Getis and Ord* (1992) introduced the G_i statistic, which "make it possible to evaluate the spatial association of a variable within a specified distance of a single point" (Getis & Ord, 1992, p. 189). It is useful for identifying *hot spots* or pockets of dependence. The G_i statistic measures the degree of concentration of a variable in a region of study. Results identify positive or negative spatial association. The G_i statistic identifies clusters that do not appear using global statistical techniques. Therefore it should be used in conjunction with other tests such as *Morans' I*. It is also only effective on aggregated data. When exact locations should be preserved other tests must be utilized.

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Cartographic Visualization

Traditionally maps have been used as communication devices that attempt to portray an accurate representation of reality while also maintaining objectivity (Hallisey, 2005; Jiang, 1996). Their primary function has been to depict patterns or other phenomena having spatial significance. More recently, maps have begun to play an entirely new role (Kraak, 1998). In addition to their traditional communication function, maps are now also being used to assist with data analysis and with problem definition and solution, a process called cartographic visualization.

Recent advances in interactive computer graphics and image processing technology have enabled cartographic visualization, which is a process whereby spatial data is depicted in various alternative perspectives and formats by using a range of software tools (MacEachren & Ganter, 1990; Jiang, 1996). The goal of this process is to gain a deeper understanding of the data and to identify any patterns or anomalies that are not necessarily anticipated (MacEachren & Ganter, 1990), in other words, to extract "the patterns trapped in the tables of facts and figures or in mathematical equations." (Dorling, 1992, p. 216). Examples particular to historical GIS include: *The application of GIS to the reconstruction of the slave-plantation economy of St. Croix, Danish West Indies* (Hopkins, Morgan, & Roberts, 2011), an examination of the economic and social systems of a slave society using maps, census data, and cadastral records; *The Geographic Origins of the Norman Conquerors of England* (Hewitt, 2010) which maps the origins of the knights in the Norman army; *Demography, Depopulation, and Devastation: Exploring the Geography of the Irish Potato Famine* (Ell & Gregory, 2005), an investigation of Irish de-population after the potato famine in which maps at varying

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scales are generated from census and agricultural data; and *Rapid Settlement Diffusion: The Development of the Semi-Peripheral Region North of San Francisco, California, 1850-1880*, a study of population settlement and economic specialization based on census data and city directories (Otterstrom, 2007).

This methodology's most significant contribution may be its potential for generating new questions and new research ideas. Therefore, it is not only being utilized for research in the earth sciences, but is also being employed by other disciplines such as diagnostic medicine and chemistry as well (MacEachren & Ganter, 1990). Four stages of visualization research have been identified, "two private visual thinking stages (exploration and confirmation) and two public visual communication stages (synthesis and presentation)" (MacEachren & Kraak, 1997, p. 336).

Cartographic visualization "generally involves manipulation of known data in a search for unknown relationships" (MacEachren & Kraak, 1997, p. 339). "There is no single correct way to represent data" (Hallisey, 2005, p. 357). Multiple views and representations are necessary for analyzing any data relationships that may exist. It is believed that these computer graphic representations stimulate visual thinking (Jiang, 1996). Humans have an inherent ability to spatialize data (Fairbairn et al., 2001) and our ability to abstract, simplify and approximate allow us to develop insights and impose order, in other words to identify patterns (MacEachren & Ganter, 1990; Jiang, 1996).

Cartographic visualization software tools include query capability, multiple representation formats, linking to related data, animation features and dimensionality (Hallisey, 2005). A mechanism to cross-reference and integrate a variety of media sources may also be useful (Jiang, 1996).

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Historic Route Mapping

Historians and archaeologists have long recognized the importance of road systems to society. Besides the utilitarian function of making travel easier, roads increase regional interaction thereby facilitating trade, communication, pilgrimages and exploration as well as increasing the ability to consolidate political control.

Scholars have recently begun to employ GIS software to explore and document historic routes and the impacts they made on the landscape. Williams and Wordsworth (2009) examined the sequent occupation associated with the ancient city of Merv (5th Century BCE – 1221 CE) located in the Murghab Delta region of eastern Turkmenistan. Scholars were aware that a major road existed in the region but its precise location was unknown. A GIS was employed to overlay the available archaeological, historical, cartographic, topographic and hydrologic data onto satellite and aerial imagery. The results were then used to conduct additional field survey work in an effort to delineate the location of the ancient road.

GIS analysis techniques have also been applied to ancient roads whose location are known in order to determine their purpose (Hendrickson, 2010). The author examined the ancient routes (9th – 13th Centuries) to Angkor in modern Cambodia and their associated infrastructure such as resting places and crossing points. It was known that these roads were used for trade, religious pilgrimages and other expeditions. However the author asserts that the presence of different types of infrastructure indicates that the roads were used for different purposes through time. The roads and their associated infrastructure "appear to have been formalized and expanded during times of relative stability and economic growth" (Hendrickson, 2010, p. 494).

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Digital gazetteer and GIS geocoding tools have been utilized to construct historic trails from documentary accounts (Piotrowski, Läubli, & Volk, 2010). The Swiss Alpine Club has published a yearbook since 1864. These books contain mountaineering accounts describing the ascent to various peaks. After these documents were scanned and subjected to OCR processing, the text was searched for toponyms. Once identified, the toponyms were compared to gazetteer data to obtain geo-coordinates. Toponym resolution was a difficult process as there are three official languages in Switzerland. The GIS can then be used to recreate the location of the described trail.

In situations where documentary and archaeological evidence is sparse, GIS can be utilized to evaluate the physical characteristics of a landscape in order to identify areas most suitable for road building. These results can then be used to provide additional clues when actual trails do not follow these 'expected' routes. Kantner (1997) employed GIS analysis techniques of this type to roadways built during the period 900-1150 by the Chaco Anasazi people of the American southwest. The purpose of the roads has long remained a mystery since this society did not utilize pack animals or wheeled vehicles. GIS spatial analysis tools were used to evaluate the physical landscape and compute idealized cost-paths between points. When compared to the actual roads, there was very little alignment between the computed and actual routes. The author concludes that these results indicate that the roads may have served a religious purpose, however it is unlikely that they had an economic function. It is possible that they served a local function by integrating the population over small areas.

GIS technology has also been used to document trails that leave no permanent trace on the landscape (Aporta, 2009). The native Inuit people in the Arctic utilize a

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network of trails that connect settlements, fishing lakes, and hunting grounds. These temporary trails consist of visible tracks in the snow created by dogsleds and snowmobiles. However "these trails follow well-established routes or itineraries that Inuit use year after year, and that are widely recognized by the community" (Aporta, 2009, p. 134). The trails are described by a sequence of place names. This information is transmitted orally through descriptions of the journey thereby allowing these trails to be recreated year to year and from generation to generation. Once these trails have become documented in map form, some scholars fear that the Inuit will rely on the maps and lose the ability to transmit this information orally.

Data Uncertainty

A fundamental problem confronted by researchers attempting to analyze historical data using GIS technology is the imprecise nature of the data. In many instances specific locations are not known with certainty and boundaries can only be estimated. This challenge can be especially difficult in areas where boundaries have been fluid (Holdsworth, 2003).

The ability to manage data uncertainty within a GIS has been the subject of much study and has resulted in the identification of five goals: (1) to reduce the amount of uncertainty; (2) to manage uncertainty within the database; (3) to manage the propagation of uncertainty by GIS functions; (4) to estimate or measure the amount of uncertainty; and (5) to understand the source or cause of the uncertainty (Plewe, 2002). The first four goals depend on the fifth as uncertainty can only be appropriately managed after it has been defined.

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Data uncertainty can be introduced by various means including misinterpretation, questionable, ambiguous or conflicting evidence, and transcription errors. But it is also important to recognize that representations of reality are simplifications and usually impose a degree of order that does not actually exist. Consequently, conceptualizing, measuring and building GIS models can also introduce data uncertainty (Plewe, 2002).

Three broad approaches to handling data uncertainty issues have been developed: the mathematical, the representational, and the documentary (Gregory & Healy, 2007). The mathematical approach relies on the concept of "fuzzy logic" which uses probability and permits the degree of certainty to be included in the data. The representational approach uses a raster depiction where individual pixels can be manipulated based on the degree of data certainty. In the last approach, historians have traditionally used documentation to overcome these types of problems. In a GIS this is accomplished using metadata or data which describes the data.

Incorporating and visualizing uncertain and imprecise historical data is another difficulty encountered by researchers. The degree of certainty can affect the kinds of conclusions reached, so users of the information should be aware of its level of accuracy. One solution designed to account for this type of data is implemented by creating two fields in a database or table; one for containing the available data value itself and one to indicate the degree of certainty or confidence (Elliott & Talbert, 2002).

Uncertainty can be displayed visually through the creative use of symbols (Elliott & Talbert, 2002). For example, a dashed line instead of a solid line or a hollow point instead of a solid point can be used to represent an approximate location. This approach

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was taken by the American Philological Association's Classical Atlas Project which created the *Barrington Atlas of the Greek and Roman World* (Talbert, 2000).

Mapping Temporal Data

To understand the evolution of a place or a phenomenon it is important to understanding change over time and the ability to trace and analyze spatial information as it changes over time continues to be a goal of GIS technology. A temporal capability would allow researchers to identify patterns or trends, describe where and how quickly change occurs, and possibly determine the cause of the changes (Langran, 1989).

Implementing time into a database typology is a complex challenge that scholars continue to struggle with (Armstrong, 1988). Generally most currently available relational database technology can store a snapshot or picture of the latest available data. A temporal database model must be able to reflect a dynamically changing world. Thus the fundamental problem becomes how to record and recognize different versions of changing objects (Langran, 1989). Progress has been made through the skillful use of multiple date fields or timestamps, unique computer generated fields comprised of date and time in microseconds at the exact moment of update. However issues still remain concerning the amount of storage required and the necessity of storing redundant data which violates the normalization rules of relational databases.

Four methods for organizing temporal data in a database structure have been identified (Armstrong, 1988). A *static database* only contains current data about an entity. When changes occur the old data is discarded therefore it is not possible to reconstruct an event sequence. A *static rollback* approach stores past states of an entity

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using a time indexed mechanism. It is possible to reconstruct past snapshots of an entity but it is only possible to update data in the current (most recent) picture. Generally the time used for indexing represents the time of transaction processing, not the time that the event occurred. The historical states of the entities are stored in an *historical database*. A valid time field is maintained and indicates the period of validity for each occurrence. Similarly a *temporal database* contains a valid time but also maintains transaction timestamps.

Complexity is increased by adding the spatial component to the problems already discussed with temporal data (Armstrong, 1988). For example, geographical entities may experience change over time. These include: (1) geometrical transformation when size, shape or location change; (2) accretion, erosion, or a change in land use type (agricultural to urban), and; (3) scale and dimensional changes, for example a change in representation such as from a point to a polygon. Finally, it is important to note that as geographical entities change their topological relationship are also likely to change as well.

Incorporating time into a GIS is a difficult process (Knowles, 2002). This is especially true when attempting to incorporate time into spatial analysis. The easiest approach is to enter date information as an attribute into the GIS database or table. Date-based queries can then be used to generate a series or sequence of maps which depict change, also known as *Iterative Mapping*. This becomes more difficult however for maps constructed from multiple layers. A second approach for displaying temporal data involves the use of a time-slider bar (ESRI Inc., 2012). Each data entity must have an associated date attribute field. The time-slider bar can be used to animate a visual presentation whereby the data is mapped based on the value contained in the date field.

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The time-slider bar can also be manipulated by the user to depict the mapped phenomena at a specific point in time.

The ESRI Story Maps website (ESRI Inc., 2015) hosts several maps which are good examples of how to display temporal data. One technique employed is the use of a time-slider bar. The *Battle of Gettysburg* map utilizes a time-slider bar that contains specific dates. As the user selects a date by moving the slider bar, the applicable map for that date is displayed. Another example, the *Battlefields of the Civil War* map, uses a slightly different version of a time-slider bar. Like in the previous example, this map permits the user to select a specific map display by moving the slider bar to the date of interest. However it also allows the user to view an animated map display of the mapped phenomenon (battles). The (Olympic) *Medals Through the Years* map is another example of an animated display. In this example the animation is automatic and does not have to be started by the user however, the user is permitted to advance or backup through the maps by clicking on forward and backward buttons. Finally, the *Hiking the Appalachian Trail* map contains a series of photographs along the bottom of the screen which serve as a timeline. A small scale map is displayed showing the locations of all the events (photos) in the timeline. When the user selects one of the photographs (by clicking on it) a large scale map is displayed which depicts a more detailed map of the location of the event.

METHODS

Software Platform

ArcMap (version 10.2.2) software from ESRI Inc., the most advanced state of the art mapping software available, was the GIS platform utilized. The basemap chosen was

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a shapefile of French diocesan boundaries as they existed in the year 1000 A.D. downloaded from the *Digital Atlas of Roman and Medieval Civilizations* website (Grigoli & Maione-Downing, 2013) and presented in Figure 1. This depiction of the diocesan boundaries is a contemporary estimation of the boundaries as they existed at the beginning of the time period under study. Since dioceses are administrative units that change over time, this shapefile may not accurately represent the diocesan boundaries over the entire length of the study period, consequently introducing error into the cartographic products and analysis.

In addition the downloaded shapefile contained four dioceses lying outside the boundaries of modern France. These diocese either did not contain any data points or contained non-French monasteries and were therefore removed from the basemap.

Input Data

Data extracted from the CCMS gazetteer database was loaded into an Excel spreadsheet and is presented as Appendix A. The data fields of interest included: monastery name, latitude, longitude, filiation, foundation-date, dissolution-date and diocese. Each field was required for processing and therefore a second data source was consulted to obtain any missing values: *Filiation des abbayes cisterciennes* (http://fr.wikipedia.org/wiki/Filiation_des_abbayes_cisterciennes). Only 266 monasteries with complete data were included in the finalized input dataset. Consequently, the input data does not represent every French Cistercian monastery.

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Figure 1: French Diocese Basemap. Created by the author using shapefiles downloaded from the *Digital Atlas of Roman and Medieval Civilizations* website (Grigoli & Maione-Downing, 2013) and ESRI.com. Projection: Europe Albers Equal Area Conic, Coordinate System: European 1950, Jon Eric K. Rasmussen, 2015.

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Two additional determinations were required which have potential impact to the results. First, in cases where the foundation-date field contained a date range, the smallest (earliest) date was selected. Sometimes this condition existed because a monastery had been initially established by another Order and only later became Cistercian. In these cases the date the monastery became Cistercian was selected.

The assignment of the diocese field also required manual correction for consistency. In some cases the modern diocese name had been assigned. In some other cases the diocese remained unknown. Consequently the assignment of the diocese field was verified for all monasteries by comparing their location to the diocesan basemap, circa 1000 A.D.

Data Analysis

Various mapping and spatial analysis tools available in ArcMap were utilized to perform point pattern analyses on the input data to observe and measure the spatial diffusion of the foundation of French Cistercian monasteries over specific time periods by filiation as well as for the entire Order. In order to emphasize the temporality of the data, the results are presented as a series of iterative maps and charts.

Examination of the foundation-date field revealed that 90% of the monasteries were founded during the 12th century. Consequently decade classes were constructed (as shown in Table 2) for data display and analysis with the final class covering the 589 years from 1200 to 1789 containing 27 monasteries. While this structure is logical and appears as appropriate as any other scheme, it is admittedly arbitrary.

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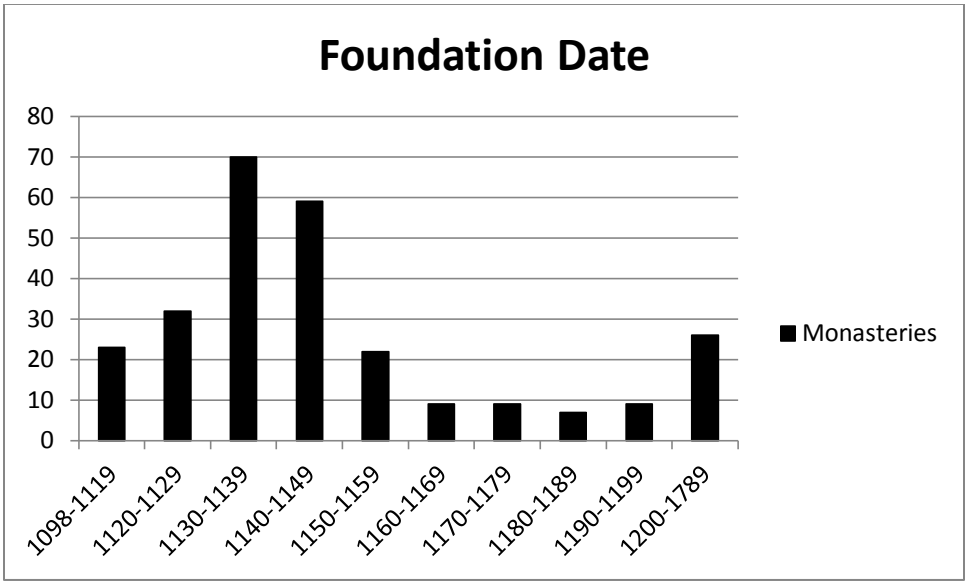
Table 1: Foundation Date Distribution. The distribution of the number of Cistercian monasteries founded by decade during the study period (1098-1789). Source: created by the author using the input data and Microsoft Excel software. Jon Eric K. Rasmussen, 2015.



Thematic maps were generated for each filiation and the Order as a whole. To assist with identification, each decade was assigned a symbol which remains consistent throughout all five maps.

Two iterative series of choropleth maps were generated using both raw and normalized data depicting monastery foundation within the diocesan administrative structure. The classes were constructed using the Jenks (Natural Breaks) method as this appeared to offer the best contrast on each individual map. The Jenks method establishes class boundaries at naturally occurring breaks between groups of data. Therefore class intervals can vary. Since the data is presented cumulatively, the map classes must be compared across maps with caution. For example, a diocese colored with the darkest (highest value) on an early map may become much lighter on future maps.

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A density map was also created using the ArcMap Point Density tool. A radius value of 30 kilometers around each point was used to represent the distance of one day's travel (Burton & Kerr, 2011). Areas of darker color show regions under the influence of more than one monastery.

The above cartographic methods provide the user with a visual image of the expansion of the Order. However visual impressions may be misleading or difficult to interpret. Consequently the application of statistical tests to measure a spatial phenomenon can be useful to either confirm or deny the visual interpretation. For this thesis, Ripley's K-Function has been chosen as an appropriate test to apply to the CCMS gazetteer data. The K-Function analyzes stationary points and assumes an homogeneous region, that is a region with no preferred point of origin or direction. Results of the test measure the presence of clustering, dispersion, or complete spatial randomness (CSR) (Ripley, 1976; Ripley, 1977). The K-Function measures the concentration of points by calculating the average number of neighbors each point has within a given distance (radius) (Albert, Casanova, & Orts, 2012). Fortunately this test also incorporates scale which is significant since patterns can change as scale changes (Zhang et al., 2014).

The ArcMap software tool uses a common transformation of Ripley's K-Function where the transformation L(d) is computed using the formula:

$$L(d) = \sqrt{\frac{A\sum_{i=1}^{N}\sum_{j=1,j\neq i}^{N} k(i,j)}{\pi N(N-1)}}$$

"where *A* is area, *N* is the number of points, *d* is the distance and *k(i, j)* is the weight, which (if there is no boundary correction) is 1 when the distance between *i* and *j* is less

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than or equal to *d* and 0 when the distance between *i* and *j* is greater than *d*. When edge correction is applied, the weight of *k(i,j)* is modified slightly" (ESRI Inc., 2014a).

The ArcMap tool begins with a user selected distance (10 km in this case) and computes for every point the average number of neighboring points (points within the 10 km distance). "If the average number of neighbors for a particular evaluation distance is higher/larger than the average concentration of features [points] throughout the study area, the distribution is considered clustered at that distance" (ESRI Inc., 2014b). The computations are performed for several distance values (or scales). As the evaluation distance increases, each point will typically have more neighbors thus increasing the chances of clustering but only if the computed value is greater than the average computed for the entire study area. The output graph results will show at which distances (or scale) clustering or dispersion is detected.

Ripley's K-Function was first applied to pattern analysis in the fields of forestry, regional science, and disease monitoring. Recently it has been applied to several other disciplines. Archaeologists have used K-Function analysis to examine the organization of space in early Anglo-Saxon cemeteries (Sayer & Wienhold, 2012). The K-Function permits researchers to formulate and test inferences about past human behavior. Specifically it has been used to evaluate whether or not "there were human decisions underlying grave placement" (Sayer & Wienhold, 2012, p. 77).

K-Function analysis has been used by geoscientists to investigate the spatial patterns "among landslide events and between gravitational slope deformations and earthquakes" (Tonini et al., 2013, p. 97). These types of geological events are frequently spatially and temporally clustered. However in this case scale is an important factor and

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the K-Function test allows researchers to determine the range of distance where clustering (or dispersion) becomes significant. Results can aid scientists trying to forecast future geologic and/or seismic events and emergency managers with loss mitigation planning.

Human geographers have applied K-Function testing to define human settlement patterns (Zhang et al., 2014). Scale can be a significant factor in this type of analysis as well, as scale changes may cause patterns to appear more clustered or more random. This type of research attempts to identify pattern variations and associations in relation to land use decisions.

Economists also have used the K-Function to evaluate spatial location patterns of manufacturing firms (Albert, Casanova, & Orts, 2012). Economic activity is known to have clustering tendencies within certain industries. However, economists are not only interested in the factors which promote concentration but are also concerned with how to "measure and characterize the patterns" (Albert, Casanova, & Orts, 2012, p. 108). By treating space as continuous and permitting variations of scale, the K-Function can determine "whether concentration exists, what its intensity is and at what distance, or spatial scale, its highest level is obtained" (Albert, Casanova, & Orts, 2012, p. 110).

Transportation during the medieval period was slow and difficult compared to contemporary standards. Consequently an individual's conception of distance cannot be assumed to be the same as that held by persons living today. To investigate the impact that distance may have had on the expansion of the Order throughout France, the ArcMap Near and Point Distance tools were used to measure the Euclidean distance between each monastery and: 1) its mother house, 2) its closest neighbor of like filiation, and 3) its

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closest neighbor of any Cistercian filiation. Minimum, maximum and average values have been tabulated and are presented and compared using tables and charts.

To demonstrate the potential for application to a specific historical question, ArcMap editing tools were also employed to reconstruct the approximate route followed by Bernard of Clairvaux on his journey through southwestern France in 1145. A 30 kilometer buffer was constructed on each side of the route and chi-square tests were applied to determine any potential impact to monastery establishment in the region after his appearance.

RESULTS

In fulfillment of the stated objectives, several GIS cartographic and spatial analysis tools were applied to the input data extracted from the CCMS digital gazetteer database and several output products were generated. This is intended to emphasize the variety of tools that are available, the valuable contributions that a GIS can make when evaluating historic landscapes, and provide examples of the new directions for future research that can be revealed.

Cartographic Methods

The first objective, to examine the spatial diffusion of the monastery point data through time to discern any patterns of clustering or avoidance that may exist, was performed using the following cartographic visualization methods: Thematic, Choropleth and Density maps. Each method depicts the data in different ways thereby providing alternative "views" which can be used to enhance the analysis.

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Thematic Maps

Thematic maps were created which portray the patterns of expansion by filiation. These are presented in Figures 2 through 6. The symbols can be used to identify the decade that each monastery was founded.

A series of iterative maps were generated depicting the spatial diffusion of the foundation process for all filiations and for the complete Order from its beginning in 1098 until the French Revolution in 1789. These results are presented in Appendix B. Close inspection of the maps reveals that while the Order as a whole spread throughout most of the country, each filiation had regions of preference.

For Cîteaux, peak expansion occurred from 1130 to 1150. During the earliest period, expansion moved to the northwest and south of the mother house. This pattern continued through the 1120s and into the 1130s when houses affiliated with Cîteaux began appearing in Brittany in the far northwest of the country. It was during the 1130s when a slight movement to the southwest began. This was reinforced during the 1140s. For Cîteaux, the region of main settlement stretched through the central part of the country from northwest to southeast with outliers in other areas. Cîteaux was the primary filiation to serve areas of southeastern France.

Results for Clairvaux show that it too experienced peak expansion from 1130 to 1150. During the early years, new monasteries or those converting from another Order appeared near the mother house as well as in the far west. During the 1120s expansion occurred chiefly in a northward direction. It also appears that it often occurred near "sister" houses (same affiliation). The general northward direction is maintained during

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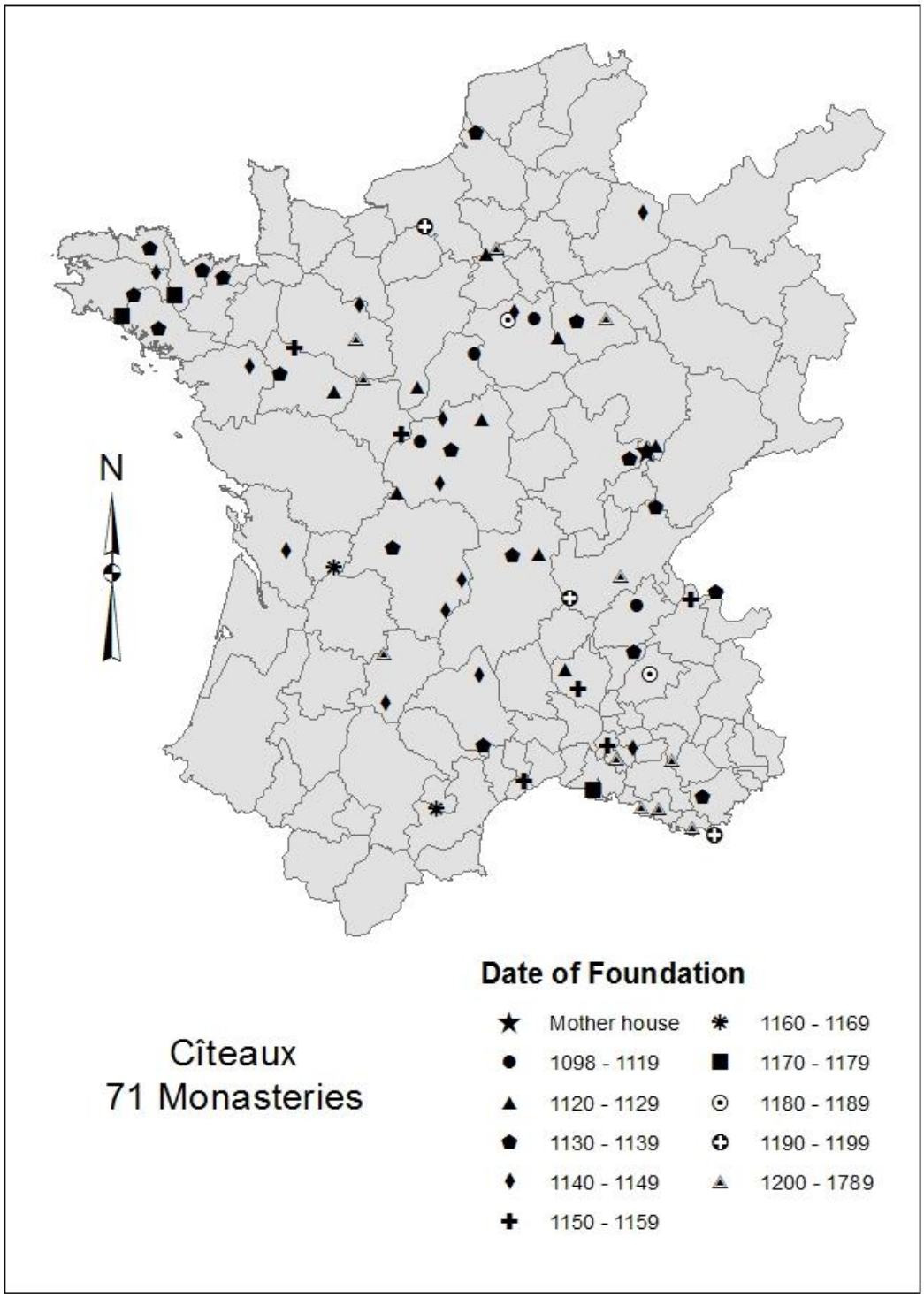

Figure 2: The Foundation of Monasteries Affiliated with Cîteaux by Decade. Created by the author using shapefile downloaded from the *Digital Atlas of Roman and Medieval Civilizations* website (Grigoli & Maione-Downing, 2013). Projection: Europe Albers Equal Area Conic, Coordinate System: European 1950, Jon Eric K. Rasmussen, 2015.

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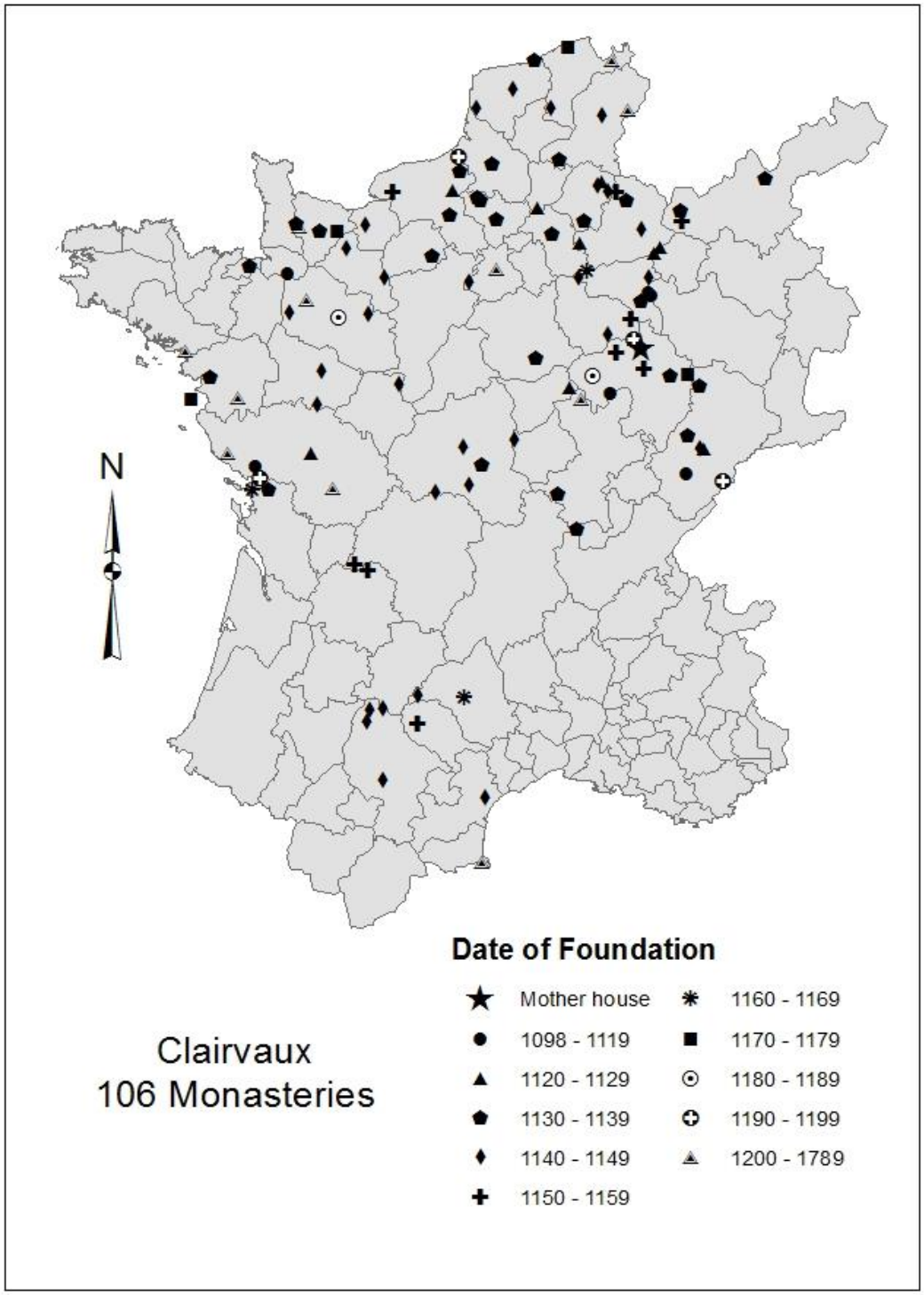

Figure 3: The Foundation of Monasteries Affiliated with Clairvaux by Decade. Created by the author using shapefile downloaded from the *Digital Atlas of Roman and Medieval Civilizations* website (Grigoli & Maione-Downing, 2013). Projection: Europe Albers Equal Area Conic, Coordinate System: European 1950, Jon Eric K. Rasmussen, 2015.

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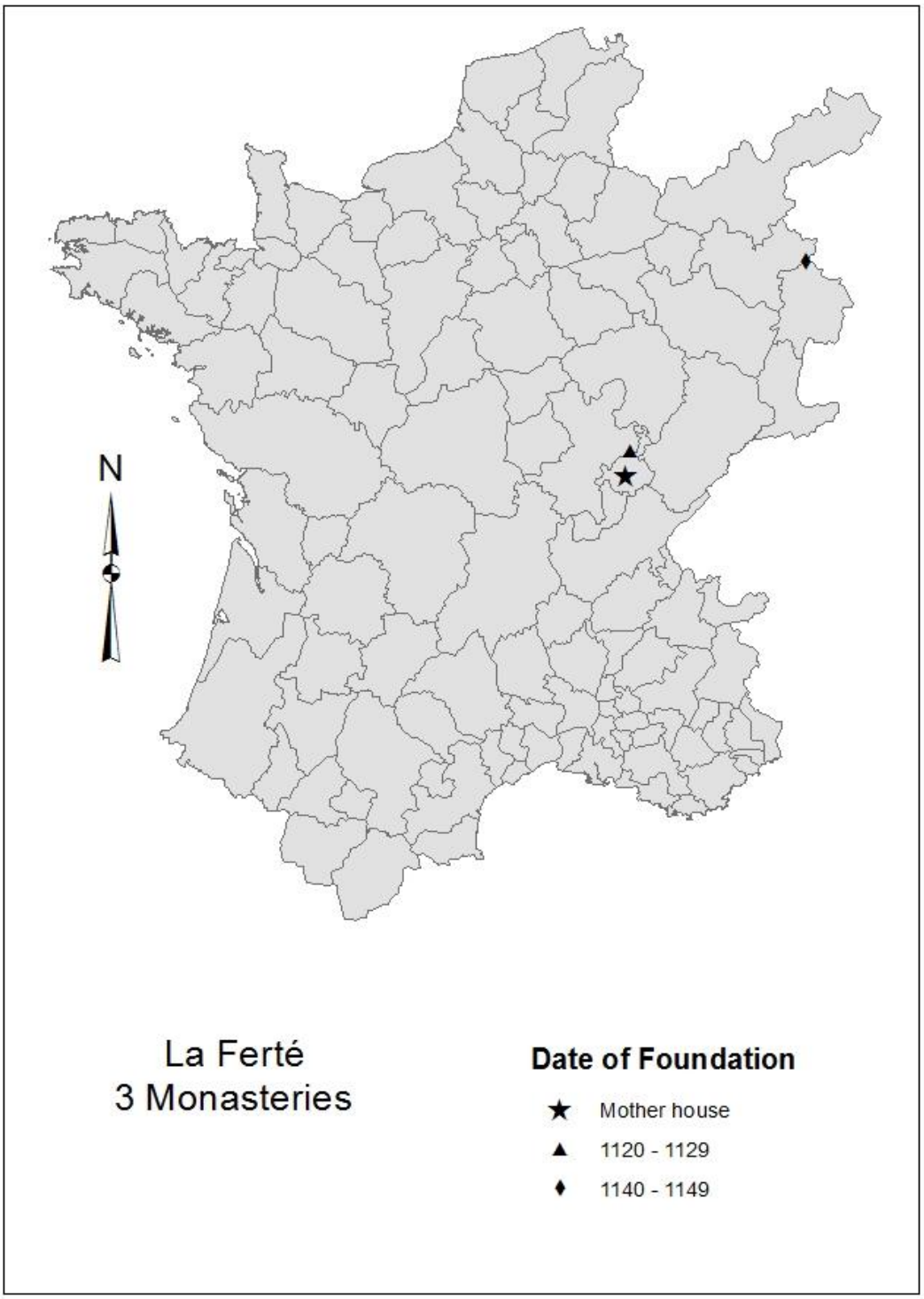

Figure 4: The Foundation of Monasteries Affiliated with La Ferté by Decade. Created by the author using shapefile downloaded from the *Digital Atlas of Roman and Medieval Civilizations* website (Grigoli & Maione-Downing, 2013). Projection: Europe Albers Equal Area Conic, Coordinate System: European 1950, Jon Eric K. Rasmussen, 2015.

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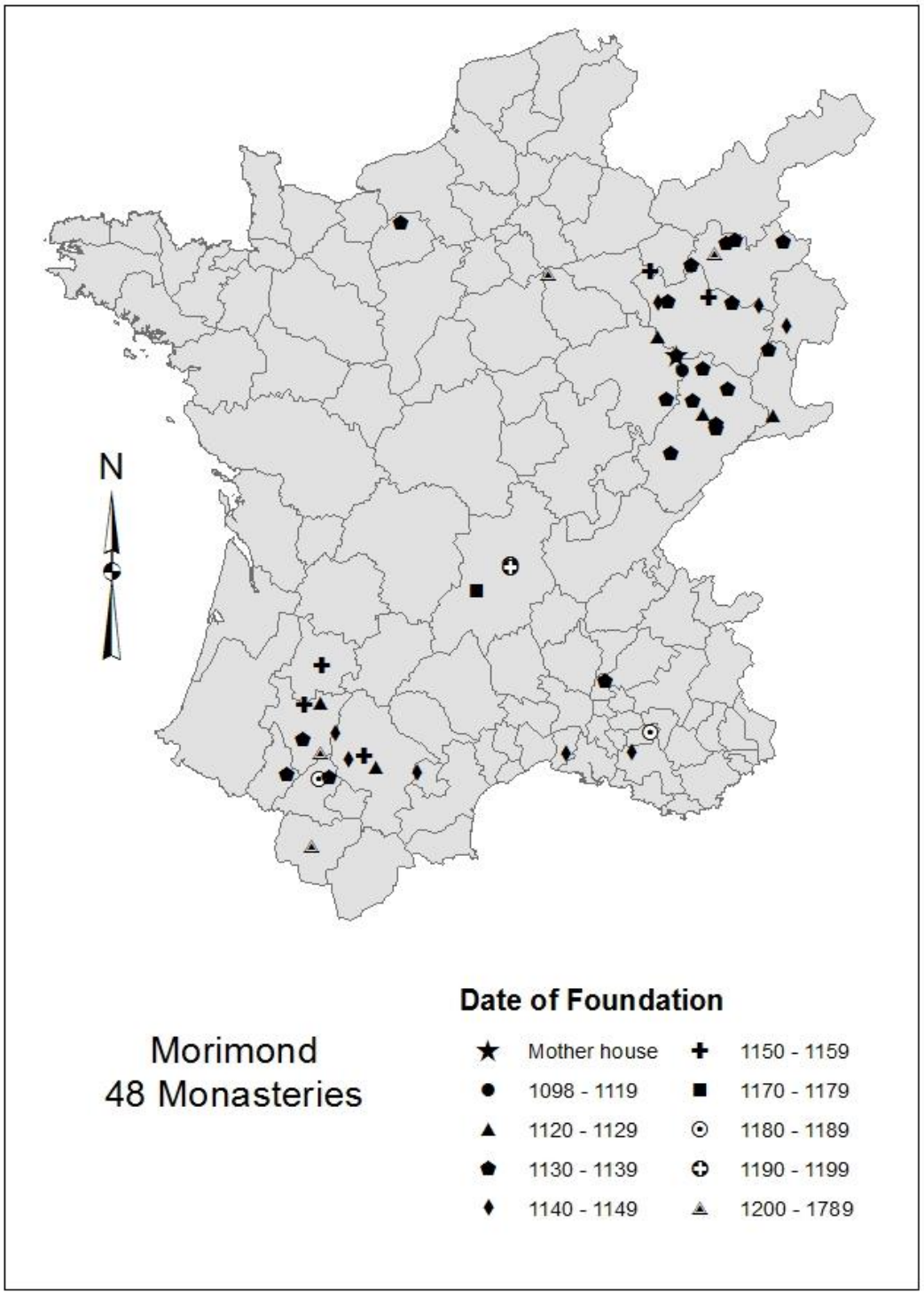

Figure 5: The Foundation of Monasteries Affiliated with Morimond by Decade. Created by the author using shapefile downloaded from the *Digital Atlas of Roman and Medieval Civilizations* website (Grigoli & Maione-Downing, 2013). Projection: Europe Albers Equal Area Conic, Coordinate System: European 1950, Jon Eric K. Rasmussen, 2015.

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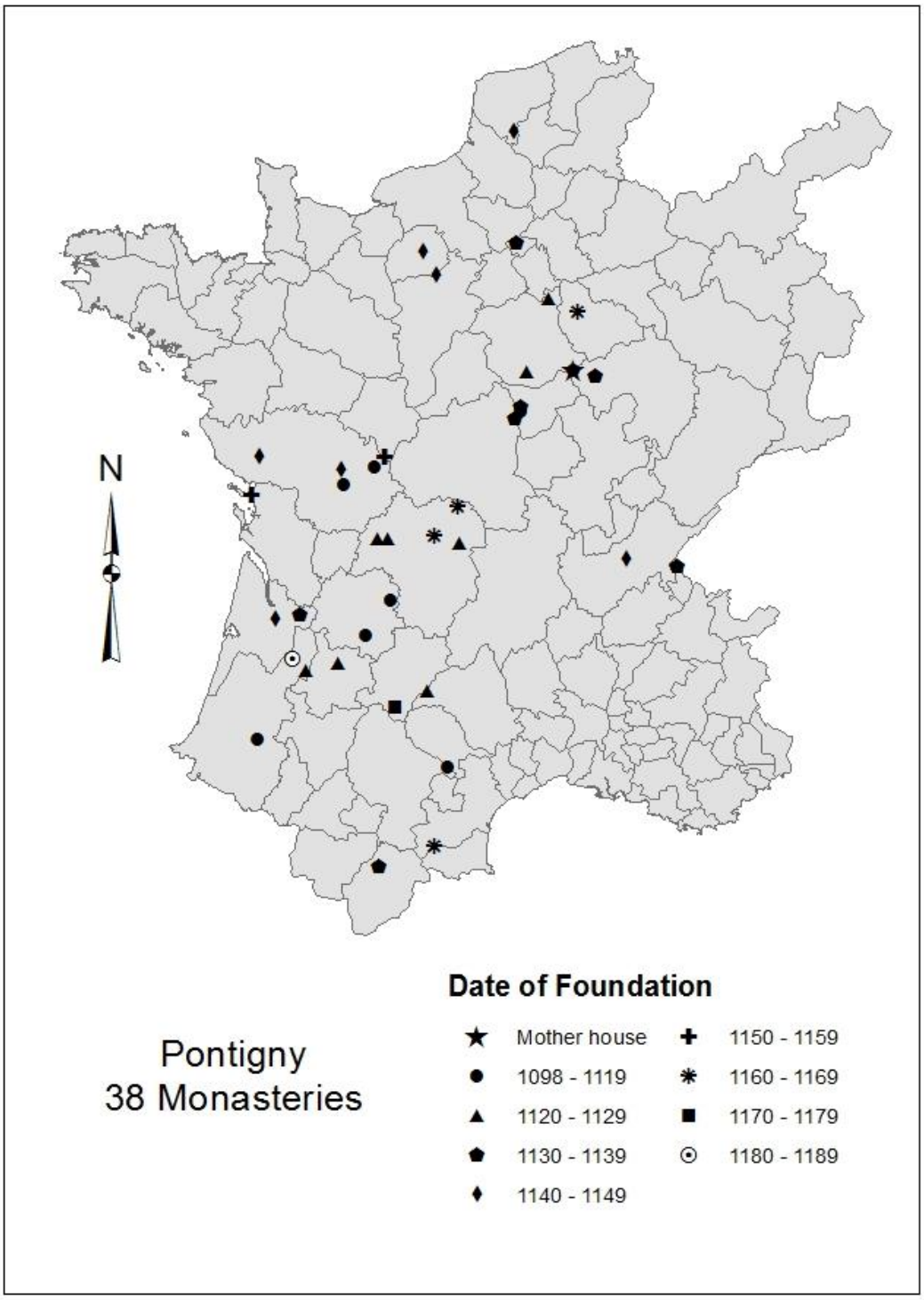

Figure 6: The Foundation of Monasteries Affiliated with Pontigny by Decade. Created by the author using shapefile downloaded from the *Digital Atlas of Roman and Medieval Civilizations* website (Grigoli & Maione-Downing, 2013). Projection: Europe Albers Equal Area Conic, Coordinate System: European 1950, Jon Eric K. Rasmussen, 2015.

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the succeeding decades. During the 1140s a small cluster appears in the southwest of the country and several additional monasteries appear in central France. The primary region of settlement for Clairvaux was chiefly northward and slightly northwestward. Some overlap with houses affiliated with Cîteaux occurred in central and northwestern France. Except for the small cluster in the southwest, the southern half of the country was avoided. Monasteries affiliated with Clairvaux are conspicuously absent in the southeast and in areas to the east of the mother house.

The La Ferté mother house undertook very little expansion. Two daughter houses, one nearby and one northeastward near the border with the Holy Roman Empire, were all that were established within France. Consequently too few points are available to discern any patterns of clustering.

As with Cîteaux and Clairvaux, Morimond experienced peak expansion from 1130 to 1150. From the beginning abbeys appear in the northeast and southwest regions of the country. During the 1140s a presence was established in the southeast as well. Based on this visual technique, Morimond appears to be the most distinctively clustered of the five filiations with primary concentrations in the northeast and southwest and a secondary concentration in the southeast.

Peak expansion for the Pontigny house occurred before 1150. Movement to the southwest from the mother house is evident from the beginning. Over time this pattern continues to be reinforced with some movement to the north and northwest as well. It appears that Potigny daughter houses tended to locate in areas also served by those affiliated with Cîteaux and Clairvaux. The northeastern, southeastern and northwestern

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regions were completely avoided. It further appears that Pontigny may have helped to "fill gaps" in areas of west-central and southwestern France served by other filiations.

A careful examination of the combined maps reveals the patterns as discussed above. Some small areas of avoidance are apparent, for example along the southwest Atlantic coast and the far southeast. In general coverage appears quite widespread throughout the country.

Choropleth Maps

Choropleth maps are another cartographic method that can be used to visualize point data. The study area is divided into areal units, usually representative of some type of administrative structure. Point data, monasteries in this case, are aggregated within these units. Units are grouped into classes using some type of logical scheme. For this study it is appropriate to use French diocese as the aggregation unit.

The results are presented as two series of iterative temporal maps in Appendix C. The first series of maps was generated using raw totals of monasteries per diocese whereas the second series was created from normalized data and depicts monasteries per square kilometer.

An examination of the first map series reveals that during the early years expansion was concentrated in the general area of the Order's origination and in the diocese of Poitiers in the far west. Reinforcement of this initial pattern occurs during the 1120s with diocese in the east-central region beginning to show dominance. A band of concentration appears to form that runs from east to west through the middle of the country and remains visible throughout the succeeding decades. Besançon parish in the

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far east-central region becomes an area of strong concentration during the 1130s. Some movement to the north and southwest of the central band of diocese becomes apparent during the 1140s.

Beginning in the 1150s an area of heavy concentration begins to emerge in the east-central diocese of Besançon, Langres and Toul, a region containing all five mother houses. An area of concentration also appears to stretch westward through central France encompassing the diocese of: Sens, Bourges, Limoges and Poitiers. By the end of expansion Toulouse and Le Mans appear as outlier areas from the central east-west band.

Results in the second series of maps using normalized data are significantly different. Similar to the first series, the early years show a concentration in an east-west band of diocese stretching through the middle of the country. However, a few outliers are also present. During the 1120s a concentration appears to form in the east-central and northern parts of the country. This southeast-northwest band contains the areas of origination and is reinforced throughout the remaining decades of the study period. In areas outside of this concentration the data appears to be more evenly distributed compared to how the data was depicted in the first series of maps.

Density Map

The final visualization method used to portray the spatial distribution of the point data is a Density map created by using the ArcMap Point Density tool. This map, presented in Figure 7, displays the location of every monastery as well as a 30 kilometer radius circle around each point. These shaded areas represent the territory most likely to contain the granges belonging to the monasteries as well as the area having the most

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accessibility to the abbey for obtaining needed services. In other words, these are the areas of the monastery's "influence."

Where overlap occurs, the shade of the color darkens. These represent locations where the local peasant population was well-served in times of need or sickness. They may also identify places where the potential for both cooperation and competition existed between the monasteries. Consequently this map moves beyond a strict focus on pattern of location to the wider impacts that the monasteries had on the landscape.

Examination of this map confirms the previous appraisals that areas of avoidance exist in the far southeast and Atlantic southwest. Additionally this map shows more clearly than the previous visualizations that while the country as a whole was fairly well "colonized", many gaps exist, even in the central east-west band that showed such high concentration on the diocese choropleth maps.

Investigating the reasons causing the Order to avoid these areas may reveal valuable information. The lack of monasteries in the far southeast may be related to topography (the Alps), the preference of local religious leaders for a different monastic order, or another unidentified factor. The scattered blank areas in the south-central region and in Brittany may also be related to topography. Areas of avoidance along the southwest coast, near Paris and in parts of Burgundy that are in near proximity to the Mother houses are more difficult to speculate about. In all cases, further research will be required to determine the environmental, political, religious and cultural factors leading to the decisions to avoid these areas.

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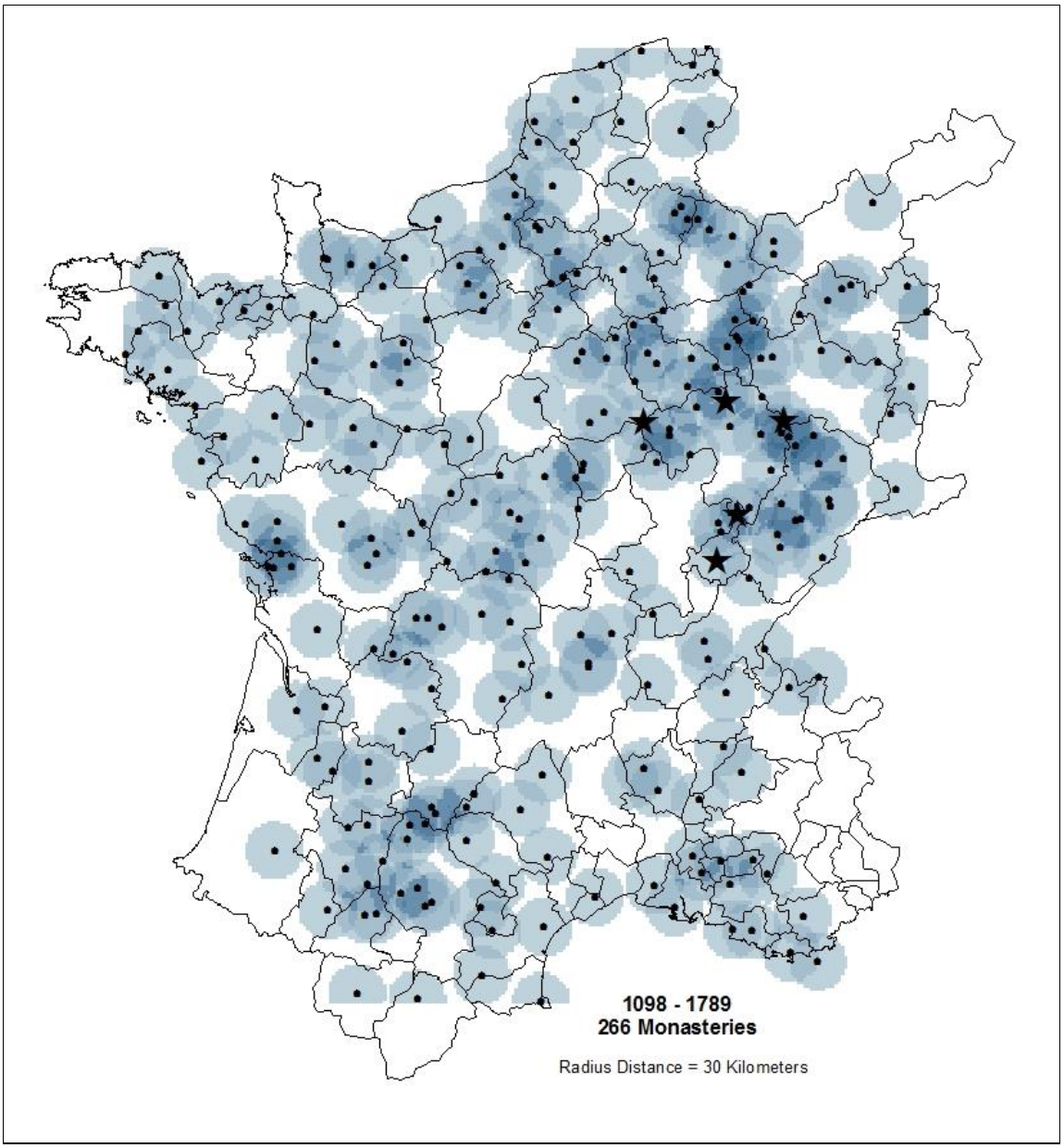

Figure 7: Density Map. Monastery locations are surrounded by a 30 kilometer radius circle, the approximate one-day walking distance. Created by the author using shapefile downloaded from the *Digital Atlas of Roman and Medieval Civilizations* website (Grigoli & Maione-Downing, 2013). Projection: Europe Albers Equal Area Conic, Coordinate System: European 1950, Jon Eric K. Rasmussen, 2015.

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Statistical Methods

The purpose of this objective is to measure the strength or weakness of any clustering and dispersion patterns that may exist. The Ripley's K-Function statistic incorporates scale into its calculations which is important since patterns can change as scale changes, thereby detecting the presence of clustering or dispersion which may have gone unrecognized using the visual methods. These results are supplemented with actual distance measurements using the ArcMap Near and Point Distance tools and the reconstruction of an historical route.

Ripley's K-Function

The K-Function graph results indicate that for the Order as a whole, neither dispersion nor clustering was detected prior to 1120. As shown in Figure 8, both the expected and observed data values fall within the confidence interval which is represented by the dashed lines. However during the 1120s clustering was detected at scale distances greater than 130 kilometers. This is shown in Figure 9 where clustering is measured above the confidence interval (use vertical axis values) and dispersion is measured below the confidence interval (use horizontal axis). At approximately 130 kilometers the line representing the observed data values crosses and remains above and out of the confidence interval. Data for the Order as a whole remained clustered for the remainder of the study period. The scale value fell to 40 kilometers during the 1130s and to 20 kilometers during the 1140s where it remained steady. K-Function tests were also applied to each individual filiation for the entire study period. These graph results are presented in Appendix D and have been summarized for comparison in Table 2.

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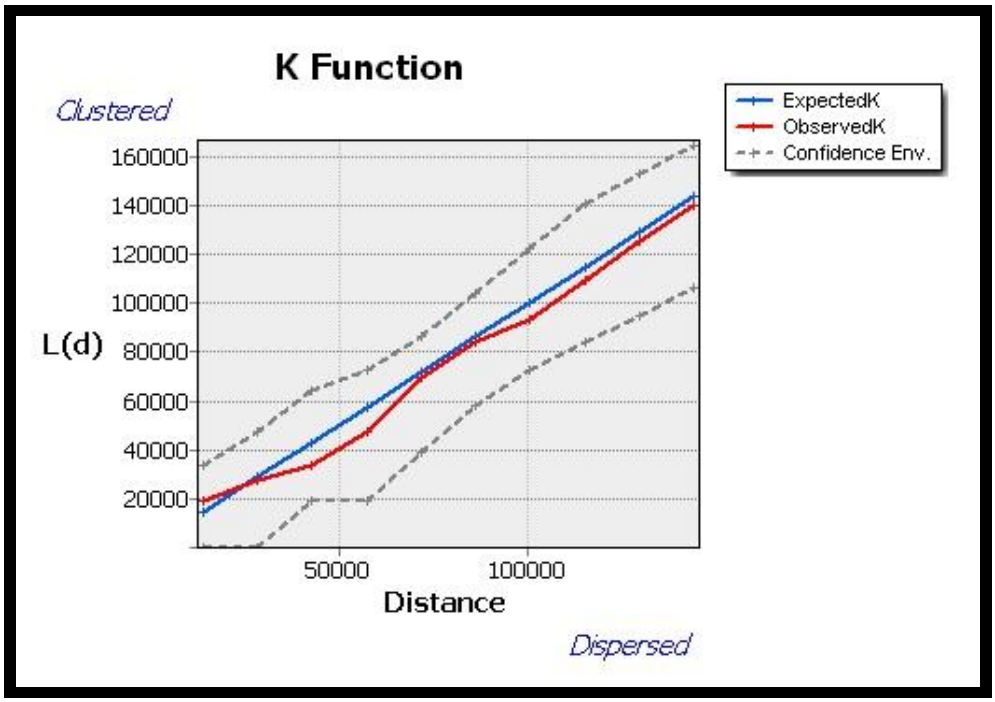

Figure 8: Ripley's K-Function Results 1098-1119. Results computed for the entire Order 1098-1119 measuring neither clustering nor dispersion. Source: calculated by author.

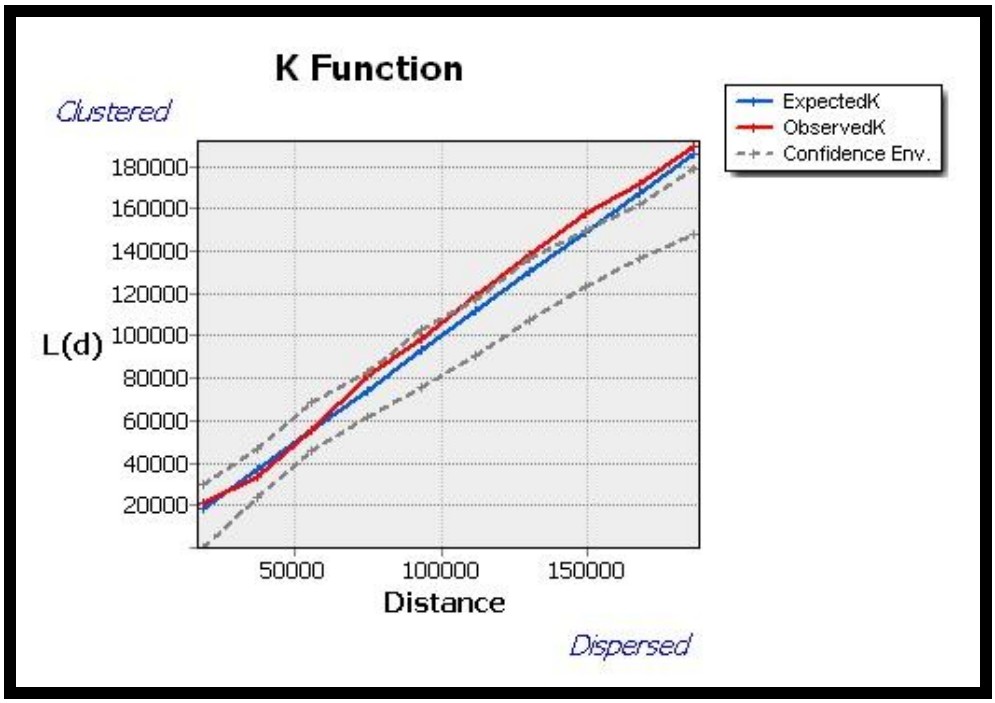

Figure 9: Ripley's K-Function Results 1098-1129. Results computed for the entire Order 1098-1129 measuring clustering at a scale of approximately 130 kilometers and greater. Source: calculated by author.

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Table 2: Ripley's K-Function Summary of Results by Filiation. All values represent distance (scale) in kilometers where clustering occurs except the shaded box which refers to dispersion. Source: created by the author using Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

	1098-1119	1120-1129	1130-1139	1140-1149	1150-1159	1160-1169	1170-1179	1180-1189	1190-1199	1200-1789
Cîteaux	60-75 km									> 70 km
Clairvaux			> 40 km	> 40 km	> 10 km	> 10 km	> 10 km	> 10 km	> 10 km	> 10 km
La Ferté										
Morimond			> 40 km	> 20 km	> 30 km	> 30 km	> 20 km	> 20 km	> 15 km	> 0 km
Pontigny				< 20 km	< 20 km	95-125 km	95-125 km			
Cistercian		>130 km	> 40 km	> 20 km	> 20 km	> 20 km	> 20 km	> 20 km	> 20 km	> 20 km

There were not enough data points to obtain meaningful results for the La Ferté filiation. For the Cîteaux house, clustering was achieved only in the very latest period and it was the only house to receive measurements of dispersion which occurred during its very earliest period. The three other houses were all determined to be clustered.

For Clairvaux the scale distance where clustering begins is 40 kilometers during the 1130s. This remains true during the 1140s but drops to 10 kilometers during the 1150s where it remains steady throughout the remainder of the study period.

The results for Morimond also show clustering beginning to occur during the 1130s at a scale distance of 40 kilometers. Over the remaining decades the data remain clustered with the scale distance making slight upward and downward fluctuations before reaching a value of zero during the last period thereby making Morimond the most clustered of the filiations.

The data for the Pontigny house does not begin to indicate the presence of clustering until the 1140s at scale distances less than 20 kilometers. This continues

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through the 1150s however a significant change occurs during the 1160s and 1170s when clustering is detected for scale distances between 95 and 125 kilometers.

Euclidean Distance

The ArcMap Spatial Analysis, Near and Point Distance tools were used to measure the following straight-line or Euclidean distances: 1) between each monastery and its mother house, 2) between each monastery and its closest neighbor of like filiation, and 3) between each monastery and its closest neighbor of any Cistercian filiation.

Numerical results are presented in Appendix E and have been summarized in graph form for trend analysis as well as comparison between filiations. Examination of the graphs reveals that all five filiations exhibit similar characteristics in trends as well as actual values.

In Figure 10 it is apparent that during the earliest decades when the number of monasteries was low, the minimum distances to the mother house were at their highest level. Over time these distances fell indicating that expansion was not comprised solely of a continuous *outward* movement away from the mother house. However this trend leveled off quickly during the 1120s for Cîteaux, Morimond and La Ferté, during the 1130s for Pontigny and during the 1150s for Clairvaux.

The opposite trend appears to be true for the maximum (Figure 11) and average (Figure 12) distances to the mother house. These distances continued to rise through the early decades and leveled off during the 1130s and 1140s with distances remaining steady thereafter. This would seem to indicate that while areas previously bypassed were being acquired, outward expansion was simultaneously occurring. It is interesting that

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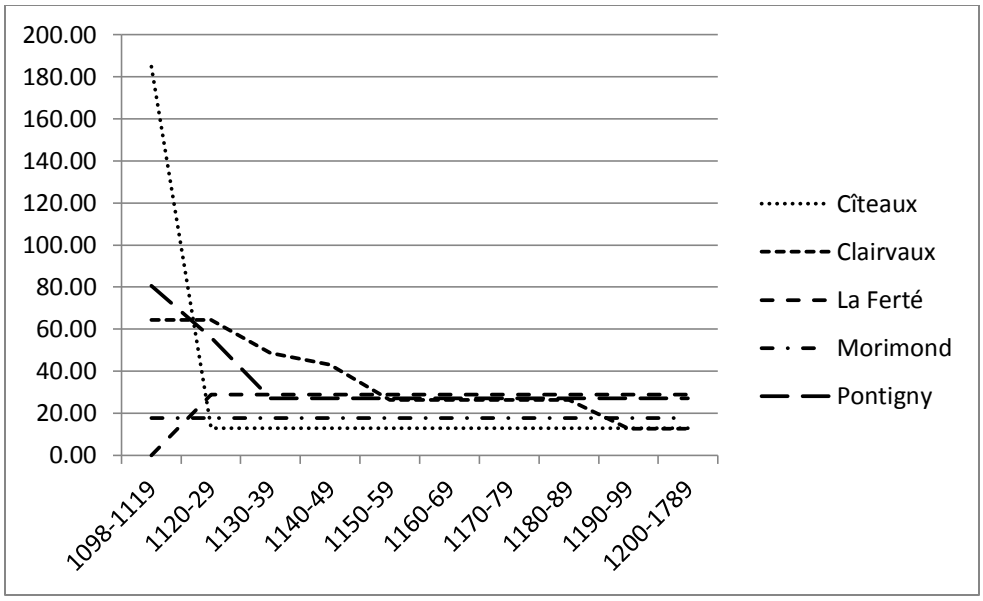

Figure 10: Minimum Distance to Mother House by Decade. Distances are measured in kilometers. Source: created by the author using Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

average distances did not decline as bypassed areas were "filled-in." This result is probably obtained because the majority of monasteries were already founded by the time the distance values level off. The low number of new monasteries founded after this point were not enough to significantly impact the established trend.

Similarly the graphs depicting the distances to the nearest house of the same filiation show that most volatility occurs during the early decades with a leveling off occurring during the 1130s or 1140s, after the period of greatest expansion. Trends and values are similar for Cîteaux, Clairvaux and Pontigny. Results for La Ferté appear out-of-line with the others, probably due to the low number of data points. Maximum distance results for Morimond appear as an exception. This is probably a reflection of the distinct cluster area occurring in the far southwest of the country, a location far removed from the mother house.

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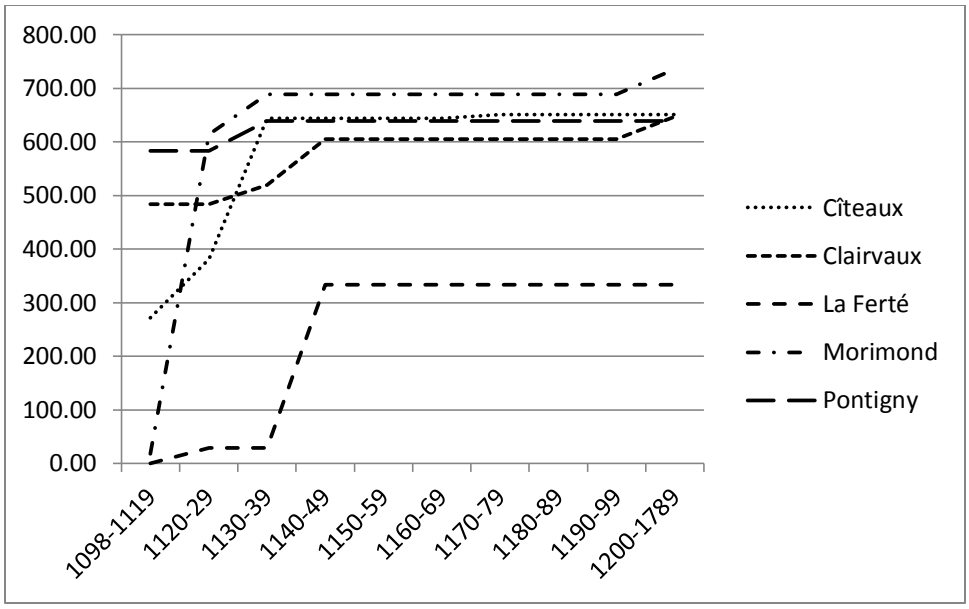

Figure 11: Maximum Distance to Mother House by Decade. Distances are measured in kilometers. Source: created by the author using Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

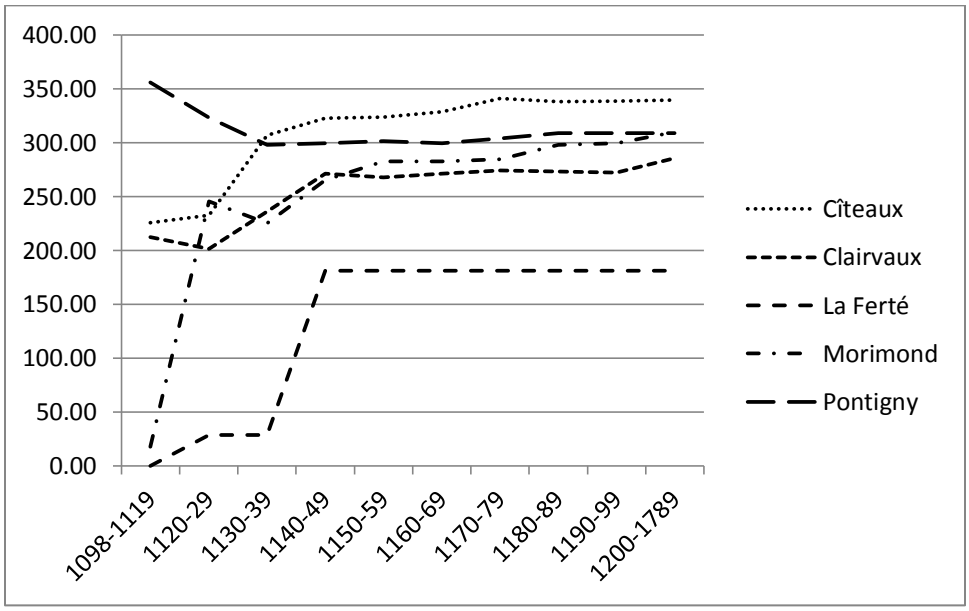

Figure 12: Average Distance to Mother House by Decade. Distances are measured in kilometers. Source: created by the author using Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

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It is also worth noting that the average distance from the nearest house of like filiation shows a decline before leveling off. This is opposite to the results for average distance to the mother house. However this seems logical as the large bypassed areas

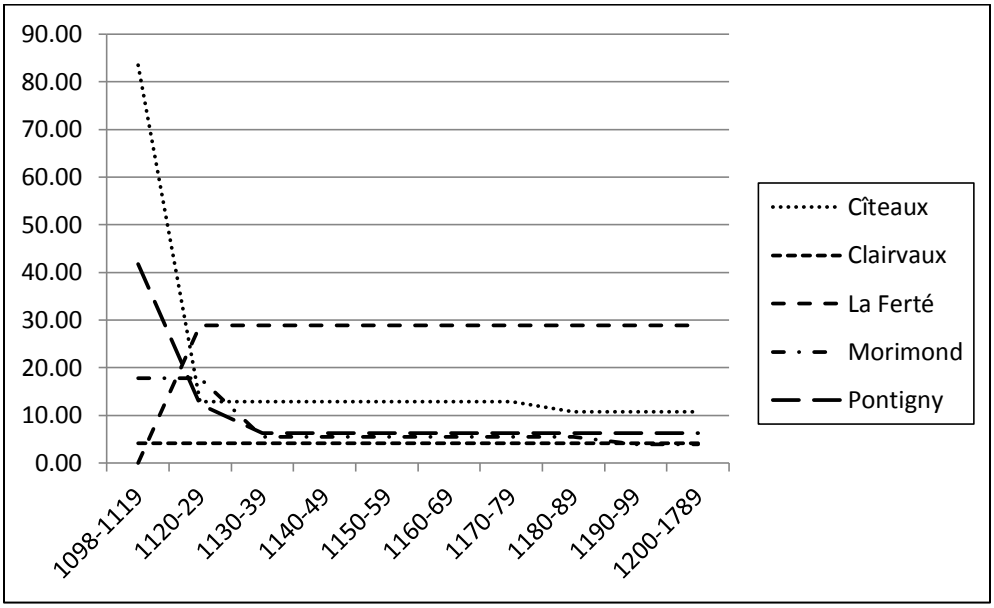

Figure 13: Minimum Distance to House of Like Filiation by Decade. Distances are measured in kilometers. Source: created by the author using Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

created in the beginning by the establishment of monasteries in remote locations from the mother house were "filled-in".

Finally, the results for distances to the nearest Cistercian house (of any affiliation) show that peak levels were reached at the beginning of Order formation, declined in the early decades during the peak of growth and levelled off in the later periods of slower growth. As is generally true for all the graphs, there was very little variation in the results for each filiation both in terms of trend and actual data values.

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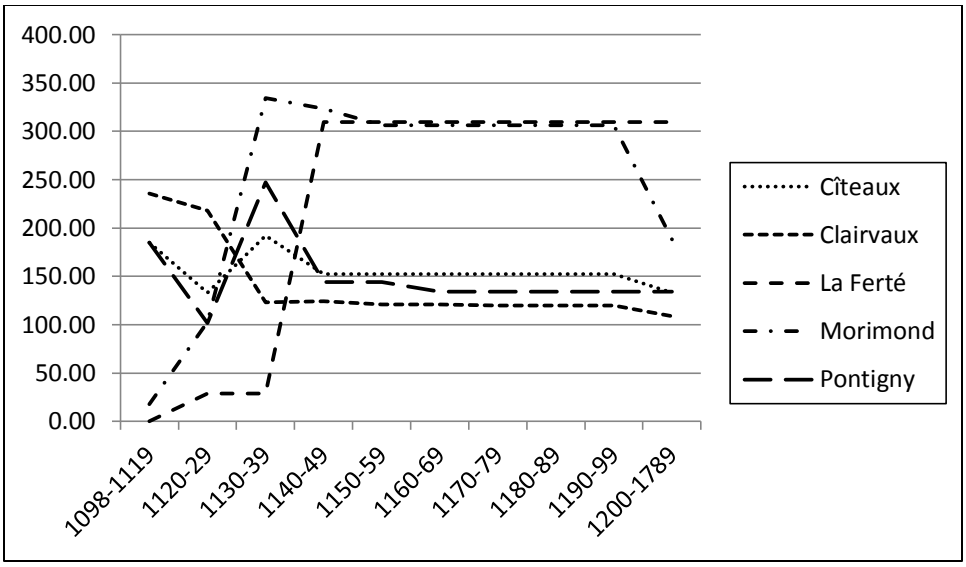

Figure 14: Maximum Distance to House of Like Filiation by Decade. Distances are measured in kilometers. Source: created by the author using Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

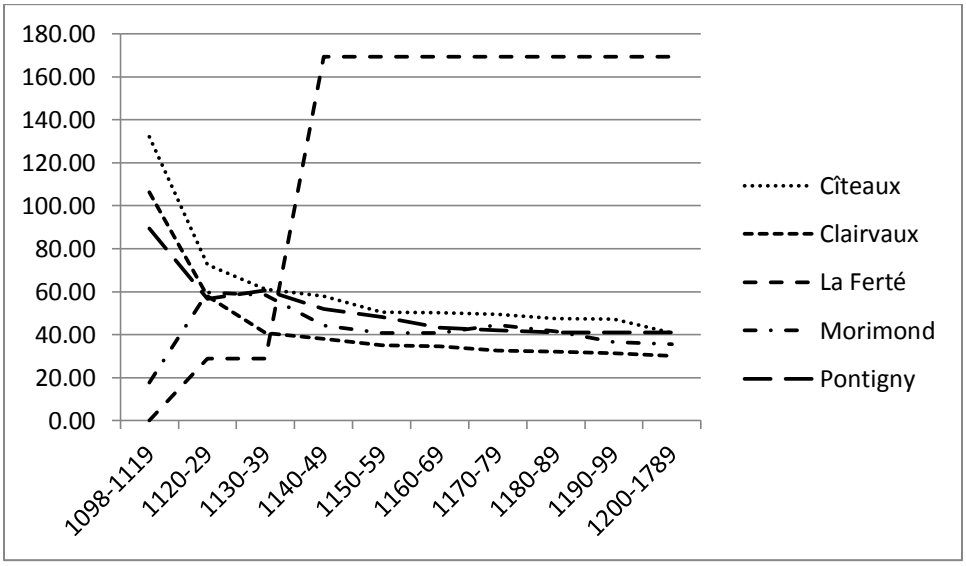

Figure 15: Average Distance to House of Like Filiation by Decade. Distances are measured in kilometers. Source: created by the author using Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

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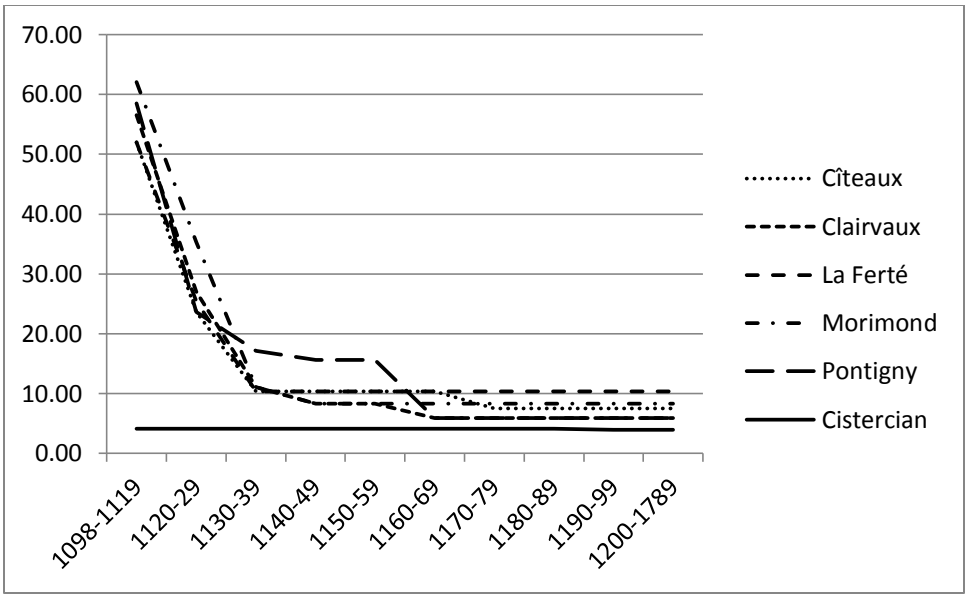

Figure 16: Minimum Distance to Another Cistercian House by Decade. Distances are measured in kilometers. Source: created by the author using Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

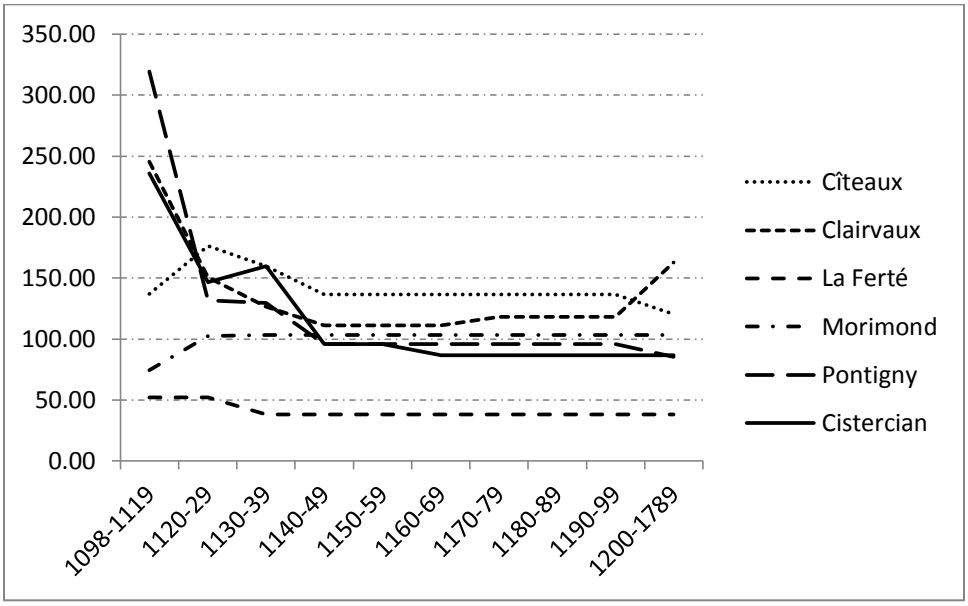

Figure 17: Maximum Distance to Another Cistercian House by Decade. Distances are measured in kilometers. Source: created by the author using Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

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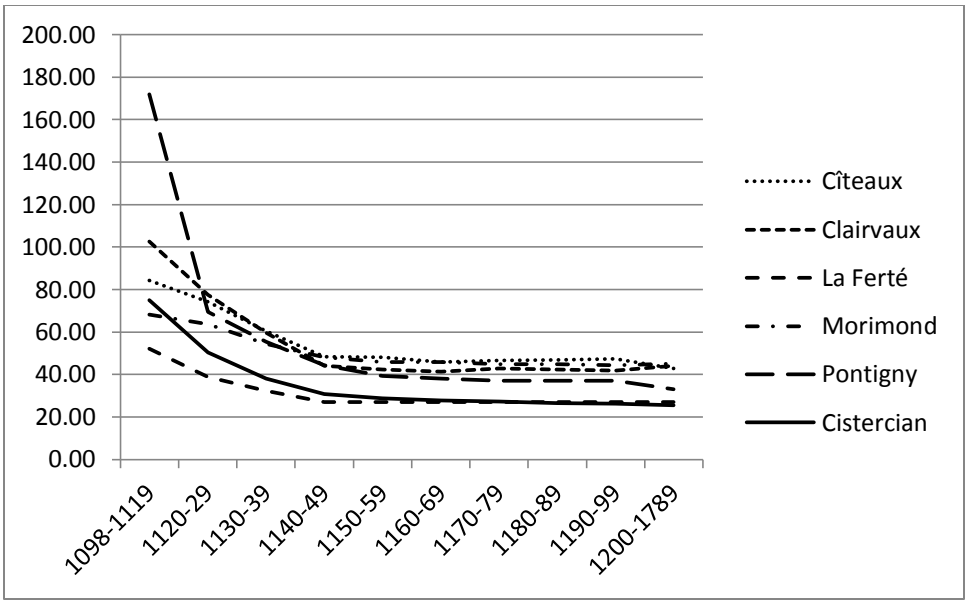

Figure 18: Average Distance to Another Cistercian House by Decade. Distances are measured in kilometers. Source: created by the author using Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

Historical Route Reconstruction

The intention of this objective is to provide an example of the GIS capabilities available for evaluating historic routes and their impact on past landscapes. St. Bernard, the founder of the monastery at Clairvaux, one of the four original daughter houses, and a man of great significance to the Cistercian movement, made a visit to Languedoc in southwestern France in 1145. This journey was documented by his biographer Geoffrey of Auxerre (Williams, 1998) and was described by Watkin Williams in his book *Saint Bernard of Clairvaux* (Williams, 1935). His route was plotted using straight line distance surrounded by a 60 kilometer buffer (30 kilometers on each side, one day's journey). Any monasteries established inside the buffer area during the following ten year period were identified and mapped and statistical tests were performed to determine whether or not

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Bernard's presence may have influenced the establishment of additional monasteries in the vicinity of his journey.

The mapped route is presented in Figures 19 and 20. During the first five year period (1145-1149) five additional Cistercian monasteries were established inside the buffer region. These included: Olivet in 1145 (Cîteaux), Feuillants in 1145 (Morimond), Garde-Dieu in 1147 (Cîteaux), Bonneval in 1147 (Cîteaux) and Calers in 1148 (Clairvaux). During the next five year period (1150-1154) an additional eight Cistercian monasteries were established inside the buffer. These included: Longuay in 1150 (Clairvaux), Clarté-Dieu in 1150 (Morimond), Merci-Dieu in 1151 (Pontigny), Candeil in 1152 (Clairvaux), Beaugerais in 1153 (Cîteaux), Mores in 1153 (Clairvaux), Peyrouse in 1153 (Clairvaux) and Boschaud in 1154 (Clairvaux).

To determine if the establishment of these thirteen new monasteries during the decade following Bernard's journey represents a statistically significant increase, the number of existing monasteries within the buffer area before and after the journey were tabulated by filiation and are presented as table 3. The number of monasteries in the buffer area established in the 46 year period before the journey are compared to the number of monasteries established in the same area during the decade after Bernard's visit using a chi-square test for independence. After removing La Ferté from consideration, the results ($\chi^2 = 0.29$, $p = 0.5902$) indicate that a significant statistical difference does not exists in the before and after totals.

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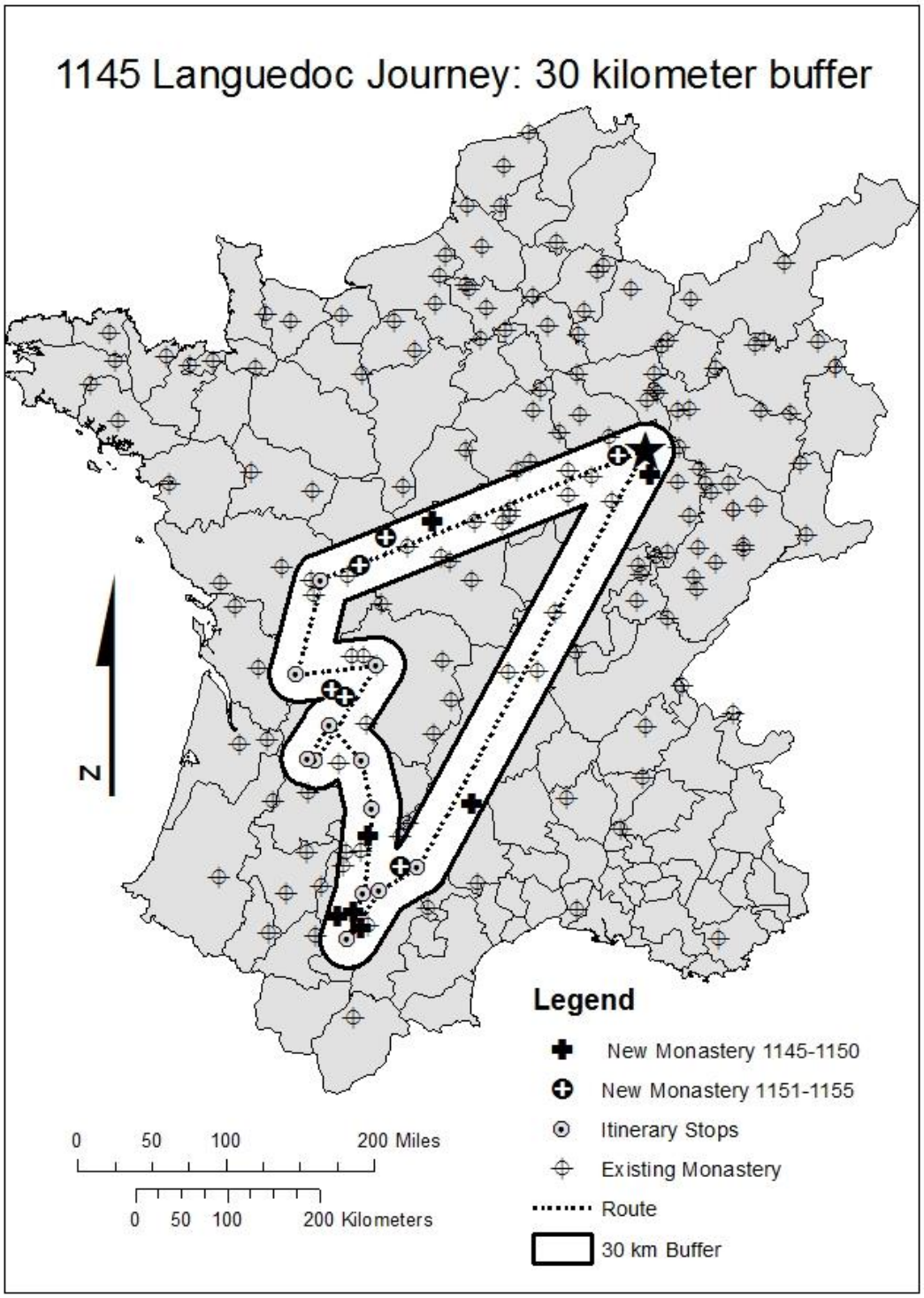

Figure 19: Map of Bernard's 1145 Languedoc Journey. Route is surrounded by a 30 kilometer-wide buffer, the approximate one-day walking distance. Created by the author using shapefile downloaded from the *Digital Atlas of Roman and Medieval Civilizations* website (Grigoli & Maione-Downing, 2013). Projection: Europe Albers Equal Area Conic, Coordinate System: European 1950, Jon Eric K. Rasmussen, 2015.

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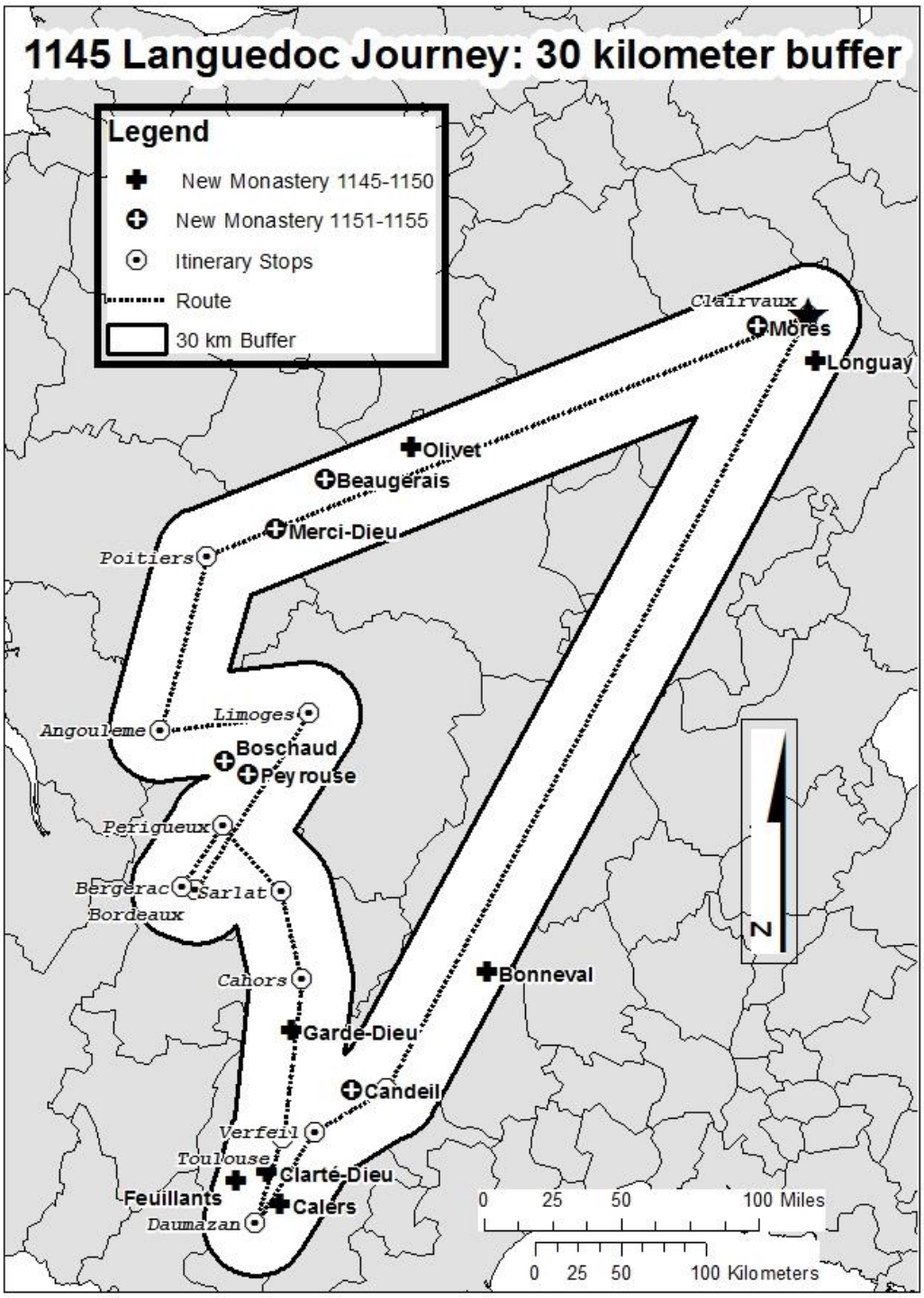

Figure 20: Detailed View of Bernard's 1145 Languedoc Journey. Route is surrounded by a 30 kilometer-wide buffer, the approximate one-day walking distance. Created by the author using shapefile downloaded from the *Digital Atlas of Roman and Medieval Civilizations* website (Grigoli & Maione-Downing, 2013). Projection: Europe Albers Equal Area Conic, Coordinate System: European 1950, Jon Eric K. Rasmussen, 2015.

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Table 3: The Number of Monasteries in the Buffer Region Before and After Bernard's 1145 Journey. Source: created by the author using Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

		Cîteaux	Clairvaux	La Ferté	Morimond	Pontigny		Total
1098-1144		5	7	0	1	12		25
1145-1154		4	6	0	2	1		13
Total		9	13	0	3	13		38

The values in the "before" period (1098-1144) in table 3 were then broken down into decadal segments and are presented in table 4. This makes it apparent that the Pontigny filiation was dominant in the region beginning at an early period. However, after Bernard's visit his own Clairvaux filiation established more monasteries within the buffer area than any other filiation, the most it had established in any decade in that region up to that time. In order to determine if these totals are statistically significant, another chi-square test for independence was conducted based on decade. As before data for the La Ferté filiation was removed before the test was conducted.

Table 4: The Number of Monasteries by Decade in the Buffer Region of Bernard's 1145 Journey. Source: created by the author using Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

		Cîteaux	Clairvaux	La Ferté	Morimond	Pontigny		Total
1098-1114		0	0	0	0	2		2
1115-1124		1	1	0	0	6		8
1125-1134		2	2	0	1	2		7
1135-1144		2	4	0	0	2		8
1145-1154		4	6	0	2	1		13
Total		9	13	0	3	13		38

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The test results (χ^2 = 7.33, p = 0.0068) indicate that the number of monasteries established by filiation *and* decade for the decades prior to and immediately after Bernard's journey do represent a significant statistical difference.

Lastly the density of monasteries per square kilometer inside and outside the buffer and for the entire country, were computed for the time periods before and after Bernard's journey. These results are presented in table 5.

Table 5: Monasteries per Square Kilometer. Numbers in parenthesis are monastery totals. Computations based on the following area values: France (576,238.05 km^2), Inside Buffer (88,624.66 km^2), Outside Buffer (487,613.39 km^2). Source: created by the author using input data and Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

Density: Monasteries per Square Kilometer			
	France (total)	Outside Buffer	Inside Buffer
1144 (before)	(149) 0.0002586	(124) 0.0002543	(25) 0.0002821
1154 (after)	(204) 0.0003540	(166) 0.0003404	(38) 0.0004288
% increase	37	34	52

These results indicate that the area inside the buffer did acquire more additional monasteries in the ten year period after Bernard's visit than what occurred in both the area outside the buffer and in the country as a whole. Consequently it appears that Bernard's presence was significant to the growth of the Order in the area especially for expansion of the Clairvaux filiation.

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DISCUSSION

The expansion of the Cistercian Order occurred by two methods; transfer from another monastic order or by the acquisition of land and the construction of a new abbey. In 1147 twenty-nine monasteries associated with the Congregation of Savigny (Savigniac Order) affiliated with Cîteaux. This event established a precedent for the future transfers which occurred thereafter.

To establish a new monastery by the second method, land had to be obtained. This fact is central and must be briefly discussed before a meaningful analysis of the results can be conducted. The settlement required not only a site for the construction of the abbey complex, but also land for one or more granges. Grange land was utilized for a productive purpose of one type or another and therefore must have been suitable enough to obtain economic gain. Generally this was for some kind of agricultural pursuit but manufacturing activities such as smelting and milling also occurred.

During the 12th century, when the majority of Cistercian expansion occurred, land could only be obtained from a very limited number of sources. Generally, the Crown was considered to own all unassigned lands within the kingdom. The two main exceptions being those lands granted to members of the royal family or to the nobility and those granted to the Church (Lekai, 1977; Williams, 1998). The granting process was complex and usually established reciprocal duties and obligations.

Lands that were granted to members of the royal family or the nobility may have included the right to bequeath the land, customarily upon death, but usually required the survival of a male heir and the approval of the Crown. This is significant because this privilege to confer land allowed these royal and noble individuals to donate land to the

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Church. The primary motivation for making such a gift was generally as an act of penitence for themselves or a deceased family member however it must be acknowledged that this practice could be heavily influenced by dynastic, religious and/or family politics.

The majority of land donated for monastery formation was granted as *frankalmoins*, a free gift with no associated monetary, tax, or military obligations (Lekai, 1977). However, sometimes a land grant did carry some form of feudal obligation, such as a tax in lieu of military service known as *scutage*, that an abbey was required to pay (Lekai, 1977; Williams, 1998). Generally the donated land was land "that no one else cared to till" (Lekai, 1977, p. 282) and varied in size "depending on the wealth of the founder and land availability" (Williams, 1998).

Over time the Church acquired a considerable amount of realty through these kinds of donations and those received directly from the Crown. The most judicious means of administering this asset was through the Diocesan hierarchy. Generally the local Bishop was a very powerful individual with deep connections to the Crown, the local nobility and to officials in Rome. These relationships meant that the Bishop wielded tremendous influence in both the acquisition and dispensation of land within his diocese. While land donations were frequently distributed for use by monasteries or local parish churches, there was usually some type of financial agreement whereby the diocese would receive a portion of the generated income. Of course in order to maintain good relations with the ruling elite, the Bishop was somewhat restrained by the wishes of the benefactor making the donation.

Consequently, when enough recruits had been assembled and the decision made to establish a new abbey, the monks' choice concerning the location of their new home

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was not entirely in their own hands. At the very least the approval and support of the local Bishop was essential. If Church land was not available a benefactor was also necessary. In many cases these were not serious issues but were required nonetheless.

All of this is not to suggest that the various filiations, or the Order in general, did not have plans of their own. The Cistercians were "the first 'order' in monastic history, possessing a clearly formulated program, held together by a firm legal framework" (Lekai, 1977, p. 17), the "first truly international religious order in Church history" (Lekai, 1977, p. 36). However, the GIS tools applied and the analysis performed in this study cannot offer explanations about the motivations of the individuals involved or the decisions made in such a complex social and political *milieu*. Undoubtedly personalities as well as numerous political and economic factors were responsible for the final outcome. The intent of this thesis is not to investigate or speculate about these issues, it is only to attempt to uncover spatial patterns, or lack thereof, and their associated geographic locations that may suggest the presence, or absence, of phenomena that need further investigation.

The three cartographic visualization tools used to represent the point (location) data in support of objective one were meant to provide the viewer the ability to see the expansion of each filiation, two of which over time. All three tests were in basic agreement, revealing that patterns of expansion do exist. Since each test provided a slightly different perspective it also became evident that the process was not as straightforward as one might imagine if only the results from one test are examined.

In the thematic map series, while there are some general areas of overlap, each filiation appears to have expanded in certain regions of choice. Examining the time

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sequence, either movement into these regions or reinforcement of initial settlement in these selected regions over time is apparent. As time progresses and the number of monasteries increases, the patterns become more difficult to visually detect. However this is not true for Morimond which maintains two very distinct concentrations throughout the study period. Areas of avoidance or at the very least areas of little presence, such as the southeastern and southwest Atlantic coastal regions are also apparent.

The two series of choropleth maps visually display the concentration or density of monasteries by diocese over time. The first series depicts the total number, or raw value, per diocese and confirms the general patterns depicted by the thematic map series. However depicting the data within an administrative framework presents a different view from which to analyze. Two things are immediately apparent: 1) the regions where data appeared concentrated in the thematic maps are actually composed of smaller geographic units with varying levels of density and, 2) "islands" of no or very low density, appear next to or even in the midst of areas of high density. This result is especially intriguing when evaluated in connection with the diocesan political realities discussed above. Providing a definitive explanation for these variations is beyond the scope of this study, however several geographic areas of interest have now been identified.

The second series of maps depicts normalized data, or number of monasteries per square kilometer. This technique eliminates misconceptions which may form when comparing data from areas of differing size. For example a small diocese may actually be more thoroughly served by one monastery than a large diocese with three or four monasteries. In fact this series of maps does reveal a different perspective. Instead of an east-west concentration through the middle of the country, a northwest-southeast

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concentration appears through the north-east central region. Monastery distribution also appears somewhat evenly spread throughout the remainder of the country. These results seem to indicate that the ability to obtain land may not have been as restricted in certain regions as the first series of maps imply.

The final visual tool, the density map, provides a third picture of the data. Scholars generally accept that the granges were usually located within a one day journey from the abbey complex. This typically would also be applicable for the poor and sick residents of the local area who travelled to the abbey for aid. For purposes of this study, this distance has been estimated to be about 30 kilometers. Consequently circles with a radius of 30 kilometers have been drawn around the monasteries. These shaded areas represent "areas of influence" that each monastery may have had over the local landscape. The results confirm the general regions of concentration as are apparent in the other map products. However they reveal two other significant facts: 1) even in areas of heaviest concentration, empty spaces or under-served areas remained present and, 2) the aid and services supplied by the monasteries in the areas of highest density may have provided the local population with beneficial choices but it remains unclear whether or not such close proximity led to cooperation or competition for resources between these monasteries as grange land was required for economic benefit. Once again this is best evaluated in conjunction with the existing social and political circumstances.

Not only the presence or absence of spatial association but the strength or degree of any relationship is dependent upon scale. For example areas that appear to contain clusters of data points when viewing a wide-area (small scale) may not appear so when viewing a small-area (large scale). Consequently this study applied the Ripley's

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K-Function statistical analysis tool to measure the effect of scale on clustering or dispersion of the input point data.

Results for Clairvaux, Morimond and Pontigny confirmed the impression formed using the visual mapping techniques that clustering was present with values for Clairvaux and Morimond being the most similar and consistent over time. Cîteaux was the only filiation to obtain a dispersed result however this only occurred in the very early period of expansion and quickly disappeared. Expansion occurring after the 12th century resulted in a clustering pattern for Cîteaux as well. Too few points were available for an evaluation of the La Ferté filiation.

Measuring the Euclidean or straight-line distance is another tool available for conducting spatial analysis. Three different distances were measured: distance between each monastery and its mother house, distance between each monastery and its closest neighbor of like filiation, and distance between each monastery and its closest neighbor of any Cistercian filiation. Except for La Ferté and its data limitations, the results were similar for the other four filiations both in terms of the measurement values obtained and the trends that developed over the study period. This is somewhat different from the results of the K-Function analysis where the results obtained for Cîteaux and Pontigny varied from those obtained for Clairvaux and Morimond.

The final objective of this study was to reconstruct Bernard's 1145 journey to southwestern France and assess his impact or lack thereof on the establishment of additional monasteries in the region. Bernard was called to the region by local Church leaders who requested his aid in combating a heresy being spread by a man named Henry, a disciple of Peter de Bruys, and his followers who were known as *Henricians* (Williams,

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1935). This false teaching asserted that: 1) infant baptism does not save the child's soul, 2) churches are unnecessary as Christians may pray directly to God, 3) crosses should be destroyed, not venerated, 4) the sacrament is not really the body and blood of Christ, and 5) sacrifices, prayers and alms offered for the dead are useless and do no good. Bernard's journey was documented by his biographer Geoffrey who appears to have accompanied Bernard on the trip.

The results confirm that new monasteries were established in the wake of Bernard's journey, five in the first five year period and eight more in the next five year period. However these results cannot measure and do not confirm that Bernard's influence or mere presence was the causal factor. Of the five monasteries founded during the period 1145-1149, only Calers was affiliated with Bernard's own Clairvaux. From 1150-1154 the tie to Clairvaux is stronger with five of the eight new monasteries, Boschaud, Candeil, Longuay, Mores and Peyrouse, being Clairvaux houses. If Bernard's presence was indeed responsible it appears that the reaction was somewhat delayed. This may be a result of the difficulties obtaining land but more investigation is necessary.

Examination of the results obtained from the statistical tests that were performed indicates that there was a greater increase in the number of monasteries established in this area during the ten year period following Bernard's visit compared to previous decades but this too requires additional investigation.

In addition, once the journey was mapped it became apparent that the travelers did not follow the most direct route as there appears to be some "doubling-back" between Bordeaux and Perigueux. Could this indicate a change to the original itinerary? More research is required to understand this unusual route selection.

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This study is only a first step toward investigating the spatial aspect of Cistercian expansion. Admittedly this study's geographic and temporal limitations have affected the results obtained and several ideas for future research come to mind. First, by expanding the area (reducing scale) to include all of Europe or the entire world, patterns of clustering and dispersion would both appear and measure differently thereby potentially revealing new information.

A second method of improving the analysis would be to obtain and add additional GIS data layers. With the addition of topographic, hydrographic, and transportation data, a more sophisticated analysis could be performed on characteristics of the sites chosen. In a similar fashion, the addition of the known road network in existence in 1145 would improve the results obtained over the route analysis conducted here. This study used straight-line connections between the itinerary stops which are admittedly unrealistic. A more accurate representation of the possible route employed should be considered.

Another area that needs further investigation is the relationship between the Order and the various dioceses. This study only displayed results for the entire Order within the diocesan framework. Repeating this procedure for each filiation may reveal additional information. Finally, since the Cistercian Order was only one of several monastic orders, expanding the study to include the locations of other abbeys may reveal additional unknown relationships.

Considered from a broad perspective, this study has attempted to demonstrate how GIS technology can be applied to reconstruct an historical landscape and promote the formulation of new perspectives and ideas for future research. However, recreating the past also relies on knowledge of the individual personalities involved and the social

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milieu during the time period in question. While it may not be possible to uncover the motivations of the actors, it is hoped that this study has revealed some evidence of the results of their actions.

Finally, this study has also attempted to model a few of the capabilities that could be incorporated into any future CCMS projects utilizing the Cistercian digital gazetteer. GIS offers many additional analysis techniques that are only limited by data availability and imagination. It is hoped that this study has demonstrated at least a few of the many possible benefits that may be achieved by applying spatial analysis to historical data.

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Appendix A

Input Data

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FID	Name	Latitude	Longitude	Foundation	Dissolution	Filiation	Diocese
1	Acey	47.24575	5.68701	1136	1791	Clairvaux	Besançon
2	Aiguebelle	44.47640	4.85130	1137	1791	Morimond	St-Paul-Trois-Châteaux
3	Almanarre	43.11954	6.13897	1220	1399	Cîteaux	Toulon
4	Ardorel	43.54194	2.34194	1114	1587	Pontigny	Albi
5	Aubazine	45.83153	1.25780	1134	1791	Cîteaux	Limoges
6	Aubepierre	46.39306	1.76611	1149	1569	Clairvaux	Limoges
7	Auberive	47.86667	5.33333	1135	1791	Clairvaux	Langres
8	Aubignac	42.39720	1.50556	1138	1790	Pontigny	Urgell
9	Aunay	49.02012	-0.63238	1131	1791	Clairvaux	Bayeux
10	Aumône	47.58333	1.33333	1121	1791	Cîteaux	Chartres
11	Balerne	46.83712	5.70504	1107	1791	Clairvaux	Besançon
12	Barbeau	48.48566	2.76528	1147	1791	Cîteaux	Sens
13	Barbery	49.04466	-0.32639	1176	1791	Clairvaux	Bayeux
14	Bégard	48.63028	-3.29639	1130	1790	Cîteaux	Tréguier
15	Barzelle	46.95000	2.00000	1138	1791	Cîteaux	Bourges
16	Baumgarten	48.36992	7.40284	1148	1525	Morimond	Strasbourg
17	Beaubec	49.64000	1.49917	1120	1791	Clairvaux	Rouen
18	Beaugerais	47.06111	1.16778	1153	1791	Cîteaux	Tours
19	Beaulieu-en-Bassigny	47.89603	5.62767	1170	1791	Clairvaux	Langres
20	Beaulieu-en-Rouergue	44.21000	1.85417	1144	1791	Clairvaux	Rodez
21	Beaupré	49.55672	1.97924	1135	1790	Clairvaux	Beauvais
22	Beaupré-sur-Meurthe	48.60000	6.50000	1135	1790	Morimond	Toul
23	Bellaigue	45.90000	3.11667	1137	1791	Cîteaux	Clermont
24	Belleau	48.78167	3.44183	1242	1510	Morimond	Troyes
25	Bellebranche	47.83333	-0.70000	1152	1791	Cîteaux	Le Mans
26	Belleperche	43.98534	1.15006	1143	1791	Clairvaux	Toulouse
27	Bellevaux	47.40445	6.12028	1120	1830	Morimond	Besançon
28	Belloc	44.01667	1.35000	1144	1791	Clairvaux	Toulouse
29	Bénisson-Dieu	46.15111	4.04528	1138	1791	Clairvaux	Lyon
30	Bénissons-Dieu	43.11667	0.73333	1184	1791	Morimond	Comminges
31	Berdoues	43.51667	0.41667	1134	1791	Morimond	Auch
32	Bernardins	48.85341	2.34880	1244	1791	Clairvaux	Paris
33	Betton	45.56667	5.93333	1150	1791	Cîteaux	Grenoble
34	Beuil	45.88867	0.90143	1123	1791	Pontigny	Limoges
35	Billon	47.10806	5.96167	1128	1789	Clairvaux	Besançon
36	Bithaine	47.68333	6.50000	1133	1791	Morimond	Besançon
37	Blanche	47.02667	-2.27056	1172	1789	Clairvaux	Nantes
38	Bœuil	45.90250	1.06056	1123	1790	Pontigny	Limoges
39	Bohéries	49.83333	3.90000	1141	1791	Clairvaux	Laon
40	Bois-Grolland	46.52472	-1.54778	1201	1790	Clairvaux	Poitiers

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41	Boissière	47.16667	-0.26667	1147	1790	Clairvaux	Angers
42	Bonlieu	44.89642	-0.50107	1141	1791	Pontigny	Bordeaux
43	Bonlieu	45.95000	2.16667	1121	1791	Pontigny	Limoges
44	Bonlieu	45.50000	4.05000	1199	1791	Cîteaux	Lyon
45	Bonnaigue	45.57472	2.36611	1143	1790	Cîteaux	Limoges
46	Bonnecombe	44.24361	2.55444	1167	1790	Clairvaux	Rodez
47	Bonnefont	43.14083	0.87417	1136	1791	Morimond	Comminges
48	Bonnefontaine	49.78528	4.24028	1154	1791	Clairvaux	Reims
49	Bonneval	44.58717	2.79345	1147	1791	Cîteaux	Rodez
50	Bonnevaux	45.47590	5.10215	1119	1791	Cîteaux	Vienne
51	Bonnevaux	46.42953	0.26443	1119	1791	Pontigny	Poitiers
52	Bonport	49.30324	1.15480	1190	1791	Cîteaux	Rouen
53	Bonrepos	48.17826	-2.75433	1172	1790	Cîteaux	St-Brieuc
54	Boquen	48.45000	-2.03333	1137	1791	Cîteaux	Dol
55	Borde	48.23333	4.71667	1198	1791	Clairvaux	Langres
56	Boschaud	45.53333	0.66667	1154	1791	Clairvaux	Limoges
57	Bouchet	45.64317	3.24638	1192	1791	Morimond	Clermont
58	Boüillas	43.93464	0.62107	1125	1791	Morimond	Auch
59	Boulancourt	48.45583	4.64639	1150	1791	Clairvaux	Troyes
60	Boulaye	49.05000	-1.03333	1134	1791	Clairvaux	Bayeux
61	Boulbonne	43.30583	1.55556	1129	1562	Morimond	Toulouse
62	Bourras	47.41101	2.92528	1119	1791	Pontigny	Auxerre
63	Bouschet-Vauluisant	45.60806	3.25194	1192	1791	Morimond	Clermont
64	Breuil-Benoît	48.90635	1.27518	1137	1790	Clairvaux	Évreux
65	Buillon	47.10250	5.88212	1148	1791	Clairvaux	Besançon
66	Bussière	47.03333	4.83333	1131	1791	Cîteaux	Autun
67	Buzay	47.28654	-2.03048	1135	1791	Clairvaux	Nantes
68	Cadouin	44.84520	0.91070	1115	1791	Pontigny	Périgueux
69	Calers	43.25972	1.47444	1148	1790	Clairvaux	Toulouse
70	Candeil	43.90160	1.89686	1152	1791	Clairvaux	Albi
71	Carnoët	47.86667	-3.55000	1170	1791	Cîteaux	Quimper
72	Castelas	43.04778	6.48028	1199	1791	Cîteaux	Toulon
73	Cercamp	50.38113	2.33407	1141	1791	Pontigny	Thérouanne
74	Cercanceaux	48.40000	2.70000	1181	1790	Cîteaux	Sens
75	Chaalis	49.20000	2.58333	1137	1786	Pontigny	Senlis
76	Chalade	49.22732	5.03509	1128	1791	Clairvaux	Verdun
77	Chalivoy	47.32889	2.83448	1133	1791	Pontigny	Auxerre
78	Chaloché	47.54111	-0.28111	1147	1790	Clairvaux	Angers
79	Chambons	44.53333	4.30000	1151	1790	Cîteaux	Viviers
80	Champagne	48.13955	-0.11418	1188	1791	Clairvaux	Le Mans
81	Charité	47.53861	5.95306	1133	1791	Morimond	Besançon

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82	Charité-les-Lézinnes	47.80089	4.08776	1184	1790	Clairvaux	Langres
83	Charmoye	48.92889	3.84639	1167	1791	Clairvaux	Châlons
84	Charon	46.30811	-0.99450	1191	1791	Clairvaux	Saintes
85	Chassagne-en-Bresse	45.94111	4.76727	1145	1791	Pontigny	Lyon
86	Châtelliers	46.65000	-0.25000	1129	1791	Clairvaux	Poitiers
87	Châtelliers	46.16667	-1.15000	1156	1791	Pontigny	Saintes
88	Châtillon	49.52096	5.36835	1153	1791	Clairvaux	Trier
89	Chaumes	46.17000	-1.07306	1168	1723	Clairvaux	Saintes
90	Chéhéry	49.40000	4.70000	1147	1791	Clairvaux	Reims
91	Cheminon	48.74000	4.90417	1102	1791	Clairvaux	Toul
92	Cherlieu	47.78139	5.82528	1131	1791	Clairvaux	Besançon
93	Cîteaux	47.12755	5.09301	1098	1791	Cîteaux	Chalon
94	Clairfontaine	47.88472	6.07056	1131	1791	Morimond	Besançon
95	Clairlieu	48.66000	6.11667	1151	1791	Morimond	Toul
96	Clairmarais	50.76889	2.30528	1140	1791	Clairvaux	Thérouanne
97	Clairvaux	48.14933	4.83228	1115	1789	Clairvaux	Langres
98	Clarté-Dieu	43.41861	1.35361	1150	1791	Morimond	Toulouse
99	Clarté-Dieu	47.60139	0.45639	1240	1791	Cîteaux	Tours
100	Clermont	48.09806	-0.93361	1145	1791	Clairvaux	Le Mans
101	Coëtmaloën	48.37675	-3.13417	1142	1791	Cîteaux	Quimper
102	Cour-Dieu	48.00583	2.19750	1119	1791	Cîteaux	Orléans
103	Crête	48.20750	5.31833	1121	1791	Morimond	Langres
104	Dalon	45.25722	1.22222	1114	1791	Pontigny	Périgueux
105	Écharlis	47.94944	3.14417	1131	1791	Clairvaux	Sens
106	Écurey	48.55833	5.26917	1144	1791	Morimond	Toul
107	Élan	49.66333	4.75639	1148	1791	Cîteaux	Reims
108	Épau	48.01418	0.26636	1228	1791	Cîteaux	Le Mans
109	Escaladieu	43.11000	0.25694	1137	1790	Morimond	Tarbes
110	Estrée	48.76694	1.30500	1145	1790	Pontigny	Chartres
111	Étoile	46.65333	0.70389	1117	1791	Pontigny	Poitiers
112	Faise	44.96833	-0.12778	1137	1790	Pontigny	Bordeaux
113	Féniers	45.32361	2.77083	1173	1791	Morimond	Clermont
114	Feuillants	43.35417	1.14000	1145	1593	Morimond	Toulouse
115	La Ferté	46.69107	4.85912	1113	1791	La Ferté	Chalon
116	Flaran	43.89008	0.37335	1151	1791	Morimond	Auch
117	Foigny	49.89222	3.97417	1121	1791	Clairvaux	Laon
118	Fontaine-Daniel	48.27778	-0.67278	1204	1791	Clairvaux	Le Mans
119	Fontaine-les-Blanches	47.49778	0.99889	1147	1791	Clairvaux	Tours
120	Fontainejean	47.84806	2.96056	1124	1790	Pontigny	Sens
121	Fontenay	47.64008	4.38992	1119	1791	Clairvaux	Autun
122	Fontfroide	43.18333	3.00000	1146	1791	Clairvaux	Narbonne

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123	Fontguilhem	44.39556	0.07083	1124	1791	Pontigny	Gascogne
124	Fontmorigny	47.04611	2.91528	1149	1790	Clairvaux	Nevers
125	Foucarmont	49.84972	1.56583	1130	1791	Clairvaux	Rouen
126	Franquevaux	43.64944	4.34778	1143	1791	Morimond	Nîmes
127	Freistroff	49.28167	6.49222	1130	1790	Morimond	Metz
128	Frenade	45.65750	-0.37278	1140	1791	Cîteaux	Saintes
129	Froidmont	49.37889	2.26194	1134	1791	Clairvaux	Beauvais
130	Garde-Dieu	49.96361	2.10333	1137	1790	Clairvaux	Amiens
131	Garde-Dieu	44.17194	1.41528	1147	1791	Cîteaux	Cahors
132	Gémenos, Saint Pons de	43.29751	5.62843	1205	1407	Cîteaux	Marseille
133	Gimont	43.62627	0.87655	1143	1791	Morimond	Toulouse
134	Gondon	44.51778	0.53389	1120	1791	Pontigny	Agen
135	Gouffern	48.86444	-0.14972	1147	1790	Clairvaux	Sées
136	Gourdon	44.70861	1.30833	1242	1650	Cîteaux	Cahors
137	Grâce-Dieu	47.25000	6.34833	1139	1791	Morimond	Besançon
138	Grâce-Dieu	46.20417	-0.84167	1135	1791	Clairvaux	Saintes
139	Grandselve	43.85639	1.13806	1144	1791	Clairvaux	Toulouse
140	Grosbot	45.55250	0.39861	1166	1791	Cîteaux	Angoulème
141	Haute-Seille	48.58917	6.92639	1140	1791	Morimond	Toul
142	Hautefontaine	48.64139	4.78667	1136	1791	Clairvaux	Châlons
143	Igny	49.21028	3.68556	1128	1790	Clairvaux	Reims
144	Jouy	48.64722	3.20639	1124	1790	Pontigny	Sens
145	La Colombe	46.43388	1.22194	1129	1791	Cîteaux	Bourges
146	La Trappe	48.61428	0.53572	1140	1791	Clairvaux	Sées
147	Lachalade	49.16500	4.95917	1128	1791	Clairvaux	Verdun
148	Landais	47.00528	1.48972	1115	1791	Cîteaux	Bourges
149	Langonnet	48.10611	-3.43222	1136	1790	Cîteaux	Vannes
150	Lannoy	49.59139	1.91194	1135	1790	Clairvaux	Beauvais
151	Lanvaux	47.80056	-2.93389	1138	1791	Cîteaux	Vannes
152	Larrivour	48.25451	4.26890	1140	1791	Clairvaux	Troyes
153	Léoncel	44.97619	5.10978	1137	1791	Cîteaux	Valence
154	Le Tart	47.18517	5.24189	1125	1791	Cîteaux	Langres
155	Lieu-Croissant	47.29806	6.33472	1134	1791	Morimond	Besançon
156	Lieu-Dieu	50.00556	1.52028	1191	1791	Clairvaux	Amiens
157	Lisle-en-Barrois	48.89528	5.12611	1150	1791	Morimond	Verdun
158	Loc-Dieu	44.33944	1.93111	1123	1793	Pontigny	Rodez
159	Longpont	49.27306	3.22056	1131	1791	Clairvaux	Soissons
160	Longuay	47.92056	4.91028	1150	1791	Clairvaux	Langres
161	Longvillers	50.53222	1.73167	1147	1791	Clairvaux	Thérouanne
162	Loos	50.61611	2.99833	1149	1791	Clairvaux	Tournai
163	Loroy	47.31972	2.41806	1129	1791	Cîteaux	Bourges

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164	Louroux	47.42139	0.02583	1121	1791	Cîteaux	Angers
165	Lucelle	47.42139	7.24639	1123	1792	Morimond	Bâle
166	Lyon	45.77361	4.83417	1631	1642	Cîteaux	Lyon
167	Maizières	46.94806	4.88694	1125	1791	La Ferté	Autun
168	Manosque	43.83361	5.78472	1634	1791	Cîteaux	Sisteron
169	Marcilly	47.54194	3.93889	1239	1791	Clairvaux	Autun
170	Mazan	44.72836	4.08909	1120	1791	Cîteaux	Viviers
171	Melleray	47.54889	-1.37778	1145	1794	Cîteaux	Nantes
172	Merci-Dieu	46.76750	0.83861	1151	1791	Pontigny	Tours
173	Miroir	46.54111	5.30889	1131	1612	Cîteaux	Lyon
174	Mollégès	43.80703	4.94934	1208	1305	Cîteaux	Avignon
175	Mont-Sion	43.30028	5.37945	1242	1791	Cîteaux	Marseille
176	Mont-St-Marie	46.77333	6.27889	1199	1790	Clairvaux	Besançon
177	Monthiers-en-Argonne	48.89861	4.87778	1144	1791	Clairvaux	Châlons
178	Montpeyroux	45.94139	3.52000	1126	1791	Cîteaux	Clermont
179	Moreilles	46.41889	-1.08083	1109	1791	Clairvaux	Poitiers
180	Mores	48.07528	4.43139	1153	1791	Clairvaux	Langres
181	Morimond	48.00778	5.64528	1115	1791	Morimond	Langres
182	Mortemer	49.36944	1.48111	1134	1789	Clairvaux	Rouen
183	Neubourg	49.15048	0.91020	1131	1791	Morimond	Évreux
184	Noë	48.99556	1.04528	1145	1791	Pontigny	Évreux
185	Noirlac	46.74528	2.46111	1136	1791	Clairvaux	Bourges
186	Olivet	47.27750	1.80306	1145	1791	Cîteaux	Bourges
187	Ourscamp	49.54378	2.94721	1129	1792	Clairvaux	Noyon
188	Palais	45.99389	1.77000	1162	1791	Pontigny	Limoges
189	Pairis	48.11722	7.12750	1138	1790	Morimond	Bâle
190	Pérignac	44.34278	0.56528	1151	1791	Morimond	Agen
191	Perseigne	48.37694	0.24674	1145	1791	Cîteaux	Le Mans
192	Peyrouse	45.48167	0.86194	1153	1793	Clairvaux	Périgueux
193	Pierres	46.51000	2.28167	1149	1790	Clairvaux	Bourges
194	Piété-Dieu-lesRamerupt	48.51500	4.29861	1229	1791	Cîteaux	Troyes
195	Pin	46.56888	0.17833	1141	1791	Pontigny	Poitiers
196	Pontaut	43.58361	-0.51667	1115	1791	Pontigny	Gascogne
197	Pontigny	47.90529	3.71198	1114	1789	Pontigny	Sens
198	Pontron	47.52250	-0.88500	1134	1791	Cîteaux	Angers
199	Preuilly	48.44611	3.11194	1118	1791	Cîteaux	Sens
200	Pontifroid	49.12722	6.17528	1323	1740	Morimond	Metz
201	Prébenoît	46.34278	2.08389	1162	1791	Pontigny	Limoges
202	Prée	46.90694	2.13222	1141	1790	Clairvaux	Bourges
203	Prières	47.52389	-2.48750	1252	1790	Clairvaux	Vannes
204	Quincy	47.85612	4.07030	1133	1790	Pontigny	Langres

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205	Reclus	48.83833	3.72444	1142	1791	Clairvaux	Châlons
206	Reigny	47.66459	3.73501	1128	1790	Clairvaux	Auxerre
207	Relec	48.44889	3.82500	1132	1791	Cîteaux	Troyes
208	Rieuntte	43.10487	2.35259	1162	1761	Cîteaux	Carcassonne
209	Rivet	44.49448	-0.14440	1189	1791	Pontigny	Gascogne
210	Roches	47.46722	2.92111	1137	1567	Pontigny	Auxerre
211	Rosières	46.95722	5.65167	1132	1790	Morimond	Besançon
212	Royaumont	49.14778	2.38194	1228	1791	Cîteaux	Beauvais
213	Sauvelade	43.39500	0.70667	1287	1791	Morimond	Auch
214	Savigny	48.52079	-1.04898	1112	1791	Clairvaux	Avaranches
215	Sellières	48.53194	3.68778	1167	1791	Pontigny	Troyes
216	Sénanque	43.92833	5.18667	1148	1791	Cîteaux	Apt
217	Sept-Fons	46.51962	3.69905	1132	1791	Clairvaux	Autun
218	Signy	49.70111	4.42222	1135	1791	Clairvaux	Reims
219	Silvacane	43.71592	5.30946	1147	1443	Morimond	Aix
220	St-Aubin des Bois	48.49139	-2.39639	1138	1791	Cîteaux	St-Brieuc
221	St-Benoît-en-Woëvre	48.98806	5.78528	1132	1810	Morimond	Metz
222	St-Catherine d'Avignon	43.95056	4.81000	1150	1790	Cîteaux	Avignon
223	St-Marcel	44.11667	1.46944	1175	1790	Pontigny	Cahors
224	St-Marie de Jau	42.68333	2.27333	1162	1791	Pontigny	Elne
225	St-Sulpice	45.89778	5.58361	1133	1791	Pontigny	Belley
226	Sturzelbronn	49.05750	7.58611	1143	1790	La Ferté	Strasbourg
227	Sylvanès	43.83417	2.96028	1136	1791	Cîteaux	Rodez
228	Tamié	45.66457	6.31121	1133	1793	Cîteaux	Grenoble
229	Theuley	47.54111	5.52083	1131	1791	Morimond	Langres
230	Thoronet	43.46018	6.26397	1136	1791	Cîteaux	Fréjus
231	Tironneau	48.21194	0.34139	1149	1791	Clairvaux	Le Mans
232	Torigny	49.03806	-0.97083	1308	1791	Clairvaux	Bayeux
233	Trizay	46.58888	-1.11389	1145	1791	Pontigny	Poitiers
234	Trois Fontaines	48.71790	4.94990	1118	1741	Clairvaux	Toul
235	Ulmet	43.46556	4.63475	1173	1437	Cîteaux	Arles
236	Val	49.07861	2.22639	1125	1790	Cîteaux	Paris
237	Valasse	49.53889	0.50556	1150	1791	Clairvaux	Rouen
238	Valette	45.23500	2.16611	1143	1791	Cîteaux	Limoges
239	Val-Richer	49.14760	0.10553	1143	1791	Clairvaux	Lisieux
240	Valcroissant	44.75000	5.36667	1188	1791	Cîteaux	Die
241	Vauluisant	48.26445	3.53722	1129	1791	Cîteaux	Sens
242	Valbonne	42.49417	3.04806	1242	1791	Clairvaux	Elne
243	Valence	46.31111	0.17306	1225	1791	Clairvaux	Poitiers
244	Valloires	50.34833	1.81917	1138	1790	Cîteaux	Amiens
245	Valmagne	43.50095	3.60723	1155	1790	Cîteaux	Agde

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246	Valroy	49.77780	4.08528	1147	1791	Clairvaux	Laon
247	Valsaintes	43.95833	5.59278	1180	1792	Morimond	Apt
248	Varennes	46.58528	1.86694	1148	1791	Cîteaux	Bourges
249	Vaucelles	50.07806	3.22444	1132	1790	Clairvaux	Cambrai
250	Vauclair	49.45306	3.74583	1134	1791	Clairvaux	Laon
251	Vaux-de-Cernay	48.68389	1.93611	1147	1790	Clairvaux	Paris
252	Vaux-en-Ornois	48.58333	5.43417	1133	1791	Morimond	Toul
253	Vaux-la-Douce	47.86194	5.73889	1111	1791	Morimond	Besançon
254	Vieuville	48.52778	-1.68611	1137	1790	Clairvaux	Dol
255	Villelongue	43.30556	2.16694	1149	1791	Morimond	Carcassonne
256	Villeneuve	47.12278	-1.53333	1201	1791	Clairvaux	Nantes
257	Villers-Bettnach	49.23389	6.36167	1134	1790	Morimond	Metz
258	Himmerod	50.03333	6.75000	1134	1802	Clairvaux	Trier
259	Wörschweiler	49.28333	7.30833	1130	1791	Morimond	Metz
260	Orval	49.63972	5.34889	1132	1791	Clairvaux	Trier
261	Boudelo	51.18333	3.98333	1215	1797	Clairvaux	Tournai
262	Cambron	50.58583	3.88639	1148	1789	Clairvaux	Cambrai
263	Les Dunes	51.10944	2.63056	1138	1796	Clairvaux	Thérouanne
264	Nizelles	50.66472	4.31444	1441	1783	Clairvaux	Cambrai
265	Ter Doest	51.28194	3.20250	1175	1624	Clairvaux	Tournai
266	Lavaix	42.38333	0.75000	1224	1835	Morimond	Roda

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Appendix B

The Foundation of Monasteries 1098-1789:
Iterative Maps

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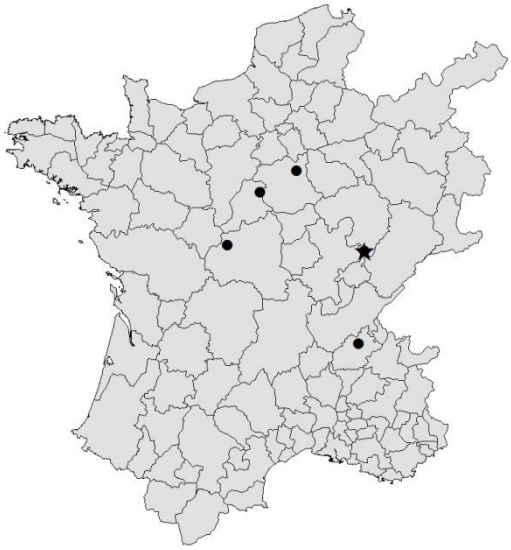
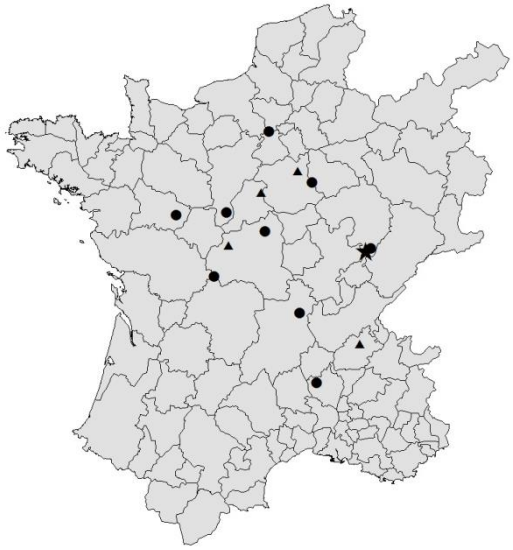
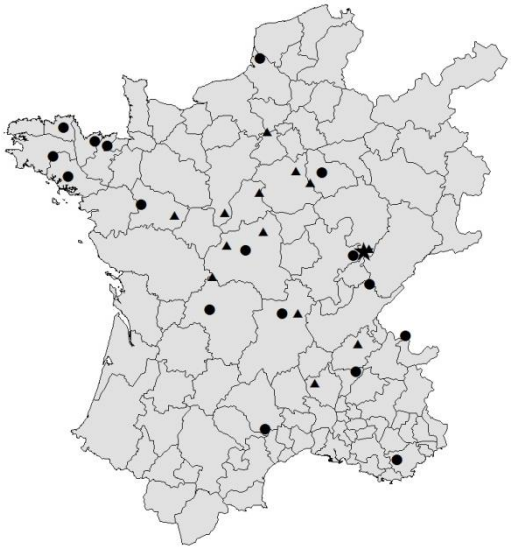
1. Cîteaux



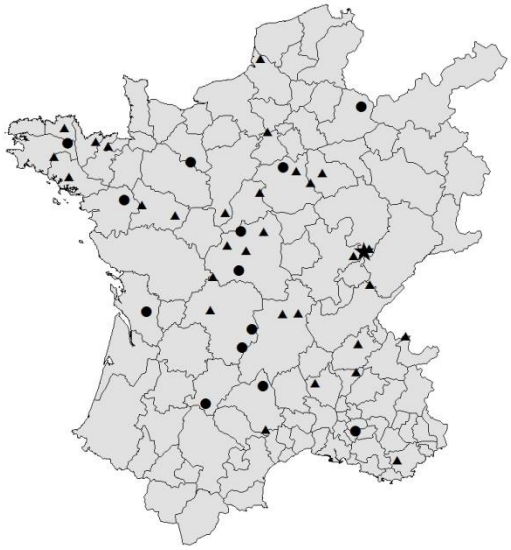
1098-1119: 5 monasteries



1098-1129: 9 new monasteries



1098-1139: 17 new monasteries



1098-1149: 13 new monasteries

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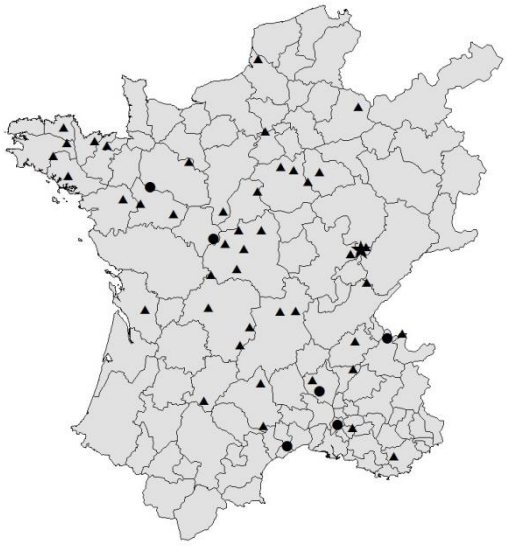
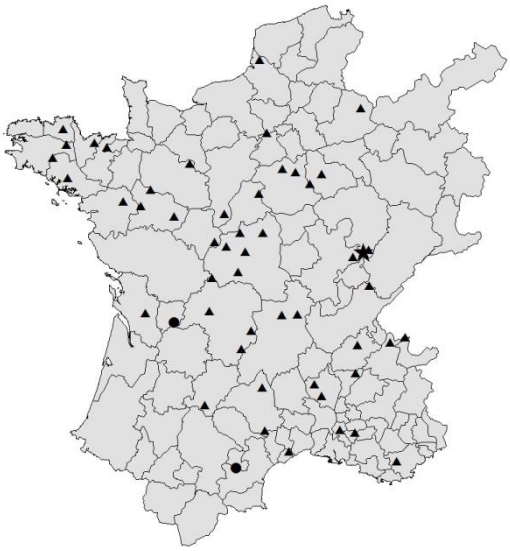
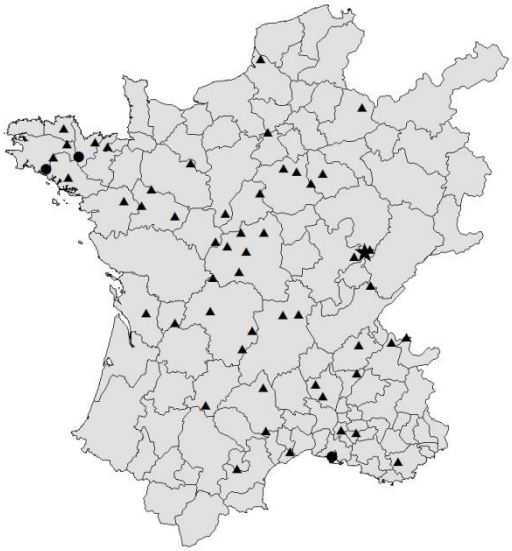


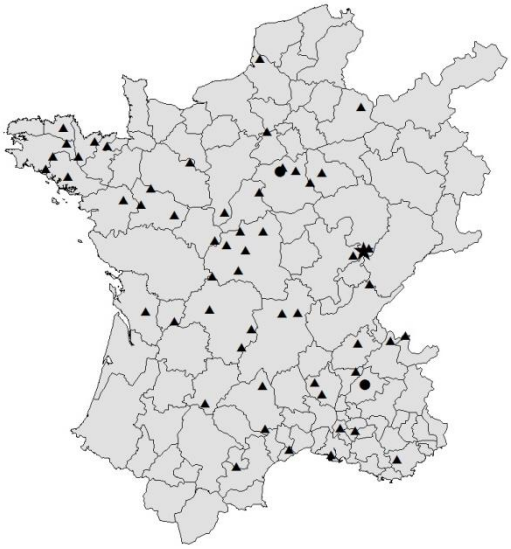
1098-1159: 6 new monasteries



1098-1169: 2 new monasteries



1098-1179: 3 new monasteries



1098-1189: 2 new monasteries

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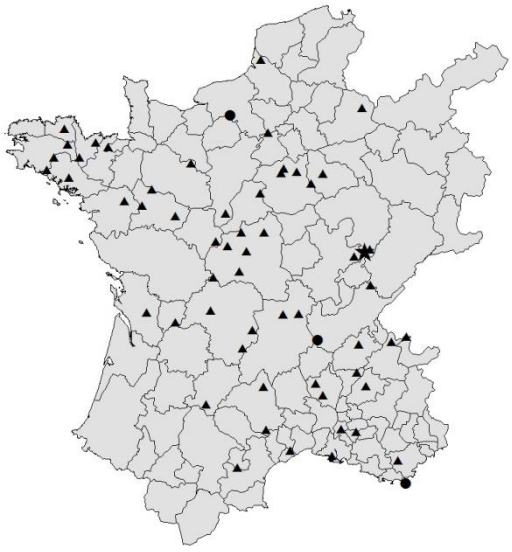
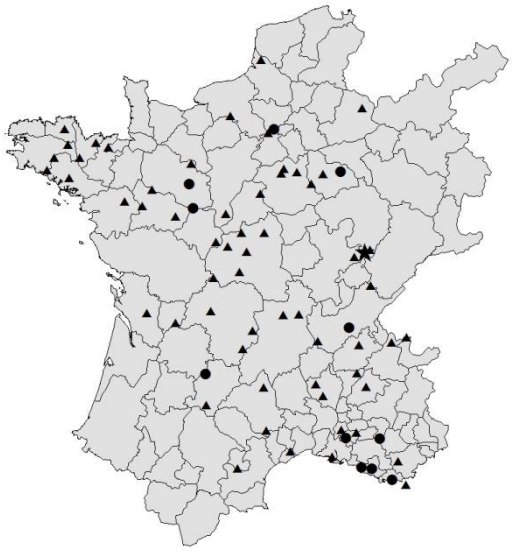


1098-1199: 3 new monasteries



1098-1789: 11 new monasteries

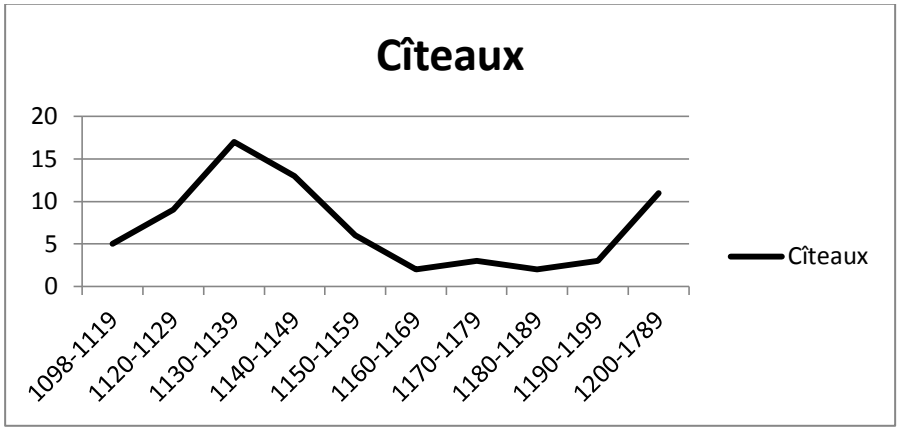


Figure 21: Number of Monasteries Founded by Decade (Cîteaux). Source: created by the author using the input data and Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

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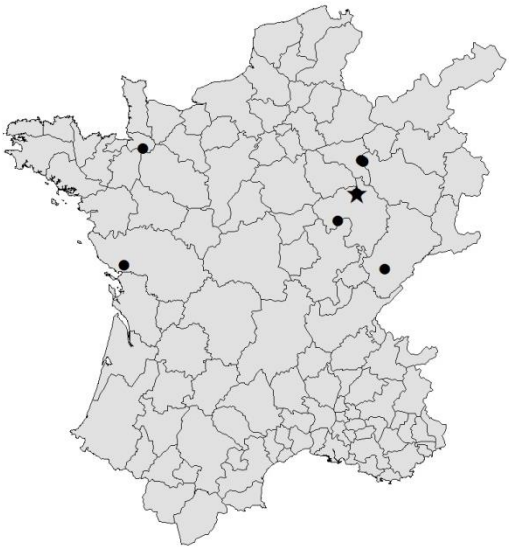
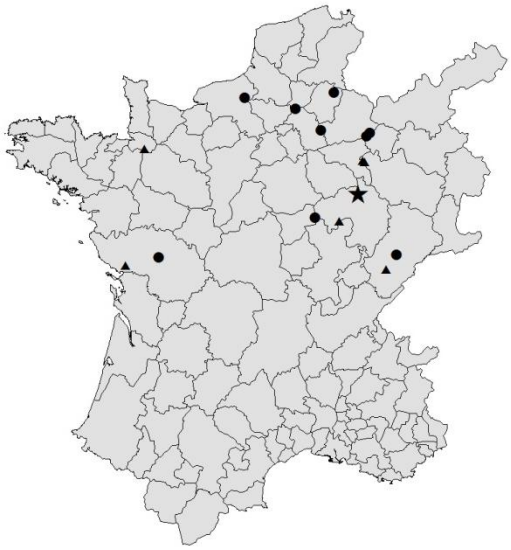
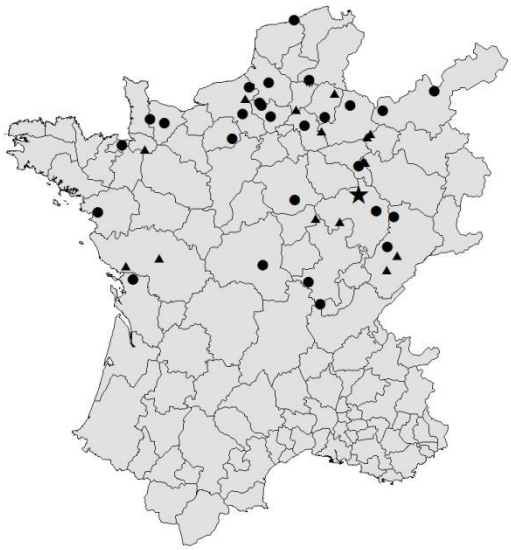
2. Clairvaux



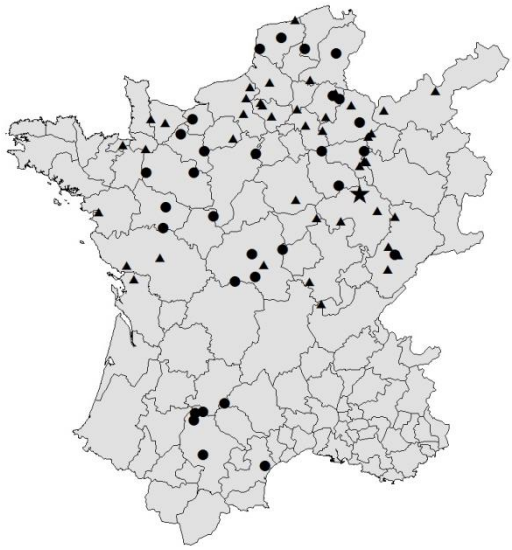
1098-1119: 7 monasteries



1098-1129: 9 new monasteries



1098-1139: 27 new monasteries



1098-1149: 30 new monasteries

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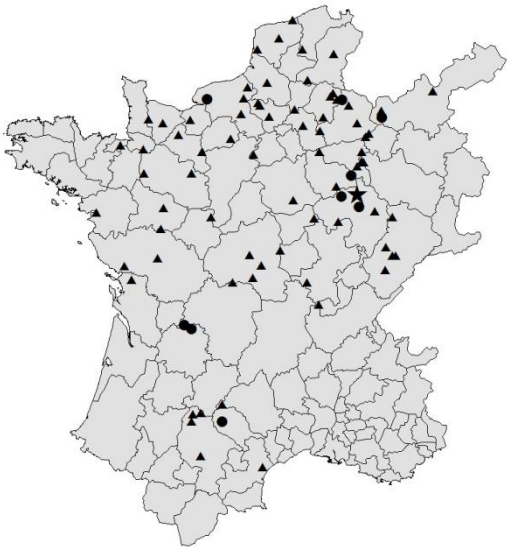
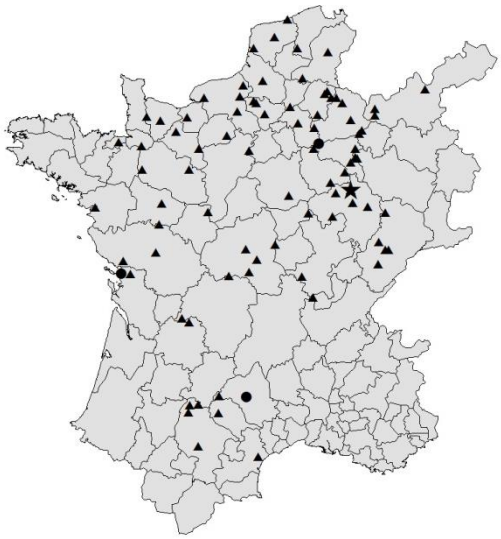
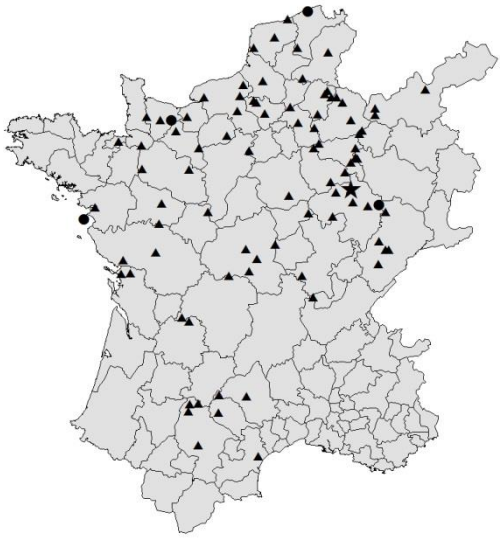


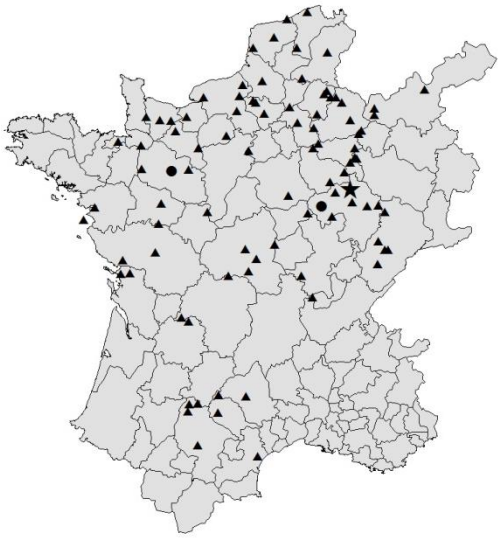
1098-1159: 9 new monasteries



1098-1169: 3 new monasteries



1098-1179: 4 new monasteries



1098-1189: 2 new monasteries

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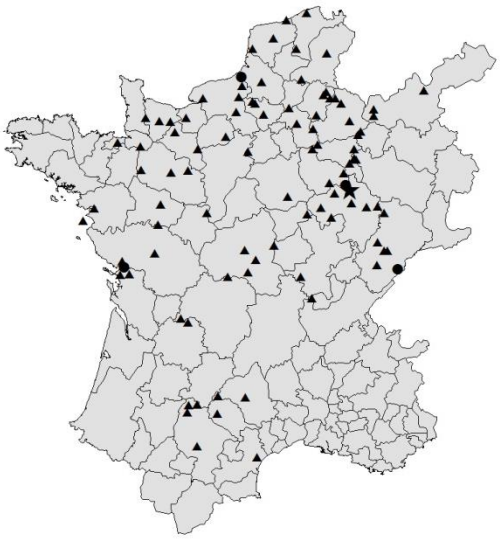
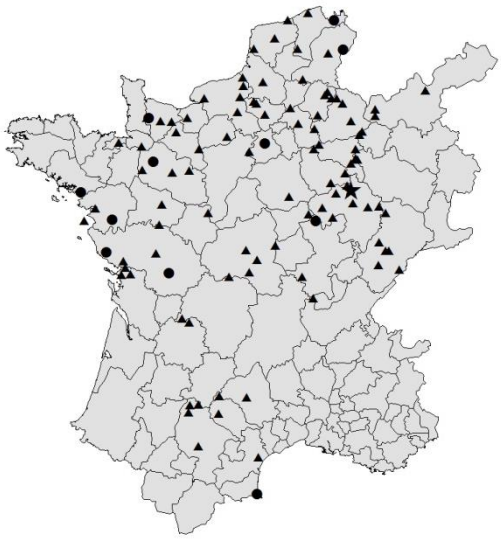


1098-1199: 4 new monasteries



1098-1789: 11 new monasteries

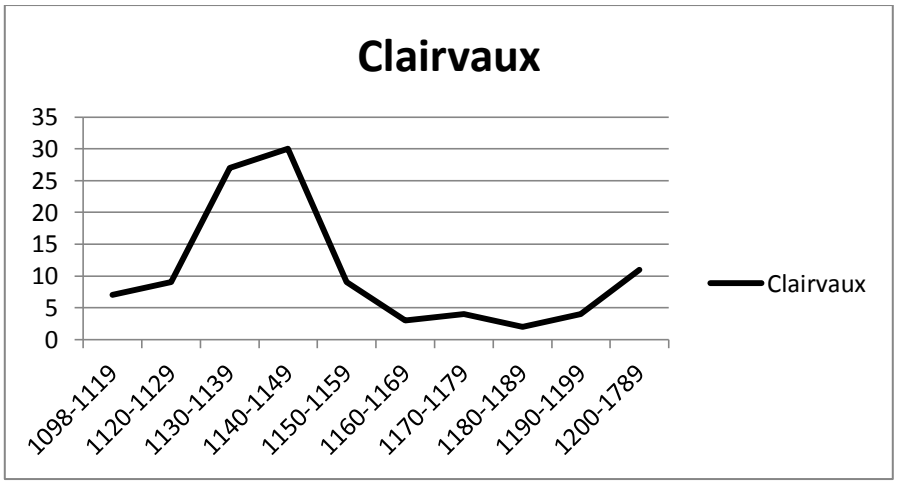


Figure 22: Number of Monasteries Founded by Decade (Clairvaux). Source: created by the author using the input data and Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

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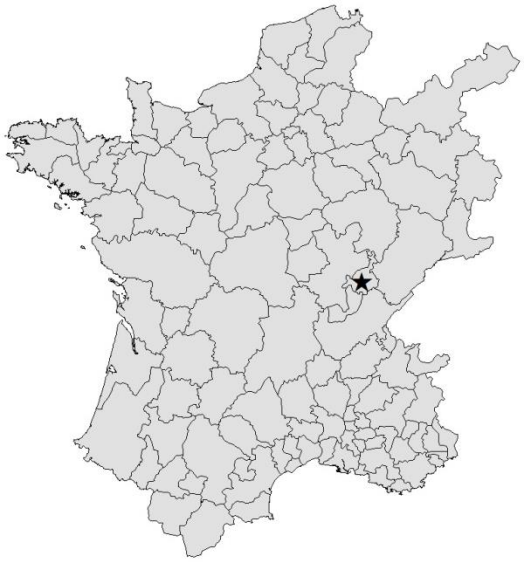
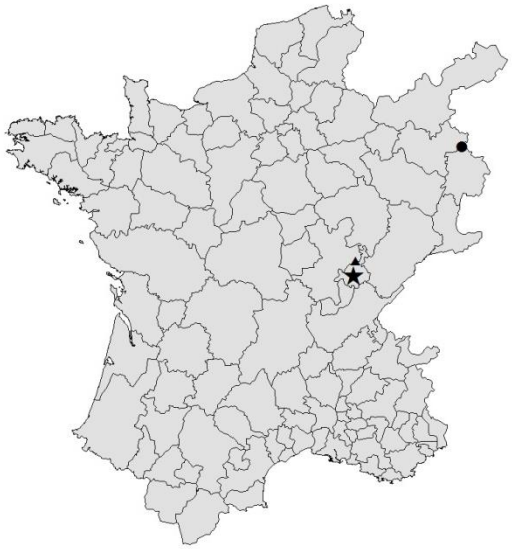
3. La Ferté



1098-1119: 1 monastery

1098-1129: 1 new monastery

1098-1139: no new monasteries



1098-1149: 1 new monastery

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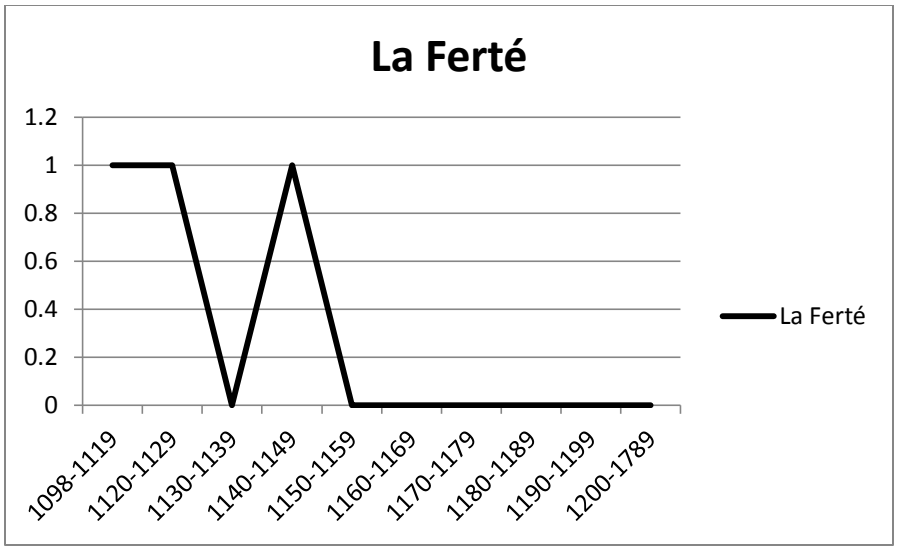

Figure 23: Number of Monasteries Founded by Decade (La Ferté). Source: created by the author using the input data and Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

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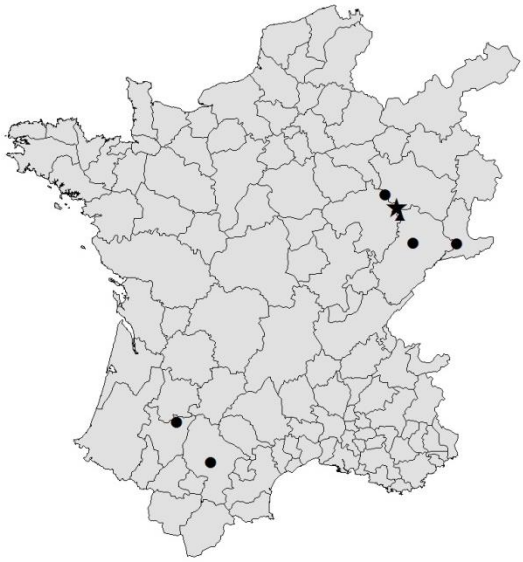
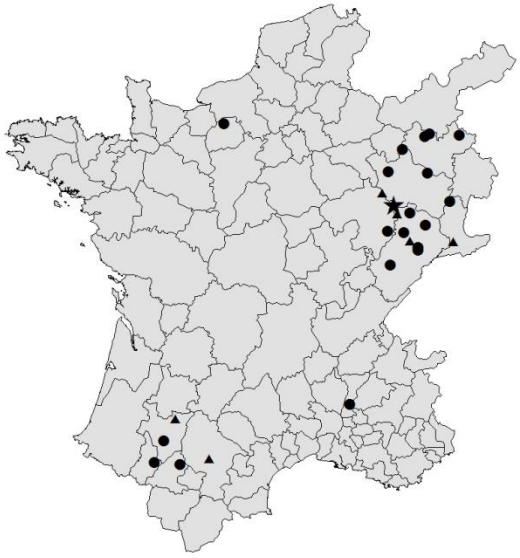
4. Morimond

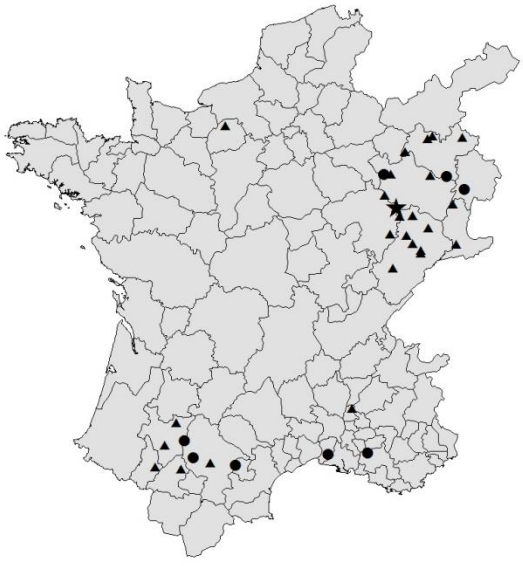
1098-1199: 2 Monasteries



1098-1129: 5 new monasteries



1098-1139: 19 new monasteries



1098-1149: 8 new monasteries

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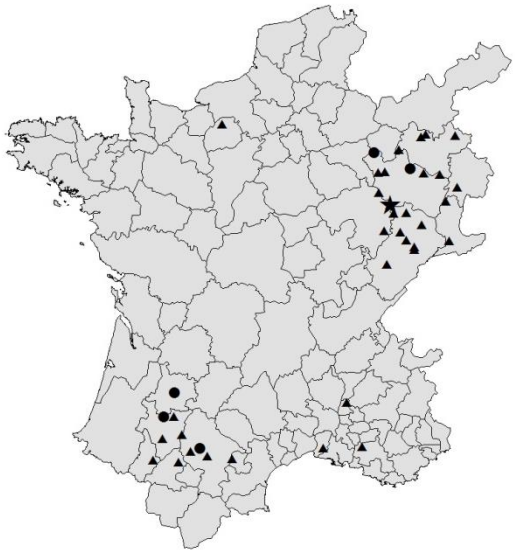
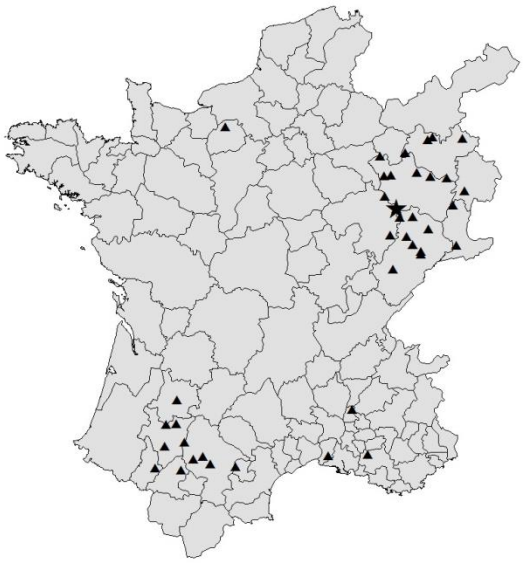
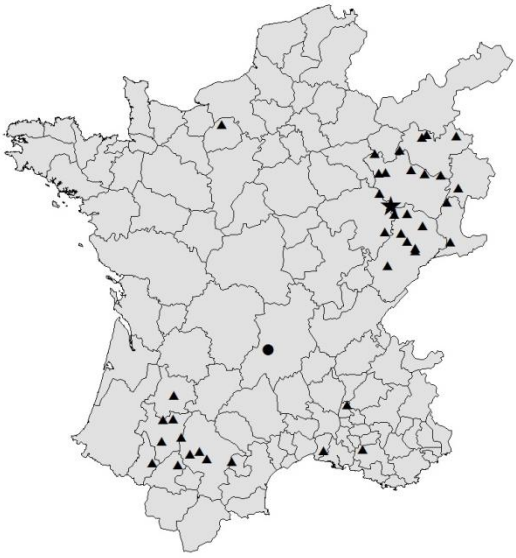


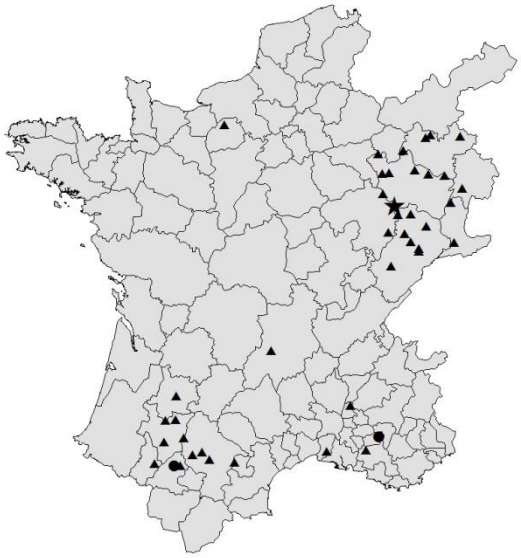
1098-1159: 5 new monasteries



1098-1169: no new monasteries



1098-1179: 1 new monastery



1098-1189: 2 new monasteries

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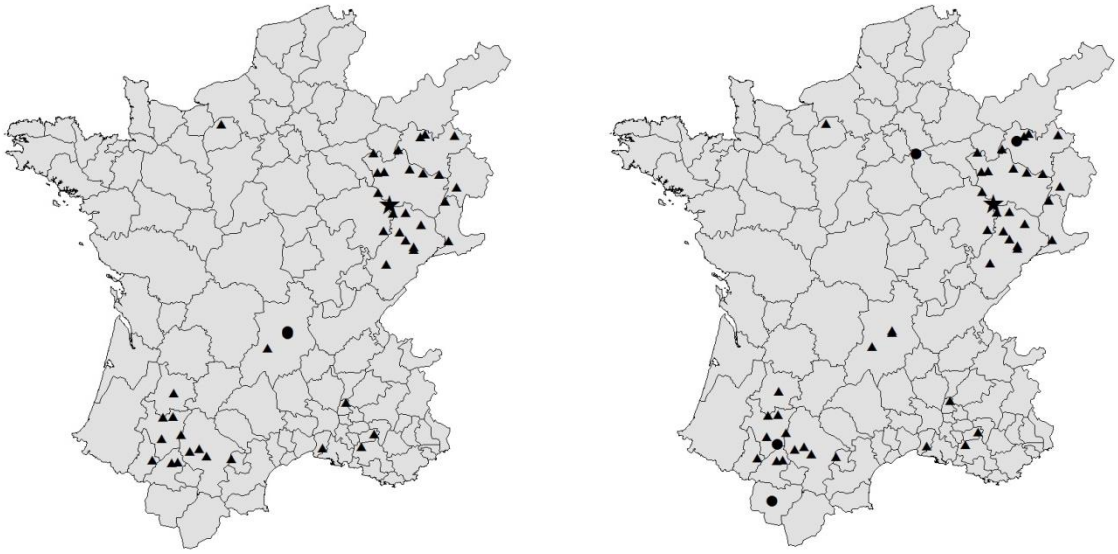

1098-1199: 2 new monasteries

1098-1789: 4 new monasteries

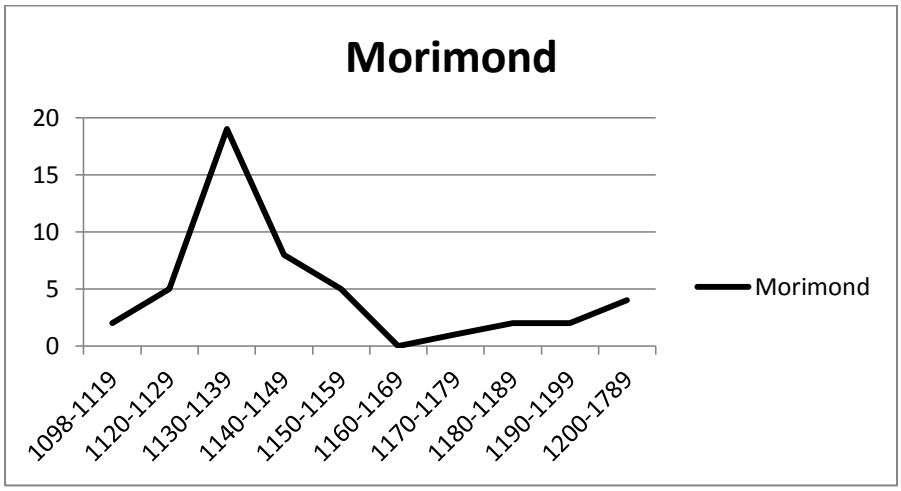

Figure 24: Number of Monasteries Founded by Decade (Morimond). Source: created by the author using the input data and Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

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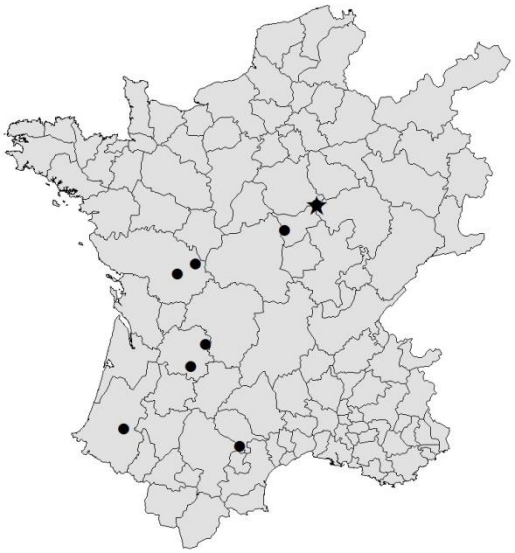
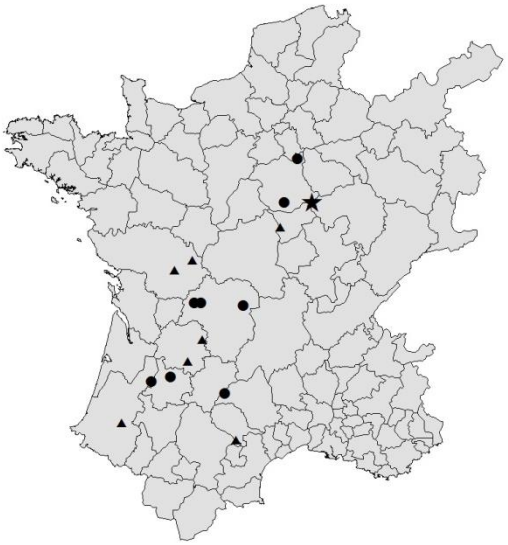
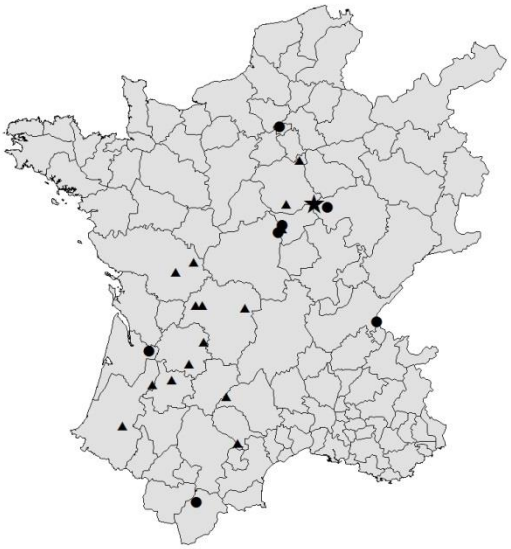
5. Pontigny



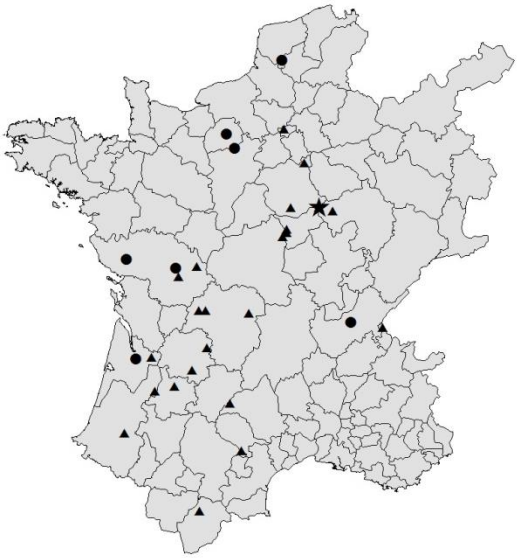
1098-1119: 8 monasteries



1120-1129: 8 new monasteries



1130-1139: 7 new monasteries



1140-1149: 7 new monasteries

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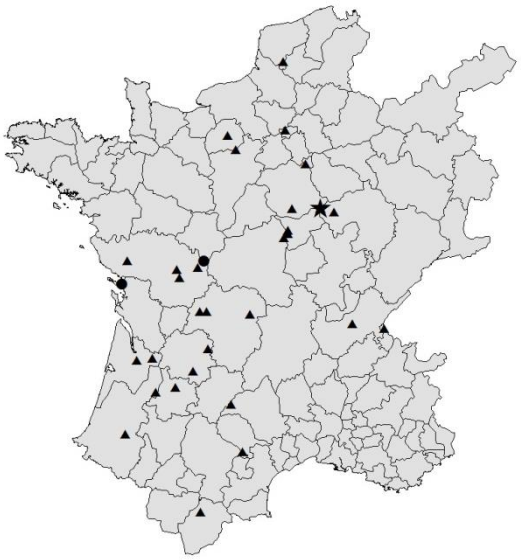
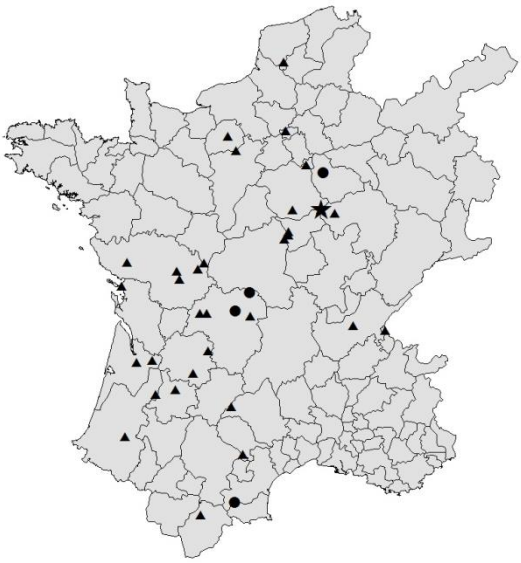
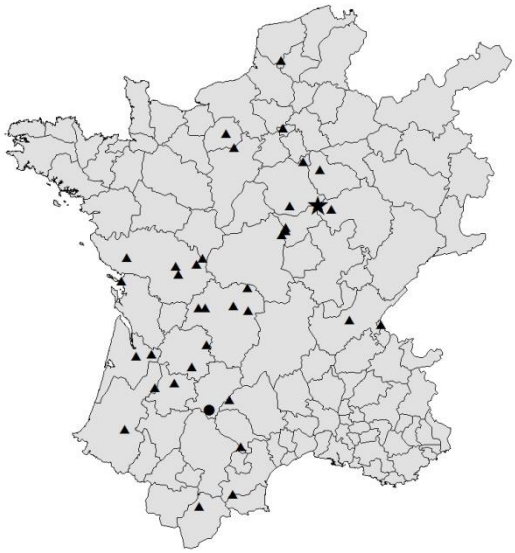


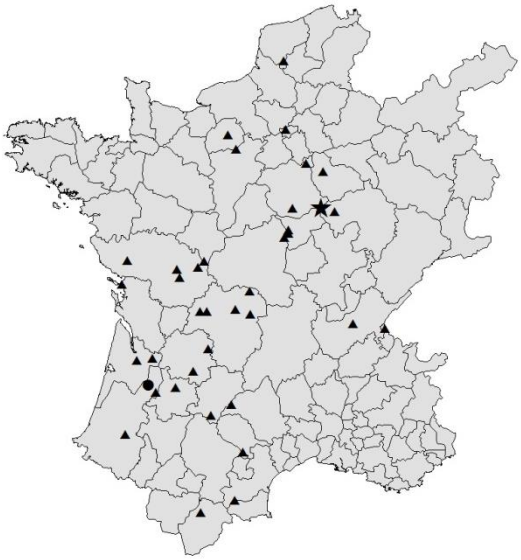
1098-1159: 2 new monasteries



1098-1169: 4 new monasteries



1098-1179: 1 new monastery



1098-1189: 1 new monastery

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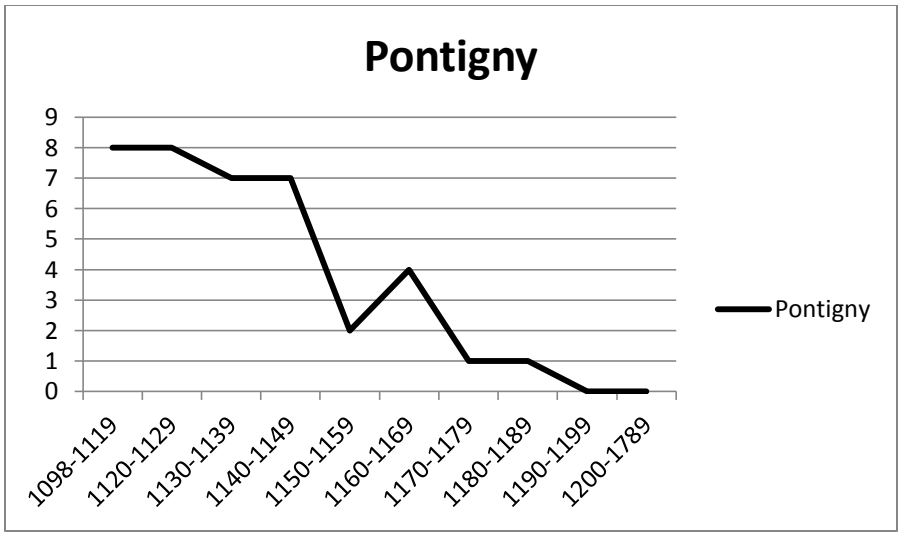

Figure 25: Number of Monasteries Founded by Decade (Pontigny). Source: created by the author using the input data and Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

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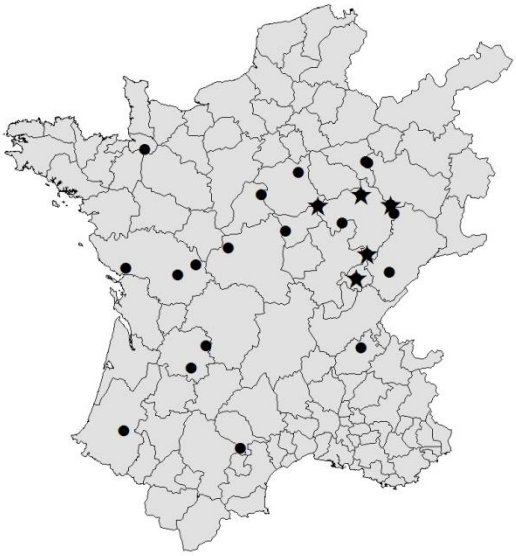
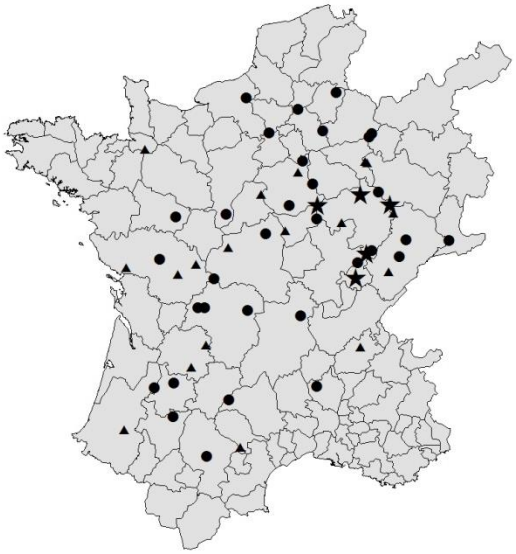
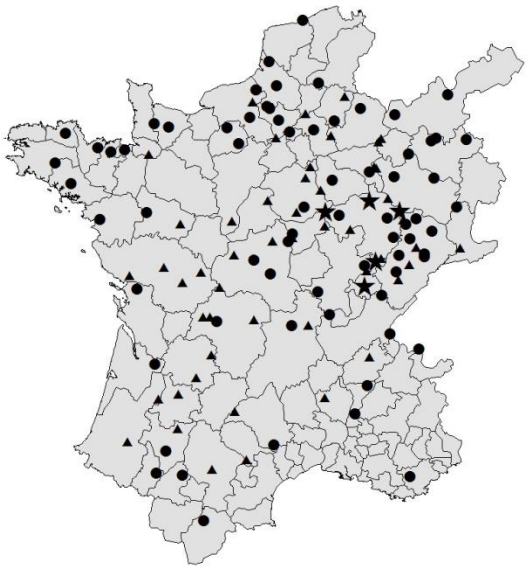
6. Combined (all Filiations)



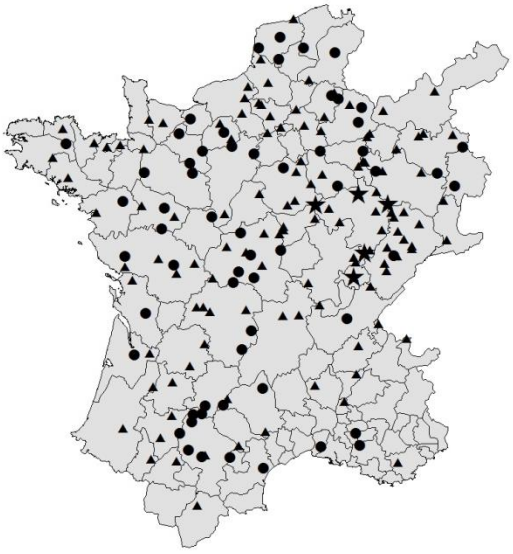
1098-1119: 23 monasteries



1098-1129: 32 new monasteries



1098-1139: 70 new monasteries



1098-1149: 59 new monasteries

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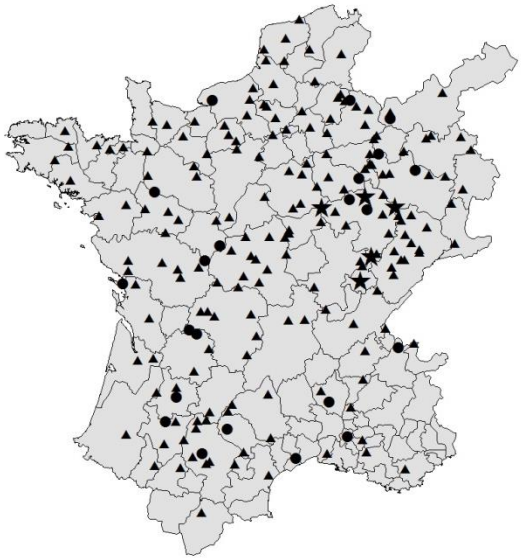
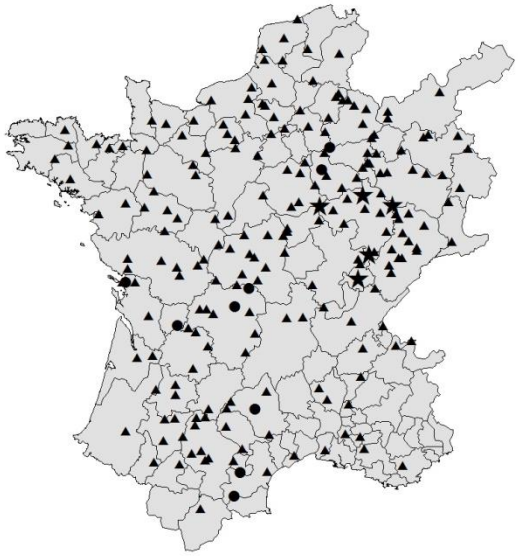
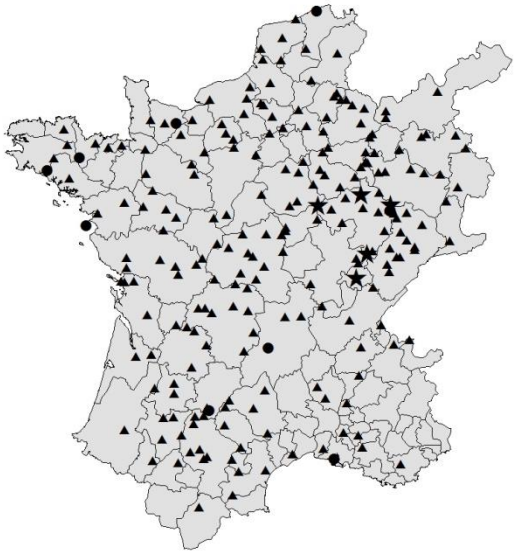


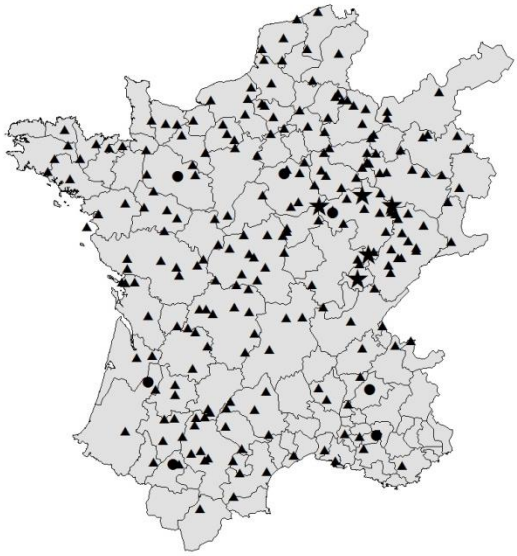
1098-1159: 22 new monasteries



1098-1169: 9 new monasteries



1098-1179: 9 new monasteries



1098-1189: 7 new monasteries

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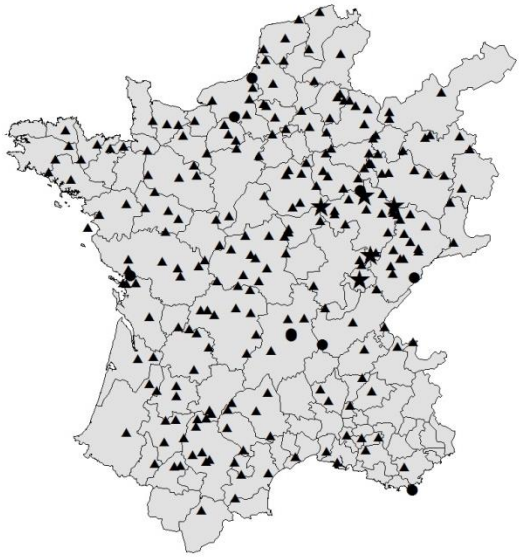
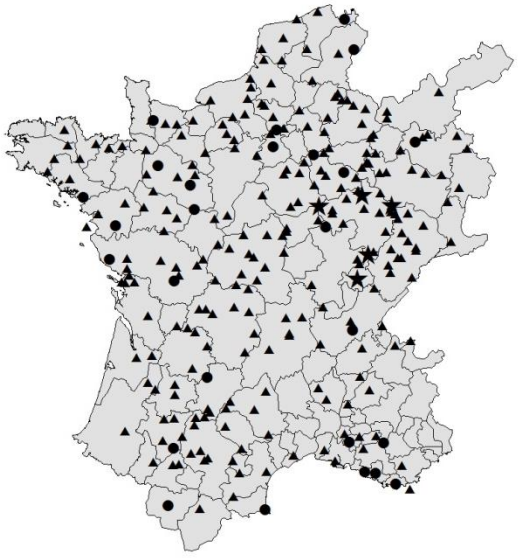


1098-1199: 9 new monasteries



1098-1789: 26 new monasteries

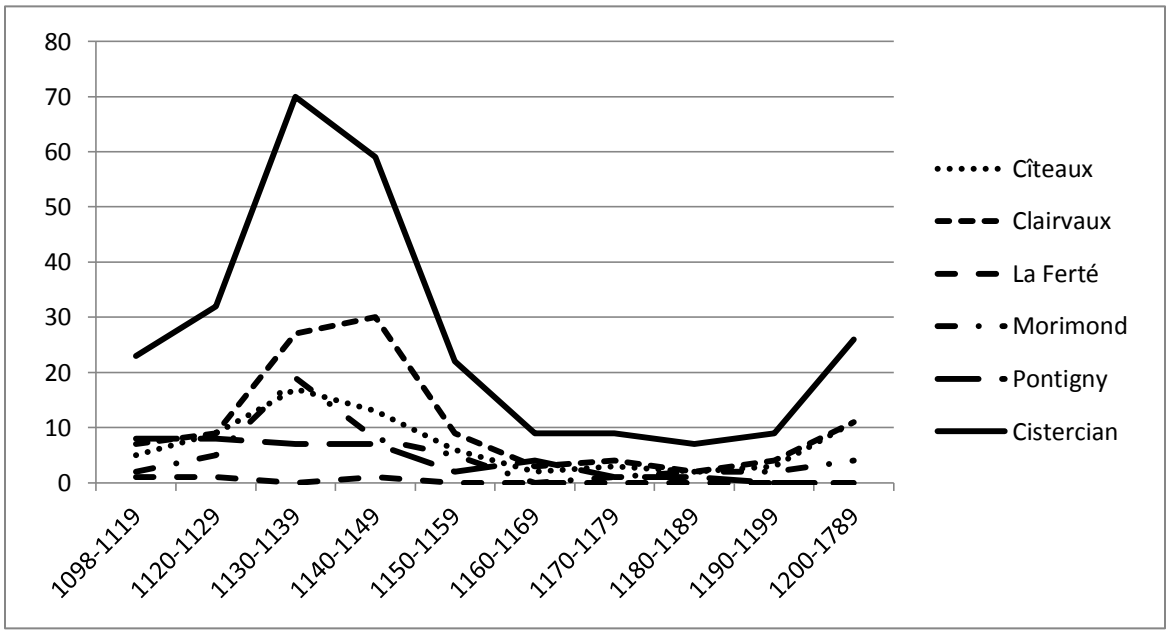


Figure 26: Number of Monasteries Founded by Decade (all Filiations). Source: created by the author using the input data and Microsoft Excel software. Jon Eric K. Rasmussen, 2015.

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Appendix C

The Establishment of Cistercian Monasteries by Diocese

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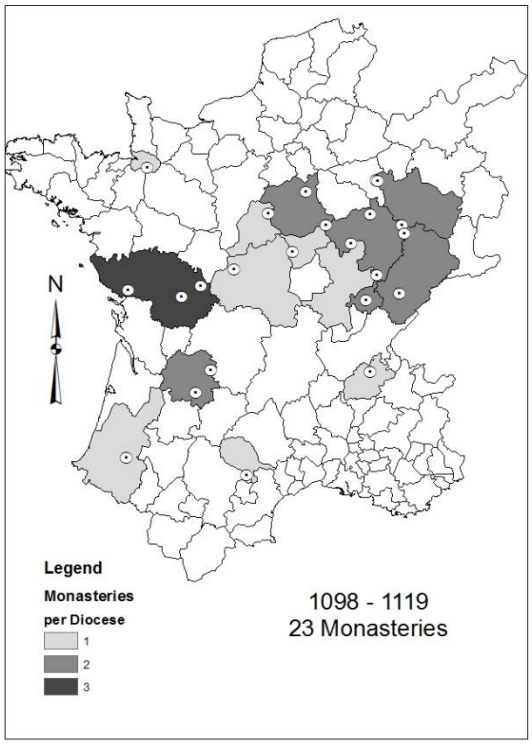
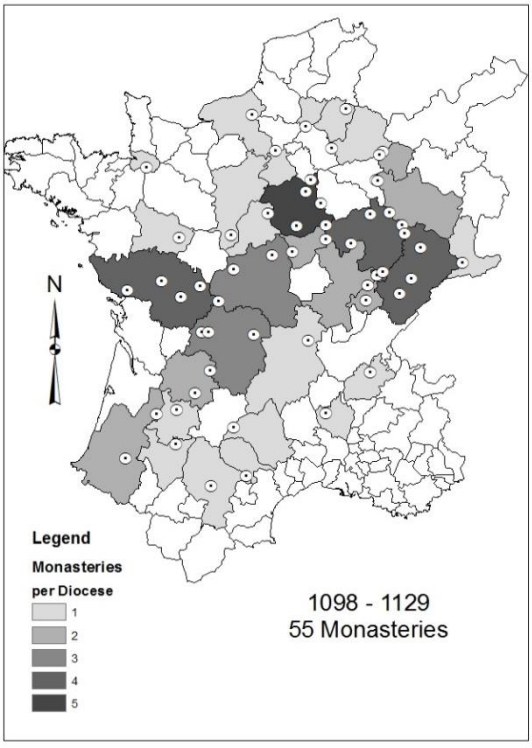
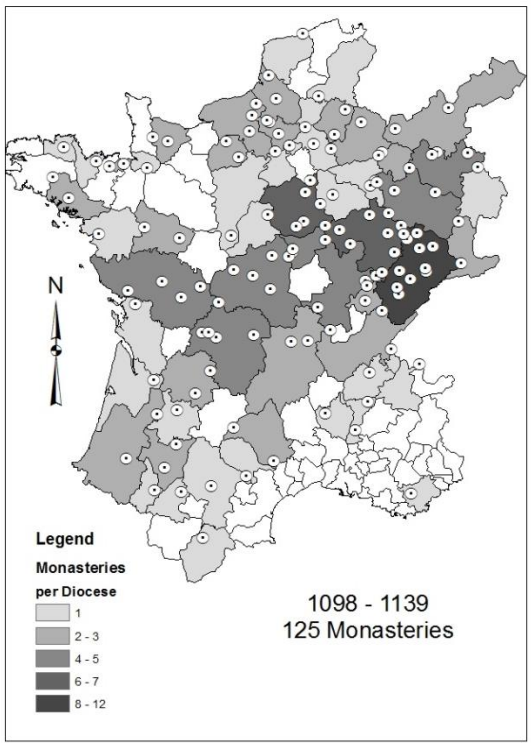
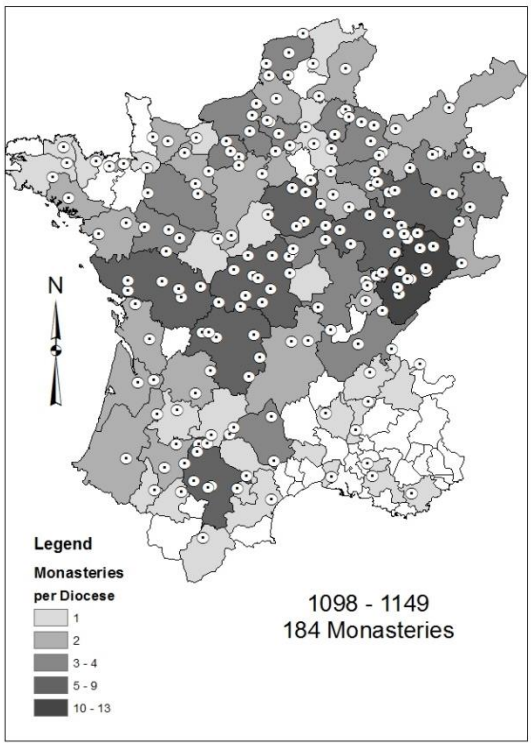
A. Series 1: Number of Monasteries per Diocese (raw)









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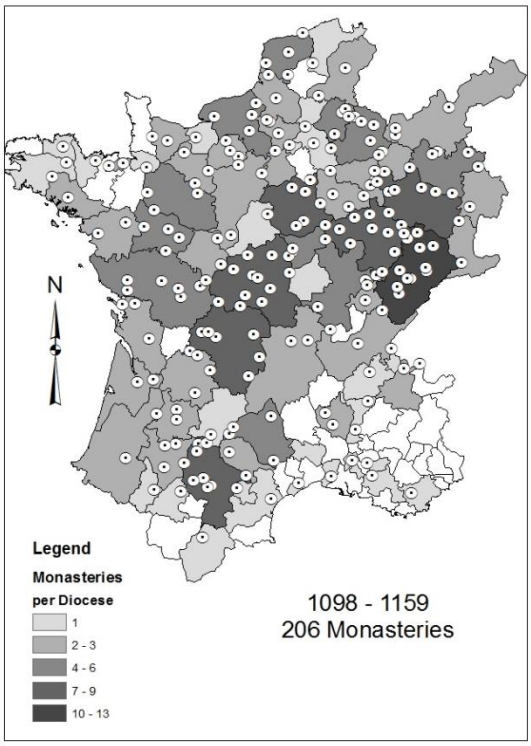

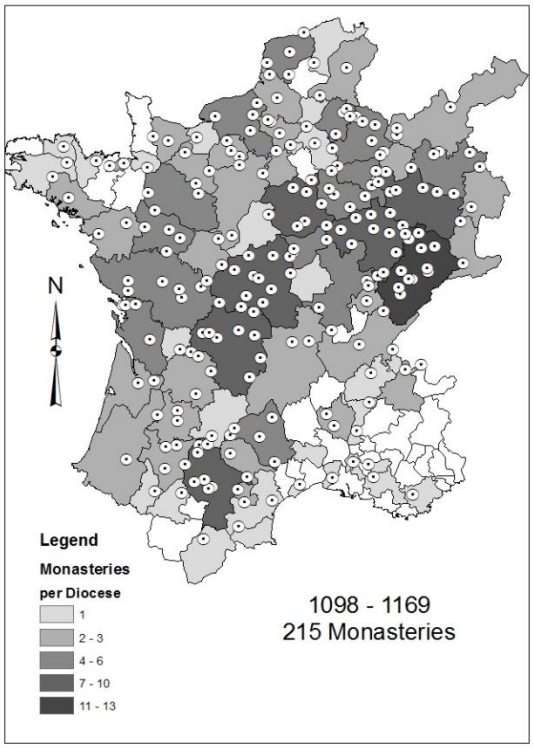

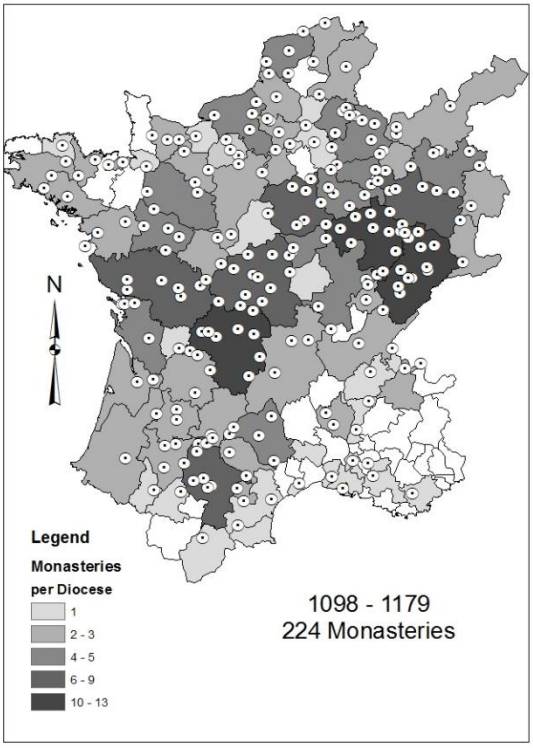

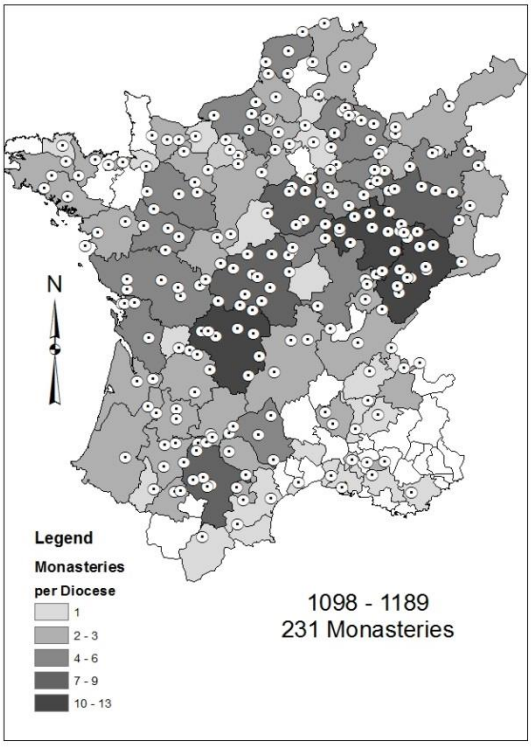

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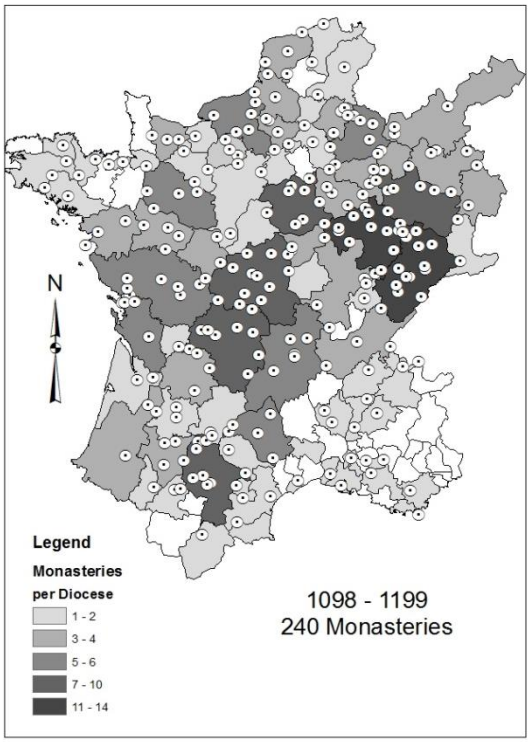
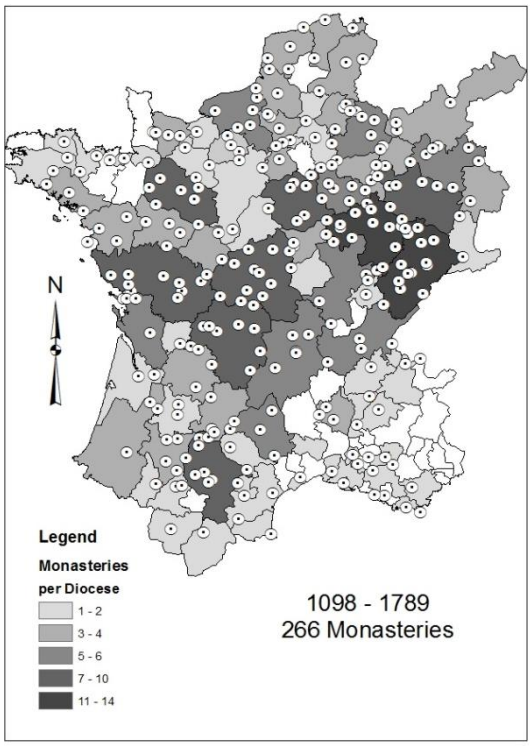
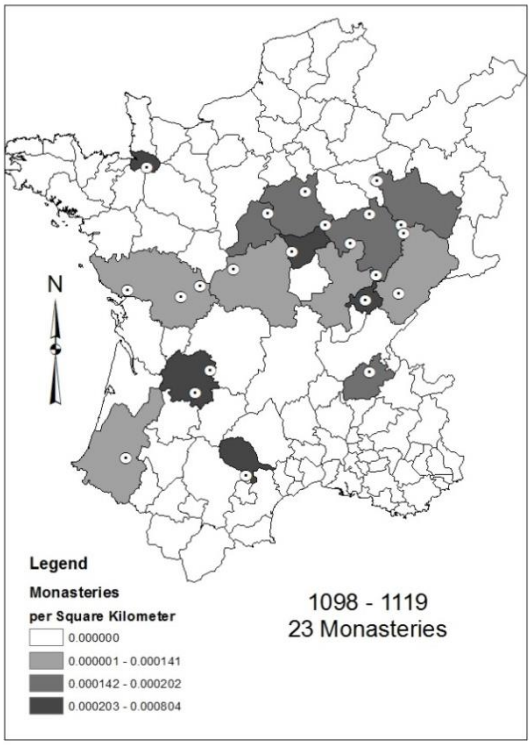
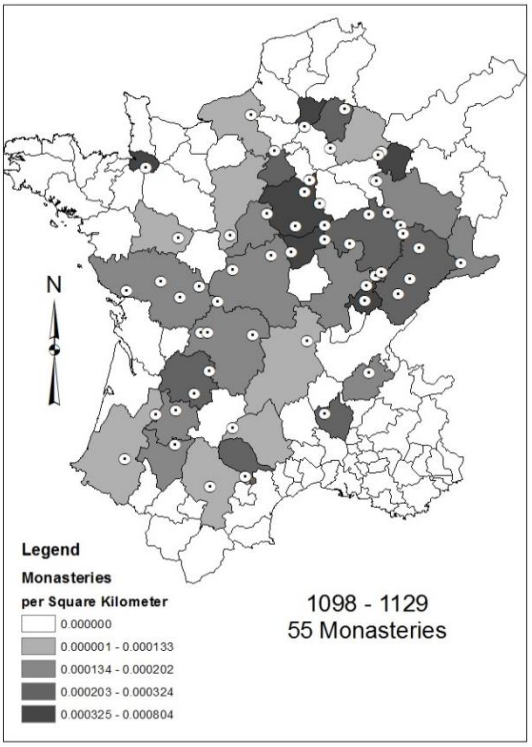




B. Series 2: Monasteries per Square Kilometer.





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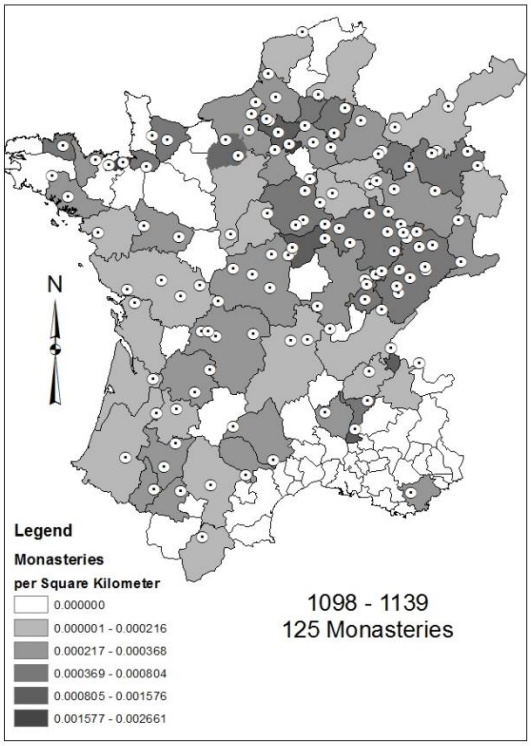

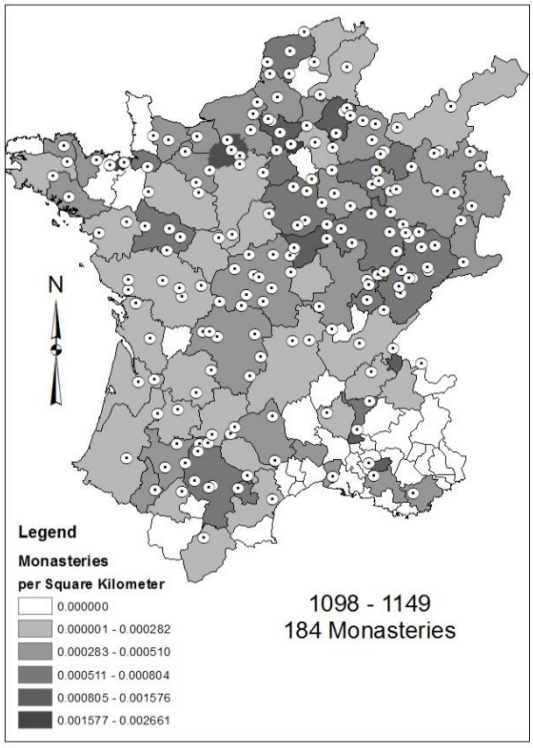

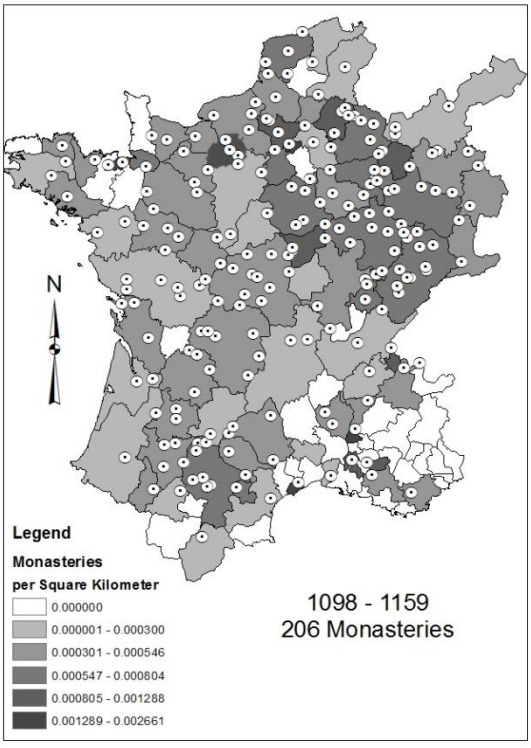

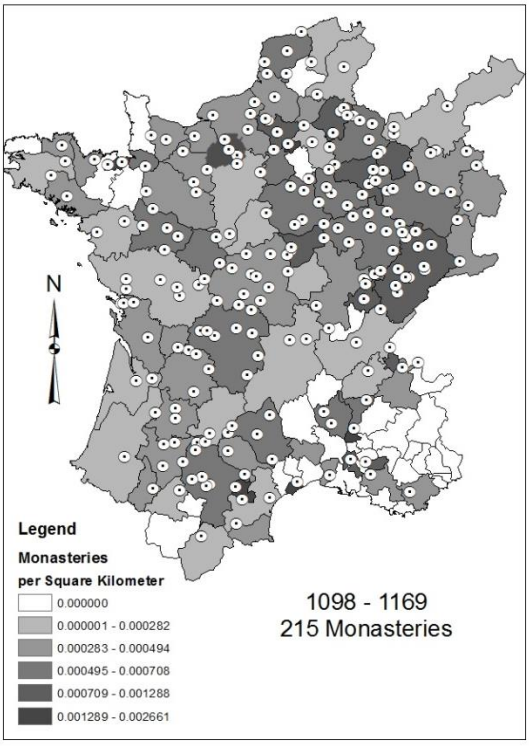

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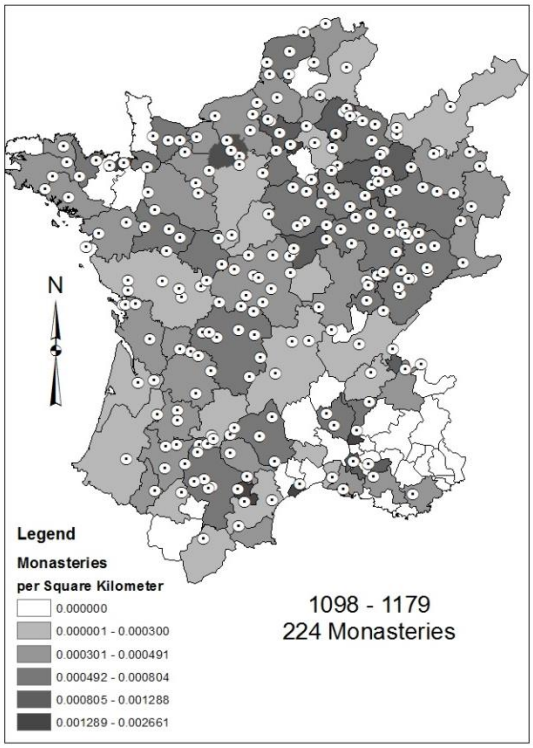

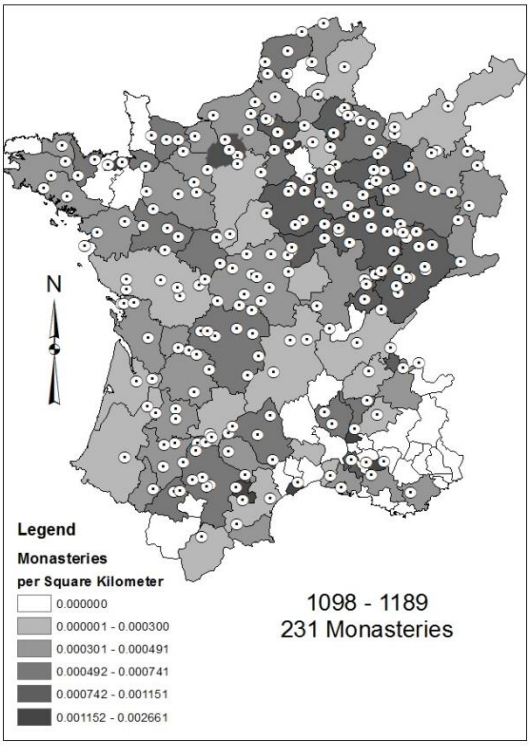

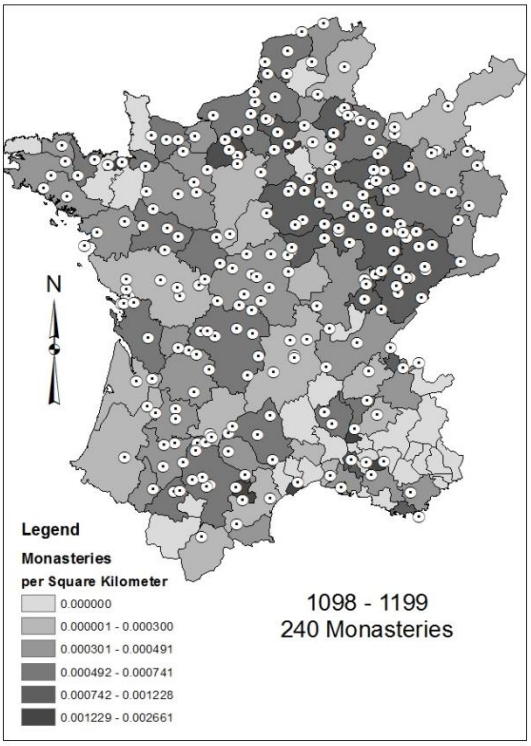

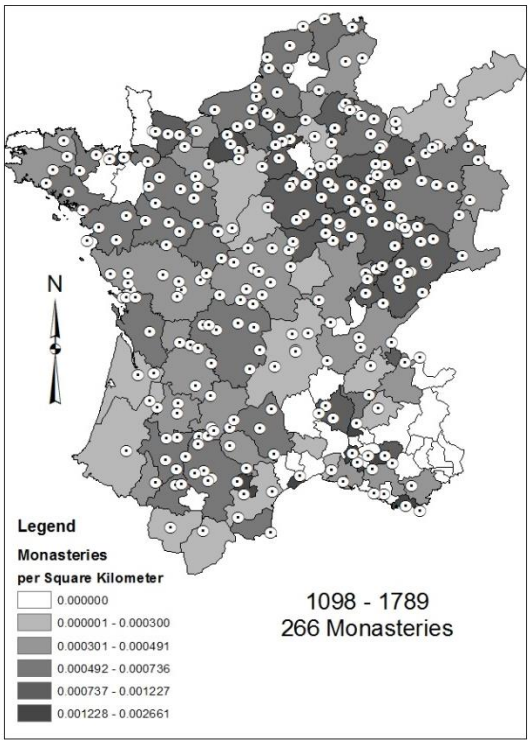

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Appendix D

Ripley's K-Function Test Results

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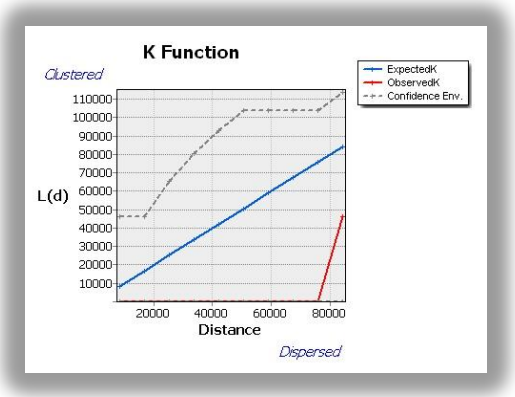
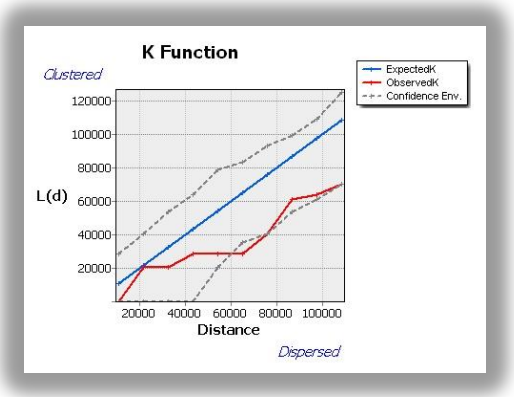
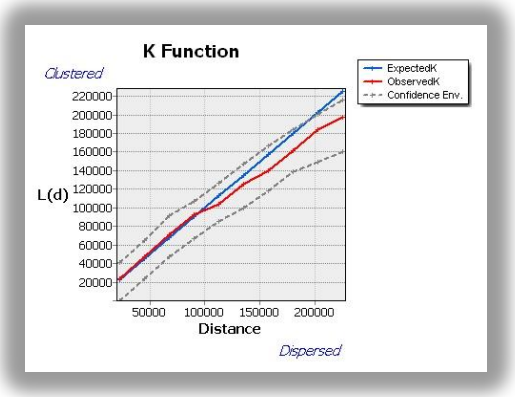
1. Cîteaux



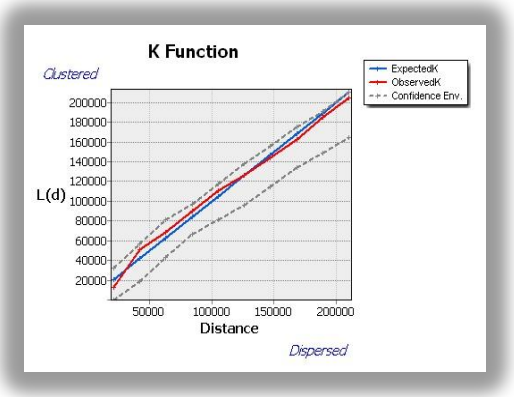
1098 – 1119



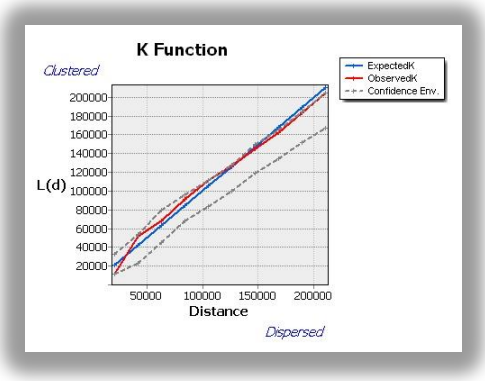
1098 - 1129



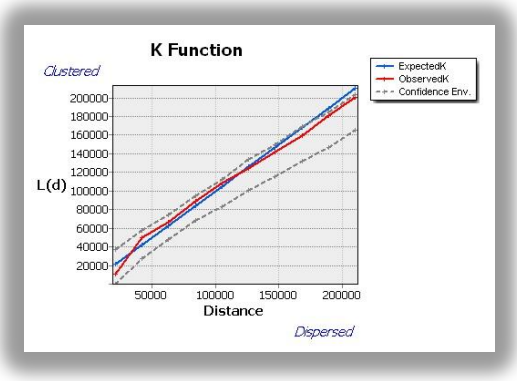
1098 – 1139



1098 - 1149



1098 – 1159



1098 - 1169

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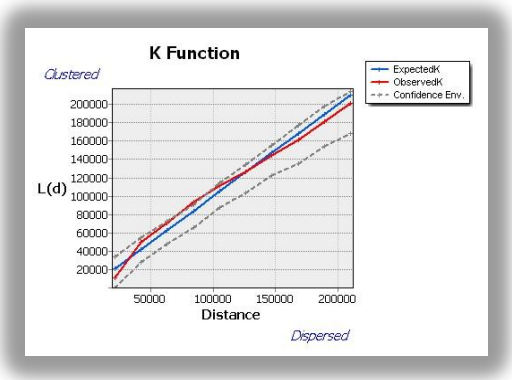

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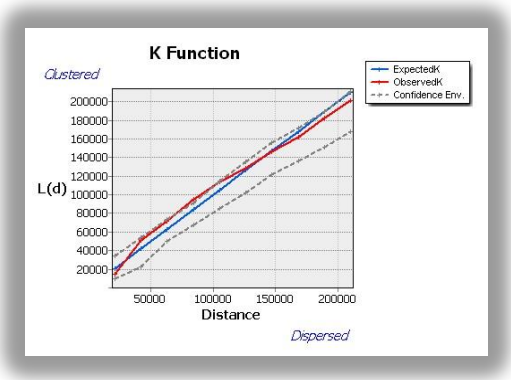

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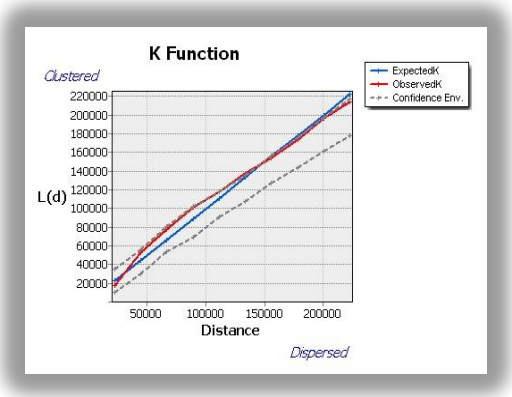

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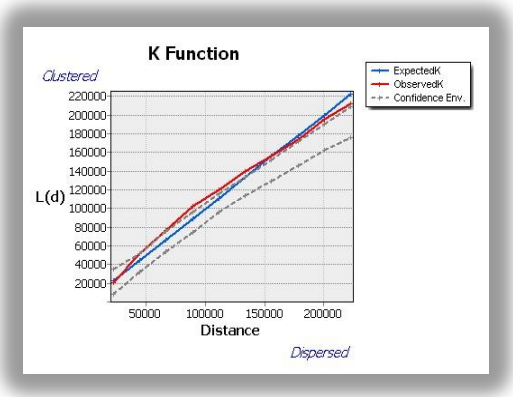
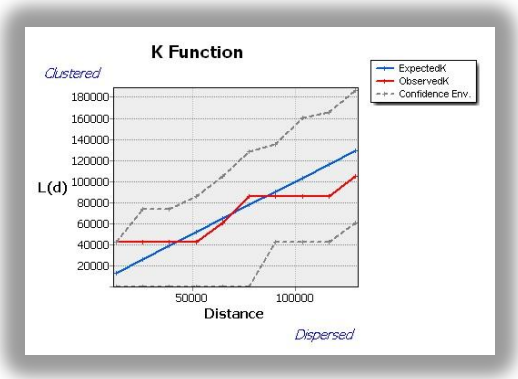


1098 - 1789

2. Clairvaux



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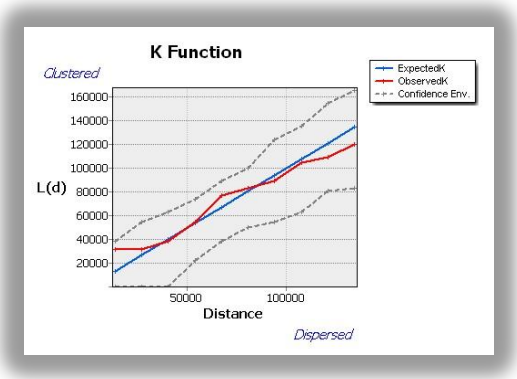

1098 - 1129

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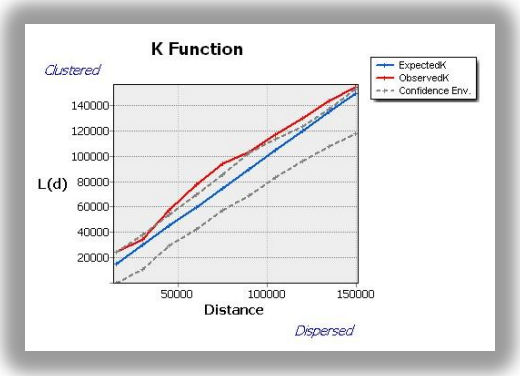

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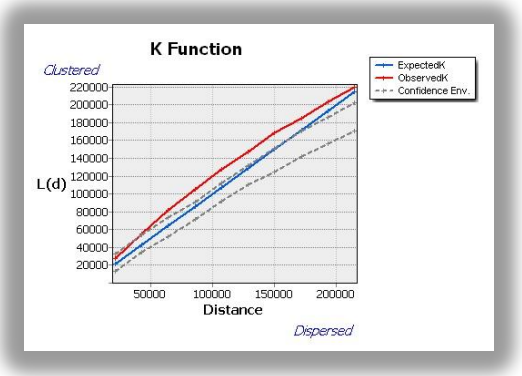

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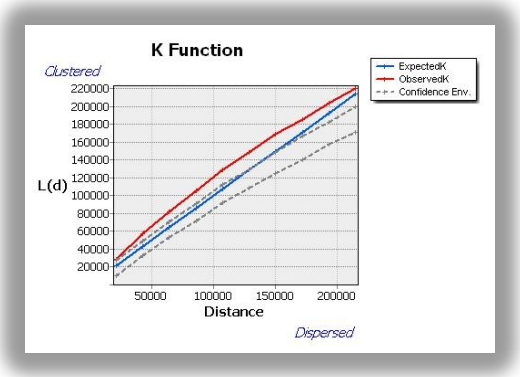

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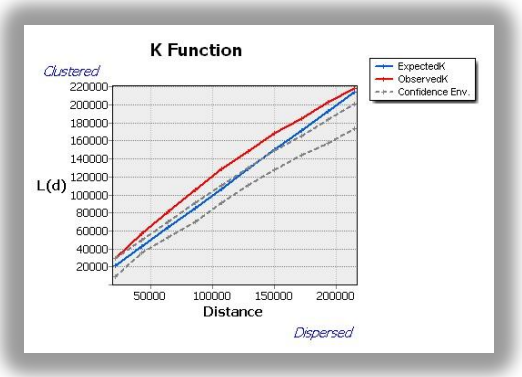

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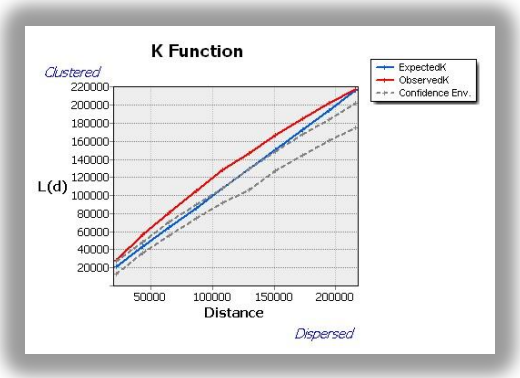

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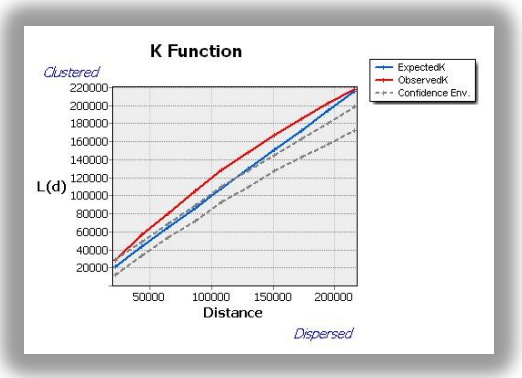

1098 - 1189

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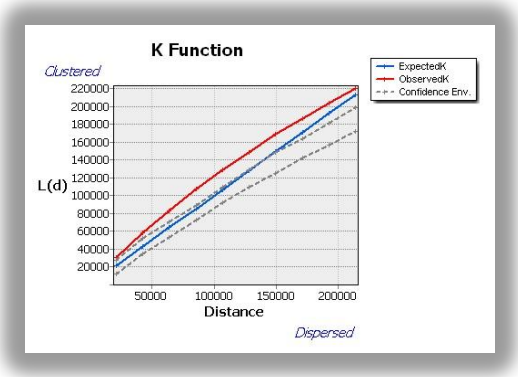
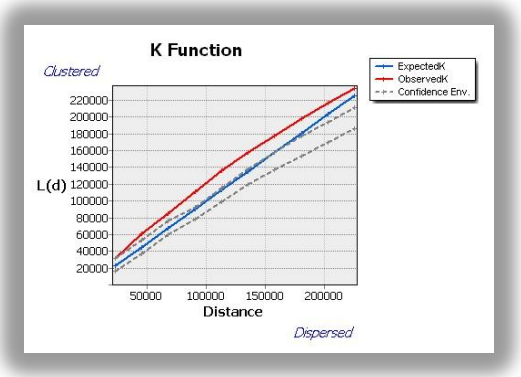


1098 - 1199

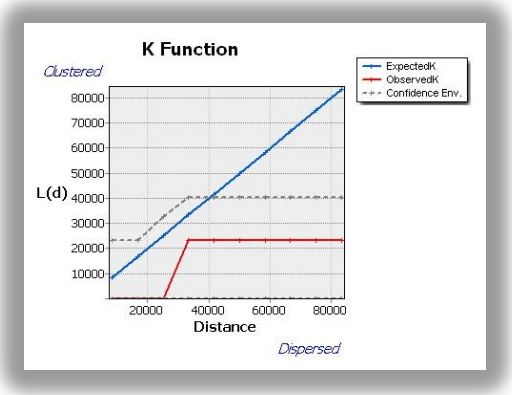


1098 - 1789

3. La Ferté

1098-1119
Test Failed: Too Few Points

1098-1129
Test Failed: Too Few Points



1098-1139
Test Failed: Too Few Points

1098 - 1149

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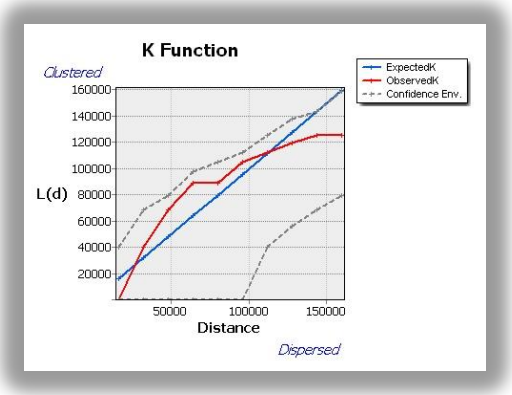
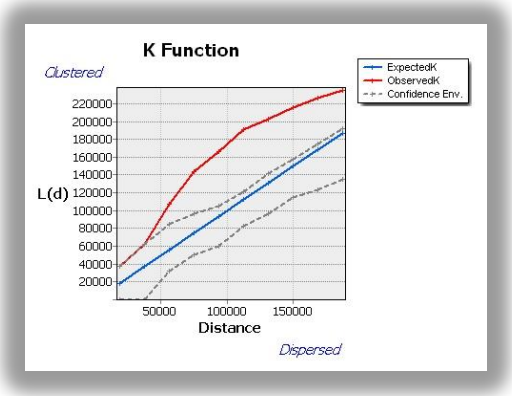
4. Morimond

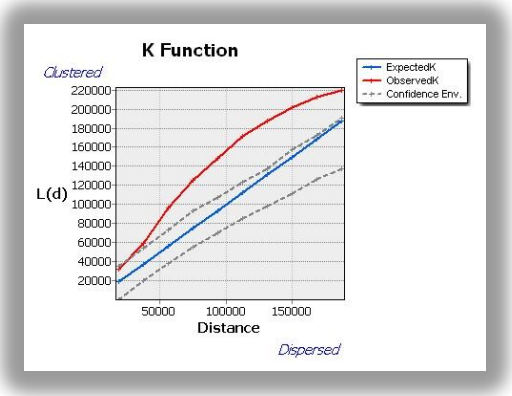


1098 - 1119
Test Failed: Too Few Points

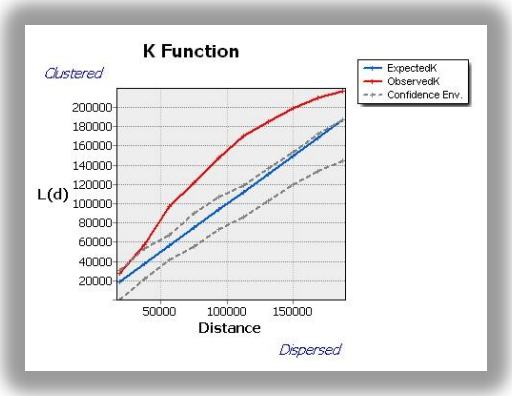
1098 - 1129



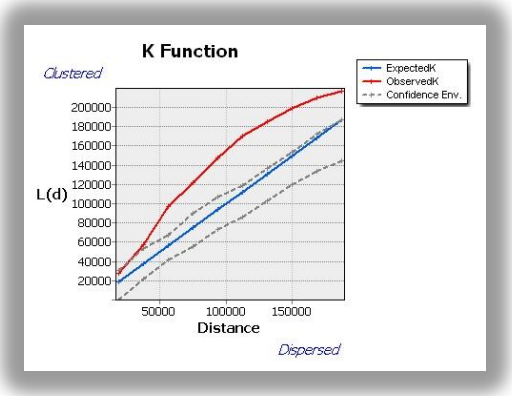
1098 – 1139



1098 - 1149



1098 – 1159



1098 – 1169 (no change)

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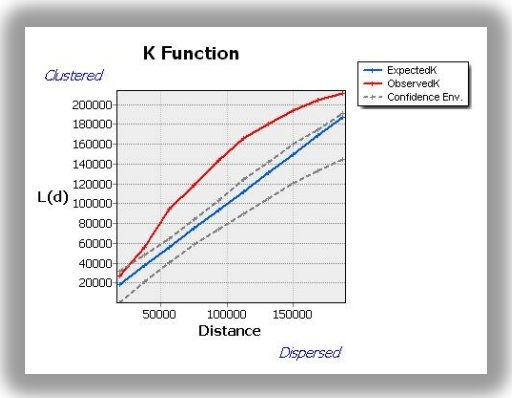
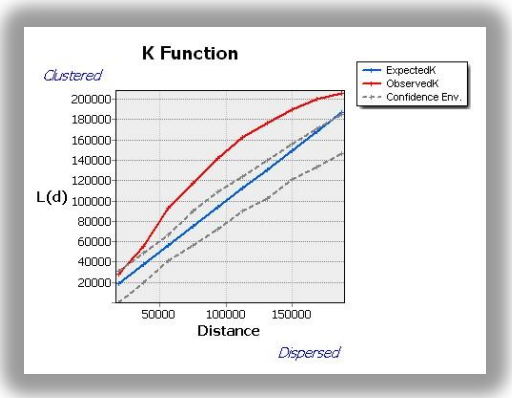


1098 – 1179



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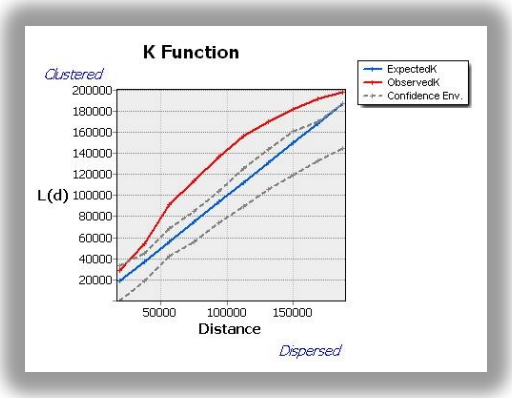

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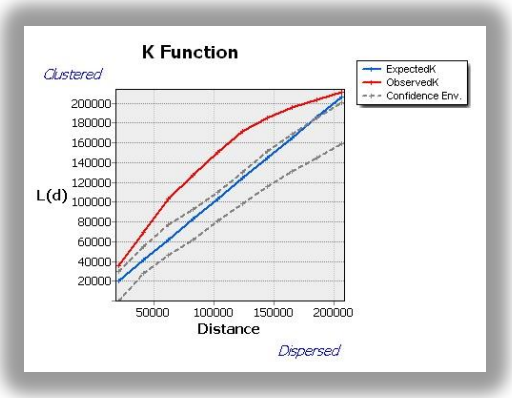
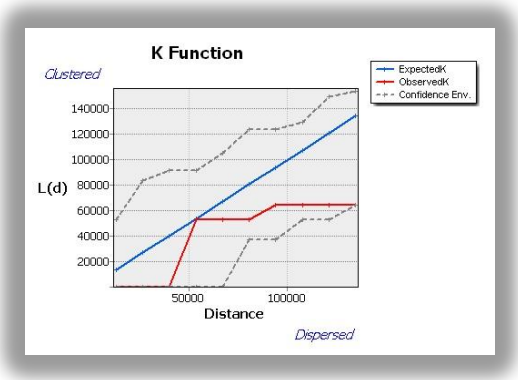
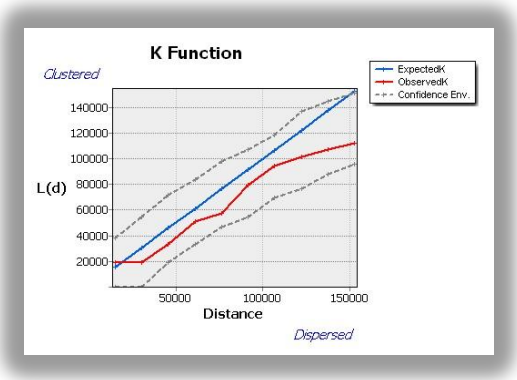


1098 – 1789

5. Pontigny



1098 – 1119



1098 – 1129

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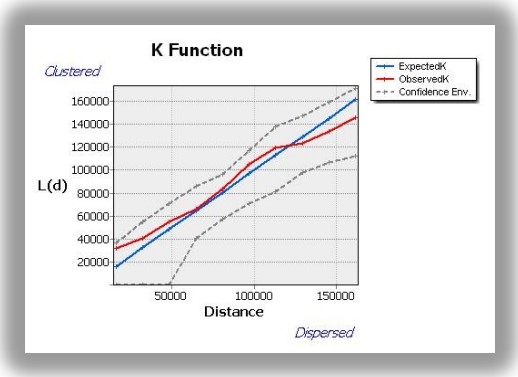
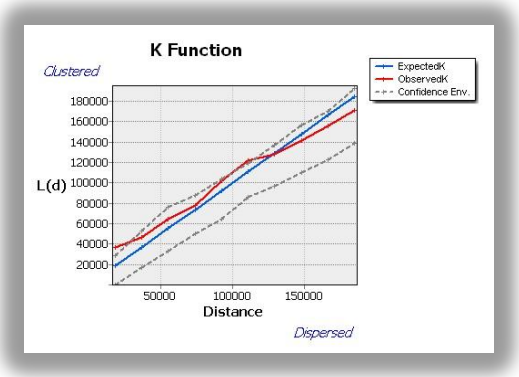
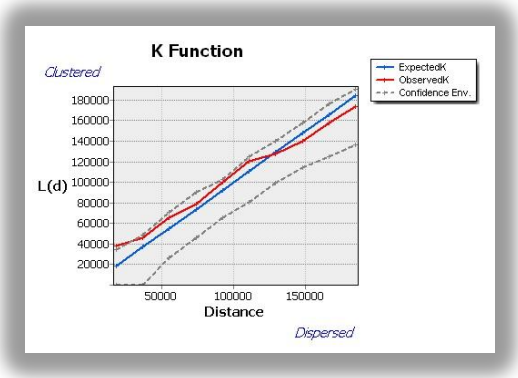


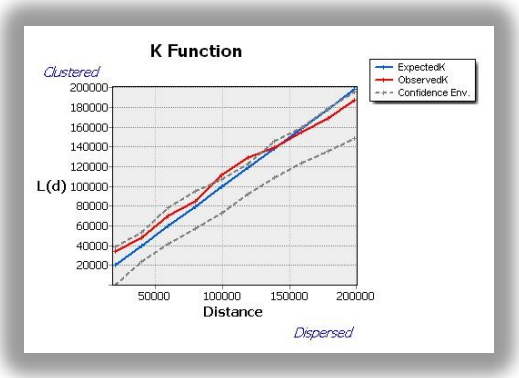
1098 – 1139



1098 – 1149



1098 – 1159



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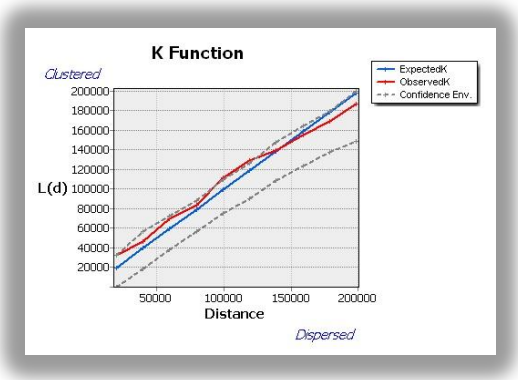
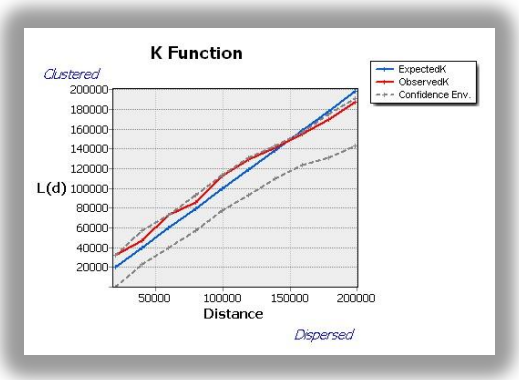


1098 – 1179



1098 – 1189

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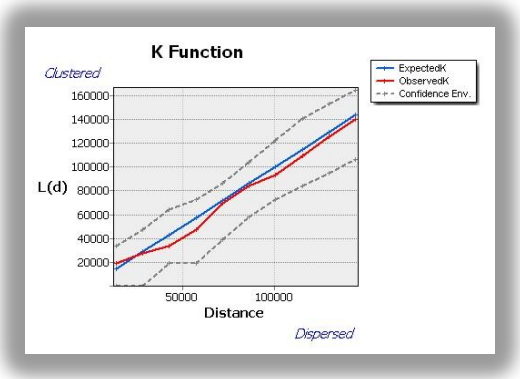
6. Combined (all Filiations)



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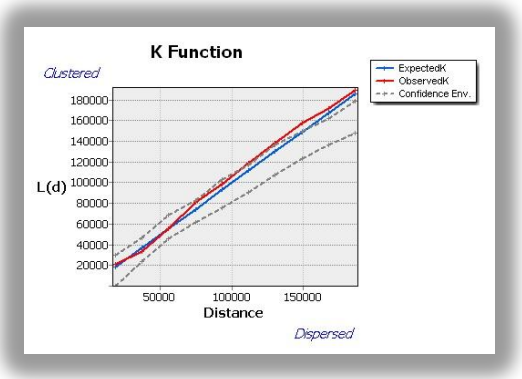

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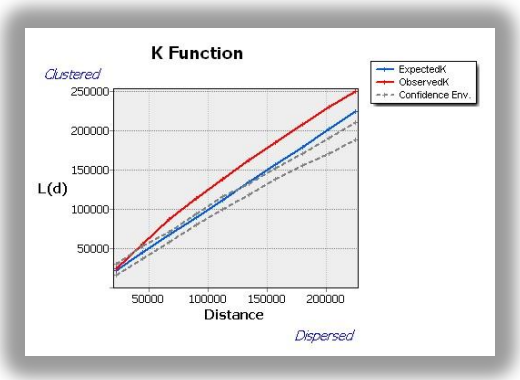

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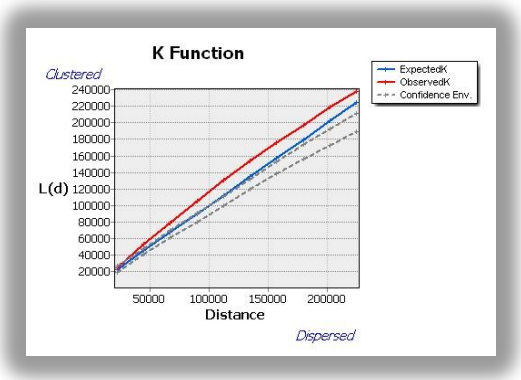

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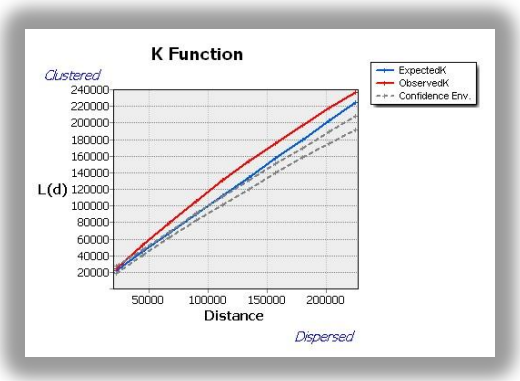

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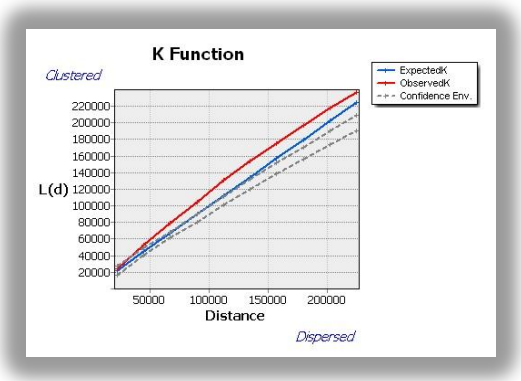

1098-1169

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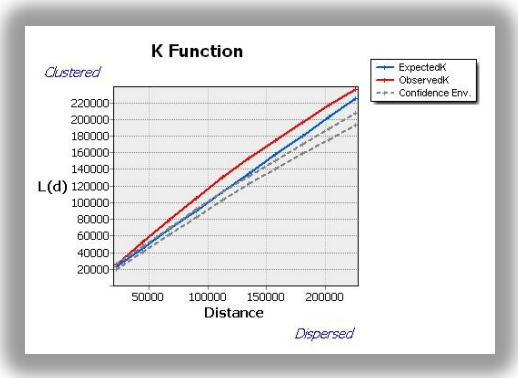

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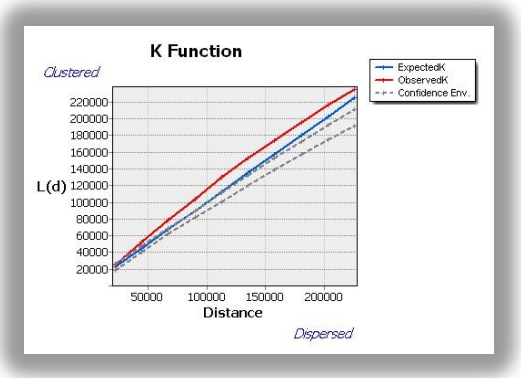
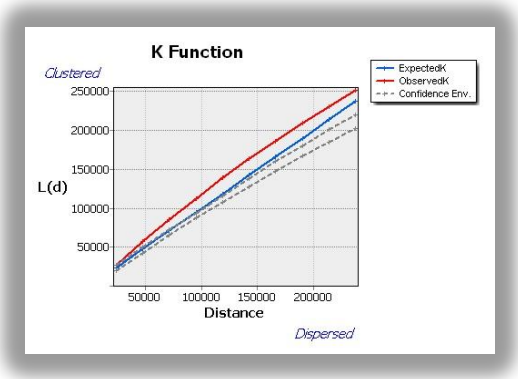
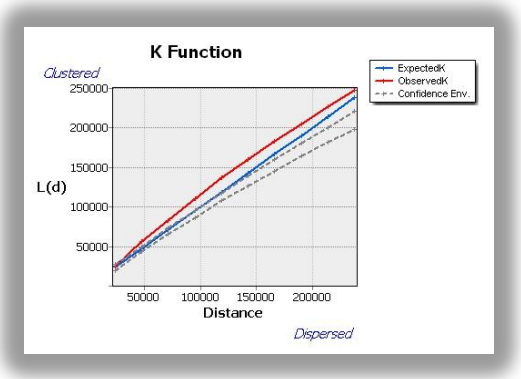


1098-1189



1098-1199



1098-1789

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Appendix E

Euclidean Distance Test Results

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Minimum Distance to the Mother House (kilometers)

	1098-1119	1120-29	1130-39	1140-49	1150-59	1160-69	1170-79	1180-89	1190-99	1200-1789
Cîteaux	184.87	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93
Clairvaux	64.45	64.45	48.77	43.12	26.32	26.32	26.32	26.32	12.71	12.71
La Ferté	NA	28.87	28.87	28.87	28.87	28.87	28.87	28.87	28.87	28.87
Morimond	17.78	17.78	17.78	17.78	17.78	17.78	17.78	17.78	17.78	17.78
Pontigny	80.66	56.05	27.12	27.12	27.12	27.12	27.12	27.12	27.12	27.12

Maximum Distance to the Mother House (kilometers)

	1098-1119	1120-29	1130-39	1140-49	1150-59	1160-69	1170-79	1180-89	1190-99	1200-1789
Cîteaux	271.81	381.52	644.18	644.18	644.18	644.18	650.42	650.42	650.42	650.42
Clairvaux	483.96	483.96	519.13	605.07	605.07	605.07	605.07	605.07	605.07	646.66
La Ferté	NA	28.87	28.87	333.70	333.70	333.70	333.70	333.70	333.70	333.70
Morimond	17.78	613.48	688.51	688.51	688.51	688.51	688.51	688.51	688.51	735.08
Pontigny	583.25	583.25	638.63	638.63	638.63	638.63	638.63	638.63	638.63	638.63

Average Distance to the Mother House (kilometers)

	1098-1119	1120-29	1130-39	1140-49	1150-59	1160-69	1170-79	1180-89	1190-99	1200-1789
Cîteaux	225.66	232.58	306.89	322.78	323.97	328.86	341.27	337.92	338.47	339.56
Clairvaux	212.57	201.52	236.01	271.22	267.91	271.20	274.44	273.14	272.18	285.73
La Ferté	NA	28.87	28.87	181.29	181.29	181.29	181.29	181.29	181.29	181.29
Morimond	17.78	245.67	225.33	265.41	282.54	282.54	284.82	298.22	299.36	309.88
Pontigny	355.99	323.50	298.19	299.42	301.56	299.60	303.99	308.82	308.82	308.82

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Minimum Distance From Nearest Like House (kilometers)

	1098-1119	1120-29	1130-39	1140-49	1150-59	1160-69	1170-79	1180-89	1190-99	1200-1789
Cîteaux	83.49	12.93	12.93	12.93	12.93	12.93	12.93	10.75	10.75	10.75
Clairvaux	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15
La Ferté	NA	28.87	28.87	28.87	28.87	28.87	28.87	28.87	28.87	28.87
Morimond	17.78	17.78	5.48	5.48	5.48	5.48	5.48	5.48	3.95	3.95
Pontigny	41.81	12.37	6.31	6.31	6.31	6.31	6.31	6.31	6.31	6.31

Maximum Distance From Nearest Like House (kilometers)

	1098-1119	1120-29	1130-39	1140-49	1150-59	1160-69	1170-79	1180-89	1190-99	1200-1789
Cîteaux	184.87	133.08	192.34	152.25	152.25	152.25	152.25	152.25	152.25	133.29
Clairvaux	235.77	218.17	123.40	124.18	120.89	120.89	119.64	119.64	119.64	109.02
La Ferté	NA	28.87	28.87	309.61	309.61	309.61	309.61	309.61	309.61	309.61
Morimond	17.78	102.80	334.45	323.35	306.30	306.30	306.30	306.30	306.30	187.99
Pontigny	184.68	101.92	247.48	144.32	144.32	134.11	134.11	134.11	134.11	134.11

Average Distance From Nearest Like House (kilometers)

	1098-1119	1120-29	1130-39	1140-49	1150-59	1160-69	1170-79	1180-89	1190-99	1200-1789
Cîteaux	132.15	72.49	61.16	58.01	50.49	50.26	49.42	47.58	47.26	40.88
Clairvaux	106.26	58.03	40.86	38.05	35.19	34.48	32.72	32.13	31.33	30.19
La Ferté	NA	28.87	28.87	169.24	169.24	169.24	169.24	169.24	169.24	169.24
Morimond	17.78	59.58	58.39	44.35	40.75	40.75	44.46	41.54	36.65	35.67
Pontigny	89.33	56.76	60.66	51.88	48.26	43.34	42.01	40.95	40.95	40.95

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Minimum Distance From Nearest Cistercian House (kilometers)

	1098-1119	1120-29	1130-39	1140-49	1150-59	1160-69	1170-79	1180-89	1190-99	1200-1789
Cîteaux	52.01	23.63	10.38	10.38	10.38	10.38	7.52	7.52	7.52	7.52
Clairvaux	56.51	27.07	11.08	8.34	8.34	5.91	5.91	5.91	5.91	5.91
La Ferté	52.01	25.42	10.38	10.38	10.38	10.38	10.38	10.38	10.38	10.38
Morimond	62.06	35.30	11.08	8.34	8.34	8.34	8.34	8.34	8.34	8.34
Pontigny	58.49	23.63	17.17	15.67	15.67	5.91	5.91	5.91	5.91	5.91
Cistercian	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	3.95	3.95

Maximum Distance From Nearest Cistercian House (kilometers)

	1098-1119	1120-29	1130-39	1140-49	1150-59	1160-69	1170-79	1180-89	1190-99	1200-1789
Cîteaux	137.23	176.35	160.00	136.68	136.68	136.68	136.68	136.68	136.68	120.44
Clairvaux	245.54	150.54	126.59	111.23	111.23	111.23	118.11	118.11	118.11	162.73
La Ferté	52.01	52.01	38.10	38.10	38.10	38.10	38.10	38.10	38.10	38.10
Morimond	74.37	102.61	103.47	103.47	103.47	103.47	103.47	103.47	103.47	103.47
Pontigny	319.56	131.58	129.66	95.81	95.81	95.81	95.81	95.81	95.81	85.60
Cistercian	235.77	146.80	160.00	95.81	95.81	86.56	86.56	86.56	86.56	86.56

Average Distance From Nearest Cistercian House (kilometers)

	1098-1119	1120-29	1130-39	1140-49	1150-59	1160-69	1170-79	1180-89	1190-99	1200-1789
Cîteaux	84.33	74.32	60.38	48.33	48.01	45.73	46.50	46.97	47.32	42.74
Clairvaux	102.65	77.59	59.62	44.13	42.34	41.39	42.80	42.34	41.74	44.17
La Ferté	52.01	38.71	32.35	26.94	26.94	26.94	26.94	26.94	26.94	26.94
Morimond	68.22	63.56	54.50	48.01	45.90	45.82	44.82	44.94	44.37	44.98
Pontigny	171.98	69.36	55.43	44.40	39.38	38.01	37.19	37.06	37.06	33.11
Cistercian	74.91	50.42	38.11	30.81	28.72	27.79	27.33	26.64	26.35	25.57

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