Declaration

I, the undersigned, declare that this work has not previously been submitted as an exercise for a degree at this or any other University, it is entirely my own work and I agree that the Library may lend or copy the thesis upon request.

__________________________
Robert J. Legg

Dated: March 15, 2006
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List of Acronyms

AD ......................................................... Anno Domini
AL ......................................................... Ancient Laws of Ireland
AML ...................................................... Arc Macro Language
AMS ...................................................... Accelerator Mass Spectrometry
AMSL ..................................................... Above Mean Sea Level
API ....................................................... Aerial Photograph Interpretation
ASCII ..................................................... American Standard Code for Information Interchange
ASI ......................................................... Archaeological Survey Ireland
BC ........................................................ Before Christ
BWV ....................................................... Black Water Valley
\textit{c.} .................................................... \textit{circa}
cm .......................................................... Centimetres
\textit{CIH} .................................................. \textit{Corpus Iuris Hibernici}
CLC ........................................................ CORINE Land Cover
Cent. Ind. ................................................. Centrality Index
Co. ........................................................ County
CORINE ............................................... COoRdinated INformation on the European environment
CPU ....................................................... Central Processing Unit
DEM ....................................................... Digital Elevation Model
DACP ..................................................... Dark Ages Cool Period
DEHLG . . . . . . . . Department of Environment Heritage and Local Government
DXF . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Drawing eXchange Format
EEA . . . . . . . . . . . . . . . . . . . . . . . . . . . European Environmental Agency
EPA . . . . . . . . . . . . . . . . . . . . . . . . . . . Environmental Protection Agency
ESRI . . . . . . . . . . . . . . . . . . . . . Environmental Systems Research Institute
ESS . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Error Sum of Squares
ETM+ . . . . . . . . . . . . . . . . . . . . . . . . . . . Enhanced Thematic Mapper
GIS . . . . . . . . . . . . . . . . . . . . . . . . . . . Geographic Information Systems
GPS . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Global Positioning System
GRID . . . . . . . . . . . . . . . . . . . . . . . . . . . Global Resource Information Database
GSI . . . . . . . . . . . . . . . . . . . . . . . . . . . Geological Survey Ireland
ha . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . hectares
ING . . . . . . . . . . . . . . . . . . . . . . . . . . . Irish National Grid
IRC . . . . . . . . . . . . . . . . . . . . . . . . . . . . Inny River Catchment
Inc. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Incorporated
km . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . kilometres
LRC . . . . . . . . . . . . . . . . . . . . . . . . . . . . Lough Ramor Catchment
m . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . metres
Mhz . . . . . . . . . . . . . . . . . . . . . . . . . . . . Megahertz (million Hertz)
MWP . . . . . . . . . . . . . . . . . . . . . . . . . . . Medieval Warm Period
no. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Number
OS . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Operating System
OSI . . . . . . . . . . . . . . . . . . . . . . . . . . . Ordnance Survey Ireland
RMP . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Record of Monument and Place
SD . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Standard Deviation
SMR . . . . . . . . . . . . . . . . . . . . . . . . . . . Sites and Monuments Record
SPSS . . . . . . . . . . . . . . . . . . . . . . . . Statistics Package for Social Scientists

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TM ................................................................. Thematic Mapper
USDA ........................................ United States Department of Agriculture
UNIX ............................. Uniplexed Information and Computing System
$\chi^2$ ................................................................. Chi squared
Chapter 1

Introduction

1.1 Introduction

The Early Medieval period\(^1\) is a pivotal time in Ireland’s emergence from pre-history. Studies examining this period have focused primarily on high-status archaeological sites, and the interpretation of historical records or have attempted to draw evidence from literary sources that are often fragmentary and complex. As a result, gaps exist in our understanding of this important period in Ireland’s past. According to Renfrew and Bahn [160], a more complete understanding is only likely to emerge from a close examination of the fundamental elements that shape and reflect a society such as systems of law, environmental conditions and settlement patterns.

Ireland’s Early Medieval legal systems are interpreted and documented in recent publications such as *A Guide to Early Irish Law* [95]. In addition, there are numerous reports on Ireland’s past environments that include the Early Medieval Period (e.g., [136], [32], [150], [118], [65], [43]). In contrast, there have been far fewer investigations of past settlement patterns, including those for the Early Medieval period. Researchers

---

\(^1\)Ireland’s Early Medieval period dates between c. 450–1100 AD. It is sometimes referred to as the Late Iron Age [5] or Early Christian [52] periods. Throughout this thesis, the term Early Medieval is used to represent this time period for Ireland.
such as Stout [180] and Limbert [104] credit this deficiency to incomplete historical records and poorly dated archaeological evidence.

Ringforts, which are described in detail in this thesis in Section 3.5, are the most numerous and well recorded type of archaeological site in Ireland [180]. Currently over 45,000 ringforts exist on the Irish landscape, and they are commonly believed to be the earthwork remains of ancient secular farmsteads. An Early Medieval period age has been established for many ringforts in Ireland, based on a mixture of radiocarbon and dendrochronological dating evidence [180]. However, well-dated sites are relatively scarce. A total of 93 dates have been obtained on material from 46 ringforts in various locations across Ireland, and these are discussed later in this thesis.

1.2 Research aims and approach

Using evidence from three case study areas in particular, this thesis aims to:

- model the current locations of ringforts in order to deepen our understanding of the societies responsible for their construction and the possible role of environmental conditions influencing their distribution.

- identify the typology, location and distributional settlement patterns associated with ringforts.

The widespread presence of ringfort sites remaining in existence today in Ireland provides a rich archaeological resource that enables the investigation of their associated settlement patterns. However, relatively few researchers have utilised this rich archaeological resource. The deficiency in studies investigating the settlement patterns associated with ringforts stems from, at least in part, a lack of data in a form that is convenient to use.

Computer-based tools such as GIS equip researchers with the ability to rapidly analyse digital spatial data in a semi-automated fashion. In addition, specialised sta-
tistical software packages provide researchers the computational means to process and analyse large archaeological datasets. Despite these improved capabilities, relatively few applications of computerised analysis of archaeological data have emerged in Ireland\(^2\).

The small number of computer-based applications that have analysed Ireland’s Early Medieval archaeology have advanced the understanding of the culture and societies that are associated with this time period to what was known previously. Stout [180], for example, investigated a relatively small ringfort dataset (c. 300 sites located in the southwest midlands of Ireland) with statistical software. Stout developed a settlement model for ringforts (discussed further in Section 3.6) from the interpretation of the results of his statistical analysis and this model is now widely used to summarise the secular settlement that existed during the Early Medieval period in Ireland (e.g., [181]). However, the relatively small number and narrow geographic range of ringforts that underpin Stout’s model are major weaknesses. In the absence of comparative analysis, the settlement patterns put forth in Stout’s model remain untested and must be used with caution, particularly when applied to other areas in Ireland.

The aims of the current research are addressed through the selection of three case study areas in different parts of the central midlands of Ireland, the use of GIS for data assembly and manipulation and the application of two separate statistical procedures: 1. predictive archaeological modelling; and 2. cluster analysis. The results of these statistical procedures are interpreted in the context of environmental ([153], [77], [165]), historical ([20], [33], [120], [95], [52]), and settlement (e.g., monastic) evidence dating to the Early Medieval period in Ireland.

The first statistical procedure, predictive archaeological modelling [199], has not previously been applied to archaeological data in Ireland and is used to quantify the

\(^2\)Relatively few computer-based applications in archaeology have the advantage of working with such a rich and complete archaeological resource as that which exists for Ireland during the Early Medieval period.
environmental influences on the siting of ringforts [102] and as a basis for exploring the nature of the societies that constructed ringforts. The second statistical procedure, cluster analysis, employs a methodology that closely resembles that followed by Stout in his earlier study (see, [179], [180]). Ringforts were constructed in a variety of morphologies, locations and distributions. Cluster analysis organises the wide variety of ringforts into separate groups, whereby each group contains ringforts with the most similar morphologies, locations and distributions per case study area. The results from the cluster analysis undertaken in the current research provide a basis for critically evaluating the settlement model developed by Stout. In addition, the results of the cluster analysis provide new data that can be used to evaluate further the settlement patterns in Ireland’s Early Medieval period.

1.3 Thesis structure

The thesis consists of a literature review which includes an introduction to the theoretical framework for this research and Ireland’s Early Medieval period (Chapter 2 and 3), an introduction to the selected case study areas (Chapter 4), methods and results (Chapters 5 through 7), and the discussion of, and conclusions from, these results (Chapter 8 through 10).

Chapter 2 provides an overview of archaeological theory relevant to the current research and the computational and statistical tools employed in the thesis.

Chapter 3 provides background information on the Early Medieval period in Ireland and discusses the characteristic environmental, historical and cultural elements of this critical period in Ireland’s history. An overview of ringforts and a selection of morphological, distributional and locational measurements associated with this class of archaeological site, together with an introduction to Stout’s model detailing the settlement patterns associated with ringforts, are also presented in this chapter.
Chapter 4 describes the three case study areas selected for the current research. Each case study area is described according to its local physiography, known Early Medieval archaeological sites, and current land cover. Ringforts within each case study area and a selection of associated descriptive characteristics—morphological, locational and distributional—are also summarised.

Chapter 5 provides an overview of the environmental and archaeological datasets that were assembled for the different case study areas selected in this current research.

Chapter 6 documents a step-by-step account of the statistical methods that were applied to the data sets, the assembly of which is described in Chapter 5. The statistical methods presented in Chapter 6 involved the application of stepwise logistic regression for probability modelling and Ward’s method optimised with $k$-means cluster analysis.

Chapter 7 presents the results of the quantitative analysis using the current ringforts dataset and the two main statistical procedures discussed previously.

Chapter 8 and Chapter 9 are two discussion chapters that examine the results from the quantitative analysis. Chapter 8 examines the results of the predictive modelling of ringforts and their environmental setting. Chapter 9 discusses the results of the cluster analysis and summarises the research findings in terms of typology, location and distribution characteristics of ringforts in the case study areas. These ringfort characteristics are related to current understanding of Ireland’s Early Medieval society. Chapter 10 outlines the main findings of the current research within the context of the aims of the thesis.
Chapter 2

Conceptual Framework

2.1 Introduction

The research presented in this thesis involves an application of GIS in the field of archaeology. The brief review of relevant archaeological theory contained within this chapter provides a foundation for the remainder of this thesis. Archaeology is defined as:

“the study of human history and prehistory through excavation of sites and the analysis of artefacts and other physical remains” [152, p. 89].

The theoretical underpinnings of this thesis are outlined in the section following. Subsequent sections discuss the use of GIS in archaeology along with predictive modelling and classification using cluster analysis.

2.2 Cognitive-processual archaeology

The cognitive-processual approach for understanding and explaining archaeological remains, such as ringforts in Ireland, provides a theoretical and methodological framework for this thesis. The cognitive-processual approach is an interdisciplinary approach
that combines scientific methods and idealistic theory with the aim of balancing the positive aspects of both [161], [160].

In archaeological practice, the excessive use of scientific methods has been criticised by archaeologists such as Hodder [84] and Shanks [167] as overly materialistic\(^1\) and has led to the development of a separate suite of archaeological practices that could be viewed as less scientific, and led to an idealistic\(^2\) approach to archaeological enquiry by some archaeologists. Growing separation between materialistic and idealistic traditions has shaped the cognitive-processual approach, which utilises both processual and post processual archaeology.

In archaeology, the branch of investigation known as classical archaeology [158] is concerned less with asking anthropological questions and more with collections, chronologies and descriptions of material culture. In the 1960s, ongoing developments in computer technology and scientific aids, such as radiocarbon dating and dendrochronology, equipped researchers with the capability to assemble information with precise chronologies. These developments and capabilities enabled archaeologists to process data rapidly and probe anthropological questions to greater depth [205], [22], [23], [24]. Increasingly, archaeological research has engaged in innovative ways of enquiring about and explaining the past [186].

Enquiry-based studies began with the use of research aims, quantitative methods [162] and testing hypotheses for validity. The introduction of enquiry-based archaeological practice directed a change in archaeological approach termed new archaeology, [160]. Those engaged in new archaeology began to view cultural change [61] as a set of behavioural processes, and brought about the term processual archaeology. Processual archaeology was based in systems theory with the view that culture\(^3\) is the sum of many

\(^1\)Materialism is a philosophical theory that matter is the only reality and that everything that exists is material and physical [135], [132].

\(^2\)Idealism is a philosophical doctrine that ideas are the only reality [163].

\(^3\)The term ‘culture’ refers to a particular society at a particular point in time [152]. Archaeologists use the term culture as shorthand for repetitively occurring characteristics visible in objects and
parts, which can be further broken down into subsystems (e.g., including subsistence, technology, trade and human ecology) [186]. The processual approach to archaeology implies that these subsystems are interlinked and overall changes in culture occur through change and modification to one subsystem, which then impacts on other subsystems [94]. Processual archaeologists argue that classical archaeology is subjective and its reasoning not explicit. Processual archaeologists maintain ideas of philosophy and science; stating that without explicit testing, conclusions are biased and invalid.

While new archaeology incorporated a critical approach to method and theory, a rejection against these developments, in particular processual archaeology, led to what is known as post processual archaeology [160]. Post processual archaeology, also referred to as ‘interpretive archaeology’ [186], questions processual theories and advances epistemological discussions. Advocated by archaeologists such as Hodder [84], [85], Leone [103], Shanks [167] and Tilley [168], post processual archaeology rejects the underlying assumptions and methods of processual archaeology, including: evolutionary generalisations; the search for universal laws; exclusively scientific methods; the importance on objectivity and neutrality; and the systems theory view of culture. Post processual archaeologists argue that the science and theory of processual archaeology is incomplete and question whether it was really possible to be objective when explaining past events and ways of life. Post processual archaeologists also question the processual archaeologist’s stance of excluding history, relying solely on universal laws, and trusting explanation without interpretation. By rejecting processual archaeology, post processual archaeologists include questions about social classes, individuals, and the importance of artefacts in culture and society (e.g., [87]).
Despite rejection by post processual archaeologists, processual archaeology, employing the use of scientific methods, provides an explicit and testable way of investigating the past. However, relying entirely on processual methods may be too constrained, too functionalist\(^6\) and lacking inclusion of social aspects \([84]\). Addressing the limitations of processual archaeology, cognitive-processual archaeologists incorporate aspects of both processual and post processual archaeology \([161]\), \([160]\), \([86]\). Therefore, the cognitive-processual approach offers a more inclusive mode of research that occupies the middle-ground \([94]\) between processual archaeology – in particular, functional-processual archaeology – and the cognitive\(^7\) aspect of post processual archaeology. The cognitive-processual approach, unlike the post processual theories, does not reject all aspects of processual archaeology. For example, the cognitive-processual approach does not reject the need for formulating hypotheses and testing them against related data. In addition, the cognitive-processual approach does not reject all aspects of post processual archaeology, in particular the need to incorporate cognitive meaning and the role of ideology as a dynamic organisational pressure on material individualism.

The Early Medieval period in Ireland is recorded in a considerable amount of physical field remains and documentary sources \([151]\), \([96]\), \([95]\), \([52]\). This record provides evidence relating to the foundational elements of society, including the social structures, legal and moral values, spatial organisation of the settlement and the political economy. A combination approach, such as the cognitive-processual approach, which includes an analysis of field archaeology in the context of the information available in historical documents, enables a more complete view of the Early Medieval period and associated cultures than relying exclusively on the classical, processual or post-processual approaches.

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\(^6\)Functionalism is a theory that all components of a culture serve a functional purpose to satisfy culturally defined requirements of individuals for the society as a whole.

\(^7\)Cognitive issues and cognitive archaeology investigate the ways humans think and how they make use of symbols \([161]\).
2.3 Archaeology and geoinformatics

Archaeological investigations, for the past forty years, have routinely involved the use of computers [106]. Computer-based techniques are incorporated into archaeological research in four main areas: data recovery; statistics; ancillary data processing and modelling [162]. Archaeological research often involves the use of data collected from different sources (e.g., digital sites and monuments, geophysics and aerial photography). Computers enable the storage and analysis of these different data simultaneously. Thus computers have gained a central role in archaeological research, further secured by their ability to store and analyse data from a wide range of sources [106].

GIS are important components of archaeological studies [2], as they can be used to preserve the spatial and locational characteristics of archaeological remains within a computer environment. Archaeological data, once in a GIS, can be combined with other information (e.g., environmental data) then analysed and presented in a wide variety of cartographic and visualisation tools. In addition, the publication of computer-oriented archaeological textbooks (e.g., [98], [74], [199]) has equipped archaeologists with literature detailing a wide variety of applications of GIS in archaeology and has led to an abundance of GIS applications in current archaeological research, including: data management; statistical analysis and mapping.

With reference to archaeology, GIS provide a useful set of data management, analysis and mapping tools, offering a wide degree of flexibility for applications over a range of spatial scales, from local to regional. However, the application of GIS in archaeological enquiry has been limited by two interconnected factors: the quality of data; and the application of the technology and a tendency for environmental information [67] to take precedence over cognitive and social information.

The problem of data quality faces all users of GIS and any data analysis is bounded by both the accuracy of data and the requirements of the application [35]. Archaeological data are highly prone to both error and missing information, primarily
because archaeological entities often exist in a fragmented and incomplete state [44]. In addition, errors in archaeological data may be the result of unsystematic survey practice, inaccurate chronology etc. (and see Table 2.1).

The tendency for GIS projects to be biased with an emphasis on the environment relates primarily to data availability, as environmental data tend to be readily available in GIS format. On the other hand, cognitive and social data (e.g., political boundaries, settlements, road networks, economic and religious centres) are not as readily available or may not be in a format compatible with GIS software [105]. The imbalance in data availability – environmental versus cognitive and social – has led to the criticism of GIS based archaeological research that it is preoccupied with the physical environment and focuses on data that are readily available [201]. While research has demonstrated that ancient cultures often had a dependent relationship with their environment (e.g., [193], [194], [41], [157]), these ancient cultures were also shaped by social and cognitive influences that are difficult to incorporate within GIS.

2.3.1 Predictive modelling

Predictive modelling is an application of geoinformatics in archaeology that is used to identify the combination of environmental and social variables that attracted or influenced ancient people to locate their habitations in particular areas. Since its inception in the 1980s, predictive modelling has become one of the more controversial applications of GIS in archaeology (e.g., [106], [203], [100], [99]). Predictive modelling involves the use of GIS and statistics to assemble data and examine the strengths of spatial relationships between archaeological sites and selected landscape or environmental variables [27]. Based on an assumption that settlements in the past were not randomly located, a variety of statistical procedures are used to identify patterns that can be represented as a mathematical model. Such a model presents researchers with an objective means to extract the influences – primarily environmental – that
<table>
<thead>
<tr>
<th>ERROR TYPE</th>
<th>SOURCE OF ERROR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment</td>
<td>The entity or object recorded is assigned to the wrong category either through measurement error or by the technician recording the data incorrectly.</td>
</tr>
<tr>
<td>Class generalisation</td>
<td>Data are grouped with objects that exhibit dissimilar properties in order to simplify the data structure.</td>
</tr>
<tr>
<td>Entry</td>
<td>Data are incorrectly coded during their entry into a GIS.</td>
</tr>
<tr>
<td>Measurement</td>
<td>Erroneous measurement in the recording of the object or entity.</td>
</tr>
<tr>
<td>Processing</td>
<td>Error arising from algorithm and rounding errors.</td>
</tr>
<tr>
<td>Spatial generalisation</td>
<td>Recorded objects through the process of cartographic generalisation are displaced, smoothed, merged together and simplified.</td>
</tr>
<tr>
<td>Temporal</td>
<td>Objects that have changed in function or character between the time of data collection and database usage (e.g., a forest area has been clear-cut since being mapped and included into a spatial database).</td>
</tr>
</tbody>
</table>

Table 2.1: Common sources of errors in GIS data, after Fisher [60].
underpin settlement patterns and, to a certain extent, predict the occurrence of similar archaeological sites in unsurveyed areas [157], [193].

Predictive modelling in archaeology refers to several modelling strategies instead of a single all-encompassing technique. These modelling strategies can be divided into two main categories, inductive and deductive [27], [67]. Inductive modelling, also known as empirical or correlative modelling, is based on a statistically-observed pattern that is derived from a data set of known archaeological sites and the relationship these sites have with a list of relevant and associated environmental variables, which are entered into the process as independent variables. The process derives a mathematical equation to describe the relationship between the dataset of known archaeological sites and the relevant independent or environmental variables. Using a GIS, the mathematical equation is applied to the independent variables, represented as cartographic layers. The results from the calculations produce a probability surface that indicates where sites are most likely located. Evaluation of a resulting quantitative inductive model involves comparing the probability surface to distributions of known archaeological sites, including sites external to the development of the model.

The second strategy, deductive modelling, begins with a predefined theory of a past human culture, such as where in the landscape a particular group would have likely located their settlement [26]. The predefined theory is then applied to the available data, often environmental, and the resulting deductive model is compared with the existing archaeological data. Using these comparisons, the deductive model can be calibrated further, or assessed for its level of predictive accuracy.

In this research, predictive modelling is used to identify the environmental influences on the location of ringforts. Specifically, an inductive method using stepwise logistic regression is developed. Stepwise logistic regression is similar to stepwise linear regression, however, in that the calculations are based on a dependent variable that is coded in binary form [124] as either zeros or ones. In archaeological applications,
Stepwise logistic regression examines the differences between site locations and non-site locations and series of their associated environmental settings. The procedure generates a mathematical equation that can be used to predict the probability that a site will occur on a given parcel of land. Stepwise logistic regression was selected because of its objectivity and because the statistical procedure allows for a wide range of data types (e.g., nominal, interval, ordinal) to be analysed simultaneously. Although previous studies, (e.g., [57], [1], [180]) discuss the environmental settings of ringforts, the modelling strategy adopted in this research represents a significant step forward as it incorporates a wider range of environmental variables (detailed in Chapter 5) and provides statistically testable results. A more detailed description of stepwise logistic regression is provided in Section 6.4.

**Predictive modelling assumptions**

Four key assumptions underpin the predictive modelling approach adopted in this research. First, the number and distribution of ringforts identified in Ireland are assumed to be approximately equal to their original number and to have a similar pattern of distribution. This first assumption is debatable, particularly since the majority of ringforts were constructed over 1,200 years ago. Given this length of time since their construction and occupation, it is conceivable that at least some were destroyed –in part or in whole– prior to the first maps produced by the OSI in the mid-1800s. It will never be possible to know their exact original number or distribution; however, there are currently about 45,000 ringforts recorded in Ireland. According to Stout [180], this number provides a close approximation of the original number and distribution, particularly in areas without a presence of intensively tilled agriculture\(^8\).

Three factors account for the preservation of ringforts. The first is that abandoned

\(^8\)Practitioners of intensively tilled agriculture are likely to have more reason to remove field archaeology, such as the remains of ringforts, as field archaeology impose obstacles to both cropping and associated agricultural equipment
ringforts were often viewed positively, primarily because of the protection against the weather they afforded to livestock. The second is that in Irish folklore a curse was put on any individual who damaged a ringfort. The third factor is that a considerable amount of manual labour is required to completely remove a ringfort, particularly in times pre-dating mechanised earth-moving equipment. These three factors possibly led to low levels of ringfort destruction, especially in areas of low intensity farming and tillage. Due to these factors, the assumption that the current number and pattern of distribution of recorded ringforts provides a good approximation of the original number and pattern appears viable.

A second assumption underpinning the predictive modelling approach is that environmental conditions, such as soil conditions, elevation and distance to water sources, influenced the settlement locations of those involved in the construction of ringforts. This assumption is reasonable, given the low level of technological advancement at the time of their construction [96]. In addition, Ireland’s Early Medieval society was agriculturally based and, to a considerable degree, dependent on the natural environment.

The third assumption is that a significant proportion of Ireland’s Early Medieval environmental conditions, which may have influenced ringfort distributions, can be reconstructed from a variety of sources of evidence. Data enabling the reconstruction of past environmental conditions are currently available in Ireland from a variety of sources. These past environmental sources include written texts, palaeoenvironmental records and cartographic data. A further description of each of these sources is presented in Chapter 5.

The final assumption of the predictive modelling approach used in this research is that, having successfully modelled the relationships between environmental conditions and known ringfort locations, the predictive model can then be extended or used to predict the most likely locations of ringforts in areas that have been poorly surveyed.
or areas where levels of destruction are likely to have been relatively high such as intensively tilled areas. Once again, this assumption seems reasonable, but it is testable. Chapter 6 in this thesis provides a text of the predictive modelling approach applied in the current research.

2.3.2 Cluster analysis

Geoinformatics enables the production and storage of large datasets, which often require statistical analysis to draw out patterns. Cluster analysis is a label for a broad range of statistical procedures used to create typologies and classifications within datasets. A clustering procedure involves a multivariate statistical technique used to find patterns and identify discrete homogeneous clusters, or groups, within a dataset containing a number of individual cases [56]. Each cluster identified using a clustering procedure represents a grouping of individual cases, each with similar characteristics in terms of the variables included in the analysis.

In archaeological applications, datasets begin with a sample of cases (e.g., sites or artefacts) and a listing of variables used to describe them [160]. Clustering procedures are applied to form groupings or clusters of cases based on the similarities and differences among the variables used in the analysis. Computers are required to carry out the clustering procedures, because a large amount of data must be compared and analysed simultaneously. After the clusters are formed, the development of a typology or classification involves detailed manual interpretation to determine what the different clusters each embody.

In the current research, a clustering procedure (see Section 6.5) closely analogous with that used in research undertaken by Stout [177], [180] on ringforts from counties Offaly and Tipperarry was applied to the ringforts in three case study areas. This clustering procedure involved a combination of Ward’s method and $k$-means cluster analysis.
Ward’s method is known as an agglomerative hierarchical clustering procedure that begins with all cases as separate entities [56]. Cases are then fused together, or agglomerated, to form small clusters, and the small clusters are then fused together to form large clusters. This agglomerative process continues until one large cluster is created. Ward’s method sets out to minimise the sum of squares for any two clusters that can be formed at each step [188].

$K$-means cluster analysis begins with the analyst prescribing the number of clusters to create (e.g., the analyst can request the formation of exactly 4 clusters as distinct as possible). When used in combination with Ward’s method, $k$-means uses a pre-specified number of clusters created first using Ward’s method, and then moves individual cases between the different clusters. The goal of moving the cases is to minimise variability within clusters while maximising variability between clusters.

In the current research, interpretation of the clusters endeavoured to identify settlement patterns associated with the ringfort groupings in terms of their typology location and distribution characteristics. A more detailed description of the cluster analysis procedures used in the current research is provided in Chapter 6.

**Cluster analysis assumptions**

Three main assumptions underpin the use of cluster analysis in the current research. First, the interpretation of the resulting clusters assumes that the construction and occupation of ringforts dates to the Early Medieval period and that their habitation was largely contemporary (for further discussion on the dating of ringforts see Section 3.5.1). Second, it is acknowledged that cluster analysis is an exploratory tool, in terms of data analysis. The procedure does not require significance testing or any *a priori* hypothesis [173]. Third, it is assumed that the use of different clustering methods can and will create different clusters, even in the same dataset [3].
Chapter 3

Early Medieval Ireland

3.1 Introduction

The Early Medieval period, dating between c. 450 and 1100 AD, left a profound mark on the Irish landscape in the form of numerous archaeological remains. In Ireland, the Early Medieval period is bracketed by the period after the fall of Roman Britain c. 450 AD and a cultural shift towards feudalism which dates to approximately 1100AD –and shortly pre-dates the arrival of the Anglo Normans (1169 AD) [52].

Technologically advanced Rome never occupied Ireland. In the fifth century Irish invaders continuously raided and plundered fallen Roman Britain marking the beginning of the Early Medieval period in Ireland. The life and works of Ireland’s patron saint, St. Patrick, symbolise the cultural shift that occurred in Ireland to mark the beginning of its Early Medieval period. Born a Roman Briton around 390 AD, during his youth Patrick became captured by Irish invaders and sold into slavery in Ireland. Eventually Patrick escaped both slavery and Ireland. In 432 AD Patrick returned to Ireland as a missionary, successfully introducing Christianity to the largely pagan population. Christianity gains Ireland-wide acceptance, and the period that follows is marked by the expansion of monastic lands, diffusion of Christianity and the
production of famous artistic and ecclesiastical works (e.g., the Book of Kells).

Separate from the ecclesiastical groups, however, the bulk of Ireland’s Early Medieval society remained secular. This secular society inhabited near-circular to sub-circular enclosed agricultural settlements [104], [180] commonly known as ringforts or raths. These enclosed settlements were the dominant habitation form during the Early Medieval period, and today approximately 45,000 are documented throughout Ireland [178], [180], [13]. The culture of those responsible for the construction of these settlements is described as tribal, rural and familiar [20]. The end of the Early Medieval period is characterised by cultural transitions including: familiar land management to manorial; tribal social organisation to feudal; and exclusively rural to increasingly urban [72]. These cultural transitions occurred around 1100AD and were secured with the arrival of the Anglo Normans [138].

3.2 Early Medieval environments

A major assumption supporting this research is that the physical environment, to a measurable degree, influenced the settlement decisions of those involved in the construction of ringforts. This assumption is reasonable considering the agricultural function of these settlements and the relatively low level of technological practice at the time of their construction [96]. A second major assumption is that past environments, to a degree, can be reconstructed from available data sources (e.g., palaeoenvironmental and cartographic information). In this research, vegetation cover and climatic conditions during the Early Medieval period were reconstructed using available evidence from environmental [62] and palaeoenvironmental research including palynology [136], [128], [77], [165], dendrochronology [9] and palaeoclimatic indicators. In Ireland, for example, palaeoclimatic events can be traced through the use of dendrochronology [7] and, more recently, speleothems [118]. This research also assumes
that historical information on soil, elevation, and slope can be derived from present-day cartographic sources (e.g., [193], [194]). It also assumes that climatic conditions and vegetation cover in Ireland during the Early Medieval period were, potentially at least, different to those of the present. As a result of their reductionist nature, environmental reconstructions are a simplification of a more complex reality. Even with a simplified vision of the past, however, it should be possible to determine any potential major environmental influences and/or constraints on people.

3.2.1 Climate

Climate exerted a significant impact upon agriculture-based communities of the Early Medieval period. For different parts of the Earth, palaeoclimatic indicators are available from a variety of records such as tree rings, glaciers, bog sediments and speleothems [197], [90]. Various indicators are now available for different European regions. The width of annual grown rings in trees are impacted by environmental conditions: favourable (warmer and drier) growing conditions produce larger tree rings while unfavourable (cooler and wetter) growing conditions produce smaller tree rings [64]. Dendrochronology, in part, can involve the dating of past climatic change through analysis and measurement of annual tree ring width; the discipline also involves studies of other qualities of wood, such as density and isotopic content. Dendrochronological records can, to a certain degree, provide an indication of palaeoclimatic conditions and trends during chronologically well-defined periods in the past [153]. For example, European oak trees in the early part of the Early Medieval period (c. 540 AD) produced very narrow tree-rings (Figure, 3.1) indicating poor growing conditions, which in turn are indicative of a cooler wetter climate [8], as oak trees thrive in drier warmer conditions. This general incidence of narrow tree rings lasted for c. 250 years. Following this period, tree-ring widths gradually increased as growing conditions improved with a warming climate.
Similar climatic patterns have been documented from stable isotopes collected from several locations in northern Europe (e.g., Greenland ice cores [75] and German and Irish speleothems [118], [134]). These sources suggest that during the initial stage of Ireland’s Early Medieval period [c. 470–700 AD] temperatures were cooler than present, with the coolest temperatures occurring during the middle of the sixth century AD. This cool period is referred to as the DACP [118]. Towards the first millennium, temperatures increased – by approximately 1–2°C – leading up to a warm period referred to as the MWP c. 1000–1300 AD [142], [118].

### 3.2.2 Vegetation and agriculture

Palaeoenvironmental reconstructions, based on sub-fossil pollen, indicate uniform vegetation occurred more-or-less throughout Ireland over the last two millennia [129], [126], [77] although there were lags in response to, for example, climatic change
because of the different dispersal abilities of plant taxa and geographic difference in proximity to seed sources [125]. The available evidence suggests that in the period preceding the Early Medieval period much of Ireland was covered by deciduous woodland and extensive tracts of peatland in the climatically and edaphically wettest areas. Moreover, at this time agricultural activity was in a depressed state, possibly in part because of climatic conditions (cooler and wetter than present) [126]. The palaeoenvironmental reconstructions show that this agricultural lull continued into the late Iron Age and ended with an eventual upsurge in agricultural indicators [126]. From pollen analysis, this upsurge is marked by an increase in forest disturbance indicators and crop cultivation (e.g., [137], [165]). This increased agricultural activity is assumed to be related to a combination of factors, including improvements in plough [30], and watermill technologies [117], land management [126], climatic conditions, increased crop diversity (e.g., introduction of oats and rye in increasing quantities) [129], [198], and more organised animal husbandry (primarily systematic dairying) [96]. These combined food sources led to better-nourished, people healthier than previous populations that in turn led to a population increase [180]. The population increase created a cycle of land clearance and food production, and gave rise to an abundance of agricultural habitations (the ringforts that are the focus of this research).

### 3.3 Social organisation

To provide a framework for social organisation, historians and archaeologists often refer to Elman Service’s [166] four-fold classification of societies (see Table 3.1). Ireland is classified as having a chiefdom-based society [72] for the duration of the Early Medieval period. Chiefdom-based societies operated on a regional scale and comprised an integrated population coordinated by a head-chieftain or king [93], [42]. Individuals, including the head-chieftain, gained their status through family lineage or personal
### Table 3.1: Elman Service’s four-fold classification of societies [166]

<table>
<thead>
<tr>
<th>Population</th>
<th>i. Mobile groups hunter-gatherer</th>
<th>ii. Segmentary society</th>
<th>iii. Chieftdom</th>
<th>iv. State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. 100</td>
<td>Max. 1000</td>
<td>5000–20,000</td>
<td>20,000 +</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social organisation</th>
<th>Unofficial leadership</th>
<th>Settled farmers</th>
<th>Semi-central accumulation</th>
<th>Centralised bureaucracy</th>
<th>hierarchical classes and armies</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Religion</th>
<th>Shamans</th>
<th>Religious elders</th>
<th>Chiefs with religious duties</th>
<th>Organised religious establishment</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Settlement typology and pattern</th>
<th>Provisional settlements (e.g., tents)</th>
<th>Permanent structures (e.g., megalithic tombs)</th>
<th>Large monuments</th>
<th>Public buildings</th>
</tr>
</thead>
</table>

Military success. Encapsulated within this system was a hierarchical ranking of kin units that represented the overall chiefdom. In Ireland, researchers such as Gibson [71] have referred to the system as *ramage*, or conical clan structure [97]. The social structure of the society is reflected in the spatial distribution of the population over the landscape; including both the distribution of activity and of settlement. This research assumes that Early Medieval settlements in Ireland were the product of a chiefdom-based society, and that elements of this social-structure are visible in extant archaeological evidence.

#### 3.3.1 Sources for reconstructing Early Irish society

Evidence depicting social structures in Ireland’s Early Medieval period is documented in seventy-nine law tract manuscripts [95] that date from mainly the fourteenth through sixteenth centuries AD. These law tract manuscripts, written in combinations of Latin,
Old Irish and Middle Irish, were based on Early Medieval documents dating from the sixth through eighth centuries AD. Oral histories were the main source of information on the Early Medieval period, with linguistic evidence indicating that oral histories in Ireland extend as far back as c. 1000 BC [95].

The law tract sources contain information on social and moral relationships among people of all social ranks. The original purpose of recording these texts is unclear; however, authors such as Binchy [21] suggest, the laws may have been recorded by clerics or members of an educated secular group, the latter with the intention of writing down and preserving the traditional Irish law in the wake of encroaching Christian ideals. Translations of these manuscripts emerged during the nineteenth century in a series of six volumes referred to as the AL volumes [78]. The AL is problematic because it contains many translation errors relating to an array of problems\(^2\) that were inherited from the original manuscripts. Subsequent translations by historians such as Thurneysen –written in German– (e.g., [185]), and Binchy [18] were an effort to re-edit and repair the inaccuracies in the AL. In 1978 Binchy produced a translation-free (in original language) series that included the bulk of the original surviving law tracts, including some outside of the AL. Binchy’s translation-free series entitled Corpus Iuris Hibernici, or CIH [21], enabled the translation of the ancient law tracts into English. The CIH also provided a foundation for the study of Early Irish Law. For example, using the CIH, Kelly [95] was able to interpret the Early Irish laws in the context of other available information, including wisdom-texts, the lives of saints, penitential and monastic rules. Kelly’s A Guide to Early Irish Law [95] provides an accessible discussion of Early Medieval social customs.

Documentary sources providing supplementary information on the Early Medieval period in Ireland include: Lives of Saints; Irish miscellaneous writing (e.g., Irish poems); and Irish Annals. The Lives of Saints idealise the lives of Irish Saints and contain a

\(^2\)The fourteenth through sixteenth century manuscripts are plagued by missing sections, fragmentary dates, uncertain origins and formidable language.
mixture of facts, legends and myths written with a view to promote a particular church or diocese [169]. They offer narrative accounts to compliment the legal information documented in the law tract sources. Miscellaneous writing, such as ancient Irish poems, also provides information about Early Medieval settlements and society, as well as insights on commonly held thoughts and values (i.e., social norms) in Early Medieval Ireland [179]. Irish Annals, recorded in monasteries from the fifth century AD, are written accounts of significant national events [172]. However, these texts are of little value for studying specific settlement types, because they often postdate the Early Medieval period, thus causing uncertainty about their Early Medieval content [190]. In contrast to these sources, the Irish law tracts provide an outline of the society and economy that occurred prior to the Norman invasion.

Other valuable sources describing different aspects of the Early Medieval period in Ireland included texts such as: Simms’ study of the transition to the Later Medieval period [171]; McCone’s analysis of Christian and pagan social influences [116]; Ó Corráin’s overview of Ireland before the Normans [138]; Patterson’s social perspective on Early Medieval Ireland [151]; and Edwards’ comprehensive history of Ireland from St. Patrick (fifth century AD) to the invasion of the Vikings in the tenth century [52].

3.3.2 Political control and territorial boundaries

To provide a sociological context for ringforts, it is important to note briefly the political organisation of Ireland during the Early Medieval period. At this time, Ireland’s entire population spoke the same language and was symbolically governed by a high-king [139]. This information implies that the country was inhabited by a cohesive group of people; however, in reality the society was divided into many autonomous political units over which the high-king had little –if any– real control. Ireland was divided into five provinces (Connaught, Ulster, Meath, Leinster, Munster), with each province further subdivided into separate petty kingdoms. These separate petty kingdoms numbered
approximately 150 [37] and were called túatha – in plural form, or túath, the singular. Each túath were, on average, c. 500km², roughly the size of an Irish barony³ [20]. Each túath included a chief, who was sometimes referred to as a king, a church, an ecclesiastical scholar [52] and up to roughly 3,000 people [33]. The population of each túath would have had the same family lineage [95] and joint ownership of the land. The society in Ireland’s Early Medieval period was hierarchical and the kings of several túatha were ruled by a higher ranking king who himself was ruled by the over-king. The system created a large aristocratic population in which the kingships and affiliations were ranked according to wealth in livestock and land. Political cohesion was facilitated through client, lord, king and over-king relationships. In the upper ranks there were three grades of king, orrí:

- the king of the túath;
- the king of three or four túatha;
- king of the kings [95].

Supporting the upper ranks were several classes of nobles, including artists, warriors and craftsmen. At the opposite end of the scale were the clients. Clients were either free or base. Free-clients included several grades of farmers (e.g., bóaire, the strong farmer, and ócaire, the small farmer) [191]. These groups borrowed cattle from lords and in return repaid food, cattle and prearranged labour duties. The base-clients also worked the land belonging to their lord(s). Below these groups were hereditary serfs and slaves who were considered the property of their lords. Arrangements and relationships between these groups were complex and individually arranged. Scholarly work [130], based on sources such as the Irish law tracts, suggest that society during

³A barony is a subdivision within an Irish county no longer in use. The origins of these subdivisions are largely unknown, although they are thought to date to the Norman period (Twelfth century AD) and may have been based on earlier land divisions [121]. In total, 331 baronies exited in Ireland.
the Early Medieval period was in a state of flux and by the tenth century, possibly in response to an increase in population, had evolved to a more centralised system with fewer kings and more concentrated wealth.

### 3.3.3 Kings, lords and clients

According to the Irish law tracts, Early Medieval society was hierarchically ranked [95]. At the top of the hierarchical social structure were over-kings who gained their position through warfare as well as aristocratic lineage. Beneath over-kings, individual status was maintained through lord and client relationships, which were based on the borrowing and lending of cattle [117]. Cattle were essential for enabling mixed agriculture: oxen provided the plough muscle; cows provided meat, butter, cheese and manure to maintain the fertility of the farmed land [96]. This system implies that high-ranking members of the chieftdom, such as kings, did not necessarily occupy more land than their clients [151], but they almost certainly had more cattle, many of which would have been loaned-out to prevent the occurrence of problems associated with high stocking densities, such as over-grazing. Many lower-ranking clients, on the other hand, may have owned too few cattle to sustain an agricultural livelihood. In order to facilitate the needs of both, cattle were granted to the client by the lord. Clients were indebted to pay annual dues for cattle they had borrowed, which were personally arranged and often included labour duties (e.g., military duty, road building and maintenance of the lord’s dwelling), an amount of agricultural produce and the return of a set amount of offspring cattle. The Irish law tracts mention that the lords engineered these contracts to keep their clients in perpetual debt, by requiring a large number of offspring cattle to be annually repaid. In addition, it was possible that a single client could become indebted to several lords [151]. During the Early Medieval period, however, Ireland’s environment was favourable—as it remains today— to animal husbandry, and the client was in a good position to raise cattle. Early Medieval society
in Ireland was partially meritocratic and, if the client was shrewd, upward social-mobility was possible. For example, depending on the initial contract, which may have covered a fixed number of years or have been binding upon the death of the lord, the client could gain possession of cattle [95]. If a client gained possession of cattle, he or she could potentially generate a surplus of cattle, at which point they would be in a position to grant cattle as a means of gaining lord status him or herself. The same rules applied to the lords. The law tracts document a fluctuating system, in which prudent clients, over time, became lords and imprudent lords became clients by having to borrow cattle to sustain an extravagant lifestyle [36]. In addition, relationships between lords and clients were not perpetually binding. Lords were under constant threat from competitive kinsmen who were in a position to loan cattle [151] and therefore to assume localised leadership through family lineage.

Cattle raiding and other threats to livestock (such as wolves) were also a major concern [58], [82], particularly since any loss or gain in cattle directly impacted upon an individual’s social status and lifestyle. In addition, contracts were variable and could fluctuate in response to the supplies of and demands for cattle. Harsh winters, by causing death and damage to livestock, could reduce supplies and lead to an increase in the value of any surviving cattle.

### 3.3.4 Individuals and rank

The inhabitants of each túath were hierarchically ranked into one of several groups. Rank in Ireland’s Early Medieval society operated from individual perceptions of status and personal relationships. Status was determined by the amount of heads of cattle [95], although a multiplicity of factors, including amount of land, number of clients, hereditary and social standing, were also contributing factors. Social standing was constantly under threat from cattle raiding, natural disasters, and losses in battle. Prudent (or alternatively inept) asset management, such as careful lending
or careless borrowing of cattle, could directly impact an individual’s status. In these circumstances, people lived with the constant motivation or threat of the possibility of upward or downward social mobility.

Besides identifying kings, lords and clients, the law tracts assess rank in terms of ‘honour-price’—a term which refers to an amount payable in cattle, slaves or labour for an attack or offence committed against an individual. An honour-price payment was made for lessening an individual’s personal esteem [95], and payments were adjusted according to an individual’s wealth and social ranking. More payment was required to compensate those people of higher status, even if the same offence was committed. Honour-price amounts were well known within the local community, and an individual’s rank and honour-price was publicised through status symbols evident in the types of clothing, dwelling, mannerisms and reputation associated with an individual. Offences committed against individuals, their kinsmen or anyone in their temporary care, resulted in a levelling of an honour-price against an offender. It was dishonourable to be either a victim of an offence without receiving payment or guilty of an offence and unable to pay.

The value of the honour-price levied dictated an individual’s privileges and standing in prominent economic and legal arrangements. For example, the size of fief⁴ granted to an individual was directly connected to an individual’s honour-price and ability to make good on payments. Consequently, the higher the honour-price, the greater the fief. The value of an individual’s word in a legal dispute was directly related to their honour-price; men of lower ranks required someone with higher or equal ranking to represent them when disputing a higher ranking opponent. Honour-price thus dictated the autonomy of a particular individual within the society [151] and increasing ones honour-price was desirable.

⁴In Ireland’s Early Medieval society, a fiefdom or fief, consisted of revenue-producing property (e.g., number of cattle) granted by a lord to a client in return for annual repayment (e.g., labour, agricultural produce and military service).
3.4 Known Early Medieval settlements

This section provides an overview of the main types of known Early Medieval settlements in Ireland other than ringforts. These settlements consist of crannógs, ecclesiastical sites and souterrains.

3.4.1 Crannógs

Crannógs are former lake dwellings (Figure 3.2) that according to O’Sullivan [149] were constructed during Ireland’s Early Medieval period. Crannógs in Ireland are either entirely man-man or built on small islands or islets. The diameter of crannógs in Ireland range from c. 12m to 40m, and were constructed either upon raised platforms made of a ring of wooden piles beaten into the lake bed, or in a bog that was in-filled with alternating layers of material, such as gravel, rocks and brush [145], [148].

Crannógs are thought to have had a similar function to that of ringforts [63], and to have served as dwelling places for people practicing mixed agriculture. Due to the large amount of labour required for their construction [148], however, crannóg lake dwellings are thought to have functioned as places for individuals of higher social status than the occupants of ringforts in general. In addition, scant evidence from the few crannógs that have been excavated suggest more industrial uses (e.g., glass production and metalworking) than would have been practiced in ringforts [63]. Agriculture tools (e.g., steel ploughs) and evidence of grain storage [165] have been excavated from crannógs and it is likely agricultural activities were located in fields nearby [149]. Crannógs are considerably less abundant on the landscape than ringforts. According to O’Sullivan, at least 1,200 crannógs are known to exist in Ireland [148].
3.4.2 Ecclesiastical centres

Ecclesiastical centres, such as churches and monasteries, were common throughout Ireland during the Early Medieval period. These sites ranged in size and form, from the individual monk’s hermitage to large, politically powerful centres, such as Armagh and Clonmacnoise. At the beginning of the Early Medieval period, Irish society was primarily rural and lacked centralised control to a large degree. Ecclesiastical monastic centres focused on learning, trade, craftsmanship and religion, and were involved in local politics and clientage with their secular neighbours [25]. In addition, these centres were supported by a workforce of monks who carried out agricultural activities with a bias towards arable cropping and milling\(^5\). The lack of centralised control in Ireland’s Early Medieval society enabled these monastic centres to fill a cultural void [25] and

\(^5\)Horizontal mills are often found affiliated with Early Medieval ecclesiastical sites [164]. Milling activity suggests that ecclesiastical communities were closely connected to tillage-based agriculture. Further evidence reinforcing the bias of these monastic sites towards arable agriculture is evident in the association of improved plough and milling technology with the arrival of Christianity [30].
become focal places within their surrounding areas. By the sixth and seventh centuries [52], widespread monastic expansion occurred. Some of these monastic communities remained small and isolated (e.g., Skellig Michael, a rocky island situated 13km off the coast of Co. Kerry); however, others (e.g., Glendalough, Clonmacnoise, Cashel and Kells), sited in more desirable locations (e.g., areas of good quality soil, near major route-ways and within well-populated areas [115]), developed to become politically powerful proto-urban centres. By the tenth and eleventh centuries some of these centres (e.g., Armagh, Cashel and Kells) had grown into small towns [115].

3.4.3 Souterrains

Souterrains are manmade subterranean chambers accessible through small entrances located at ground level. The majority of these structures was constructed of dry stone masonry; however, tunnelled bedrock, clay and wooden examples are also documented [45]. Souterrains primarily functioned as places of refuge in times of crisis, although some were used for cold storage of food and dairy products as they maintain year-round constant temperatures of between 6–7°C. More than 3,000 souterrains [104] are recorded in Irish archaeological archives and 83% of these are found within ringforts. The location of souterrains within ringforts suggests that they were used during the Early Medieval period [189]. Several solitary souterrains have also been documented, indicating that some –at least– were unenclosed by earthworks. These unenclosed souterrains may be indicative of a form of unenclosed settlement. However, evidence of unenclosed settlements dating to the Early Medieval period remains speculative [146].

3.5 Ringforts

Ringforts typically feature an earthen enclosure that is circular or oval in shape and delineated by a system of banks and ditches – the latter referred to in this thesis as
fosses. They are known also by a variety of terms, including *rath*, *caiseal*, *lios*, *cathair* or *dún*. O’Riordáin [146, pages 29–30] describes ringforts as:

>a space most frequently circular, surrounded by a bank and fosse or simply a rampart of stone. The bank is generally built up by piling up inside the fosse the material obtained by digging the latter. Ringforts vary very considerably in size. In the more elaborately defined examples, the defences take up a much greater area than that of the enclosure.

From the nineteenth century, several key researchers have contributed to the current understanding of ringforts and the people who inhabited and constructed them. Westropp was the first author to formally discuss ringforts in a series of articles entitled *The Ancient Forts of Ireland* [200]. Westropp’s publications mainly contained an analysis of the distribution of ringforts, along with an initial estimate (c. 30,000) of their total number. The next significant study appeared in 1935, published under the Belfast Naturalists Field Club Survey of Antiquities, by Evans and Gaffinin [55]. This study provided surveys of ringforts and attempted to explain their distributional patterns. This seminal study led to several other studies on the distribution patterns of ringforts (see Watson [196], [195]; Proudfoot [154], [155]; and Fahy [57]).

Later Barrett [10] compared the distribution of ringforts sites in the north (Donegal) and south (Dingle Peninsula, Co. Kerry) of Ireland. Barrett’s grounds for choosing these two areas was that they were less likely to have been contaminated by Anglo Norman settlements (1169–1369 AD) [50]. Barrett’s thesis used the $\chi^2$ statistical test to examine if ringforts clustered in particular environments. Barrett’s $\chi^2$ analysis identified that ringfort sites were located in hospitable natural environments, and at elevations between 60 and 90m AMSL, also noted in Fahy’s early work [57].

Barrett’s study additionally included a reconnaissance technique using API, which was employed as a means to amend and verify ringfort distributions. Barrett’s work
enabled an estimation of ringfort destruction rates, albeit basic, prior to the recording of these features in the First Edition OSI maps (c. 150 years ago). Recognising the exploratory capabilities of API, a national survey using 1:30,000 scale photographs (commissioned by the GSI) was undertaken by the SMR Office and county surveys [175]. The API analysis has systematically raised county archaeological records by c. 10% [180] on average. Using API to locate unknown archaeological sites remains part of current survey practice (Figure 3.3) [13].

Subsequent to Barrett’s work, there have been several examinations of ringforts throughout Ireland (e.g.,[110], [191] and [104]); however, the most recent comprehensive study of ringforts was undertaken by Stout [178], [179], [180] and [181]. The key component in Stout’s research was the statistical analysis of a ringfort dataset from sites in the baronies of Clonlisk, Co. Offaly and Irerkin, Co. Tipperary [174] in the southwest midlands of Ireland. This analysis, based on cluster analysis, grouped individual ringforts into one of five categories depending on the values of a range of variables (morphological, locational and distributional) collected on a site-by-site basis. By comparing the results of his classification to the remaining Early Medieval documentary evidence (e.g., Irish law tracts), Stout proposed a settlement model (described in Section 3.6) [180].

3.5.1 Chronology

The chronology of ringforts is a contentious issue due to: the absence of dateable evidence\(^6\); the cost of acquiring reliable dates; the ordinary nature of these sites (a deterrent to the cost associated with acquiring dates); and the preference among archaeologists in Ireland of leaving field sites undisturbed. Despite these limitations, some dating evidence exists and this information has transformed the understanding

\(^6\)The lack of locating dateable evidence is a problem often cited in rescue archaeology see rescue archaeology reports on http://www.irisharchaeology.org for a detailed discussion.
Fig. 3.3: Oblique aerial photography from Barrett’s 1989–2000 API survey of Ireland [13]. Image A shows two conjoined atypical curvilinear enclosures acquired in Castleroe West, Co. Kildare. Image B features a crop marking of two concentric enclosures located in Kilmartin, Co. Dublin. The site in Kilmartin is thought to have once served in a ritual or ceremonial function.
of ringforts and Early Medieval Ireland.

For example, prior to precise dating in the form of dates from both radiocarbon and dendrochronological techniques (e.g., [110]), there was disagreement amongst archaeologists and historians over the time period during which ringforts in Ireland were constructed and occupied. DePaor, for instance, proposed that ringforts were first built in the Later Bronze Age [47] (c. 1000–600 BC) while authors such as Simms [170] and Barrett and Graham [14] suggested that their construction continued through the Iron Age (c. 200 BC – c. 300 AD), the Early Medieval and into the later Medieval period (i.e., to c. 1300 AD). A strong rebuttal of this long duration of ringfort construction and occupation was published by Lynn [108], who noted that ringforts may have offered some functional use (e.g., as shelter for cattle) as recently as the later Medieval period (c. 1700 AD). Lynn proposed that ringforts had been given an earlier construction date as a simple and convenient solution to an apparent gap in the settlement evidence between c. 200 BC and c. 500 AD [109].

Radiocarbon dated evidence suggests that ringforts were constructed and inhabited mainly between c. 600–900 AD; with building tapering off around c. 1000 AD [180]. The histogram (Figure 3.4) shows 94 radiocarbon dates from 47 ringfort sites ranging in date between 236 AD and 1387 AD. Around 54% of the ringforts were constructed and occupied between 540 AD and 884 AD, two-thirds of which have a mid-date between 600–900 AD. In addition to the dating evidence, it is apparent that some ringforts experienced different several construction and re-construction phases, and numerous activities (e.g., livestock production, crop based agriculture [96]) along with periods of habitation and abandonment that potentially accommodated a broad span of time.

While the histogram presented in Figure 3.4 is informative, it is problematic because only a relatively small number of ringforts are dated and over half of these dates are from excavations in Northern Ireland [180]. Although many ringforts have been excavated, particularly with recent development (e.g., the construction of roads,
Fig. 3.4: The histogram shows the frequency of the construction of ringforts per century and is based upon information in Stout [180]. These construction dates have been provided by radiocarbon dating evidence. The frequency count demonstrates that the histogram only counts for a minuscule sample of the total number of ringforts. Radiocarbon dates are provided in calibrated (calibrated with CALIB 3.0.3) years AD and are given within plus or minus (±) one SD. This accuracy implies that there is an about a one third chance that the date assigned is inaccurate by up to 100 years on either side.
laying of pipelines), radiocarbon dating is rarely carried out on material excavated from these sites. Until additional dating evidence suggests otherwise, it is widely assumed that the main phase of construction and occupation of ringforts occurred during the Early Medieval period. Currently, the acquisition of radiocarbon dates for ringforts, in addition to those presented in [180], remains a project in progress within the Department of Archaeology in Queen’s University, Belfast.

3.5.2 Origins

Ascribing an Early Medieval date to the majority of ringforts raises the question of what happened during the sixth century AD to initiate the construction of thousands of ringforts across Ireland? It is plausible that ringforts represent a continuation of an older circular building tradition [15], as is seen in hillfort sites dating to the Bronze Age (c. 2200–500 BC). It is also possible that the construction of the large numbers of ringforts relates to a greater population density and that the population increased in response to improved agricultural productivity and additional food supplies. Increased agricultural productivity, and hence the availability of food, could have followed improved climate conditions and advances in agricultural practice in the run-up to the Early Medieval period. Agricultural practices advanced with the arrival of Christianity and closer links with technologically advanced Roman Britain, which facilitated the spread of agricultural technology including, watermills, efficient ploughs [117] and possibly systematic dairying [96].

7Current datable material for ringforts is in the process of being collected by Finbar McCormick of Queen’s University Belfast. Acquiring radiocarbon dates for this collected material from ringforts is currently postponed until the construction of the new AMS dating facility at Queen’s University is completed.
3.5.3 Function

Functionally, ringforts offered a dual role as potentially they could facilitate both human habitation—with houses built on the platform inside the enclosures—and safe keeping of cattle and other livestock [104]. Archaeological evidence suggests the economy of these habitations was characterised by mixed agriculture [156], comprising small scale cultivation, the raising of cattle—including systematic dairying—and to a lesser extent sheep and swine [96].

During the Early Medieval period, the landscape was dotted with dispersed agricultural settlements (Figure 3.5), referred to by Proudfoot [156] as *einzelhöfe* settlement\(^8\). The high density of ringfort locations, with ringforts often separated by a few hundred metres, may have enabled communal defence among neighbouring sites within a túath or kin group. Strong defences were required to protect people and livestock from attacks and plundering raids [114]. Additional security is demonstrated in the defensive style of the construction, which features fosses and banks (see a plan example introduced in Section 3.5.4), and it seems likely that most ringforts provided at least a basic level of protection. Even a basic level of protection would have been a strong deterrent to cattle raiders [117]—a widespread threat [151] at the time. In addition, the building style would have provided protection for their livestock from wild predators such as wolves [82].

3.5.4 Morphology

Ringforts were constructed entirely using material from the local environment. Most were constructed with a mixture of earth and stone, although some, classified as cashels (Figure 3.6), incorporated dry stone walling. Cashels are limited in geographic extent and correlate with the major carboniferous limestone regions in western Ireland, or, alternatively, are found in areas where there is an abundance of glacier-transported

\(^8\) *Einzelhöfe* settlement is a term based on earlier work by Mietzen [123] in 1895.
erratics [104]. Since the distinction between ringforts and cashels and the mixture of stones used in their banks is dependent on the surrounding environment, they are considered to have the same cultural and chronological associations [146].

Ringforts often comprise earthwork defences –termed *vallum*\(^9\). These are in the form of raised bank and excavated fosses (Figure 3.7). Banks now vary from completely degraded to over 2.5m in height. Fosses may be absent due to years of in-filling. At one time fosses would have been a feature included with the majority of ringforts. Existing fosse depths range from negligible to 1.5m. Some excavated ringforts, such as Castle Balfour Demesne, Co. Fermanagh, however, have revealed original fosse depths measuring up to 2m [31]. The living space within a ringfort is the area enclosed by the

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\(^9\)The term *vallum* refers to the earthwork bank that is raised and forms the overall shape of a ringfort. Ringforts often have only one bank; however around 10% [180], referred to as bivallate, have a second earthen bank, and to a lesser extent (less than 1%) some ringforts have three (trivallate) and possibly even four (quadrivallate) banks.

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Fig. 3.5: Artistic rendition depicting ringforts within the ancient Irish landscape [1].
Fig. 3.6: Drumena cashel located in the townland of Drumena Co. Down. (A) The walls of this cashel were rebuilt during the 1920s and the site features the foundations of an original house in its interior. The cashels overall dimensions of the cashel measure c. 40m×32m with banks approximately 2.75m high and over 3m thick (B). Cashels usually lack an enclosing fosse as evident the current example. [Source of photographs http://www.themodernantiquarian.com/]
circumference of the inner bank. A ringfort’s and overall size refers to the maximum
diameter of a ringfort’s outermost bank. Within the current research the term BankI
refers to the inner bank of a ringfort and the term BankII refers to its outer bank, if
present (and see sub-section 5.5.1).

3.5.5 Distribution

Using known ringfort locations, Barrett [10], Limbert [104] and Stout [179] provide
a general overview of the distribution of ringforts in Ireland. Stout, in particular,
compared maps, cartographic information, palaeoenvironmental information, statisti-
cal methods and historical knowledge, and described distribution patterns of ringforts
for various parts of the country. After carefully analysing their distributions, Stout,
[179] proposed that ringforts tended to be located:

• at locations hospitable to agriculture, avoiding areas with poor drainage, high
altitude, exposed rock and waterlogged soils;

• on hilly or sloping terrain and areas featuring drumlins;

• in good quality soil;

• away from lower lying elevations, irrespective of soil quality and drainage; or

• at elevations between 70–160m AMSL, with the majority below 100m AMSL
and never above 300m AMSL (the upper altitudinal limit of agriculturally fertile
soils).

3.5.6 Demise

In addition to establishing the factors that influenced the location and density of
ringforts, it is also worth determining the context within which they were abandoned.
Fig. 3.7: Schematic diagram of a bivallate ringfort in the townland of Knockavrogreen, Co. Kerry based on plan from the Dingle Peninsula Archaeological Survey [46]. Labels representing morphological features are listed as follows: I. Maximum Internal Diameter (MID); II. Maximum Overall Diameter (MOD); III. Fosse depth (FD); VI. BankI height or height of a ringfort’s inner bank; V. BankII height or height of the second (outer) bank.
It is likely that a combination of external and internal factors were responsible for the apparently widespread abandonment of ringforts around the beginning of the second millennium AD [180]. One possibility is that the earthwork defences were too weak to protect against violent Vikings raids [176]. As a reaction to Viking invasions, the dispersed petty kingdoms amalgamated into larger units, which offered better protection [89]. Another possibility put forth by Lucas [107] is that the Viking invasions brought about a social change, or a change to social disorder. The initial attacks may have involved the Vikings; however, in the political and economic instability that followed, locals could have become involved in equally fierce raids. To afford greater protection, the dispersed population amalgamated into larger, centrally located societies [73]. The cultural changes introduced with the Anglo-Norman invasion and its aftermath [109] also provide another possible explanation as to why ringforts were abandoned as habitations. After the Anglo-Norman arrival, Irish society favoured more nucleated forms of settlement.

3.5.7 Preservation and destruction

Many ringforts remain intact (albeit in various stages of repair), despite having been long-abandoned. The remnant distribution of ringforts was first systematically mapped as part of the First Edition OSI maps (c. 1826–1844 AD). Since current ringfort distribution, based on these early mapping exercises, forms a basis for the present research, it is important to discuss the extent to which this early mapping exercise (along with ongoing amendments) accounted for the original number and distribution of ringforts. While this research assumes that current distributions are largely equivalent to the original, given the many years of exposure to the elements and human destruction it is inevitable that many ringforts will have been destroyed since their abandonment as habitations. For example, it is very possible –and pragmatic– that within superior agricultural lands, ringforts may have been removed to create more open space for
farming after the Early Medieval period. This possibility roughly corresponds to the 
distribution map (Figure 3.8), the ringfort density map (Figure 3.9) and the agricultural 
land quality map (Figure 3.10). Looking over these three figures together it is apparent 
that areas of favourable agricultural quality, such as in the east and southeast of Ireland, 
have lower ringfort densities. Since people who inhabited ringforts were agriculturally 
based, higher quality land would have been more attractive and, therefore, presumably 
more densely settled. However, the actual distribution pattern appears to differ from 
that predicted on the basis of intuition, and it is possible that these areas were, for 
some reason or combination of reasons, avoided by those involved in the construction 
of ringforts.

3.6 Stout’s settlement model

Ringforts occur in a wide variety of morphologies and locations. To organise ringforts 
into different categories, the cluster analysis method applied by Stout [177], [180] 
classified ringforts into five separate groups based on morphological, locational and 
distributional variables obtained from a dataset of ringforts from the southwest 
midlands of Ireland. Stout’s settlement model (summarised in Figure 3.11) linked 
his classification or groups of ringforts to the different social classes outlined in the 
Ancient Irish Law Tracts [95].

The variables that underpinned Stout’s model (Table 3.2) comprise structural 
characteristics of the ringfort sites (overall size, specific dimensions and defences), 
and topographic (slope, elevation, aspect) and sociological (distance to the nearest 
ecclesiastical centre –which may have represented potential proto-urban centres–, 
distance to the nearest neighbouring ringfort site, and location within respective 
territories using existing townland boundaries) parameters. Further description of these 
variables is provided in Section 5.5. In his research, Stout listed the most dominant
Fig. 3.8: Current distribution of recorded ringforts in Ireland, after Stout [180].
Fig. 3.9: Density of ringforts per square kilometre in each of the baronies in Ireland, after Stout [179].
Fig. 3.10: Map illustrating areas of current varying agricultural land quality as presented in the *Atlas of the Irish Rural Landscape* [1].
Table 3.2: Summary table listing the morphological, location and distributional variables used by Stout to generate groups of ringforts using a combination of Ward’s Method and $k$-means cluster analysis using Clustan Inc. software [177]. Two additional location variables associated with individual ringforts (Townland size, Parish size) were not entered into the statistical clustering algorithms. However, they were included as components within the cluster descriptions.

<table>
<thead>
<tr>
<th>Morphological</th>
<th>Locational</th>
<th>Distributional</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maximum-Internal Diameter (MID)</td>
<td>8. Townland Size (TS)</td>
<td>13. Nearest Neighbour (NN) distance</td>
</tr>
<tr>
<td>2. Circularity Index (CI)</td>
<td>9. Parish Size (PS)</td>
<td>14. Centrality IndeX (CIDX)</td>
</tr>
<tr>
<td>3. Maximum-Overall Diameter (MOD)</td>
<td>10. Slope (Se)</td>
<td>15. Distance to Townland Centre (DTC)</td>
</tr>
<tr>
<td>4. Height of BankI (BHI)</td>
<td>11. Altitude (Ae)</td>
<td>16. Distance to the nearest Early Medieval Ecclesiastical Centre (DEC)</td>
</tr>
<tr>
<td>5. Maximum Fosse Depth (FD)</td>
<td>12. Aspect(At)</td>
<td></td>
</tr>
<tr>
<td>6. Height of BankII (BHII)</td>
<td>7. Elevation of Living Space (ELS)</td>
<td></td>
</tr>
</tbody>
</table>

characteristics of the different ringfort groupings [177], [179]. A complete listing of the mean values associated with each variable and each group is provided (Table 3.3).

- **Group 1** – low-status, low-lying ringforts – morphologically these ringforts feature one bank, a shallow fosse (c. 0.05m), and a raised living space. These sites are located at low lying elevations (c. 100m AMSL), which are prone to waterlogging and therefore necessitated the construction of a raised living space. These ringforts tend to be located some distance (c. 1000m) from their nearest neighbouring ringfort. The inhabitants of these ringforts were likely of low social status.

- **Group 2** – high-status, bivallate ringforts – morphologically these ringforts feature small interiors (c. 30m) and double banks, with a fosse measuring on average 0.8m deep. In comparison to the other ringfort groups, ringforts in this category tend to be located relatively close to neighbouring ringforts (mean distance of 440m) and ecclesiastical centres (mean distance of 1390m). The inhabitants of these ringforts are believed to have had a higher social status than those inhabiting ringforts in Group 1, and were probably members of the upper echelons of Early Medieval society.
• **Group 3** – typical ringforts – morphologically these ringforts are univallate and are small in terms of internal and overall diameters (mean values of 30m and 40m, respectively). These ringforts were located on a wide range of elevations and slopes with a mean value of 2°. In terms of distribution, these ringforts are, on average, found at a distance of 440m from the nearest neighbouring ringfort. The occupants of these ringforts are believed to have had a middle-status social ranking.

• **Group 4** – large univallate multi-functional ringforts – morphologically these ringforts are larger when compared with the other ringfort groups, in terms of their internal diameters, and have deep fosses (0.8m in depth on average). These ringforts are often sub-circular and, on average, are found at elevations of c. 130m AMSL on gentle slopes measuring 1.7° and closer to townland boundaries than any other ringfort groups. Their large internal living spaces may have functioned as cattle stockades for seized livestock or for some military purpose.

• **Group 5** – low-status, upland ringforts – morphologically these ringforts are small, in terms of internal and overall diameters (c. 32m and 40m, respectively), single banked earthworks with shallow fosse depths measuring on average 0.24m. The ringforts in this group are set apart from the other groups because they have a mean altitude of 212m AMSL, which is a higher mean altitude value than any of the other groupings in Stout’s study area. In terms of distribution, these ringforts are, on average, located a distance of 430m from neighbouring sites and are located at greater distances from ecclesiastical centres (average of c. 3000m) than any of the other groupings in Stout’s study area.

Currently Stout’s settlement model, encapsulated in Figure 3.11, remains the key descriptive tool to summarise the organisation of secular society during the Early Medieval period in Ireland (e.g., [1]). The accuracy of this settlement model is limited
Fig. 3.11: Hypothetical model of Early Medieval society and pattern of settlement in Ireland, developed by Stout [180]. Measurement variables associated with these sites are provided in Table 3.3.
Table 3.3: Mean values associated with each variable and group [177] used to develop Stout’s settlement model providing a summary of the settlement patterns associated with those who constructed and occupied ringforts in Early Medieval Ireland (Figure 3.11).
by a relatively small dataset from a geographically-restricted region in the southwest midlands of Ireland. Additional ringfort datasets, with a similar range of variables, from other areas of Ireland need to be analysed in a similar statistical fashion in order to gauge the general applicability of Stout’s model.
Chapter 4

Study Areas

4.1 Introduction

This research investigates ringfort settlement patterns within three study areas labelled as 1. Blackwater valley; 2. Inny River catchment; and 3. Lough Ramor catchment (Figure 4.1 and Figure 4.2). The three study areas are contiguous to minimise transportation time between the ringfort sites during fieldwork. In addition, the three contiguous study areas can be merged into a single mega study area. As a single study area a contiguous group of ringforts can be analysed. For comparison of Early Medieval settlement patterns, each of these study areas offers a broad assortment of landscapes and ringfort distributions. Further detailed descriptions of each of these study areas are provided in the following three sections.

The reasoning underpinning the selection of these three study areas is that they accommodate a range of environments, historical settings and ringfort distributions. The Blackwater valley, for example, occupies a prominent position in Ireland’s settlement history and is situated near important historical sites, including Lough Crew, the Hill of Tara, Newgrange and the Boyne River valley. In addition, the study area itself contains monastic sites of Donnaghpatrick and the Kells monastery. The Blackwater
valley, relative to the other study areas, features a low density of ringfort sites and more fertile agricultural soils. The Lough Ramor catchment is located farther from high-status historical sites, yet has a higher density of ringforts than the Blackwater valley. The Inny River catchment is poorly drained in comparison to both the Blackwater valley and Lough Ramor catchment, and features high densities of ringforts and a broad range of terrains. In addition, the Inny River catchment has a long history of pasture-based agriculture. Pasture-based agriculture is less likely to damage ringforts in years preceding their occupation than more intensive forms of tillage-based agriculture (e.g., arable cropping).

4.2 Blackwater valley

The Blackwater valley (Figure 4.3) study area covers an area of 345km$^2$. The valley contains 58 recorded ringfort locations (at a density of approximately 1 site 5.8km$^{-2}$), and although largely in Co. Meath the study area extends into Co. Cavan. The study area comprises a broad fertile plain, drained by the Blackwater River and its tributary the Moynalty River (Figure 4.3). The Moynalty River enters the study area in the northwest through a narrow pass locally called the Gates of Mullagh, and flows southeast, eventually joining the Blackwater River in the townland of Bloomsbury. The Blackwater River drains Lough Ramor, Co. Cavan, flows southeast past the town of Kells and into Navan, where it joins the River Boyne. The boundaries of this study area were delineated by archaeologists working in the area using interpreted historical documentation [183] and the topographic high ground forming the watershed for the Blackwater River [133].

The Blackwater valley study area is dominated by two major geomorphological units; a flat plain in the southeast and an area of drumlins to the northwest. The southeast plain features prominent Early Medieval settlements, such as Donnaghpatrick
Fig. 4.1: Location map showing the three study areas in Ireland, including county boundaries and major cities.
Fig. 4.2: Location map of the three case study areas with topographic visualisation based on a hill-shaded terrain model. The hill-shaded terrain model was derived from the Ordnance Survey Ireland 1:50,000 Discovery Series digital data [143]. Shading represents brightness values from 0–255 and is based on a light source azimuth of 315° with an angle of sun illumination calculated at 45° [39].
Fig. 4.3: Distribution of ringforts within the Blackwater valley study area. These sites have been superimposed on a hill-shaded terrain model featuring a light source azimuth of 315° and simulated sun angle of 45°.
(the site of St. Patrick’s church), the royal site of Rath Airthir in the townland of Gibstown Demisen [184], and Kells –an Early Medieval monastic settlement famous for once holding the Book of Kells. The hilly terrain to the northwest is the location for the majority of the ringforts in the study area, and includes the northwest entrance to the valley at the Gates of Mullagh. Elevations in the Blackwater valley range from 26m to over 200m AMSL.

Geologically, the area is characterised by Lower Carboniferous limestone (Figure 5.3, 5.1 A) and Pre-Devonian outcrops of the Silurian system, such as shales, siltstones, sandstones and greywackes occur to the west of the study area and in the east near Kells and Drumbaragh [122]. According to the CLC 2000 (see Section 5.3.7), land use in the study area is currently a combination of managed pasture, arable agriculture and expanding urban areas (Table 5.5 A).

Ringforts within the study area were constructed in a variety of sizes, shapes and locations at elevations ranging over 48.5m to 140, AMSL (mean = 81m AMSL, SD = ±23m, and on slopes up to 8° (mean = 1°, SD = ± 1.75°). Their internal diameters range from 22m to 68m with a mean value of 38m SD = ± 11m. Their maximum overall diameters range from 30m to 80m, with a mean value of 53m SD = ±17m. In circularity, these sites range from oval to circular, with circularity index values\(^1\) ranging from 0.66 to 0.99 and a mean value of 0.93 SD = ±0.08. Seventeen percent (10 out a total of 58) feature a second bank and therefore are considered bivallate ringforts. Current bank heights range from subtle traces to 2.2m in height, with a mean height of 1.1m SD = ±0.65m for BankI and 1.0m SD = ±0.45m for ringforts with a BankII measurement. Current fosse depths range from completely in-filled to approximately 1.5m in depth, with an average depth of 0.4m SD = ±0.30m. Ringforts in the Blackwater valley study area have nearest neighbour distances ranging from 90m to 2850m, with an average nearest neighbour distance of 910m (SD =±687m).

\(^1\)Circularity index values are ratio values that are calculated by dividing a ringfort’s maximum internal diameter by its minimum internal diameter (and see sub-section 5.5.1).
Current archaeological records document thirty-one ecclesiastical centres and no crannógs. A sample of sites and landscape photographs from the Blackwater valley study area is provided in Figure 4.4 A through C.

4.3 Inny River catchment

The Inny River catchment study area is delineated by the Inny River watershed boundary [70] (Figure 4.5), covers an area of 1282km$^2$, contains 1070 recorded ringfort locations (a density of approximately 1 site 1.2km$^{-2}$) and extends through the counties of Meath, Westmeath, Longford and Cavan. Elevations within the Inny River catchment range from 30m to over 270m AMSL. Geologically, the area is mainly characterised by Carboniferous limestone (Figure 5.3 and Table 5.1 B), upon which are superimposed features formed from glacial sediments [68]. The predominant glacio-morphological features are drumlins in the north and west, and eskers in the south and east [204]. Poor drainage characterises low-lying parts of the study area, where it has led to the development of raised bog and basin peat (Figure 5.12). The majority of soils are grey brown podzolic, peats and, to a lesser extent, acid brown earths and gleys (Figure 5.8 and Table 5.3) [68]. The majority of the Inny River catchment is under managed pasture (Table 5.5 B), with areas of basin peat according to CLC 2000 data [38].

Ringforts within the Inny River catchment study area were constructed in a variety of sizes, shapes, locations at elevations ranging from 39m to 202, AMSL (mean = 100m AMSL, SD = ±26m) and on slopes that range from 0.0° to 15.0° (mean = 1.8°, SD = ±2.3). Their internal diameters range from 12.5m to 95m with an average value of 37m SD = ±12m. Their average maximum overall diameter is 49m SD = ±14m, and ranges from 22m to 132m. In terms of circularity, these sites range from oval to circular in shape, with circularity index values ranging from 0.50 to 0.99 and a mean
Fig. 4.4: A. A univallate ringfort in the townland of Lietrim, Co. Cavan. This ringfort features a maximum overall diameter measuring 52m.; B. Photograph of the Moynalty River in the north of the Blackwater valley study area in the townland of Donore, Co. Meath; C. High cross carving at Kells, Co. Meath. The carving dates between the eighth and eleventh centuries AD and illustrates the artistic craftsmanship that occurred in local monasteries. [photographs taken by the author]
Fig. 4.5: Distribution of ringforts within the Inny River catchment study area. These sites have been superimposed on a hill-shaded terrain model featuring a light source azimuth of 315° and simulated sun angle of 45°.
value of 0.89 SD = ±0.08. Fifteen percent (160 out of a total of 1070) of these ringforts feature a second bank and are considered bivallate ringforts. Four ringforts within this study area feature a third bank and are considered trivallate ringforts. Current bank heights range from trace presence to 2.5m in height, with a mean height of 0.8m (SD = ±0.49m) for BankI and 0.7m (SD = ±0.38m) for BankII, when present. Current fosse depths range from completely filled in to approximately 1.5m in depth, with a mean depth of 0.5m, SD = ±0.24m. In terms of distribution, inter-ringfort distances range from 14m to 2300m (mean = 460m, SD = ±322m).

Current archaeological records document other Early Medieval settlements in the study area in addition to ringforts. The Inny River catchment features 26 crannóg sites, many recently researched (see [149], [165]), and 46 Early Medieval ecclesiastical centres. The study area is also situated near the Hill of Úisneach (located in the southeast of the Inny River catchment), which is referred to in Early Medieval literature as the meeting place of Ireland’s five provinces [49], [111]. Two photographs from selected areas within the Inny River catchment study area are provided in Figure 4.6.

4.4 Lough Ramor catchment

The Lough Ramor catchment study area (Figure 4.7), defined by the Lough Ramor catchment boundary [70], covers an area of 353km$^2$ and contains 186 ringfort locations at a density of approximately 1 site 1.9km$^{-2}$. The landscape of this study area, situated in the counties of Cavan and Meath, is composed of an area of low elevation land surrounding Lough Ramor that increases in elevation in a northwards direction. In addition to Lough Ramor there are 54 smaller loughs—ranging in size from 0.1ha to 84ha—and numerous small streams. The majority of the area is drained by the Blackwater River, which runs towards the southeast and into the Blackwater valley. This study area is relatively hilly, when compared with the other two selected study
Fig. 4.6: Two photographs from the Inny river catchment study area. Photograph A shows the tree-covered remains of a massive univallate ringfort in the townland of Rackavara Co. Westmeath at a site located approximately 3km southwest from the Hill of Uisneach. This ringfort features a maximum BankI height of 2.5m, a maximum internal diameter of 54m and a maximum overall diameter of 72m. Photograph B features a south facing view of Inny River in the townland of Ballinalack Co. Westmeath, approximately 5km northwest of Lough Owel, roughly in the centre of the study area. [photographs taken by the author].
areas, and features several hilltops with elevations above 200m AMSL. Currently the main land use is managed pasture (Table 5.5 C), although a small amount of land is used for crop-based agriculture, according to CLC 2000 data [38]. Geologically the study area is dominated by carboniferous limestone (Figure 5.3 and Table 5.1 C) with glacio-morphological features, such as drumlins [204], also common. The majority of soils within the study area are heavy gleys. Acid brown earths and podzols are also present (Figure 5.8 and Table 5.3) [68].

Ringforts in the Lough Ramor catchment study area are located at elevations ranging from 89m to 220m AMSL (mean value = 143m, AMSL, SD = ±26m) on slopes ranging from 0.0° to 9° (mean = 2.9°, SD = ±2.2m). Inter-ringfort distances are between 114m and 1684m with an average nearest neighbour distance of 646m (SD = ±330m). They feature internal diameters ranging from 19m to 60m, with a mean value of 32m (SD = ±8.0m). Their maximum overall diameters range from 27m to 76m, with a mean value of 43m (SD = ±12.5m). In terms of circularity, these sites range from oval to circular, with circularity index values ranging from 0.63 to 0.99 and a mean value of 0.93 (SD = ±0.09m). Eight percent (15 out a total of 186) of these ringforts feature a second bank and are considered bivallate ringforts, while one features three banks and is considered a trivallate ringfort. Current bank heights range from trace presence to 2.5m in height, with a mean height of 0.80m (SD = ±0.45m) for BankI and 0.96m (SD = ±0.38m) for the BankII, when present. Current fosse depths range from completely filled in, to approximately 1.50m in depth, with an average depth of 0.42m SD = ±0.2m.

Current archaeological records show evidence of other Early Medieval settlement within the Lough Ramor catchment. In addition to ringforts, this study area also features 21 crannóg lake dwellings (16 of these crannógs are located within Lough Ramor itself) and 5 Early Medieval ecclesiastical centres. Two photographs from the Lough Ramor catchment are provided in Figure 4.8.
Fig. 4.7: Distribution of ringforts within the Lough Ramor catchment study area. These sites have been superimposed on a hill-shaded terrain model featuring a light source azimuth of 315° and simulated sun angle of 45°.
Fig. 4.8: Photographs from the Lough Ramor catchment study area. Photograph A shows tree covered remains of a univallate ringfort featuring a maximum internal diameter of 48m and a maximum overall diameter of 60m. The ringfort is located in the townland of Drumagolan, Co. Cavan and the site is on hilly terrain approximately 5km north of Lough Ramor. B features Lough Lisgrea located 3km north of Lough Ramor in the townland of Cornaslieve, Co. Cavan. This image provides an example of the undulating and marshy terrain characterising the majority the Lough Ramor catchment. [photographs taken by the author].
Chapter 5

Methodological Framework and Assembly of GIS Datasets

5.1 Introduction

The following chapter describes the overall methodological framework and the GIS datasets that were assembled for three study areas. GIS data were processed using ESRI ArcGIS software version 9.0 [54], [147]. ArcGIS is a large GIS software package featuring sub-programs such as ArcInfo and ArcMap. For the purposes of this research, ArcInfo software was used for the production and assembly of GIS datasets. Cartographic output was generated using ArcMap software. GIS data were maintained in both raster and vector formats, and specifically as ESRI coverages\(^1\) and GRID\(^2\) files. To enable the digital cartographic layers to overlay, all GIS data were projected to the ING\(^3\) coordinates. All raster-based data within the current research use a \(20\times20\) m cell size as the basic unit of spatial analysis. In addition to the GIS software, tabular data

\(^1\)Coverage refers to the digital cartographic files used for vector data storage native to ESRI ArcInfo software.
\(^2\)The term GRID refers to the raster file format native to ESRI software.
\(^3\)The ING is based on a Transverse Mercator projection using the Modified Airy 1965 ellipsoid.
were assembled and managed using Microsoft Access. All processing was performed on an Intel Pentium–M (1300 Mhz) CPU running a Windows XP © OS.

This chapter comprises four sections. The first section sets out the methodological framework and the organisation of techniques for data collection and analysis. The second section describes the assembly of the GIS data, including all environmental data as well as ringfort locations. The third section describes the assembly of variables used in stepwise logistic regression. The final section describes the collection and assembly of data used in cluster analysis, and in particular the preparation of available morphological, locational and distributional data for each ringfort site in the three study areas.

5.2 Methodological framework

The methodology implemented in the current research seeks to address the two research aims stated on page 2. Figure 5.1 illustrates the methodological framework that underpins the current research.

A predictive archaeological model was developed using stepwise logistic regression to address the first aim of the research, which seeks to model the current locations of ringforts. The predictive model was developed by assembling a selection of environmental variables that were likely to have exerted a significant influence on where ringforts were located. Non-ringfort site locations were not analysed in this interpretation of the statistical results. The environmental variables which included elevation, surface slope, aspect, soil type, potential natural habitats, distance to rivers, distance to streams, and distance to lakes, were selected because of their current availability in cartographic datasets and because they represent factors that were likely to have influenced decisions over the siting of ringforts during the Early Medieval period.

Existing summaries of the environmental settings of ringforts are described in the
Fig. 5.1: Schematic illustration of the methodological processes applied to address the aims of the current research, as outlined on Page 2.
current literature [57], [1], [180] and are summarised in Section 3.6. This literature, however, is insufficient because it provides large scale only (Ireland-wide) [180], and therefore presumably general locational trends, which may or may not be present in the current study areas. In addition, the existing summaries merely describe where ringforts are located without comparing them with other possible locations. A robust analysis of ringfort locations involves a comparison of the location of ringforts with a random selection of non-ringfort site locations from the same geographic area. A random selection of non-ringfort site locations provides an unbiased sample representing a potentially broader range of settlement locations within the geographic area of interest. The location of ringforts was unlikely to have been random and was probably the outcome of a complex of factors (cultural, environmental and practical (e.g., the availability of suitable land). Comparing ringfort locations to randomly selected non-ringfort locations provides a means to highlight the bias associated with the siting of ringfort locations. Comparing ringforts to randomly selected non-ringfort site locations is the basis for the stepwise logistic regression analysis applied in the current research.

The result of the stepwise logistic regression analysis is a mathematical equation or model that indicates those environmental variables that appear to have been either preferentially avoided or sought after in relation to where ringforts were located. Stepwise logistic regression also provides statistics that indicate the strength of relationships between site locations and the resulting mathematical model. In addition, the resulting model can be applied and tested in other geographic areas. The purpose of carrying out these tests is to assess the validity of the resulting mathematical model not only within the area in which it was developed, but also in other areas. Such robust testing will also provide a further indication of the kinds of environments preferred by those who constructed ringforts, especially if the test study areas feature different physiographic settings, as the do in the current research.

The methodology applied to address the second research aim involves the applica-
tion of a cluster analysis procedure (discussed further in Section 6.5), similar to that carried out by Stout on ringforts in the southwest midlands of Ireland [177], [179], [180]. The cluster analysis procedure results in groups or clusters of ringforts, whereby each cluster contains ringforts with the most similar morphological, locational and distributional characteristics specific to the variables used in the analysis. The clusters formed with data from the current case study areas are compared with those groups listed in Stout’s settlement model, as described in Section 3.6.

As indicated in Stout’s [180] settlement model (Section 3.6), the variation in morphology of ringforts provides a means to identify and describe different ringfort types. The different ringfort types have been partially related to the hierarchical ranking system for members of society in Early Medieval Ireland [180]. Higher ranking members of Ireland’s Early Medieval society, for example, are thought to have been associated with more elaborate and larger ringfort sites [191], [180]. Existing morphological measurements for ringforts in the three study areas that form the focus of this current research fall into the following categories (see Figure 3.7):

- Maximum internal diameter;
- Circularity index;
- Maximum overall diameter;
- Height of BankI;
- Maximum fosse depth;
- Height of BankII.

Maximum internal diameter provides a measure of a ringfort’s original living space, which possibly is a partial indication of the status of its occupant during the Early Medieval period [180]. Ringforts were rarely constructed in perfect circles and the
degree of circularity may provide a link to the status of the occupant. This theory is based on an ancient Irish poem, “Críth Gablach,” the content of which implies that a king of a túath was expected to have a perfectly circular stockade [112]. Thus ringforts with increasing circularity (to a maximum of perfectly circular) may be associated with higher status occupants.

Maximum overall diameter provides a measure of the overall size of a ringfort. Ringforts, particularly those with additional banks, required more labour to build and maintain. Larger ringforts are linked to higher status individuals who had access to the labour required to build up the earthworks. The current maximum heights of BankI, BankII and the depth of the fosse may provide an indication of the original height and depth of the structures. However, it is apparent that differing degrees of weathering and exposure and in-filling have worn down these features, so that some at least will bear little resemblance to their original dimensions in the Early Medieval period. The law tracts, described by McNeill [112], state that average fosse depth and bank height were originally 1.8m; however, given the long period of time that has passed since the construction and occupation of ringfort settlements, the preservation of banks and fosses will have varied considerably. Nevertheless, existing measurements are often the only indication of the features’ original dimensions.

There are five categories of location that describe ringfort locations in Stout’s settlement model of ringforts: elevation, aspect, slope, townland size and parish size. Townland and parish sizes were recorded to examine whether any relationship exists between these variables and the resulting clusters (e.g., are bivallate ringforts associated more with larger townlands than univallate ringforts). Townlands are the smallest level of territorial land division in Ireland and have origins that may date from Ireland’s Early Medieval period [119]. The parish system in Ireland dates to the Later Medieval

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4The ancient Irish poem “Críth Gablach” [19], associates the degree of circularity to the status of the occupant and specifically that a king’s residence was absolutely circular; “Seven score feet of perfect feet are the measure of his stockade on every side” [112].
period (c. 1100–1700 AD); however, research has shown that parish boundaries, based on earlier land divisions, were possibly created during the Early Medieval period [81].

As indicated in Stout’s settlement model (e.g., Section 3.6), the characteristics of ringforts are associated with the status of the original occupant and function of the ringfort. For all ringforts within the three study areas, distribution variables were recorded in the following categories:

- nearest neighbour;
- centrality within a townland;
- distance to townland centre;
- and distance to the nearest Early Medieval ecclesiastical centre.

The nearest neighbour distances are the distances between a ringfort and its closest neighbouring site. Centrality within a townland provides a measure of how central and important the ringfort was within a townland. The inclusion of this variable is based on the assumption that townlands were, at least in part, derived from Early Medieval systems of land division [119]. The measurement provides an indication of whether or not central position within a townland was preferred, in particular, by the higher ranking members of Early Medieval society in Ireland.

Distance to townland centre provides a measurement of the distance from a ringfort to the centroid location for the townland associated with a ringfort. These values fluctuate, depending on the size and shape of the townland and the distance a ringfort is from the centre of a townland (centroid position).

The distance to the nearest Early Medieval ecclesiastical centre is a measure of the distance between each ringfort and the nearest documented ecclesiastical centre, or potential proto-urban community [115]. The current research assumes that ecclesiastical sites listed in the county archaeological inventories (e.g., [131], [140]) were established
prior to the arrival of the Anglo Normans [182], [81]. Evidence in the Early Medieval law tracts indicates that kings of the different túatha established ecclesiastical centres [151], [191] and Stout’s settlement model (see Section 3.6) would appear to support this as it indicates that Early Medieval ecclesiastical centres were located closer to higher status bivallate ringforts than other ringfort types (see Figure 3.11) [180].

Distances calculated between Early Medieval ecclesiastical centres and ringforts within the three study areas provide a means of examining possible location patterns between the status of the occupants of ringforts and ecclesiastical sites, as well as examining the patterns identified in Stout’s settlement model [180] (Section 3.6).

5.3 Collection and assembly of ringfort and environmental data

5.3.1 Ringfort point data

Digital ringfort distribution data were acquired from the DEHLG, Ireland. These data document known archaeological sites in Ireland, using database files and ArcInfo coverages. In the ArcInfo coverages, sites are identified with ING coordinates and unique identification codes, known as RMP codes. For each RMP identification code, a matching code in separate database files linked the site locations to class descriptions. These descriptions indicate the typology classification for each recorded archaeological site in Ireland. To extract information on ringfort sites, the point coverage and tabular data were related using the unique RMP code. A separate ringfort coverage was created by extracting out only sites classified as ringfort sites.
5.3.2 Field survey

A site-by-site pilot field survey of 58 ringfort locations was undertaken in the Blackwater valley study area (Figure 5.2). The pilot field survey was carried out in order to verify the accuracy and reliability of existing cartographic and digital ASI records. These existing ASI records provide geographic (x,y) positions, brief descriptions and measurements for each archaeological site recorded in Ireland. The locations of ringforts were verified by visits to the sites in the pilot field with a hand-held GPS (accurate to \( \pm 10\text{m} \)). The pilot field survey demonstrated that the existing digital ASI records provided accurate locational information for all identified and recorded ringfort sites.

The pilot field study also verified the accuracy of the ASI archaeological records documenting the ringfort measurements and descriptions. Morphologically, the current status and repair of extant ringforts could be compared with the reports listed in the ASI archaeological archives – often carried out in the late 1960s and early 1970s – and cartographic measurements from the 1:2,500 or 10,560 scale OSI maps [178]. In the years since these ASI surveys were undertaken, exposure of the field archaeology to natural elements, livestock and human land use has damaged ringforts. The survey concluded that existing archaeological and cartographic records were often more complete – in terms of information available – than the field archaeology, because of ongoing disturbance and destruction.

5.3.3 Geology

Digital geological data were acquired (under academic license) from the GSI (Figure 5.3) in ESRI shape-file format and were then converted into ESRI coverage format and projected on to the ING within ArcInfo. In all three study areas, the majority of underlying geology is Carboniferous limestone [204]. A summary of the different types
Fig. 5.2: **A** Photograph of a univallate ringfort in the townland of Clonmagaden, Co. Meath. This ringfort has a maximum overall diameter of 50m. **B** Field survey measurement of the BankI height of the same univallate ringfort in the townland of Clonmagaden. [photographs taken by the author]
of bedrock surfaces within the each of the three study areas is provided in Table 5.1.

### 5.3.4 Elevation, aspect and slope

Elevation, aspect and slope values were obtained from the OSI 1:50,000 Discovery series digital contour lines [143]. These data were acquired in AutoCad DXF format [143] and converted to ESRI line coverages using the DXFARC command in ArcInfo. The elevation line data were interpolated to produce a 20×20m resolution DEM using the TOPOGRID module within ArcInfo (Figure 5.4). The TOPOGRID module also required river and lake data to incorporate hydrological processes in the creation of the DEM [91]. To inspect the quality of the DEM, a hill-shaded terrain model was generated using the HILLSHADE command on the DEM (Figure 5.5). The hill-shaded terrain model renders an image with simulated surface shadow. Obvious errors in the DEM data are conspicuous as shaded anomalies on the hill-shaded terrain model. No significant errors were evident in the hill-shaded terrain model and thus the contour lines required no further processing.

Calculations of aspect and slope were obtained using the DEM, and the ASPECT and SLOPE commands in ESRI’s GRID module. The aspect coverage consisted of a raster surface in which individual cell values represented compass directions (Figure

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<th>C. Lough Ramor catchment</th>
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</tr>
<tr>
<td>13</td>
<td>Carboniferous, Old Red Sandstone</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>Lake (surface water)</td>
<td>0.9%</td>
<td>3.2%</td>
<td>2.0%</td>
</tr>
<tr>
<td>16 1</td>
<td>Lower Carboniferous limestone</td>
<td>31.4%</td>
<td>45.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>16 2</td>
<td>Middle Carboniferous limestone</td>
<td>16.9%</td>
<td>40.4%</td>
<td>0.0%</td>
</tr>
<tr>
<td>16 3</td>
<td>Upper Carboniferous limestone</td>
<td>0.6%</td>
<td>1.6%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

**Table 5.1:** Percentages for each class of subsurface geology within each of the three study areas [69].
Fig. 5.3: Underlying geology acquired from the GSI. These data were mapped at a scale of 1:750,000 and based on GSI field survey results [69].
Compass directions were calculated by identifying the direction of the maximum rate of change between elevation cell values in the DEM. The slope coverage (Figure 5.7) was calculated using the maximum rate of change in elevation between raster cell values and their neighbouring cell values [34]. Two measures for slope values were available: percent slope and degree slope. Slope values were calculated in percent slope (Equation 5.1), as opposed to degree slope (Equation 5.2), for use in the stepwise logistic regression. Percent slope provides more contrast than degree slope among the narrow slope gradients prevalent in the current study areas.

\[
\% \text{ slope} = \frac{\text{Rise, elevation (m)}}{\text{Run, distance (m)}} \quad \text{(Equation 5.1)}
\]

\[
\text{degree slope } \Rightarrow (\tan \theta = \frac{\text{rise}}{\text{run}}) \quad \text{(Equation 5.2)}
\]

### 5.3.5 Soil

Digital soil data were obtained from Teagasc, the agriculture and food development authority in Ireland, at a scale of 1:250,000. Data, originally in ESRI shapefile format, were converted to ESRI coverage format using the SHAPEARC command. Soils in Ireland have been classified into ten Great Groups, using the classification scheme (Table 5.2) established by the USDA in 1938 [68], and have been further grouped into 44 separate soil associations (for the complete listing see Gardiner and Radford [68]). Each soil association is made up of two or more of the ten Great Groups and is linked to one of five major physiographic divisions [68]:

1. Mountain and Hill;
2. Hill;
3. Rolling Lowland;
Fig. 5.4: The image above provides cartographic representation of the DEM, which was interpolated using the TOPOGRID module in ArcInfo. Elevations are provided in metres AMSL and the DEM was created from digital contour lines (AutoCad DXF files) [143] purchased under academic license from the OSI. Each raster cell represents a 20×20m land parcel.
Fig. 5.5: The image above provides cartographic representation of the hill-shaded terrain model created using the DEM (Fig 5.4). The hill-shaded terrain model above features a north west light source with an angle of incidence of 45°.
Fig. 5.6: The image above depict an aspect raster coverage created in ArcInfo using the \textit{ASPECT} command and the DEM (Figure 5.4). Raster cells in these images represent $20 \times 20$ m land parcels.
Fig. 5.7: The image above shows the slope raster coverage created in ArcInfo using the SLOPE commands, as well as the DEM (Figure 5.4). Raster cells in these images represent 20×20m land parcels.
Great Group soil classification scheme (USDA 1938)

1 – Podzols
2 – Brown Podzolics
3 – Brown Earths
4 – Grey Brown Podzolics
5 – Blanket Peats
6 – Gleys
7 – Basin Peats
8 – Rendzinas
9 – Regosols
10 – Lithosols

Table 5.2: Ten soil classes from the Great Group classification scheme (USDA, 1938). The Great Group classification scheme has been applied to soils in Ireland, see Gardiner and Radford [68].

4. Drumlins;

5. Flat to Undulating Lowland.

The soil data for the three study areas includes a total of 14 soil associations – excluding water– (Figure 5.8 and Table 5.8) which are linked to four out of the five major physiographic divisions.

The Mountain and Hill physiographic division comprises areas of high elevations (above 500m AMSL) with very steep slopes (12–16°). Soil associations linked to the Mountain and Hill physiographic division are not found within any of the three study areas in the current research.

The Hill physiographic division comprises areas with altitudes between 150m and 365m AMSL on slopes less than 12°. A single soil association (no. 9, Figure 5.8), linked to the Hill physiographic division, appears only in the northeast of the Inny River catchment study area. Hill soils are suitable only for summer grazing due to their shallow depth and relatively high altitude occurrence.
The Rolling Lowland physiographic division comprises areas with elevations below 150m AMSL (except in areas with low level blanket peat) and slopes between 2° and 6°. Soil associations linked to the Rolling Lowland physiographic division are found within each of the three study areas. The soil associations linked to the Rolling Lowland physiographic division tend to be rich, well-drained, acidic brown earths that are suitable for a wide range of uses, including cropping, fruit growing and pasture.

Drumlins are small hills containing poorly drained thick boulder clays deposited by glaciers. As large as 800m in length and 90m in height, these features are positioned parallel to the direction of glacial ice movement [204]. Drumlins are found in each of the three study areas but occur to a much greater extent in the Lough Ramor catchment. Soil associations linked with the Drumlin physiographic division (including inter-drumlin areas) are often poorly drained, supporting only summer pastoral activities and short periods of cropping.

The Flat to Undulating Lowland physiographic division comprises areas of lower elevations (below 100m AMSL) and slopes of less than 3°. Soil associations linked with this physiographic division appear only in the Inny River catchment and Blackwater valley study areas. Except for occasional areas of poor drainage, soils associated with Flat to Undulating Lowland support a wide range of uses, including vegetable and fruit crops, as well as year-round cropping. In contrast, poorer drained types of these soils are waterlogged and limited in use. These poorly drained soil types are found in valley bottom locations, which often contain accumulations of basin peat.

5.3.6 Surface water

Three separate surface water coverages were created using data for the streams, rivers and lakes data extracted from the OSI 1:50,000 Discovery Series data [143]. The OSI Discovery series represents stream, river and lake boundaries as vectors in AutoCad DXF layers. Stream and rivers were classified by the OSI and required no further
Fig. 5.8: Soil associations and physiographic divisions within the three study areas, according to the 1:250,000 National soil series dataset [68]. Soil associations comprise two or more of the ten Great Group classifications based on the USDA, 1938 soil classification (Table 5.2).
<table>
<thead>
<tr>
<th>Code</th>
<th>Physiographic division and soil associations</th>
<th>A. Blackwater valley</th>
<th>B. Inny River catchment</th>
<th>C. Lough Ramor catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Hill: Brown podzolics (80%), Gleys (15%), Podzolics (5%)</td>
<td>0.0%</td>
<td>0.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td>14</td>
<td>Rolling Lowland: Acid brown earth (75%), Gleys (15%), Brown podzolics (10%)</td>
<td>33.8%</td>
<td>6.3%</td>
<td>12.4%</td>
</tr>
<tr>
<td>21</td>
<td>Drumlins: Gleys (75%), Peaty gleys (25%)</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>25</td>
<td>Gleys (50%), Acid brown earth (40%), Interdrumlin peat and peaty gleys (10%)</td>
<td>0.0%</td>
<td>4.5%</td>
<td>68.1%</td>
</tr>
<tr>
<td>27</td>
<td>Gleys (85%), Interdrumlin peats and peaty gleys (15%)</td>
<td>1.5%</td>
<td>0.0%</td>
<td>4.9%</td>
</tr>
<tr>
<td>28</td>
<td>Gleys brown podzolics (60%), Gleys (20%), Interdrumlin peat and peaty gleys (20%)</td>
<td>3.2%</td>
<td>19.3%</td>
<td>0.0%</td>
</tr>
<tr>
<td>29</td>
<td>Gleys brown podzolics (75%), Interdrumlin peats and peaty gleys (25%)</td>
<td>7.5%</td>
<td>0.0%</td>
<td>12.5%</td>
</tr>
<tr>
<td>30</td>
<td>Flat to Undulating Lowland: Grey brown podzolics (70%), Brown earth (20%), Gleys (5%), Peat (5%)</td>
<td>0.0%</td>
<td>6.4%</td>
<td>0.0%</td>
</tr>
<tr>
<td>31</td>
<td>Minimal grey brown podzolics (80%), Gleys (10%), Brown earths (5%), Basin peat (5%)</td>
<td>7.4%</td>
<td>26.8%</td>
<td>0.0%</td>
</tr>
<tr>
<td>34</td>
<td>Minimal grey brown podzolics (70%), Gleys (20%), Brown earths (10%)</td>
<td>0.0%</td>
<td>0.2%</td>
<td>0.0%</td>
</tr>
<tr>
<td>37</td>
<td>Grey brown podzolics (75%), Gleys (20%), Brown earths (5%)</td>
<td>37.9%</td>
<td>19.8%</td>
<td>0.0%</td>
</tr>
<tr>
<td>39</td>
<td>Gleys (90%), Grey brown podzolics (10%)</td>
<td>5.7%</td>
<td>1.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>40</td>
<td>Gleys (80%), Grey brown podzolics (20%)</td>
<td>5.3%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>44</td>
<td>Gleys (60%), Brown earths (20%), Peaty gleys (20%)</td>
<td>2.8%</td>
<td>11.3%</td>
<td>0.0%</td>
</tr>
<tr>
<td>50</td>
<td>Water: Loughs</td>
<td>0.0%</td>
<td>3.9%</td>
<td>2.1%</td>
</tr>
</tbody>
</table>

| Total | 100.0% | 100.0% | 100.0% |

**Table 5.3:** Percentages of each soil association within each of the current study areas arranged by physiographic division. These percentages were compiled using the National 1:250,000 soil series data (Figure 5.8). Soil associations comprise two or more of the ten Great Group classifications based on the USDA 1938 soil classification (Table 5.2).
sorting.

Using the ARCDXF command, these AutoCad vectors were converted to separate line and polygon coverages, which were then converted into separate raster GRID files using the ARCGRID and POLYGRID commands. The EUCDISTANCE command, using these separate GRID files, was used to calculate distance values for each raster cell closest to specified features (e.g., stream, river, lake) and create the new GRID files (Figures 5.9–5.11).

5.3.7 CORINE land cover

CLC are environmental data that provide an up-to-date overview of current land cover types. CLC 2000 data were used in the current research to provide an indication of current agricultural potential and land use within each of the three study areas. The variety and distribution of vegetation identified by the CLC 2000 data does not relate closely to what existed in the Early Medieval period. The link between the current land cover types and what existed in the Early Medieval period is complex and was not modelled in this research. It is assumed, however, that the CLC 2000 data will provide a rough approximation of agricultural potential dating to the Early Medieval period.

Originally conceived in 1985, CLC provides a relatively coarse Europe-wide land cover classification (1:100,000 scale) [29]. In 1990, the first CLC database for Ireland (CLC 1990), based on Landsat TM satellite earth observation imagery (from 1989 and 1990) [144], became available. In 2003, the release of the CLC 2000 dataset offered a much needed update of the CLC 1990 data [38], and a means to estimate land-use change. CLC 2000 is based on Landsat 7 ETM+ imagery. Using a methodology dictated by the EEA, the CLC 2000 incorporates 35 classes and a 25 ha minimum mapping unit. To accommodate land cover classes specific to Ireland, specifically varieties of peat bog and pasture (Table 5.4), additional classification procedures and
Fig. 5.9: Distance to streams and rivers raster layer. Pixels represent 20×20m land parcels. Each pixel is assigned a numeric value indicating its distance to the nearest stream or river.
Fig. 5.10: Distance to rivers raster layer. Each 20×20m pixel represents a numeric value indicating its distance to the nearest river.
Fig. 5.11: Distance to lakes raster layer. Each 20×20m pixel represents a numeric value indicating its distance to the nearest lake shore.
Table 5.4: Additional levels of classification precision for peat bog and pasture land cover classes within the CLC 2000 data. Classification of bogs and pasture with the improved levels of classification precision was required to delineate the wider variety of bog and pasture types present in Ireland [38].

<table>
<thead>
<tr>
<th>CORINE Level–3</th>
<th>Level–4</th>
<th>Level–5</th>
<th>Level–6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peat bog</td>
<td>Raised bog</td>
<td>Exploited</td>
<td>Intact</td>
</tr>
<tr>
<td></td>
<td>Blanket bog</td>
<td>Upland</td>
<td>Exploited</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lowland</td>
<td>Intact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mountain</td>
<td>Exploited</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intact</td>
</tr>
<tr>
<td>Pasture</td>
<td>Improved</td>
<td>Unimproved dry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unimproved</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unimproved wet</td>
<td></td>
</tr>
</tbody>
</table>

classes were included in the supervised classification process. These additional classes enabled a finer delineation of the different peat bog and pasture land cover types.

CLC data for Ireland are currently maintained by the EPA. CLC 2000 data were purchased (under academic license) in ESRI shape-file format for the current research. Shape-files were converted into ArcInfo coverages and projected on to the ING using the SHAPEARC and PROJECT commands in ArcInfo. The cartographic representation of the CLC 2000 data within the three study areas is provided in Figure 5.12. Table 5.5 provides a summary of the different land cover classes within each of the current study areas.

5.3.8 Palaeoenvironmental habitat

Use of several environmental datasets enabled the creation of a potential natural habitats land coverage for the three study areas during the Early Medieval period. Palaeoenvironmental information from three separate pollen diagrams [136], [128] and [165] (Figure 5.13) provides evidence for vegetation cover in the central
Fig. 5.12: Cartographic representation of the CLC 2000 land cover categories within the three study areas. Table 5.5 provides a summary of the areas associated with each land cover class. The CLC dataset for Ireland comprises a land cover database of 44 separate classes using the CLC nomenclature. Classifications are based on Landsat 7 ETM+ imagery from the year 2000 with a minimum mapping area of no less than 5ha. The relationship between current land cover types and those in the Early Medieval period are complex. CLC land cover types, however, are used in this research to provide an approximation of the agricultural potential in the Early Medieval. Specific land cover patterns will have changed dramatically in the time between now and the Early Medieval period.
<table>
<thead>
<tr>
<th>CORINE land cover classification</th>
<th>A. Blackwater valley</th>
<th>B. Inny River catchment</th>
<th>C. Lough Ramor catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broad leafed forest</td>
<td>0.0%</td>
<td>0.5%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Complex cultivation patterns</td>
<td>2.0%</td>
<td>0.7%</td>
<td>0.9%</td>
</tr>
<tr>
<td>Coniferous forest</td>
<td>0.5%</td>
<td>1.6%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Construction site</td>
<td>0.1%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Discontinuous urban fabric</td>
<td>1.7%</td>
<td>0.4%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Pasture, improved</td>
<td>33.2%</td>
<td>32.8%</td>
<td>30.9%</td>
</tr>
<tr>
<td>Pasture, unimproved dry</td>
<td>35.0%</td>
<td>45.8%</td>
<td>51.6%</td>
</tr>
<tr>
<td>Inland marshes</td>
<td>0.0%</td>
<td>0.9%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Land principally occupied by agriculture</td>
<td>1.4%</td>
<td>1.9%</td>
<td>8.0%</td>
</tr>
<tr>
<td>Mineral extraction sites</td>
<td>0.6%</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Mixed forest</td>
<td>0.6%</td>
<td>0.4%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Natural grassland</td>
<td>0.0%</td>
<td>0.2%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Non-irrigated arable land</td>
<td>22.7%</td>
<td>1.8%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Peat bog, blanket lowland intact</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Peat bog, raised exploited</td>
<td>0.2%</td>
<td>5.2%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Peat bog, raised intact</td>
<td>0.5%</td>
<td>1.7%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Sport and leisure</td>
<td>0.5%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Stream courses</td>
<td>0.1%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Transitional woodland scrub</td>
<td>0.5%</td>
<td>2.3%</td>
<td>2.6%</td>
</tr>
<tr>
<td>Water bodies</td>
<td>0.4%</td>
<td>3.4%</td>
<td>2.9%</td>
</tr>
<tr>
<td>Wet unimproved pasture</td>
<td>0.1%</td>
<td>0.3%</td>
<td>0.4%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0%</strong></td>
<td><strong>100.0%</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

**Table 5.5**: Percentage of the total area calculated per study area for each separate land cover classification in the CLC 2000 dataset [38].
midlands of Ireland and particularly the three study areas (spanning the Holocene). O’Connell [136] reconstructed Holocene vegetation based on evidence from Scragh Bog\(^5\), Co. Westmeath. O’Connell documents an upsurge in woodland clearance and agricultural activity (e.g., expansion of pasture, cereal production) shortly prior to the Early Medieval period (c. 400 AD) in Ireland. Unpublished research by Molloy [128] documents the vegetation and land-use history of the locality surrounding Fletcherstown (Emlagh) Bog in the centre of the Blackwater valley, Co. Meath. Pollen, charcoal and plant macrofossils were used to reconstruct past environmental conditions, whilst chronological control was provided by radiocarbon dating and tephra horizons. Molloy’s work [128] provides evidence of both woodland clearance and agricultural production—including pasture and cereals—dating to the Early Medieval period. Selby \textit{et al.} [165] explores the palaeoenvironmental history of two lakes in the vicinity of Lough Sheelin, situated in the northwest of the Inny River catchment on the borders of counties Meath, Westmeath, Cavan and Longford. Radiocarbon dated palynological evidence demonstrates that the Early Medieval period was associated with increased deforestation in midland Ireland, open grassland and mixed agriculture, including cultivation of cereal crops such as oats and barley [165].

Natural habitats discussed in Fossitt’s text [62] \textit{A Guide to Habitats in Ireland}, provides a standard classification for Irish habitat—including ancient\(^6\) habitat. In the current research, ancient habitat classifications were linked with corresponding soil, river and elevation data. The land cover map (Figure 5.14) and associated table (Table 5.6) approximates the vegetation coverage before the agricultural expansion and widespread deforestation dating to Early Medieval period. The natural habitat land cover approximation is limited primarily by the lack of availability of larger scale soil

\(^5\)Scragh Bog is fed by a small (c. 1.3km long and 0.2km wide) fen that lies approximately 10km northwest of Mullingar, Co. Westmeath.

\(^6\)Natural or ancient vegetation in Ireland is very rare as most stands of trees have experienced modification in some way; semi natural is a term used to describe woodland approximately close to its ancient or natural state, whilst recognising that it has likely been altered in some way or another.
Fig. 5.13: Location map illustrating the sites used to provide palaeoenvironmental information within the current research. The references for these sites are as follows: Scragh bog [136], Fletcherstown (Emlagh) bog [128] and Lough Kinale [165].
surveys for all counties within the three study areas. Descriptions of the main habitat classes referred to in the current research follow:

- WN1 – Oak-Birch-Holly – broad-leafed woodland found primarily on acid or base-poor soils that are either dry or humid but never waterlogged. Minor tree species include downy birch (*Betula pubescens*), holly (*Ilex aquifolium*) and rowan (*Sorbus aucuparia*). Ground flora features ling (*Calluna vulgaris*), bilberry (*Vaccinium myrtillus*), bracken (*Pteridium aquilinum*), hard fern (*Blechnum spicant*), great wood-rush (*Luzula sylvatica*), velvet bent (*Agrostis canina*) and wood sage (*Teucrium scorodonia*).

- WN2 – Oak-Ash woodland – broad-leafed woodland found on base-rich or calcareous soils that are either dry or well-drained or include those in rocky limestone environments. Tree stands primarily comprise pedunculate oak (*Quercus robur*), ash (*Fraxinus excelsior*), or hazel (*Corylus avellana*), or various mixtures of each. Other trees (e.g., yew (*Taxus baccata*)) are also present, however, to a much lesser extent than in WN2. Ground flora is represented by species such as ivy (*Geum urbanum*), wood avens (*Geum urbanum*), sanicle (*Sanicula europaea*), bluebell (*Hyacinthoides non-scriptus*) and ferns (*Dryopteris filix-mas*, *Polystichum setiferum*, *Asplenium scolopendrium*, *Athyrium filix-femina*).

- WN4 – Wet Pedunculate Oak-Ash woodland – broad-leafed woodland associated with waterlogged areas that seasonally dry out during the summer months. This woodland occurs in periodically-flooded alluvial areas, in drumlins areas or at locations with heavy, poorly drained gley soil. Tree stands include pedunculate oak (*Quercus robur*), ash (*Fraxinus excelsior*), hazel (*Corylus avellana*), hawthorn (*Crataegus monogyna*), holly (*Ilex aquifolium*) and willows (*Salix spp.*) are also present – particularly in wetter areas. Ground flora is
represented by a variety of species including, enchanter’s-nightshade (*Circaea lutetiana*), meadowsweet (*Filipendula ulmaria*), primrose (*Primula vulgaris*), ivy (*Hedera helix*), bramble (*Rubus fruticosus agg.*), remote sedge (*Carex remota*), golden-saxifrage (*Chrysosplenium oppositifolium*) and ramsons (*Allium ursinum*).

- **WN5** - Riparian woodland – wet broad-leafed woodlands situated along the edges of rivers that are subject to frequent flooding. Characterised primarily by Willow (*Salix cinerea, S. purpurea, S. triandra*) as well as alder (*Alnus glutinosa*). Ground flora is represented by herbs such as nettle (*Urtica dioica*), creeping buttercup (*Ranunculus repens*), wood dock (*Rumex sanguineus*) and bindweed (*Calystegia sepium*). Stands of reed canary-grass (*Phalaris arundinacea*) are also frequent.

- **PB1** – Raised bog – This category includes deep accumulations of acidic peat (3m to 12m deep) originating in surface hollows or shallow lake basins. The name is derived from the elevated surface that forms when peat grows up from the surface. Typical bog woodland occurs on deep acidic peat that has relatively well drained upper layers. Tree stands are dominated by downy birch (*Betula pubescens*) and may form pure tree-stands. Other trees include rowan (*Sorbus aucuparia*), scots pine (*Pinus sylvestris*), oaks (*Quercus spp.*) and willows (*Salix spp.*). The shrub layer may included bracken (*Pteridium aquilinum*), bramble (*Rubus fruticosus agg.*), ivy (*Hedera helix*), purple moor-grass (*Molinia caerulea*) and honeysuckle (*Lonicera periclymenum*).
Fig. 5.14: Approximated potential natural habitats land cover before agricultural expansion and woodland clearance during the Early Medieval period. Map coverage is based on available soil [68], palaeoenvironmental data [136], [118], [165] and Irish habitats [62] data.
Code | Habitat and Woodland | A. Blackwater valley | B. Inny River catchment | C. Lough Ramor catchment
--- | --- | --- | --- | ---
PB1 | Raised bog | 2.8\% | 11.1\% | 0.0\%
Water | Water (lakes) | 0.0\% | 4.0\% | 2.1\%
WN1 | Oak-Birch-Holly | 33.8\% | 6.0\% | 12.2\%
WN1-4 | Mixed (Wet Pedunculate Oak-Ash and Oak-Birch-Holly) | 7.6\% | 0.0\% | 12.2\%
WN2 | Oak-Ash woodland | 50.8\% | 55.0\% | 0.0\%
WN2-4 | Mixed (Wet Pedunculate Oak-Ash and Oak-Ash woodland) | 3.2\% | 19.2\% | 0.0\%
WN4 | Wet Pedunculate Oak-Ash | 1.4\% | 4.3\% | 73.0\%
WN5 | Riparian | 103\% | 0.3\% | 0.5\%

Table 5.6: Percentages for each class of natural habitat land coverage within each of the three study areas.

### 5.4 Assembly of logistic regression variables

Development of a stepwise logistic regression model was carried out exclusively using data from the Inny River catchment. Data from the Blackwater valley and Lough Ramor catchment study areas were left outside the model’s development, in order to provide a means of evaluating the performance of the resulting model.

The stepwise logistic regression procedure requires a table of data that consists of binary coded dependent variables (ringfort sites and non-ringfort site locations) and a list of their associated independent variables (environmental variables). As detailed in comparable archaeological studies [192], [193], ringfort and non-ringfort\(^7\) site locations formed the dependent variables and were numerically coded as ones and zeros respectively.

#### 5.4.1 Dependent variables

Non-ringfort locations were assembled using a random sample of x,y locations within the three study areas [203]. Non-ringfort locations found in non-terrestrial locations

\(^7\)Non-ringfort site locations refer to randomly sampled terrestrial locations that are not within 75m of a current ringfort.
Logistic regression requires aspect variables to be represented as categorical variables [79]. The above image illustrates the process of dividing aspects into four labelled quadrants (I–IV).

were removed from the dependent variable database prior to any statistical analysis. To prevent overlap between the ringforts and non-ringfort locations, and to account for the approximate size of land holdings [96], a 75m buffer zone was placed around the location of each ringfort. Randomly located x,y coordinates found in this buffer zone were removed from the database prior to the analysis.

5.4.2 Independent variables

Thirty independent environmental variables were prepared using the GIS environmental coverages and ArcInfo GIS software. The aspect coverage (Figure 5.6 presented a challenge for stepwise logistic regression calculations. For example, in the aspect layer values 359 and 1 represent similar aspects; however, numerically these values are very different. To overcome this problem, aspect values were condensed into four labelled quadrants (Figure 5.15).

Within the Inny River catchment, slope values have a mean value of 2.7%, the range is from 0 to 51%, the latter representing a small area of steeper slopes within
Table 5.7: Subset of a larger ASCII text file containing the data that were assembled for the stepwise logistic regression analysis in this research. The complete table contains 778 independent variables (non-ringfort locations), 778 dependent variables (ringfort locations), environmental variables (Table 5.8) and a unique code identifying each case (ringfort site and non-ringfort site location) within the Inny River catchment.

this catchment. To isolate different slope categories, slope values were converted to their categorical equivalents, ranging from level to steep (Table 5.8, Slope Categories). Using these slope coverages, a sampling command (SAMPLE) was used to create an ASCII text file with all dependent variables (ringforts and non-ringfort sites) and their associated independent variables available within the various GIS environmental coverages (Table 5.7). The data within each GIS environmental coverage were coded according to one of three basic data-types: nominal, interval and ratio (Table 5.8).

For stepwise logistic regression analysis, these different data types cannot be analysed together in their present form. Specifically, ratio data is incompatible with nominal and interval data. Compatibility was enabled by converting the nominal and interval data into categorical (dummy) variables [79], [16]. Stepwise logistic regression is biased by discrepancies between the number of 1s and 0s within the dependent variable [124]. To eliminate this problem, a balanced number of ringfort and non-ringfort locations were selected from the complete dataset. This balanced number comprised 778 ringforts and 778 non-ringfort site locations. The remaining ringfort site locations and random non-ringfort site locations withheld from this table were available for the further testing of the model’s performance (discussed in detail in Section 6.4.2) [203].

Table 5.8 provides a complete listing of the map sources, the data type and the
<table>
<thead>
<tr>
<th>No.</th>
<th>Map source and associated variables</th>
<th>Name</th>
<th>Type</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS</td>
<td>Dependant variables (sites)</td>
<td>DEPVAR</td>
<td>Binary</td>
<td>1 or 0</td>
</tr>
<tr>
<td></td>
<td>Irish Soil Survey</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>09 – Brown podzolics (80%) Gleys (15%)</td>
<td>SOIL09</td>
<td>Nominal</td>
<td>Categorical</td>
</tr>
<tr>
<td>2</td>
<td>14 – Acid brown earth (75%) Gleys (15%)</td>
<td>SOIL14</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>25 – Gleys (50%) Acid brown earth (40%)</td>
<td>SOIL25</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4</td>
<td>28 – Gleys brown podzolics (60%) Gleys (20%)</td>
<td>SOIL28</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>5</td>
<td>30 – Grey brown podzolics (70%) Brown earth (20%)</td>
<td>SOIL30</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>6</td>
<td>31 – Grey brown podzolics (80%) Gleys (10%)</td>
<td>SOIL31</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>7</td>
<td>34 – Grey brown podzolics (70%) Gleys (20%)</td>
<td>SOIL34</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>8</td>
<td>37 – Grey brown podzolics (75%) Gleys (20%)</td>
<td>SOIL37</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>9</td>
<td>39 – Gleys (90%) Grey brown podzolics (10%)</td>
<td>SOIL39</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>10</td>
<td>44 – Basin peat</td>
<td>SOIL44</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Ordnance Survey Ireland (OSI)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Elevation</td>
<td>ELEV</td>
<td>Ratio</td>
<td>Metres</td>
</tr>
<tr>
<td>12</td>
<td>Level</td>
<td>SLOPE0</td>
<td>Interval</td>
<td>Percent</td>
</tr>
<tr>
<td>13</td>
<td>Nearly level</td>
<td>SLOPE1</td>
<td>–</td>
<td>1.0 – 2.0%</td>
</tr>
<tr>
<td>14</td>
<td>Very gentle</td>
<td>SLOPE2</td>
<td>–</td>
<td>2.0 – 4.0%</td>
</tr>
<tr>
<td>15</td>
<td>Gentle</td>
<td>SLOPE3</td>
<td>–</td>
<td>4.0 – 9.0%</td>
</tr>
<tr>
<td>16</td>
<td>Moderate</td>
<td>SLOPE4</td>
<td>–</td>
<td>9.0 – 16.5%</td>
</tr>
<tr>
<td>17</td>
<td>Steep</td>
<td>SLOPE5</td>
<td>–</td>
<td>16.5 – %</td>
</tr>
<tr>
<td></td>
<td>Aspect</td>
<td>ASPECT</td>
<td>Nominal</td>
<td>Degrees</td>
</tr>
<tr>
<td>18</td>
<td>Northeast</td>
<td>ASPECT–1</td>
<td>–</td>
<td>0 – 90°</td>
</tr>
<tr>
<td>19</td>
<td>Southeast</td>
<td>ASPECT–2</td>
<td>–</td>
<td>90 – 180°</td>
</tr>
<tr>
<td>20</td>
<td>Southwest</td>
<td>ASPECT–3</td>
<td>–</td>
<td>180 – 270°</td>
</tr>
<tr>
<td>21</td>
<td>Northwest</td>
<td>ASPECT–4</td>
<td>–</td>
<td>270 – 360°</td>
</tr>
<tr>
<td>22</td>
<td>Distance to rivers</td>
<td>RIVDIST</td>
<td>Ratio</td>
<td>Metres</td>
</tr>
<tr>
<td>23</td>
<td>Distance to streams</td>
<td>STRMDIST</td>
<td>Ratio</td>
<td>Metres</td>
</tr>
<tr>
<td>24</td>
<td>Distance to lakes</td>
<td>LAKEDIST</td>
<td>Ratio</td>
<td>Metres</td>
</tr>
<tr>
<td></td>
<td>Soils; Pollen; Natural habitats Ireland</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Natural woodland vegetation</td>
<td>NAT-HAB</td>
<td>Nominal</td>
<td>Categorical</td>
</tr>
<tr>
<td>25</td>
<td>Oak-birch holly</td>
<td>WN1</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>26</td>
<td>Oak-ash hazel</td>
<td>WN2</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>27</td>
<td>Wet pedunculate oak ash</td>
<td>WN4</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>28</td>
<td>Combination, wet pedunculate oak ash and oak ash hazel</td>
<td>WN2–4</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>29</td>
<td>Riparian woodland (located along river edges)</td>
<td>WN5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>30</td>
<td>Raised bog (peat)</td>
<td>PB−1</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Table 5.8: Table detailing the thirty environmental variables prepared for the stepwise logistic regression analysis. The sources and associated measurement scales for all ringfort sites and non-ringfort site locations within the Inny River catchment are also listed.
scales used to measure and represent the thirty environmental variables assembled for the stepwise logistic regression analysis. Summaries of the dependent variables and their corresponding independent variables are shown in the frequency distributions (Figure 5.16) and box-plots (Figure 5.17).

5.5 Collection and assembly of cluster analysis variables

A total of fourteen types of variables (Table 5.9) were collected for all ringfort sites within the three study areas. Of these, twelve (Table 5.10) variables were prepared for use in the software that was employed to generate clusters or groupings of different ringforts.

Quantitative data were collected from available sources that included: measurements taken from 1:2,500 and 1:10,560 scale OSI maps [178]; published archaeological inventories [131], [140]; and archaeological records held within the ASI (Figure 5.18). The collection of morphological information was a time consuming, manual process that involved a review of both ASI archives and 1:2,500 and 1:10,560 scale OSI maps. The assembly of locational and distributional variables involved customised and automated processes using several ArcInfo AML scripts [53] (Appendix A) and digital GIS coverages. The following subsections detail the process involved in creating the separate variable types.

8The two variables remaining (townland size and parish size), excluded from the cluster analysis procedure, were required for subsequent analysis and evaluation of the grouped data.

9Within the current research, archaeological records refer to those held within the ASI. These include RMP that are held within the National Monuments Section, DEHLG.
Fig. 5.16: Frequency charts visually summarising the data prepared for the stepwise logistic regression analysis. Data have been separated to enable visual comparison between the environmental variables associated with ringforts (1s) and non-ringfort site locations (0s). Frequency diagrams indicate the distribution of observed frequencies of occurrence of the values per variable.

<table>
<thead>
<tr>
<th>Morphological</th>
<th>Locational</th>
<th>Distributional</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maximum-Internal Diameter (MID)</td>
<td>7. Townland Size (TS)</td>
<td>11. Nearest Neighbour (NN) distance</td>
</tr>
<tr>
<td>2. Circularity Index (CI)</td>
<td>8. Parish Size (PS)</td>
<td>12. Centrality InDeX (CIDX)</td>
</tr>
<tr>
<td>3. Maximum-Overall Diameter (MOD)</td>
<td>9. Slope (Se)</td>
<td>13. Distance to Townland Centre (CTC)</td>
</tr>
<tr>
<td>4. Height of BankI (BHI)</td>
<td>10. Altitude (Ae)</td>
<td>14. Distance to the nearest Early Medieval Ecclesiastical Centre (DEC)</td>
</tr>
<tr>
<td>5. Maximum Fosse Depth (FD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Height of BankII (BHII)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.9: Variable types assembled for ringforts in the three study areas.
Fig. 5.17: Box-plots summarising data prepared for the stepwise logistic regression statistical analysis. Box-plots provide a summary for each variable based on the median, quartiles and extreme values. The shaded box represents the interquartile range, which contains 50% of values. The whiskers are lines that extend from the box to the highest and lowest values. The asterisks represent outlier values per variable. The line across the box indicates the median value per variable.

<table>
<thead>
<tr>
<th>Morphological</th>
<th>Locational</th>
<th>Distributional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum-Internal Diameter (MID)</td>
<td>Slope (Se)</td>
<td>Nearest Neighbour (NN) distance</td>
</tr>
<tr>
<td>Circularity Index (CI)</td>
<td>Altitude (Ae)</td>
<td>Centrality Index (CIDX)</td>
</tr>
<tr>
<td>Maximum-Overall Diameter (MOD)</td>
<td>Nearest Neighbour (NN) distance</td>
<td>Distance to Townland Centre (DTC)</td>
</tr>
<tr>
<td>Height of BankI (BHI)</td>
<td>Distance to the nearest Early Medieval</td>
<td>Distance to the nearest Early Medieval</td>
</tr>
<tr>
<td>Maximum Fosse Depth (FD)</td>
<td>Ecclesiastical Centre (DEC)</td>
<td>Ecclesiastical Centre (DEC)</td>
</tr>
<tr>
<td>Height of BankII (BHII)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.10: Table listing the twelve separate variables types that were entered into the cluster analysis software ClustanGraphics 7.01 applied in the current research.
Fig. 5.18: Sample of the contents of ASI archive folders. A. 1971 field report describing a ringfort in Rackavara, Co. Westmeath; B. 1:2,500 OSI map depicting ringforts in Rackavara, Co. Westmeath accompanying the field report (A.). C. Oblique aerial photograph of a ringfort in Kilgawny, Co. Westmeath. D. Field report describing the ringfort in Kilgawny, Co. Westmeath. E. Profile of a ringfort in Gigginstown, Co. Westmeath. F. Application for archaeological land reclamation (i.e., site removal) by landowner in Kilgawny, Co. Westmeath. [photographs taken by author]
5.5.1 Morphological variables

In the current analysis, the following morphological features (Figure 3.7 and Figure 5.19) were used to describe ringforts: living space (represented by internal diameter and shape); defences (represented by the bank heights and depth of fosse) and overall size (represented by the maximum overall diameter).

Currently, ringfort morphological data are available in two main forms. The first is the existing field archaeology and the second is in the form of completed archaeological surveys. As discussed previously, morphologically ringforts, over time, have experienced different degrees of bank erosion, fosse in-filling, and in some cases, complete destruction. Past archaeological surveys (including both cartographic surveys and field reports) completed within the last c. 150 years are often superior, and in some cases the only, sources of information on ringforts in Ireland [178].

ASI archives contain information about every recorded site in Ireland and are currently available for public viewing (Figure 5.18). In these archives, each ringfort site
is associated with a folder that may contain files including archaeological field reports\textsuperscript{10}, a statement on the current state of repair of the site, measurements of the features (e.g., bank heights) of a site at the time of survey associated photographs (including aerial photography), a copy of an OSI 1:2,500 or 1:10,560 scale map; drafted cross-sections; and any planning proposals that request to include the site in a development. The following morphological variables were assembled from the contents of these folders.

**Internal diameter**

Internal diameter refers to the maximum diameter of the inner banks of a ringfort. These measurements are available from field archaeology reports and measurements taken from the 1:2,500 or 1:10,560 scale OSI maps [178].

**Circularity index**

Ringforts are and have been graded in the current research from oval through to circular using a circularity index value. The circularity index is calculated by dividing the minimum internal diameter by the maximum internal diameter. The circularity index has possible values from $c.$ 0.1 to 1.0 (1.0 is perfectly circular). To account for slight surveying and measurement differences, variables associated with the circularity index were converted into categorical variables (Table 5.11 A).

**Maximum overall diameter**

Maximum overall diameter refers to the long axis length of the outer most banks of a ringfort (measurement labelled II on Figure 3.7). These measurements were gained from the 1:2,500 or 10,560 scale OSI maps [178].

\textsuperscript{10}Archaeological field reports provide a short hand written description of each archaeological site. These descriptions contain information such as the site’s features dimensions, surroundings and current state of preservation. The main purpose of this description is to validate if the site exists or not (Figure 5.18 A).
<table>
<thead>
<tr>
<th>Entity</th>
<th>Qualitative measurement</th>
<th>Measurement</th>
<th>Categorical code</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Circularity index</td>
<td>Circular</td>
<td>0.98 – 1.00</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Nearly-circular</td>
<td>0.93 – 0.98</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Sub-circular</td>
<td>0.90 – 0.93</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Nearly-oval</td>
<td>0.85 – 0.90</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Oval</td>
<td>0.01 – 0.85</td>
<td>5</td>
</tr>
<tr>
<td>B. Bank height</td>
<td>No visible trace</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Trace</td>
<td>0.00 – 0.20</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>0.20 – 0.50</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Moderately-high</td>
<td>0.50 – 0.75</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.75 – 1.30</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Substantially-high</td>
<td>1.30 – +</td>
<td>5</td>
</tr>
<tr>
<td>C. Fosse depth</td>
<td>No visible trace</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Trace</td>
<td>0.00 – 0.20</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Shallow</td>
<td>0.20 – 0.35</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Moderately-deep</td>
<td>0.35 – 0.55</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Deep</td>
<td>0.55 – 1.00</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Substantial</td>
<td>1.00+</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 5.11:** Categorically coded variables used for measures of circularity index, bank height and fosse depth.

**Height of BankI and BankII**

Height of BankI and BankII refers to the heights of the first and second banks, as measured by field archaeologists. Often these measurements are given in either a qualitative format (e.g., ‘trace existence’, ‘substantial banks’) or quantitative format measured in cm. A categorical scheme (Table 5.11 B) was used to group these measurements into a common scale.

**Fosse depth**

Fosse depth provides an indication of the depth of the fosse, or ditch surrounding the ringfort. The depths of fosses were recorded by the ASI and these measurements were given in either metric units, or as a qualitative description (e.g., trace fosse). To assemble these measurements into a common scale, a categorical coding scheme was applied (Table 5.11 C).
5.5.2 Locational variables

Locational data describe where the ringfort is situated in relation to the local topography and townland boundaries and parish sizes. Assembly of these data required the use of a digital townlands coverage (for townlands), the *Townland Index* (for parish boundaries) [83], and a DEM detailed in Section 5.3.4. The process through which these data were assembled is described in the following subsections.

**Townland size**

Townland size was measured (in ha) using 1:50,000 scale digital OSI townlands coverage. The digital townlands data were originally acquired in shapefile format and converted to ArcInfo coverages using the SHAPEARC command. The dataset contained a complete inventory of the shape, name and area (m$^2$) of each townland (Figure 5.20). The area of the townland within which each ringfort was located was determined by combining the ringfort distribution and townlands coverage datasets and using the INTERSECT$^{11}$ command in ArcInfo. The area of each townland was then mathematically converted to ha and recorded in an attribute table of the new coverage.

**Parish size**

Parish sizes were unavailable in digital format. Instead, parish sizes were collected manually from the *Townland Index* [83]. Tables within the *Townland Index* list areas (in m$^2$) for counties, townlands and parishes. Ringforts within the study areas were matched to their associated parishes as listed in the *Townland Index* [83]. Parish sizes were converted to ha and entered into the database.

$^{11}$The INTERSECT command calculates the geometric intersection between two ArcInfo coverages. The output is a new coverage that preserves features in the areas common to both input coverages.
Fig. 5.20: Illustration of the Irish townlands dataset on a subsection of the Lough Ramor catchment study area.
Altitude and slope

Altitude variables were determined from the DEM coverages detailed in Section 5.3.4. Slopes variables were calculated as degree slopes, in contrast to percent slopes, using the original DEM and the SLOPE command set to use the degrees slope option (Equation 5.2). Altitude and slope variables were assembled for each ringfort, using the DEM GRID coverages and the INTERSECT command.

5.5.3 Distributional variables

A range of measures of the distance of a particular ringfort to neighbouring ringforts, Early Medieval ecclesiastical centres and political boundaries, such as townlands, were calculated using AML scripts (Appendix A) and other ArcInfo commands.

Nearest neighbour

Data from outside the three study areas were used when the actual location of the nearest ringfort was not within the boundaries of the study areas. The nearest neighbour calculation was performed using ArcInfo’s NEAR command.

In its basic application, the NEAR command is unsuited to calculating nearest neighbour distances between ringforts in a single coverage, because it computes the distance from a point in the first coverage to the nearest point in a second coverage. Thus to utilise the NEAR command, ringforts were extracted, one by one, from the complete ringforts coverage. The process created two separate temporary coverages. The first temporary coverage contained a single ringfort location, while the second contained the remaining ringfort locations. The NEAR command was applied to these temporary coverages and the resulting nearest neighbour distance value was then added to the database. An AML script (NearestNeighbour.AML, Appendix A) was written to automate this process.
Centrality index

The centrality index was calculated by measuring the minimum distance between a ringfort and its corresponding townland boundary and dividing this value by the distance to the townland centre plus the minimum distance to the townland boundary (see Equation 5.3). A maximum value of one indicates that a ringfort is located centrally in the townland, and values of less than one indicate that a ringfort is located away from the centre and toward one of the adjacent townland boundaries.

\[
\text{Cent. Ind.} = \frac{\text{Min. distance to townland boundary}}{\text{Distance to townland centre} + \text{Min. distance to townland boundary}}
\] (Equation 5.3)

The calculation of the centrality index involved three main stages. Stage one involved calculating the minimum distance between individual ringforts and their corresponding townland centres\(^{12}\) using the \textit{NEAR} command in ArcInfo. However, the \textit{NEAR} command is limited in that it only generates distances between the closest point in two separate coverages. The command does not have the functionality to match features with specified attributes (e.g., to match a ringfort in townland Balsaw with the centre point for townland Balsaw). In many cases ringforts were located closer to the centres of neighbouring townlands, particularly when they were located close to their townland boundaries. To overcome this problem, ringforts and their associated townland centroid were placed, one by one, into separate temporary coverages. The \textit{NEAR} command was then deployed to analyse these temporary coverages. Resulting distances were assembled into the database and labelled as a database item called TownCentDist. Stage two involved calculating the minimum distance between a ringfort and its corresponding townland boundary. Since the \textit{NEAR} command only works with point files, townland polygons were first converted into a series of temporary point coverages.

\(^{12}\)Townland centres were equivalent to the centroid values ArcInfo uses to label polygons. Townland labels were isolated from the townland polygon coverage and then assembled into a point coverage.
using the ARCPOINT command before the separate point coverages (ringforts and townland boundaries) were compared using the NEAR command. Distances were assembled into a database item called BorderDist. Stage three involved use of a mathematical formula (Equation 5.3) which calculated the values for the centrality index using the aforementioned database items.

The above process was automated by developing the AML script CentralityIndex.AML (Appendix A). This script used all townland data for counties Meath, Cavan, Longford and Westmeath. The inclusion of extra townland data ensured that ringfort sites, located close to study area boundaries, were compared with the correct townland centres. The alternative, of using townland data cropped to the extent of the study area boundaries, would have distorted the shape of a townland and the location of its centre point.

**Distance to Early Medieval ecclesiastical centres**

Distances to Early Medieval ecclesiastical centres were calculated using the ringfort dataset and a dataset comprising information on Early Medieval ecclesiastical centres. Early Medieval ecclesiastical centres were isolated from the complete archaeological database, as detailed in Section 5.3.1. Calculating the distance to Early Medieval ecclesiastical centres involved the application of the NEAR command using the ringforts and an Early Medieval ecclesiastical centres coverage in ArcInfo. A short AML script was written to automate this procedure (Church-Dist.AML, Appendix A). This script first isolates the Early Medieval ecclesiastical centres from the general archaeological coverage for Ireland before calculating the distance between these Early Medieval ecclesiastical centres and the nearest ringfort locations.
Table 5.12: Sample portion of a larger dataset containing the data that were assembled for the cluster analysis portion of this research.

5.5.4 Table containing all variables used in the cluster analysis

Once the cluster analysis variables were prepared a final database containing all completed variables was created. A sample portion of the overall database is shown in Table 5.12. Summaries of the variables collected for the cluster analysis are provided in Figures A.1, A.2 and A.3 in Appendix A.
Chapter 6

Data Analysis

6.1 Introduction

The following sections describe the statistical procedures that were applied to the datasets, the assembly of which was described in the previous chapter. The first section describes the organisation of the statistical techniques employed in the current research. The second section describes the predictive modelling methodology using stepwise logistic regression undertaken in SPSS version 11.0. The third section describes the cluster analysis technique employed in the current research.

6.2 Organisation of statistical techniques

6.2.1 Stepwise logistic regression

Stepwise logistic regression provides information on ringforts in terms of site location and the preferred environmental setting by their occupants. Application of stepwise logistic regression is justified in the current research since it provides a testable and repeatable methodology using data that are readily available at national scales.
6.2.2 Cluster analysis

The version of cluster analysis adopted here (Ward’s method optimised with \( k \)-means analysis) is similar to that used by Stout [179] to develop his model of ringfort distributions in Ireland (Section 3.6). This is advantageous in that it allows for a comparison of the results between this study and that produced by Stout [180].

The cluster analysis technique employed here (Ward’s method optimised with \( k \)-means cluster analysis) is repeatable for ringforts in other areas in Ireland, and represents a considerable improvement on Stout’s previous use of cluster analysis, as the current application benefits from improved data preparation and storage facilitates, combined with greater analytical power of modern GIS technologies.

6.3 Data quality

In the current research, accuracy of the results of both the stepwise logistic regression and cluster analysis rely on the quality of the datasets. Steps were taken to ensure the quality of these data in terms of consistency and survey accuracy.

All soil measurements were collected from the National Soil Survey data at a scale of 1:250,000. These soil data provide soil information with consistency in scale and classification for each of the current study areas. Data from larger (1:50,000) scale soil surveys are available for Co. Meath and Co. Westmeath [59]. These data were not included in the current analysis as they do not cover all locations included in this research.

Slope, aspect, elevation, river, stream and lake locational data were collected from the OSI Discovery Series digital dataset. These data were acquired using a 10m contour interval. Procedures operating on these data within ArcInfo preserve the original accuracy of the dataset.

Site locations, including both those of Early Medieval ecclesiastical centres and
Ringforts were originally surveyed by the OSI in the 1:2,500 and 1:10,560 scale OSI maps [178]. The accuracy of these location data was found to be very reliable as they were initially mapped at a large scale of 1:10,560. In addition, a pilot field survey of sites within the Blackwater valley using a hand-held GPS confirmed the positional accuracy of these original surveys to be accurate (and see subsection 5.3.2).

Townland polygons were acquired from an OSI 1:50,000 scale dataset. The dataset was checked in ArcInfo for sliver polygons [35] and missing polygon label points, and none were found within this dataset. The centroid values (used to represent the centre position of a townland) were calculated in ArcInfo using the CLEAN procedure in ArcInfo's ArcEdit module. The CLEAN procedure assigns the label point for each townland polygon and places this label point in the polygon's centroid position. This procedure was selected as it can be consistently replicated for all townland data available in Ireland.

Distribution measurements were calculated using data from the ringfort sites dataset, Early Medieval ecclesiastical centres dataset, townland centroid locations and the measurement functions within ArcInfo. Consistency was ensured, as calculations were automated within ArcInfo. The procedures were warranted as they provide consistent results and can be replicated in other case study areas if required. The alternative—to gather these measurements manually—would introduce inconsistent measurements in addition to labour intensive calculations.

Ringfort morphological measurements were recorded from a combination of ASI archives, published county archaeology inventories (e.g., [131], [140]) and measurements from ringfort plans on the 1:2,500 and 1:10,560 scale OSI maps. Consistent measurements for both maximum internal and maximum overall diameter were gathered by using measurements obtained from the 1:2,500 and 1:10,560 scale OSI maps. Morphological measurements recorded on the 1:2,500 and 1:10,560 scale OSI maps were accurately surveyed originally, as acknowledged by Stout [178] and field workers.
such as Healy [80]. Field surveys were not undertaken as a component of the current research in all three study areas, other than the pilot study already discussed, as the full dataset included over 1,300 ringforts for investigation and it was not possible to visit and survey all these sites.

Measurement of bank heights and fosse depths –recorded from the field survey reports held with the ASI– are the least accurate measurements in the dataset. This is because fosse depths and bank heights are highly susceptible to infill and ongoing erosion. Adding to this limitation, the measurements were provided by many different field archaeologists who did not all carry out their surveys or report their findings in a systematic manner. To account for measurement variation between the different ASI field surveyors, a categorical coding scheme (Table 5.11) was applied. While this categorical coding scheme reduced the measurement information slightly, it increased the consistency of the measurements from site to site.

### 6.4 Calculating relationships between sites and environment

Stepwise logistic regression [88] was used to identify the combination of independent environmental variables that appeared to exert the most influence over the location of ringforts. Stepwise logistic regression is a variant of stepwise linear regression. Stepwise logistic regression is based on a dependent variable coded in binary form [124] as either 0s or 1s, in comparison to stepwise linear regression, where the dependent variable can range from negative to positive infinity. In stepwise logistic regression, as in logistic regression, the relationship is non-linear, as the dependent variable cannot be less than 0 or more than 1 (along the $y$-axis). This numerical limitation results in a $S$-shaped probability curve [124] (Figure 6.1).

Stepwise logistic regression is flexible in so far that it can readily accept independent
Fig. 6.1: The S-shaped curve logistic regression model. All values must fall between 0, non-ringfort site locations, and 1, ringfort site locations.

variables of different data types (e.g., nominal, interval and ratio data), provided the nominal and interval data are coded as categorical variables [79]. The result of the logistic regression analysis produces an intercept value ($\alpha$) and a listing, either negative or positive, of regression coefficients ($\beta_i$) for all significant independent variables. In the current research, negative regression coefficients indicate a negative weighting, or land parcels less likely to have ringforts than those with a positive weighting. Positive regression coefficients equate to positive weighting, or land parcels more likely to have ringforts than those with a negative weighting. During the regression steps, significance levels were set to 0.05 and 0.10 for entry and removal from the model respectively. All variables in the resulting model had significance values less than or equal to 0.05 ($p \leq 0.05$). The values of the regression coefficients and the intercept are applied to the standard logistic regression equation (Equation 6.1). Using ArcInfo GIS software, the standard logistic regression equation was applied to the Environmental GRID.
surfaces to produce a probability value for any land parcel based on its combination of independent variables. The standard logistic regression equation and GRID surfaces can be used to generate a probability map that graphically depicts the archaeological sensitivity of land parcels, with respect to ringfort locations. Probabilities are given as a number that ranges between 0 (low probability) and 1 (high probability). In the current research, the central probability value 0.50 serves as the dividing point, or cut-off value, between ringforts and non-ringfort site locations. In an idealised logistic regression example, all high probability values will lie above 0.50 and all low probability values will lie below 0.50. The 0.50 cut-off value was selected as the model assessment calculations are based on this value, and it is standard practice in logistic regression [124]. In addition, the probability cut-off value is used within SPSS to assess the performance of the model, described further in Section 6.4.1.  

\[
p(B) = \frac{1}{1 + e^{-(\alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_i x_i)}} \tag{Equation 6.1}
\]

### 6.4.1 Validating modelled relationships

The validation of modelled relationships was based on a test of a null hypothesis that the independent variables (environmental data) were not related to the dependent variables (ringfort locations). Two statistics were utilised [124]: \( G_m \), or the model \( \chi^2 \), and \( R^2_L \). The statistic \( G_m \) is a measure of the overall accuracy or goodness of fit and identifies whether the model is able to make predictions beyond what can be attributed to chance. The requirements of this test of validation necessitate that the value of \( G_m \) is statistically significant (\( p \leq 0.05 \)). \( R^2_L \) identifies the strength of a relationship. Multiplying \( R^2_L \) by 100 yields a percentage value that indicates the improvement in

---

1 In Equation 6.1, \( p(B) \) is the probability (\( p \)) that the particular case \( i \) is a member of \( B \), where \( p(B) = 1 \) if it is true; \( e \) refers to Euler’s number, the natural logarithm of which is \( \ln(10) = 2.71828 \); \( \alpha \) is the intercept constant; \( \beta \) values are the regression coefficients for each of the independent variables; the values of \( x \) are the values of the independent variables for the matching \( \beta \) regression coefficient.
prediction when using the model in comparison to a chance prediction.

The predictive efficiency index $\lambda_p$ indicates the level of improved predictive capability from using the logistic regression model [124]. This statistic potentially ranges in positive values up to 1 and negative values of $1 - N$ cases. Positive values indicate the proportional reductions in error. Negative values indicate the proportional increase in error [124]. Before the $\lambda_p$ statistic can be used, the binomial statistic $d$ must be calculated [124] and evaluated for statistical significance. The calculation of the binomial statistic $d$ indicates whether the proportion, predicted incorrectly by the model, differs significantly from the proportion predicted incorrectly without the model. The null hypothesis for this calculation is that there is no significant difference between the proportional reduction in error and implies that the prediction of the dependent variable is not related to the values of the independent variables.

### 6.4.2 Assessing the model’s performance

According to Wheatley and Gillings [203], the best way to assess performance of a predictive model in archaeology is to compare the results of the model with archaeological site locations external to the development of the model, yet within the study same general area where the model was developed. Further assessment of the current predictive model used a random selection of 200 ringfort site locations and 200 non-ringfort site locations from the Inny River catchment study area, separate to those 778 ringfort and 778 non-ringfort site locations used in initial development of the model. In addition, a further test of predictive capability involved extending the model to the neighbouring study areas in the Blackwater valley and Lough Ramor catchment study areas. In both tests, the predictive capability of the model was evaluated by calculating the number and percentage of ringfort sites found in locations with predicted probabilities in excess of 0.50 (expected location of a ringfort site), and calculating the proportion of non-ringfort sites locations found in locations with
predicted probabilities below 0.50 (expected locations avoided by those who constructed ringforts).

6.5 Cluster analysis of ringfort data

Ringforts in this study feature twelve variables (Table 5.10), which were used to form clusters. In the current research, a cluster is simply a group of ringforts that are most readily related, based on the value of their associated variables. Cluster analysis is the analysis of the resulting clusters. Initially the process begins by treating each case as a separate cluster [3] and, in a step-by-step fashion, fuses cases and then clusters until a single large cluster is created. The technique is best illustrated using a dendrogram (Figure 6.2). On the left of the dendrogram, numerous cases are present, each representing individual entities. Towards the right of the dendrogram, larger groupings occur as the classification criteria for distinguishing between the separate entities and clusters relaxes. On the far right, eventually only one large cluster is produced, representing the entire dataset as one cluster. In the current research the upper limit of clusters for each study area was set at five (the number of groups of ringfort previously identified by Stout [180]).

Cluster analysis was used in the current research to classify ringforts into homogeneous groups, or clusters, within each of the three case study areas. The resulting clusters from each study area were compared to highlight differences in morphology, location and distribution characteristics of ringforts. In addition the clusters were compared to those produced by Stout (detailed in Section 3.6) [180]. This comparison is possible given the methodological similarities between the current research and Stout’s study [179], notwithstanding the fact that the results from any cluster analysis are a product of the content of the dataset, the nature of the statistical algorithms applied, and the interpretation by the researcher.
Fig. 6.2: This sample dendrogram illustrates the agglomerative clustering method. The process begins with each case as a separate entity and in a set-by-step fashion merges cases into clusters and small clusters into large clusters, eventually resulting in one large cluster; as seen on the right side of this diagram.

### 6.5.1 Techniques of cluster analysis

One third of the ringfort sites in the current research had been (in part or in whole) damaged since they ceased to be occupied. Damaged ringforts often do not provide all of the desired morphological variables, and ringforts featuring missing morphological variables were removed from the cluster analysis in Stout’s research [177], [179]. ClustanGraphics 7.01, the software used for cluster analysis in the current research, is capable of operating with datasets that include cases with missing variables [207]. In the current research, cases with missing variables were included in the analysis.

Separate datasets for each of the three study areas were imported into ClustanGraphics 7.01. These datasets contained a unique code for each ringfort and a listing of variables associated with each site (Table 5.9). During importation, all ringfort variables were standardised to z-score values (Equation 6.2) using a feature within ClustanGraphics 7.01. Because of the large variance in the ranges of variables (e.g.,
distance to Early Medieval ecclesiastical centre) all variables were transformed to $z$-score values (Equation 6.2). This transformation had the effect of standardising all variables to the same scale [3].

\[ z_i = \frac{x_i - \bar{x}}{\sigma} \]  

(Equation 6.2)

### 6.5.2 Applied clustering procedure

As stated in Chapter 2, the current research involves a combination of Ward’s method and $k$-means cluster analysis. Multiple cluster methods were not used in this thesis as they would deviate from those methods used by Stout. Multiple cluster methods may be applied to these data in future research, however, for this research only Ward’s method will be applied. Using Ward’s method, pairs of cases are fused to form clusters based on the identification of the pair that minimises the Squared Euclidean increase in the ESS [56]. The process begins with individual cases, where the ESS value is zero, and continues to merge clusters in a stepwise manner until only one large cluster remains. Clustering data using Ward’s method is described as an agglomerative process [3], whereby each step in the clustering process requires the fusion of preceding clusters. A limitation of agglomerative methods is that when cases are included into clusters early in the process, they remain in that branch (e.g., Figure 6.2), even if at a later stage they are better suited in other clusters. The $k$-means optimisation procedure is used in the current research to correct for this limitation.

$K$-means cluster analysis optimises clusters by moving cases into other clusters within which they have a greatest affinity. The process identifies the cases that need to move by computing the distances between individual cases and the means of all clusters. If a case within one cluster is discovered to be closer to the mean of another cluster, it is relocated to that other cluster. After every move, the composition of clusters change, and as a result cluster means must be recalculated. The process is
repeated until all clusters become stable and cases no longer move.

In the current research, Ward’s method produced an initial structure of five clusters that were later optimised using \( k \)-means cluster analysis. Specifically, \( k \)-means cluster analysis is an iterative process that operates in the following manner:

- **Step 1** – an initial number (\( k \)) of clusters to optimise is prescribed. The prescribed number of clusters contain those grouped together using Ward’s method.

- **Step 2** – the distance from each case to the mean of the cluster is computed and cases are reassigned to the closest cluster.

- **Step 3** – cluster means are calculated following any change of cluster membership at step 2.

- **Step 4** – steps 2 and 3 are repeated until no changes occur in the cluster membership and a stable number of clusters is produced [113].

### 6.5.3 Classification descriptions

Within the current research, the finished cluster analysis model consisted of five homogenous clusters per study site. No specification as to what these groups would contain was setup in advance of the cluster analysis.

To identify the types of ringforts contained within each cluster, each cluster was examined and described separately. Initially clusters were characterised by the cluster exemplar. The cluster exemplar, or exemplary cases, are the most typical or modal case associated with each cluster (i.e., they are the cases that are the closest to the mean for each cluster). Exemplary cases are selected at the final stage of the \( k \)-means analysis in ClustanGraphics 7.01.
In addition to exemplary cases, clusters were also described using $F$-ratio and $t$-value values. These values were calculated for each variable within each cluster. The $F$-ratio calculations provided an indication of the variables that are most similar and have the closest range of values within each cluster. $F$-ratio values were calculated by dividing the standard deviation of each variable, per cluster, by the overall standard deviation of that variable. A variable that is calculated as 1 indicates a random distribution. Values less than 1 indicate a clumping of values.

$T$-value calculations provided an indication of how different the variables within a cluster are from their associated variables within the overall distribution. The $t$-values were calculated by subtracting the mean of the particular variable within a cluster from the overall mean. The resulting value was then divided by the standard deviation for all variables within the cluster. A $t$-value of 1.0 is the expected product of random sampling. Positive $t$-values indicate the degree to which the mean within the cluster is greater than the overall mean. Negative $t$-values indicate the degree to which these values are less than the overall mean. A $t$-value of zero implies the mean value for the variable in the particular cluster is identical to the overall mean for the same variable in the entire dataset. $T$-values will increase in value both positively or negatively, as the difference between the cluster mean and overall mean increases in magnitude.

To describe each cluster in the current research the five smallest $F$-ratios and five largest $t$-values were listed. Only the first five $F$-ratio values and first five $t$-values were used to examine the clusters to concentrate and summarise the amount of information describing each cluster. These values thus indicate those variables that best characterise the ringforts within each cluster.
Chapter 7

Results

7.1 Introduction

This chapter presents the results of both the stepwise logistic regression and the cluster analysis procedures detailed in the previous chapter. The stepwise logistic regression model describes the environments that appear to have influenced where ringforts were located. Non-ringfort site locations were not analysed in the current research. The cluster analysis model describes the differences in types of ringforts in terms of morphology, location and distribution.

7.2 Relationship between sites and environment

Of the thirty independent environmental variables originally selected (Table 5.8), stepwise logistic regression analysis identified nineteen as unimportant for ringfort location in the Inny River catchment (Table 7.1). These nineteen variables were not incorporated in the model, and not considered further (Section 6.4). The remaining eleven variables, including categories of elevation, slope and soil, were found to have a significant influence. These variables, along with their corresponding regression
Table 7.1: Environmental variables not found to have a significant relationship with ringfort locations (see Table 5.8).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOPES (β)</td>
<td>+ 0.355(SLOPE3) - 1.189(SLOPE5)</td>
</tr>
<tr>
<td>ELEVATION (β)</td>
<td>+ 0.026(ELEV)</td>
</tr>
<tr>
<td>SOIL ASSOCIATION (β)</td>
<td>+ 0.762(SOIL14) + 1.605(SOIL28) + 1.669(SOIL30) + 1.545(SOIL31) + 0.166(SOIL34) + 1.361(SOIL37) + 2.98(SOIL39)</td>
</tr>
<tr>
<td>INTERCEPT CONST. (α)</td>
<td>- 3.699</td>
</tr>
</tbody>
</table>

Table 7.2: Regression coefficients (β) and intercept constant (α) entered into the modelling equation (Equation 6.1).

coefficients and the intercept constant, are shown in Table 7.2.

7.2.1 Stepwise logistic regression model validation and performance

The test for validation of the modelled relationships, $G_m$, was statistically significant at 245.39 (significance $p = 0.001$). This high level of significance allows for the rejection of the null hypothesis, and indicates that the dependent variables are significantly related to the independent variables. A moderately weak relationship is suggested by the value of $R^2_L$, which was calculated at 0.1138 (based on a -2 Log likelihood of 1911.68), or 11.38%. The test of predictive efficiency generated a binomial statistic, $d$, of 12.03 (significance $p = 0.001$), thus supporting the rejection of the null hypothesis. The value of $\lambda_p$ is equal to 0.29, indicating a relatively slight reduction in the prediction error.
7.2.2 Probability surface

Probability values were calculated for all 20×20m grid cells in the Inny River catchment and extended to the Blackwater valley and Lough Ramor catchment study area. These probability values range from 0.00 to 1.00 and are represented as a graphical surface (Figure 7.1). This surface was created using the regression coefficients (Table 7.2), their associated ArcInfo environmental GRID layers and the standard logistic regression equation (Equation 6.1). A probability value of 0.50 was used as the cut-off value between ringfort and non-ringfort site locations. Thus, in Figure 7.1 the range 0.83–0.99 indicates a very high probability of ringfort occurrence, whereas values of 0.02–0.16 indicate a very low probability of ringfort occurrence, and therefore a high probability of there being no ringforts sited in that area.

7.2.3 Evaluation of model in the Inny River catchment case study area

Evaluation of the performance of the stepwise logistic regression model used the probability surface and ringfort and non-ringfort site locations. Two tests were formed: The first used locations that had been used to develop the model, while the second used locations that had been withheld during the development of the model. Again a probability cut-off value of 0.50 was used to discriminate between probability values for ringfort and non-ringfort site locations. For locations used to develop the model, a total of 64% (500 out of a total of 778) of the ringfort site locations were found in areas with probability values in excess of 0.50. Sixty-five percent (505 out of a total of 778) of the non-ringfort site were found in areas with probability values below the 0.50 cut-off. For locations within the Inny River catchment, withheld from the development of the model, a total of 90% (180 out of 200) of randomly selected ringfort sites were found in locations with probability values in excess of the 0.50 cut-
Fig. 7.1: Probability surface modelling the siting of ringforts. The surface was developed using a sample of 778 ringforts and 778 non-ringfort site locations in the Inny River catchment study area. The Blackwater valley and Lough Ramor catchment study areas are used as two comparative areas for evaluation of the model’s performance. The cartographic surface represents different probabilities of ringfort locations.
off value. Sixty-nine (137 out of a total of 200) of randomly selected, non-ringfort site locations were found in areas with probability values below 0.50.

### 7.2.4 Evaluation of the model in neighbouring study areas

Evaluation of the model in the Blackwater valley and Lough Ramor catchment study areas yielded the following results when compared to actual locations of ringforts and randomly selected locations. Within the Blackwater valley study area, 45 randomly selected ringfort locations and 45 randomly selected non-ringfort site locations were assessed. A total of 13% (6 out of 45) ringfort locations were found in areas with probability values in excess of 0.50, and a total of 87% (39 out of a total of 45) of the non-ringfort site locations were found in areas with probability values below 0.50. From a random sample of 100 ringforts and 100 non-ringfort site locations in the Lough Ramor catchment study area 76% of the ringfort locations were found in areas with probability values in excess of 0.50, and 41% of the non-ringfort locations were located in areas with probability values below 0.50.

The difference between the results in these two separate case study areas indicates that predictions from this model have a tendency to be erratic. The errors in these predictions are the product of a model with moderately weak $R^2_L$ and $p$ values, as well as differences in terrain composition and ringfort distributions within each of the study areas as, discussed in Sections 4.2 through 4.3. These results indicate that the predictions from this model must be used with caution. Nevertheless, the success of the model is demonstrated by the cartographic output compared to the actual distributions of ringforts. The lower probability values (i.e., values below 0.50) are predominately mapped throughout the majority of the Blackwater valley study area. These lower values predict low densities of ringfort sites for this area. Higher probabilities (i.e., those above 0.50) are predominantly mapped throughout the majority of the Lough Ramor catchment study area. The higher values predict higher densities of ringfort
sites for this area. These results are broadly in line with recorded, extant distributions of ringforts in the two study areas.

7.3 Cluster analysis

Ringforts were classified into one of five clusters or categories within each of the three case study areas using the software package ClustanGraphics 7.01, as described in Chapter 6. Summary statistics for the clusters, including mean values, standard deviations, \textit{t-values} and \textit{F-ratio}, were calculated using Microsoft Excel 11.0.

The clusters of ringforts for each study area are described in the subsections that follow. In these descriptions, categorically coded measurements are used to refer to: circularity, fosse depth and bank height (see Table 5.11). Slope values in the cluster descriptions are provided in degrees of slope and are not referenced to any categorical scale. Table 7.3 summarises the contents of each cluster according to mean values, \textit{t-values} and \textit{F-ratio} values calculated for each cluster.

Maps illustrating the locations of ringforts are provided for each study area (Figures 7.2, 7.6 and 7.10). In these maps, ringforts are symbolised by their designated cluster numbers. Several box-plots graphically summarising the variables comprising each cluster are also provided for each separate study area.

7.4 Classification of ringforts in the Blackwater valley case study area

Figure 7.2 illustrates the distribution of ringforts according to the five types of clusters identified in the cluster analysis and described below. All descriptions of clusters in the following subsections relate only to ringforts within the Blackwater valley case study area, and are based on an exemplary ringfort for each cluster and variables associated
<table>
<thead>
<tr>
<th>Study Site</th>
<th>Var.</th>
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<th>Overall</th>
<th>Cluster no.</th>
<th>Cluster no.</th>
<th>Cluster no.</th>
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</thead>
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<td>σ</td>
<td>μ</td>
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<td>II</td>
<td>III</td>
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<tr>
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Table 7.3: Summary of the results of cluster analysis for ringflats in each of the three study areas in the current research, 1. Blackwater valley (BWV) 2. Inny River catchment (IRC); and 3. Lough Ramor catchment (LRC). The mean, F-ratio and t-value variables are provided for each cluster and associated variables.
with the five lowest \textit{F-ratio} and the five \textit{t-values} of greatest magnitude in each cluster.

A complete listing of the summary statistics and associated \textit{F-ratio} and \textit{t-values} for each cluster is provided (Table 7.3, Blackwater valley).

All variables within each cluster are summarised in the box-plot diagrams in Figures 7.3, 7.4 and 7.5.

\subsection*{7.4.1 Cluster number I}

The first cluster comprises 29\% (17 out of a total of 58) of the total number of ringforts within the Blackwater valley study area. Measurements for the five lowest \textit{F-ratios} and five \textit{t-values} of greatest magnitude for cluster number I –Blackwater valley– are listed in Table 7.4.

The exemplary –or typical– ringfort characterising cluster number I is located within the townland of Leggah, Co. Meath. It is oval in shape and has maximum internal and overall diameters measuring 51m and 61m, respectively. This ringfort is univallate, features a low BankI height and a trace fosse depth, and is located on terrain with a 0.7° slope and an elevation of 73m AMSL. In addition, its associated townland and parish are 420ha and 2290ha in area, respectively. In terms of distribution, the exemplary ringfort is located at a distance of 860m from the nearest neighbouring ringfort and at a distance of 1180m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for this site is 0.17.

\subsection*{7.4.2 Cluster number II}

The second cluster accounts for 38\% (22 out of a total of 58) of the total number of ringforts within the Blackwater valley study area. Measurements for the five lowest \textit{F-ratios} and five \textit{t-values} of greatest magnitude for cluster number II –Blackwater valley– are provided in Table 7.5.
Fig. 7.2: Distribution of the ringforts within the Blackwater valley case study area. These ringforts are symbolised in the above map according to the five groups identified using $k$-means cluster analysis in the current research.
Fig. 7.3: Box-plots featuring ringfort morphological variables within each of the five separate clusters calculated for the ringforts within the Blackwater valley study area. Asterisks represent outlier values.
Fig. 7.4: Box-plots featuring ringfort locational variables within each of the five separate clusters calculated for the ringforts with the Blackwater valley study area. Asterisks represent outlier values.
Fig. 7.5: Box-plots featuring ringfort distributional variables within each of the five separate clusters calculated for the ringforts within the Blackwater valley study area. Asterisks represent outlier values.
Cluster Standard F-ratio

Variable mean deviation

0.81 Maximum overall diameter 70m ± 14
0.69 Fosse depth 1 ± 0.7
0.77 Slope 1.3° ± 1.3
0.87 Altitude (AMSL) 80m ± 20
0.37 Centrality index 0.14 ± 0.07

Table 7.4: The five smallest F-ratios and five t-values of greatest magnitude as well as associated summary statistics –cluster number I, Blackwater valley study area.

The exemplary ringfort typifying the second cluster is located within the townland of Farranadoony, Co. Meath. This ringfort is nearly-circular, features maximum internal and overall diameters of 25m and 32m, respectively, has one low bank, a trace fosse depth, and is sited on a slope of 0.8° at an elevation of 67m AMSL. The associated townland and parish are 84ha and 2678ha in area, respectively. This exemplary ringfort is located on the periphery of its townland, as indicated by a centrality index value of 0.16 and a distance of 706m to the townland centre. In addition this site is located a distance of 375m from the nearest neighbouring ringfort site and a distance of 1645m from the nearest Early Medieval ecclesiastical centre.

7.4.3 Cluster number III

Cluster number III accounts for 15% (9 out of a total of 58) of the total number of ringforts within the Blackwater valley study area. The measurements for the five lowest F-ratios and five t-values of greatest magnitude for cluster number III –Blackwater valley– are listed in Table 7.6.
Cluster Standard F-ratio Variable mean deviation
1.04 BankI height 3 ± 1.4
0.87 Fosse depth 1 ± 1.1
0.92 Townland size 268ha ± 200
0.92 Parish size 6844ha ± 3980
1.04 Centrality index 0.17 ± 0.1

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<td>-1.20</td>
<td>Maximum internal diameter</td>
<td>31m</td>
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<tr>
<td>-1.28</td>
<td>Maximum overall diameters</td>
<td>41m</td>
<td>± 9</td>
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<tr>
<td>-0.71</td>
<td>Slope</td>
<td>0.8°</td>
<td>± 0.7</td>
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<td>-0.83</td>
<td>Centrality index</td>
<td>0.17</td>
<td>± 1.8</td>
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<td>1.27</td>
<td>Distance to the townland centre</td>
<td>750m</td>
<td>± 408</td>
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**Table 7.5**: The five smallest *F-ratios* and five *t-values* of greatest magnitude along with associated summary statistics for cluster number II, Blackwater valley.

The exemplary ringfort typifying this cluster is located within the townland of Raffin, Co. Meath. It is nearly-circular and features maximum internal and overall diameters of 38m and 53m, respectively, is univallate with a low BankI and features a fosse that is completely filled-in. The areas of the associated townland and parish are 111ha and 2692ha, respectively. The exemplary site is situated on a slope of 0.8°, at an elevation of 80m AMSL, a distance of 822m from its nearest neighbouring ringfort, a distance of 108m from the townland centre and a distance of 1727m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for this site was calculated at 0.69.

### 7.4.4 Cluster number IV

Cluster number IV accounts for 12% (7 out of a total of 58) of the total number of ringforts in the Blackwater valley study area. The measurements for the five lowest *F-ratios* and five *t-values* of greatest magnitude for cluster number IV –Blackwater valley– are given in Table 7.7.
Cluster Standard F-ratio Variable mean deviation

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<th>Cluster mean</th>
<th>Standard deviation</th>
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<td>Circularity index</td>
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<tr>
<td>0.42</td>
<td>Maximum overall diameter</td>
<td>51m ± 7</td>
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<tr>
<td>0.44</td>
<td>Fosse depth</td>
<td>0.5 ± 0.4</td>
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<tr>
<td>0.33</td>
<td>Slope</td>
<td>0.6° ± 0.6</td>
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<tr>
<td>0.47</td>
<td>Centrality index</td>
<td>0.54 ± 0.2</td>
<td></td>
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</table>

\[-0.70 \text{ Circularity index} \quad 2 ± 0.6
\[-1.80 \text{ Fosse depth} \quad 0 ± 0.4
\[-1.23 \text{ Slope} \quad 0.6° ± 0.6
\[1.49 \text{ Centrality index} \quad 0.54 ± 0.2
\[-1.93 \text{ Distance to townland centre} \quad 288m ± 212

\textbf{Table 7.6:} The five smallest \textit{F-ratios} and five \textit{t-values} of greatest magnitude along with associated summary statistics for cluster number III, Blackwater valley.

The exemplary ringfort characterising this cluster is located within the townland of Rahendrick, Co. Meath. It is nearly-circular, features maximum internal and overall diameters of 32m and 40m, and is univallate. The exemplary site features a low BankI, a filled in fosse, and is located within a townland of 195ha and a parish of 5114ha. In addition, this exemplary site is situated on terrain with a slope of 3° at an elevation of 98m AMSL, and is 820m from its nearest neighbouring ringfort 930m from the townland centre and 2519m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for this exemplary site is 0.35.

\textbf{7.4.5 Cluster number V}

Cluster number V accounts for 5\% (3 out of a total of 58) of the total number of ringforts in the Blackwater valley study area. The measurements for the five lowest \textit{F-ratios} and five \textit{t-values} of greatest magnitude for cluster number V –Blackwater valley– are shown in Table 7.8.

The exemplary ringfort typifying the fifth cluster is located within the townland
of Moat, Co. Meath and is nearly-circular. It has a maximum internal and overall diameters of 56m and 80m, respectively. The exemplary ringfort is bivallate, features two substantial banks and a fosse of moderate depth, and is associated with a townland and parish areas of 137ha and 4242ha, respectively. It is sited on a 4° slope and at an elevation of 121m AMSL. In addition, this exemplary ringfort is located 734m from its nearest neighbouring ringfort, 354m from the townland centre and 2724m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for this exemplary ringfort is 0.42.

7.5 Classification of ringforts in the Inny River catchment case study area

Figure 7.6 illustrates the distribution of ringforts –in the north of the Inny River catchment– according to the five types of clusters identified in the cluster analysis and described below. All descriptions of cluster in the subsections following relate only

Table 7.7: The five smallest $F$-ratios and five $t$-values of greatest magnitude along with associated summary statistics for cluster number IV, Blackwater valley.
Table 7.8: The five smallest $F$-ratios and five $t$-values of greatest magnitude along with associated summary statistics for cluster number V, Blackwater valley.

to ringforts within the Inny River catchment study area, and are based on an exemplary ringfort for each cluster and variables associated with the five lowest $F$-ratio and the five $t$-values of greatest magnitude in each cluster.

A complete listing of the summary statistics and associated $F$-ratio and $t$-values for each cluster is provided in Table 7.3 (see Inny River catchment (IRC)). All variables within each cluster are summarised in the box-plot diagrams (Figures 7.7–7.9).

### 7.5.1 Cluster number I

Cluster number I represents 13% (138 out of 1070) of the total number of ringforts in the Inny River catchment study area. The measurements for the five lowest $F$-ratios and five $t$-values of greatest magnitude for cluster number I –Inny River catchment– are provided in Table 7.9.

The exemplary ringfort typifying this cluster is located within the townland of Kilgawny, Co. Westmeath. It is oval in shape, has maximum internal and overall diameters of 68m and 77m, respectively, is univallate and features a moderately-high
Fig. 7.6: Distribution of ringforts classified into the five groups according to the cluster analysis model for ringforts in the Inny River catchment study area used in the current research. This diagram shows the northern portion of the Inny River catchment study area only.
Fig. 7.7: Box-plots of ringfort morphological variables within each of the five separate clusters calculated for the ringforts within the Inny River catchment study area. Asterisks represent outlier values.
Fig. 7.8: Box-plots of ringfort locational variables within each of the five separate clusters calculated for the ringforts with the Inny River catchment study area. Asterisks represent outlier values.
Fig. 7.9: Box-plots of ringfort distributional variables within each of the five separate clusters calculated for the ringforts within the Inny River catchment study area. Asterisks represent outlier values.
Table 7.9: The five smallest $F$-ratios and five $t$-values of greatest magnitude along with associated summary statistics for cluster number I, Inny River catchment.

BankI and a trace fosse depth. This exemplary ringfort is located within a townland of 215ha, a parish of 4220ha and on a slope of 0.3° at an elevation of 90m AMSL. It is located 394m from its nearest neighbouring ringfort site, 788m from the townland centre and 2143m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value 0.04.

### 7.5.2 Cluster number II

The second cluster accounts for 26% (278 out of 1070) of the total number of ringforts in the Inny River catchment study area. The measurements for the five lowest $F$-ratios and five $t$-values of greatest magnitude for cluster number II –Inny River catchment– are listed in Table 7.10.

The exemplary ringfort typifying this cluster is sited within the townland of Gigginstown, Co. Westmeath. It is nearly-circular, features maximum internal and overall diameters measuring 35m and 43m, respectively is univallate and has a moderately-high BankI and an in-filled fosse. In addition, its associated townland and parish are
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<td>± 1</td>
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<tr>
<td>0.31</td>
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<td>± 0</td>
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<tr>
<td>0.67</td>
<td>Slope</td>
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<td>0.39</td>
<td>Centrality index</td>
<td>0.11</td>
<td>±0.07</td>
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$-0.54$ Maximum internal diameter 33m ± 7
$1.22$ Circularity index 3 ± 1
$-0.96$ Maximum overall diameter 44m ± 9
$-2.08$ Centrality index 0.11 ± 0.07
$0.88$ Distance to townland centre 908m ± 378

**Table 7.10**: The five smallest $F$-ratios and five $t$-values of greatest magnitude along with associated summary statistics for cluster number II, Inny River catchment.

228ha and 8145ha in area, respectively. It is located on a 0.6° slope, at an altitude of 102m AMSL and at a distance of 408m from its nearest neighbouring ringfort. This site is 848m from the townland centre and 2060m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for this exemplary ringfort was calculated at 0.7.

### 7.5.3 Cluster number III

Cluster number III accounts for 28% (296 out of 1070) of the total number of ringforts in the Inny River catchment study area. The measurements for the five lowest $F$-ratios and five $t$-values of greatest magnitude for cluster number III –Inny River catchment– are provided in Table 7.11.

The exemplary ringfort characterising this cluster is sited within the townland of Aghacreavy, Co. Cavan. It is nearly-circular and features maximum internal and overall diameters measuring 35m and 45m, respectively, is univallate with one moderately-high bank, a trace fosse. The areas of the associated townland and parish are 58ha.
Cluster number III

The exemplary ringfort is located on a 0.3° slope at an elevation of 68m AMSL, a distance of 98m from its nearest neighbouring ringfort, a distance of 478m from the townland centre and 2749m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for this exemplary site was calculated at 0.17.

### 7.5.4 Cluster number IV

Cluster number IV accounts for 22% (232 out of 1070) of the total number of ringforts in the Inny River catchment study area. The measurements for the five lowest \( F\)-ratios and five \( t\)-values of greatest magnitude for cluster number IV –Inny River catchment– are provided in Table 7.12.

The exemplary ringfort characterising cluster number IV is sited within the townland of Rackavra, Co. Westmeath. It is oval, features maximum internal and overall diameters measuring 33m and 40m, respectively and is univallate. The exemplary site features a moderately-high BankI, an in-filled fosse, and is located within a townland.
Cluster Standard F-ratio
Variable mean deviation
0.68 Maximum internal diameter 34m ± 8
0.43 Circularity index 3 ± 1
0.31 BankII height 0 ± 0
0.73 Centrality index 0.38 ± 0.19
0.69 Distance to townland centre 412m ± 245
t-value
1.30 Circularity index 3 ± 1
-0.66 Maximum overall diameter 41m ± 11
-0.91 BankII height 0 ± 0
1.25 Slope 3.4° ± 3.4
-0.66 Distance to townland centre 412m ± 245

Table 7.12: The five smallest F-ratios and five t-values of greatest magnitude along with associated summary statistics for cluster number IV, Inny River catchment.

of 260ha and a parish of 11281ha. In addition, this exemplary site is located on a 3° slope at an altitude of 122m AMSL and is 203m from its nearest neighbouring ringfort, 4400m from the townland centre and 1790m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for this exemplary site was calculated at 0.28.

7.5.5 Cluster number V

Cluster number V accounts for 12% (126 out of 1070) of the total number of ringforts in the Inny River catchment study area. The measurements for the five lowest F-ratios and five t-values of greatest magnitude for cluster number V –Inny River catchment– are provided in Table 7.13.

The exemplary ringfort characterising cluster number V is sited within the townland of Raheen, Co. Westmeath and is oval in shape. It has maximum internal and overall diameters measuring 42m and 55m, respectively. This exemplary ringfort is bivallate, features a high BankI, a moderately-deep fosse, a moderately-high BankII and is
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<td>0.89</td>
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<td>-0.87</td>
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<td>± 97</td>
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Table 7.13: The five smallest $F$-ratios and five $t$-values of greatest magnitude along with associated summary statistics for cluster number V, Inny River catchment.

associated with a townland and parish of 274ha and 10465ha, respectively. It is sited on a slope of 2.2° at an elevation of 100m AMSL. In addition, this exemplary ringfort is located 488m from the nearest neighbouring ringfort, 598m from the townland centre and 3371m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for this exemplary ringfort is 0.34.

7.6 Classification of ringforts in the Lough Ramor catchment case study area

Figure 7.10 illustrates the distribution of ringforts –in the southeast part of the Lough Ramor catchment– according to the five types of clusters identified in the cluster analysis and is described below. All descriptions of clusters in the following subsections only relate to ringforts within the Lough Ramor catchment study area, and are based on an exemplary ringfort for each cluster and variables associated with the five lowest $F$-ratio and the five $t$-values of greatest magnitude in each cluster.
A complete listing of the summary statistics and associated $F$-ratio and $t$-values for each cluster is provided in Table 7.3 (see Lough Ramor catchment (LRC)). All variables within each cluster are summarised in the box-plot diagrams Figures 7.11–7.13.

### 7.6.1 Cluster number I

Cluster number I represents 13% (24 out of 186) of the total number of ringforts in the Lough Ramor catchment study area. The measurements for the five lowest $F$-ratios and five $t$-values of greatest magnitude for cluster number I–Lough Ramor catchment–are provided in Table 7.14.

The exemplary ringfort characterising this cluster is located within the townland of Lurganboy, Co. Cavan. It is circular in shape and has maximum internal and overall diameters measuring 50m and 59m, respectively. This exemplary ringfort does not have a recorded fosse depth or any recorded bank heights. It is located within a townland and parish of 113ha and 7432ha, respectively, and is situated on a slope of 1.6°, at an elevation of 160m AMSL. Furthermore it is located 437m from its nearest neighbouring ringfort, 659m from the townland centre and 1721m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for the exemplary ringfort for cluster number I is 0.27.

### 7.6.2 Cluster number II

The second cluster accounts for 31% (58 out of 186) of the total number of ringforts in the Lough Ramor catchment study area. Measurements for the five lowest $F$-ratios and five $t$-values of greatest magnitude for cluster number II–Lough Ramor catchment–are provided in Table 7.15.

The exemplary ringfort typifying cluster number II is sited within the townland of Annagharnet, Co. Cavan. This exemplary ringfort is nearly-circular, features maximum internal and overall diameters of 35m and 44m, respectively. The exemplary ringfort
Fig. 7.10: Distribution of ringforts in the south east region of the Lough Ramor catchment case study area. Ringforts have been classified into the five groups according to the cluster analysis model generated in ClustanGraphics 7.01.
Fig. 7.11: Box-plots featuring ringfort morphological variables within each of the five separate clusters calculated for the ringforts within the Lough Ramor catchment case study area. Asterisks represent outlier values.
Fig. 7.12: Box-plots featuring ringfort locational variables within each of the five separate clusters calculated for the ringforts with the Lough Ramor catchment case study area. Asterisks represent outlier values.
Fig. 7.13: Box-plots featuring ringfort distributional variables within each of the five separate clusters calculated for the ringforts within the Lough Ramor catchment case study area. Asterisks represent outlier values.
Table 7.14: The five smallest \textit{F-ratios} and five \textit{t-values} of greatest magnitude along with associated summary statistics for cluster number I, Lough Ramor catchment.

does not have any recorded bank heights or fosse depths, is located within a townland of 217ha, a parish of 12872ha and on a 3.4° slope at an elevation of 150m AMSL. In addition, this ringfort is located 470m from the nearest neighbouring ringfort, 620m from the townland centre and 6460m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for this exemplary ringfort was calculated at 0.25.

7.6.3 Cluster number III

Cluster number III accounts for 20% (38 out of 186) of the total number of ringforts recorded in the Lough Ramor catchment study area. The measurements for the five lowest \textit{F-ratios} and five \textit{t-values} of greatest magnitude for cluster number III –Lough Ramor catchment– are provided in Table 7.16.

The exemplary ringfort typifying this cluster is located within the townland of Killeter, Co. Cavan. It is nearly-circular, features maximum internal and overall diameter of 32m and 41m, respectively, is univallate with a low BankI and an in-
<table>
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<td>Fosse depth</td>
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<td>BankII height</td>
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<td>±0</td>
</tr>
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<td>904m</td>
<td>±204</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>t-value</th>
<th>Variable</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.88</td>
<td>Maximum overall diameter</td>
<td>39m</td>
<td>±3</td>
</tr>
<tr>
<td>-0.57</td>
<td>BankI height</td>
<td>1</td>
<td>±1</td>
</tr>
<tr>
<td>-0.78</td>
<td>Fosse depth</td>
<td>0</td>
<td>±1</td>
</tr>
<tr>
<td>-1.59</td>
<td>BankII height</td>
<td>0</td>
<td>±0</td>
</tr>
<tr>
<td>0.60</td>
<td>Altitude (AMSL)</td>
<td>155m</td>
<td>±19</td>
</tr>
</tbody>
</table>

Table 7.15: The five smallest F-ratios and five t-values of greatest magnitude along with associated summary statistics for cluster number II, Lough Ramor catchment.

filled fosse. The areas of the associated townland and parish are 245ha and 12872ha, respectively. The exemplary site is situated on a slope of 0.1° at an elevation of 121m AMSL. It is a distance of 629m from its nearest neighbouring ringfort, 1172m from the townland centre and 2585m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for this exemplary ringfort was calculated at 0.18.

7.6.4 Cluster number IV

Cluster number IV accounts for 19% (35 out of 186) of the total number of ringforts recorded in the Lough Ramor catchment study area. The measurements for the five lowest F-ratios and five t-values of greatest magnitude for cluster number IV –Lough Ramor catchment– are provided in Table 7.17.

The exemplary ringfort characterising this cluster is sited within the townland of Gallonnabrahner, Co. Cavan. It is nearly-circular in shape, features a maximum internal and overall diameter measuring 37m and 48m, respectively, and is univallate. The exemplary site features a substantial-high BankI, a shallow fosse depth and is
Table 7.16: The five smallest \textit{F-ratios} and five \textit{t-values} of greatest magnitude along with associated summary statistics for cluster number III, Lough Ramor catchment.

<table>
<thead>
<tr>
<th>\textit{F-ratio}</th>
<th>Variable</th>
<th>Cluster mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.59</td>
<td>Maximum internal diameter</td>
<td>30m</td>
<td>± 5</td>
</tr>
<tr>
<td>0.45</td>
<td>Maximum overall diameter</td>
<td>39m</td>
<td>± 4</td>
</tr>
<tr>
<td>0.00</td>
<td>BankII height</td>
<td>0</td>
<td>± 0</td>
</tr>
<tr>
<td>0.57</td>
<td>Altitude (AMSL)</td>
<td>113m</td>
<td>± 15</td>
</tr>
<tr>
<td>0.57</td>
<td>Centrality Index</td>
<td>0.17</td>
<td>±0.12</td>
</tr>
</tbody>
</table>

\textit{t-value}

<table>
<thead>
<tr>
<th>\textit{t-value}</th>
<th>Variable</th>
<th>Cluster mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.26</td>
<td>Maximum overall diameter</td>
<td>39m</td>
<td>± 4</td>
</tr>
<tr>
<td>-1.98</td>
<td>Altitude (AMSL)</td>
<td>113m</td>
<td>± 15</td>
</tr>
<tr>
<td>-1.19</td>
<td>Centrality index</td>
<td>0.17</td>
<td>± 0.12</td>
</tr>
<tr>
<td>0.72</td>
<td>Distance to townland centre</td>
<td>904m</td>
<td>± 466</td>
</tr>
<tr>
<td>-1.43</td>
<td>Distance to nearest Early Medieval ecclesiastical centre</td>
<td>2800m</td>
<td>± 1137</td>
</tr>
</tbody>
</table>

located in a townland of 113ha, and in a parish of 11327ha. In addition, this exemplary site is situated on terrain with a slope of 5.6° at an elevation of 166m AMSL, and is located 559m from the nearest neighbouring ringfort, 366m from the townland centre and 4858m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for this exemplary ringfort was calculated at 0.35.

7.6.5 Cluster number V

Cluster number V makes up 17% (31 out of 186) of the total number of ringforts in the Lough Ramor catchment study area. The measurements for the five lowest \textit{F-ratios} and five \textit{t-values} of greatest magnitude for cluster number V –Lough Ramor catchment– are provided in Table 7.18.

The exemplary ringfort characterising cluster number V is located within the townland of Drummanbane, Co. Cavan and is nearly-circular. It features maximum internal and overall diameters of 37m and 48m, respectively. The exemplary ringfort is univallate with a low BankI, a trace fosse depth and is located in a townland of 103ha.
<table>
<thead>
<tr>
<th>F-ratio</th>
<th>Variable</th>
<th>Cluster mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.79</td>
<td>Maximum internal diameter</td>
<td>33m</td>
<td>± 6</td>
</tr>
<tr>
<td>0.57</td>
<td>BankI height</td>
<td>4</td>
<td>± 1</td>
</tr>
<tr>
<td>0.75</td>
<td>Fosse depth</td>
<td>2</td>
<td>± 1</td>
</tr>
<tr>
<td>0.70</td>
<td>Townland size</td>
<td>156ha</td>
<td>± 82</td>
</tr>
<tr>
<td>0.79</td>
<td>Distance to townland centre</td>
<td>555m</td>
<td>±295</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>t-value</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.23</td>
<td>Circularity index</td>
<td>2</td>
<td>± 1</td>
</tr>
<tr>
<td>0.47</td>
<td>Maximum overall diameter</td>
<td>49m</td>
<td>± 10</td>
</tr>
<tr>
<td>0.53</td>
<td>BankII height</td>
<td>1</td>
<td>± 2</td>
</tr>
<tr>
<td>0.55</td>
<td>Altitude (AMSL)</td>
<td>157m</td>
<td>±25</td>
</tr>
<tr>
<td>0.30</td>
<td>Nearest neighbour</td>
<td>783m</td>
<td>± 454</td>
</tr>
</tbody>
</table>

Table 7.17: The five smallest F-ratios and five t-values of greatest magnitude along with associated summary statistics for cluster number IV, Lough Ramor catchment.

<table>
<thead>
<tr>
<th>F-ratio</th>
<th>Variable</th>
<th>Cluster mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.76</td>
<td>BankI height</td>
<td>1</td>
<td>± 1</td>
</tr>
<tr>
<td>0.29</td>
<td>BankII height</td>
<td>0</td>
<td>± 0</td>
</tr>
<tr>
<td>0.55</td>
<td>Centrality index</td>
<td>0.64</td>
<td>± 0.18</td>
</tr>
<tr>
<td>0.29</td>
<td>Distance to townland centre</td>
<td>201m</td>
<td>± 108</td>
</tr>
<tr>
<td>0.74</td>
<td>Distance to nearest Early Medieval ecclesiastical centre</td>
<td>3208m</td>
<td>± 1363</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>t-value</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.07</td>
<td>BankII height</td>
<td>0</td>
<td>± 0</td>
</tr>
<tr>
<td>-0.40</td>
<td>Slope</td>
<td>2.2°</td>
<td>± 1.7</td>
</tr>
<tr>
<td>2.74</td>
<td>Centrality index</td>
<td>0.64</td>
<td>± 0.18</td>
</tr>
<tr>
<td>-3.33</td>
<td>Distance to townland centre</td>
<td>201m</td>
<td>± 108</td>
</tr>
<tr>
<td>-0.89</td>
<td>Distance to nearest Early Medieval ecclesiastical centre</td>
<td>3208m</td>
<td>± 1363</td>
</tr>
</tbody>
</table>

Table 7.18: The five smallest F-ratios and five t-values of greatest magnitude along with associated summary statistics for cluster number V, Lough Ramor catchment.
and in a parish of 10678ha. It is sited on a slope of 0.8° at an elevation of 161m AMSL. In addition, this exemplary ringfort is located 552m from the nearest neighbouring ringfort, 114m from the townland centre and 4253m from the nearest Early Medieval ecclesiastical centre. The townland centrality index value for this exemplary ringfort is 0.65.

7.7 Summary of ringfort types

Morphological measurements are the dominant variables that delineate and describe ringforts, both in Stout’s model [180], and the within the current research. For example, the presence of a second, or outer bank, in addition to the size of a ringfort’s internal and overall diameters, provides a measurement to distinguish between two different types of ringforts; univallate and bivallate. The location of ringforts, in terms of their elevation (AMSL), provides the next dominant variable to distinguish between the different types of ringforts (e.g., upland verses lowland).

Six ringfort types were identified through interpretation of the different morphological and locational measurements associated with the ringfort clusters in the current research. These ringfort types were identified by comparing the mean values, of the variables within each cluster, to the mean values of the ringforts variables (primarily morphology and location) within each study area and to the mean values of the ringfort variables within the three study areas combined. The six ringfort types identified in the three study areas were labelled as: low-lying univallate; typical univallate; upland univallate; intermediate univallate; large; multi-functional univallate and bivallate. These ringfort types were compared with the ringfort groups detailed in Stout’s research (Table 3.3). Using morphological and locational similarities, equivalent ringfort clusters in the current research and those in Stout’s research were identified and described in Table 7.19. Ringfort clusters making up each ringfort type were combined and
summarised (i.e., if made up of more than one cluster). The associated morphological, locational and distributional variables for each ringfort type (e.g., large, univallate multi-functional) were summarised and were listed in Table 7.20.

In addition to the six ringfort types, a summary listing the morphological, locational and distributional characteristics of the 5 trivallate ringforts located in the Inny River and Lough Ramor catchments were also assembled. The summarised morphological, locational, distributional variables for these trivallate ringfort were listed in Table 7.20.
<table>
<thead>
<tr>
<th>Stout’s Clusters (Group)</th>
<th>Morphological summary of ringfort clusters in Stout’s research</th>
<th>Equivalent cluster/s in the current research</th>
<th>Morphological summary of ringfort clusters in the current research (Ringfort types)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low-status, low-lying univallate – ringforts featuring mean maximum internal and overall diameters measuring 39m and 51m, respectively. These ringforts are typically univallate, nearly-oval in shape and feature raised interiors, low banks and trace fosses.</td>
<td>BWV–II; IRC–III; LRC–III</td>
<td>Low-lying, univallate – ringforts that are nearly-oval to sub-circular in shape with mean maximum internal and overall diameters measuring 34m and 44m, respectively. These ringforts feature, on average, low banks and trace fosse depths.</td>
</tr>
<tr>
<td>2</td>
<td>High-status, bivallate – ringforts with mean maximum internal and overall diameters measuring 29m and 50m, respectively. These ringforts are, on average, nearly-oval in shape and feature moderate and substantially high BankI and BankII measurements. Deep fosses are also associated with these sites, on average.</td>
<td>BWV–V; IRC–V; LRC–IV</td>
<td>High-status, bivallate – ringforts that are nearly-oval to sub-circular double-banked enclosures with mean maximum internal and overall diameters measuring 37m and 58m, respectively. These ringforts, on average, feature high BankI measurements, moderately deep fosses and shallow BankII measurements.</td>
</tr>
<tr>
<td>3</td>
<td>Typical univallate – ringforts with mean maximum internal and overall diameters measuring 30.5m and 44m metres, respectively. These ringforts, on average, are nearly-oval in shape and feature moderately-high banks and moderately-deep fosses.</td>
<td>BWV–IV; IRC–II,IV; LRC–V</td>
<td>Typical univallate – ringforts that are nearly-oval to sub-circular univallate enclosures with mean maximum internal and overall diameters measuring 34m and 43m, respectively. These ringforts, on average, feature low banks and trace fosse depths.</td>
</tr>
<tr>
<td>4</td>
<td>Large, univallate, multi-functional – ringforts sub-circular in shape featuring mean maximum internal and overall diameters measuring 45m and 67m, respectively. These ringforts typically feature high banks and deep fosses.</td>
<td>BWV–I; IRC–I; LRC–I</td>
<td>Large, univallate, multi-functional – ringforts that, on average, feature maximum internal and overall diameters measuring 57m and 70.5m respectively. These ringforts range from oval to circular in shape and feature low banks and trace fosse depths, on average.</td>
</tr>
<tr>
<td>5</td>
<td>Low-status, upland (hilltop) univallate – ringforts with mean maximum internal and overall diameters measuring 28m and 39m, respectively. These ringforts are, on average, nearly-oval in shape and feature substantially high BankI measurements and shallow fosse depths.</td>
<td>LRC–II</td>
<td>Low-status, upland univallate – ringforts that are circular to sub-circular univallate ringforts with mean maximum internal and overall diameters measuring 29m and 39m, respectively. These ringforts feature trace bank heights and in-filled fosses.</td>
</tr>
</tbody>
</table>

Table 7.19: Ringfort groups from Stout’s research and equivalent ringfort clusters in the current research. A summary listing of the morphological, location and distributional variables associated with clusters forming each ringfort type is provided in Table 7.20.
Table 7.20: Summary table of the ringfort types based on combined cluster analysis results in the Blackwater valley, Inny River catchment and Lough Ramor catchment study areas. The study area and associated ringfort clusters for each of the above types are listed in Table 7.19.
Chapter 8

Corollaries and Consequences: Predictive Modelling

8.1 Introduction

The application of stepwise logistic regression to the ringfort and environmental datasets assembled in this research (Table 5.8) for the three study areas provided a means of identifying the types of environments preferred by those who constructed and occupied ringforts and therefore a further insight into the Early Medieval society in Ireland. The following chapter discusses the results of the stepwise logistic regression and a random selection of ringfort sites and non-ringfort site locations within the Inny River catchment study area with reference to what is known about the construction and occupation of ringforts and society in Ireland during the Early Medieval period.

8.2 Key assumptions

Four key assumptions stated at the outset (see Section 2.3.1) underpin the predictive modelling approach used in the current research. To reiterate, the first assumption
is that current ringfort distributions, available in ASI records, approximate to the original number and distribution. This assumption is reasonable given that much of the information on ringforts in the ASI dates to mapping work first carried out c. 150 years ago, that earthworks continue to provide shelter for livestock after their abandonment as settlements (and therefore they continue to have an agricultural use), and Irish superstition that maintained that anyone who damaged a ringfort would be cursed. In addition, this assumption is particularly reasonable in relation to pasture-based areas that experienced less intensive tillage, as this agricultural land use involves the removal of few, if any, ringforts. This is exemplified in the Inny River catchment, an area historically free from tillage activity [1], [165], where the predominant land cover is currently pasture-land (Table 5.5 B) with areas of peat bog found in valley bottom locations (Figure 8.1).
The second assumption, that environmental conditions (including soil conditions, altitude and distance to water sources) influenced the settlement decisions of those involved in the construction of ringforts, does not imply an argument in favour of environmental determinism in the strictest sense, which has been rejected by many archaeologists ([4], [67], [66]) and remains a contentious issue within the field of predictive archaeological modelling ([101], [51], [202]). Rather, it acknowledges the likelihood that ringforts were located to best suit a wide range of factors (of which only part comprised environmental considerations) such as the availability of suitable land for construction, farming, and ease of defence. Many of these environmental factors have either remained largely unchanged over the last c. 1,500–1,000 years, or their former state can be reconstructed from the available palaeoenvironmental evidence. This itself satisfies the third assumption: palaeoenvironmental conditions can be reconstructed from available sources of evidence, such as pollen diagrams [77] and tree ring records [8].

The final assumption was that, when completed, the predictive archaeological model could be used in areas that may have been poorly surveyed or in areas where destruction rates may be relatively high (including areas that have experienced intensive tillage). This assumption was addressed with the extension and evaluation of the resulting predictive archaeological model to the two neighbouring study areas. The Blackwater valley has experienced intensive tillage and, potentially at least, relatively high rates of ringfort destruction.

8.3 Ringforts and environment

Three different groupings of environmental variables emerged from the current research as exerting a significant influence over the location of ringforts in the Inny River catchment study area. These variables comprised elevation, slope and soil.
Elevation and ringfort locations were found to correlate positively up to 150m AMSL. Relatively few ringforts (on average 1 out of 4) were found to have been sited below 80m or above 150m, despite these areas accounting for 42% of the habitable study area (i.e., the area of land remaining once areas of basin peat and water, as indicated on the OSI and soils dataset, were excluded).

Climate is likely to have exerted a significant influence on the agricultural communities who constructed and occupied ringforts. High-resolution reconstructions of climatic conditions for north western Europe during the Early Medieval period in Ireland are now available from a range of sources (e.g., [92], [75], [90], [118]). Analysis of these indicates a possible link between the construction of ringforts and climatic amelioration, as a majority of adequately dated ringforts were constructed in upland (hilltop) areas around the same time that climates were improving during the initial phases of the Medieval Warm Period (MWP) [1], [118], [127]. Thus, higher altitude locations were being settled on a more permanent basis and in greater numbers from c. 600 AD and coincident with climatic warming, associated with the beginning of the MWP. Possibly because as climates warmed then upland areas became more attractive for settlement and food production. This possible pull factor may have been added to by a strong push, caused by high rates of population increase (and therefore shortages of land for building and farming) in lowland areas.

Gentle slopes from 4–9 % were found to correlate positively with ringfort locations, while slopes of ≥ 16% were avoided. Pragmatically, slopes of ≥ 16% are impractical for both mixed farming and the construction and occupation of ringforts, while slopes of 4–9% may have been preferred to more level terrain because soils on these slopes tended to be better drained. In addition, living on sloping terrain improves intervisibility between neighbouring sites, and the possibility of seeing, in good time, approaching raiders intending to plunder valuable livestock [117].

Ringforts were found to correlate positively with several soil associations from the
following physiographic divisions (see Section 5.3.5): Rolling Lowland; Drumlins; and Flat to Undulating Lowland. This finding is to be expected, given that these areas contain soil associations that offered good agricultural potential and are suitable for the mixed farming practiced at these locations [96]. Ringfort locations and soil associations found within the Hill physiographic division, on the other hand, did not correlate. These soils have shallow depth and are only suitable for summer grazing. This finding reinforces the hypothesis that environmental variables were important contributing factors to the location of ringforts.

8.4 Practical applicability of predictive modelling in Ireland

This study adds to a growing list of studies (e.g., [28], [194], [76], [157]) that demonstrate that probability models can provide a reliable prediction of where archaeological sites are located and not located within a given landscape.

8.4.1 Predictive archaeological modelling in Ireland

This is the first study to apply predictive modelling to archaeological sites in Ireland. With the available data (e.g., palaeoenvironmental, physiographic etc.) a significant, although relatively weak, relationship ($R^2_L$ 11.38%) and predictive efficiency index ($\lambda_p$ 0.29) were obtained for ringforts along with a range of important environmental variables (Table 7.2). These statistics demonstrate that significant relationships exist between archaeological sites and environment. The research presented in this thesis establishes a blueprint for similar studies that may be carried out in neighbouring areas, with other types of archaeological sites, or using improved spatial datasets – when available.
The model constructed and used in the current thesis was able to predict both ringfort sites and non-ringfort site locations for the majority of cases examined. The stepwise logistic regression model (Equation 6.1) used the variables listed in Table 7.2 and probability surface (Figure 7.1), and was able to discriminate between the expected locations of ringfort and non-ringfort sites in the majority of cases in the three study areas. More specifically, of those sites used to develop the model within the Inny River catchment, 64% of ringfort locations were located in areas with probability values in excess of the 0.50 cut-off value (expected areas of ringfort sites) and 65% of non-ringfort site locations were found in areas with probability values below the 0.50 cut-off value (expected areas of non-ringfort site locations). The predictive capability of the resulting model was further tested using 200 ringfort and 200 non-ringfort site locations randomly selected from those ringforts within the Inny River catchment and separate to the development of the stepwise logistic regression model. Of these, 90% of the ringfort sites were found in areas with probability scores in excess of the 0.50 cut-off value. Non-ringfort site locations were found in areas with probability scores below the 0.50 cut-off value for 69% of the cases examined. The two separate tests of the performance of the stepwise logistic regression model demonstrated that those people who constructed and lived in ringforts preferred to locate their settlements in relatively consistent physiographic settings that are, to an extent, predictable using this methodology. The recurrent tendency for ringforts to have been sited and constructed more often in certain locations suggests that a particular lifestyle and economy was associated with these settlements, and that the lifestyle and economy were, in part, dependent upon local environmental conditions. Many ringfort sites, however, are found in areas with low probabilities, as calculated with the current predictive archaeological model. Ringforts found in areas with low probabilities (Figure 7.1) represent inaccurate classifications. These inaccurate classifications demonstrate the limits of the predictive modelling techniques used in the current research in that they provide only partial explanations
of the process that individuals, families and communities went through when selecting a location for their dwelling. By acknowledging the potential for error associated with the predictions created using the predictive modelling technique, the chances of misuse [208] of these procedures are perhaps reduced. Potential misuse would involve the exclusive reliance on predictive modelling techniques as the only means to describe the settlement patterns of those who constructed and occupied ringforts.

8.4.2 Assessment of the Inny River catchment predictive model in the neighbouring study areas

The application of the model to the Blackwater valley and Lough Ramor catchment study areas produced results largely in keeping with the extant ringfort distributions. The lower probability values associated with the majority of the Blackwater valley study area (Figure 7.1) are particularly notable. The Blackwater valley study area is highly suitable for agriculture (Table 5.5 A) and it is possible that the reduced number of ringforts is attributed to ringfort destruction, particularly as a result of several centuries of tillage-based agriculture [128]. It is also possible, as the results from this model suggest, that areas of tillage-based agriculture were not occupied by the societies who constructed ringforts. Instead, the reason for the lower numbers of ringforts may be due to competition from the large number of Early Medieval ecclesiastical centres, having been located in the area at the beginning of the Early Medieval period and prior to the major phase in the construction of ringforts.

Socially and politically powerful monastic settlements, such as Donnaghpatrick and Kells, emerged at the beginning of the Early Medieval period, shortly prior to the major construction phase of ringforts. As both the populations of monastic communities and ringforts grew, many of those who constructed ringforts may have competed for land with ecclesiastical settlements in the same area.

The ringfort location pattern identified in the current research supports a recent
study that described the Blackwater valley as an important ecclesiastical and royal area [183] from the outset of the Early Medieval period. The Blackwater valley represents a unique social and environmental landscape in comparison with the two other study areas as it is situated on the periphery of the Hill of Tara – the symbolic seat of the high kings of Ireland with ritual use dating back to c. 3500 BC [17] – and contains several high-status monastic settlements. The results of the predictive model imply that those who constructed ringforts were generally excluded from high-status and monastic areas, regardless of environmental conditions.

Evidence confirming the exclusion of ringforts from monastic and high-status areas is seen again in the Lough Ramor catchment study area, which has the highest density of ringforts (1 ringfort site 1.9km$^{-2}$) of the three study areas, as well as the smallest number and density of monastic settlements (1 Early Medieval ecclesiastical centre 70km$^{-2}$). Land quality may have been influential. The Lough Ramor catchment, as is evident in the soil information and the recent CLC 2000 data (Table 5.5), is an inferior area for the growing of arable crops. Monastic communities in Ireland during the Early Medieval period were biased towards arable cropping [115]. The lower numbers of Early Medieval ecclesiastical centres indicates that this area was settled less by monastic communities. With less competition from monastic settlements coupled with a natural environment that was predominantly suited to pasture-based farming, those societies who occupied ringforts must have tended towards more extensive forms of food production, notably the keeping of livestock.

8.4.3 Accuracy of recorded ringfort distributions

The distribution pattern identified through the stepwise logistic regression analysis, suggests that the majority of ringforts were constructed in areas predominantly suited for pasture-based farming. Concerns over the accuracy and extent to which existing distribution records of ringforts are flawed affects analysis of the distribution of extant
ringforts and attempts to understand the lifestyle of the people who inhabited them [11], [141], [180]. The concern stems from the cartographic records that show lower numbers of ringforts in areas with good quality agricultural land, a finding that raises the possibility that the lower numbers of ringforts, particularly in intensively tilled areas, are an artefact of destruction rather than a representation of their original distribution [12]. For example, regions with extensive tillage and arable cropping, including the Blackwater valley (Figure 8.2) and comparable areas in the central eastern part of Ireland (e.g., the province of Leinster), may be associated with widespread damage and destruction of ringforts in the c. 1000 years after abandonment and their initial recording by the OSI (Figure 3.8) [11], [141]. In the time-span after the Early Medieval period, those occupying intensively tillage-based areas may have removed or levelled ringforts to increase the amount of land available for arable cropping.

In contrast, it is also possible that those who constructed and occupied ringforts did not demonstrate a tendency to locate their sites in areas best suited to tillage-based agriculture. Evidence from the application of the current stepwise logistic regression analysis suggests that existing ringfort distributions are for the most part well simulated. To a large extent ringforts occur in much higher numbers in areas with low potential for tillage-based arable agriculture activities, such as the Lough Ramor catchment (Figure 7.1).

Additional support for this finding is evident in API surveys undertaken by the SMR using 1:30,000 scale GSI aerial photographs. Efforts to recover hidden archaeological sites in these API surveys successfully added c. 10% to the total number of ringfort sites mapped within southern Ireland. Ringfort sites identified through these API surveys do not occur in significantly higher numbers in areas with relatively high proportions of agriculturally-fertile soils (e.g., the province of Leinster) in comparison with other areas in Ireland that have less potential for arable agriculture [180]. During the main phase of construction and occupation of ringforts (600–900 AD), the current research suggests
that forms of settlement other than ringforts occupied areas suited to arable cropping. The high density of ecclesiastical sites within the Blackwater valley, in comparison to either the Inny River catchment or the Lough Ramor catchment, suggests that ecclesiastical groups practiced arable agriculture in environments best suited to these activities. The research presented here therefore suggests that current recorded ringfort distributions are accurate and largely free from high destruction rates in the years following their use as agricultural habitations.

8.5 Future directions

The results of the stepwise logistic regression analysis hold some promise for predictive modelling as a tool for archaeological prospecting in Ireland, and supports the notion that the location of ringforts was the outcome of decision processes that while not being simply driven by environmental considerations, were influenced by environmental conditions, such as climate, soil and topography. The approach therefore provides only
a partial explanation of the factors underpinning the settlement decisions of those in
the past. The development of the current predictive archaeological model contributes
significantly to the overall understanding of ringfort distributions by unequivocally
quantifying and elucidating the degree to which environment and socioeconomic fac-
tors, reconstructed from available data, influenced the locations of ringforts settlements
in three case study areas that, between them, represent a broad range of conditions in
Ireland.

This research outlines a repeatable methodology with findings that provide a basis
to compare ringfort distributions with coexisting settlement types from the same time
period (e.g., ecclesiastical settlements). In addition, the findings stimulate further
research into Early Medieval society and settlement in Ireland. For example, the
collection of accurate and precise dating evidence should be a priority in order to
investigate whether or not ringforts located in upland and marginal agricultural areas
of Ireland are of a different age than ringforts located in lower lying or potentially
agriculturally rich areas. The possibility that ringforts in upland and agriculturally
marginal areas were constructed and settled at a later date than those in the lower
lying and agriculturally rich areas ties in with events that occurred simultaneously
during the Early Medieval period. Thus climatic amelioration leading up to the
MWP [127] may have improved the living conditions in upland and other agriculturally
marginal environments when compared with the DACP [118], thus a means of releasing
population pressures at lower altitudes. Accurate and precise chronological control
should allow temporal and geographic patterns of ringfort construction and occupation
in Ireland to be determined and evaluated in a broader cultural, socio-economic and
environmental context.

It is apparent from the results presented in this thesis that predictive modelling
using stepwise logistic regression will prove of great value to archaeologists in Ireland
and elsewhere when used as a tool within a broadly-based methodological framework
that also considers the full range of settlement-related factors, including socioeconomic conditions, trade relationships and the manner in which former societies may have perceived and interacted with their environments ([158], [105], [159]).
Chapter 9

Corollaries and Consequences: Cluster Analysis

9.1 Introduction

Stout [180] produced a settlement model (see Section 3.6) for the Early Medieval period in Ireland that focused on ringforts and that has provided both a firm foundation and a basis for comparison for the research presented in this thesis. The cluster analysis methodology developed for the current research improves on Stout’s previous work [177], [180] as it incorporates expanded and improved datasets, such as a higher-resolution DEM, and avoids the entry of potentially erroneous data (e.g., untransformed aspect variables) into the statistical algorithms. In addition, the current research has developed methods that are repeatable to enable further investigation in other case study areas. These methods include the use of existing archaeological information, such as those held in ASI archives, the use of existing digital spatial datasets (e.g., townlands and DEM) and the assembly of location and distribution data in a GIS.

The research in this thesis has developed Stout’s methodology and advanced current understanding of ringforts in Early Medieval Ireland by: investigating a larger sample
of sites from three distinct study areas; incorporating higher quality spatial datasets; undertaking repeatable data collection techniques through a review of existing ASI survey reports and OSI maps; incorporating the use of GIS software along with customised AML scripts (Appendix A) and the use of improved statistical procedures that are incorporated within an updated cluster analysis software package, ClustanGraphics 7.01. For example, Stout utilised an earlier OSI elevation source which had a relatively coarse contour interval of 31m, as that was all that was available at the time. The use of the OSI Discovery Series digital elevation data with a 10m contour interval enabled the creation of a new raster surface (DEM) for the current research. In addition, the ArcInfo process, TOPOGRID, used to create the new DEM, incorporated digital contour lines, river and lake data to factor in the hydrological (drainage) system with the creation of the elevation surface [91]. The TOPOGRID process has generated a highly accurate model of surface elevation, slope and aspect.

One of the key strengths of Stout’s work was that it made available and accessible a mass of archaeological data that had been collated over a 10 year period from surveys in the baronies of Ikerrin [174] and Clonlisk in the southwest midlands of Ireland. A dataset of this quality is currently not available for ringforts in other parts of the country. The wealth of archaeological survey data already existing in ASI archives (Figure 5.18) and OSI 1:2,500 and 1:10,560 scale maps provides available information for ringforts. Measurements, however, that are recorded in reports –particularly of fosse depth and bank height– were carried out in a non-systematic way in many of the ASI field surveys. These poor measurements are recorded in resulting ASI reports. Furthermore, it is difficult to gather consistent information on maximum fosse depth or maximum bank height from the ASI sources. These difficulties are primarily because measurements for both the depth of fosse and bank height are highly variable even for the same ringfort. The use of categorical variables (Table 5.11) in the current research provided a means to integrate poorly measured bank height and fosse depth into the
cluster analysis procedure.

The cluster analysis procedure used in the current research (see Section 6.5) discriminated five clusters per study area, each determined by the variables used to describe the ringforts (e.g., fosse depth, elevation, slope etc.) [3], [206]. The inclusion of aspect as a continuous variable in Stout’s work may have led to inaccuracies within the groupings. Aspect variables (as discussed in Section 5.4.2) must be transformed into categorical variables, because values such as 1 and 359, which essentially represent the same aspect bearing, are very different numerically. These numerical values, without transformation, inevitably introduce error if they are added directly into a $k$-means cluster analysis algorithm. $K$-means cluster analysis is not equipped to include these variables transformed on a categorical scale and as a result, aspect variables were not included into the current analysis procedure.

Ringforts exist in varying states of repair, and it was not always possible to obtain the total range of morphological measurements for highly damaged ringforts. In Stout’s research [177], [180] ringforts with missing morphological variables were removed prior to performing cluster analysis on the data. In the development of the Ikerin and Clonlisk model, over 300 sites were available for analysis. Without the facility to include cases with missing morphological variables, over one third of the data was not analysed and it is not known whether all types of ringforts were equally represented in these missing data, or whether some types were more represented than others. In areas of urban and intensive agricultural land use, for example, the chances for damage to ringforts are far greater than in remote areas with a lower potential for human interference and therefore the kinds of ringforts found in the more intensively farmed or populated parts of Ireland are likely to be preferentially damaged. In Stout’s cluster analysis, the ringforts with missing morphological variables, possibly from urban or intensively tilled areas, were not analysed.

The use of the software ClustanGraphics 7.01 in the current research has facilitated
the inclusion of cases (ringforts) with missing variables. A step forward for researching ringforts using cluster analysis is to enter all cases within a dataset, including those cases with missing variables. In ClustanGraphics 7.01, missing data are replaced with estimates based on the range of existing values [207]. Although these estimates can never fully replace the missing data, the process is more rigorous than an approach that simply casts aside all cases with missing information.

9.2 Acknowledgements and assumptions

Three assumptions underpin the cluster analysis applied in the current research, as stated in Chapter 2. The first assumption accepts that the meaning assigned to each of the current clusters is subject to interpretation by the researcher, which is in turn linked to the second and third assumptions. The second assumption accepts current evidence, which suggests that the occupation of ringforts dates largely to the Early Medieval period [180]. Radiocarbon and dendrochronology dating evidence (see Section 3.5.1) of ringfort sites from various locations throughout Ireland indicates that their main period of construction and habitation occurred between about 600 and 900 AD. The narrow dating range combined with evidence indicating that individual ringforts may have been occupied by several generations (i.e., for two or more centuries) [180], suggests that many ringforts were occupied at the same time. The third assumption assumes that those who constructed and occupied ringforts were tribal, hierarchical, rural and familiar (after Binchy [20]) and that Ireland during the Early Medieval period consisted of a large number of tribes or petty kingdoms (approximately numbering 150, each c. 500km² in area on average, with a mean population of around 3,000 people [33]). This third assumption assumes that during the Early Medieval period, the people of Ireland operated as a chiefdom-based society –similar to those listed in Elman Service’s classification of societies (Table 3.1)– and that the remains of their habitations will
reflect this hierarchical and class-based social organisation. Chiefdom-based societies are characterised by the hierarchical ranking of different members. Each member will gain rank and status primarily through heredity and descent. Society during the Early Medieval period in Ireland partially deviated from this model as social hierarchy was not based entirely on heredity and descent [151]. As mentioned previously status could also be attained through personal wealth obtained through clientship. Clientship involved the lending of cattle [117] along with physical and legal protection in return for a negotiated form of repayment. Repayment consisted of the annual render of cattle, food, military service and hospitality for the king and his entourage [120], [95]. Upward or downward social mobility among members of the same family lineage was related to the prudent management of assets [151], particularly among those individuals with similar heredity. Gaining and preserving wealth was essential to increase and maintain a particular level of social status in this society.

The varying number of banks around ringforts has been interpreted by researchers such as Warner [191] and Stout [180] as confirmation of a hierarchical society at the *túath* level. Sites with similar morphology would likely have been occupied by individuals with similar status [187]. Warner hypothesised that the upper echelons of the *túath* occupied the multivallate ringforts and those of lesser ranks, such as the ordinary farmers, inhabited univallate sites [191]. Stout [180] elaborated on this model by investigating associations between the differing typologies of ringforts and their topographical setting using a sample of ringfort sites in the baronies of Ikerin and Clonlisk.

Stout’s research identified topographical associations with the different typologies of ringforts. Specifically, he found that low-status, univallate ringforts were located in lowlands; high-status bivallate ringforts were located centrally in their townlands; typical univallate ringforts were located on good agricultural land without strategic placement; large, potentially military ringforts, were located on boundaries such as
townland boundaries and exceedingly low-status, ringforts, such as small enclosures, were located nearer high-status sites than any of the other ringfort types and in upland locations (for more detail, see Section 3.6). The results of the current cluster analysis are interpreted below.

9.3 Typology

Morphological measurements, including living space and defences, were analysed in the current research (Table 7.19 and 7.20). The morphology of a ringfort was in part originally determined by social customs, as documented in the ancient Irish laws [95]. The kings and upper echelons of the túatha, for example, were expected by the society to display signs of status [37] through feasting, exotic material assemblage (e.g., objects from foreign lands) [48] and the size and complexity of their dwelling [191]. The dwelling place of a king or chief, for example, was expected to have been heavily fortified (e.g., with a surrounding wooden palisade) and constructed with defence in mind (e.g., either with higher or additional banks). The more defensively constructed ringforts are exemplified by trivallate ringfort remains [191]. Stout found correlations with specific morphological characteristics and the status of a ringforts, in addition to the size of defences of a ringfort. Specifically, he found that high-status bivallate ringforts correlated with increased values of circularity [180] as indicated in an ancient Irish poem Críth Gablach [19]. The increasing values of circularity were thus interpreted as a social custom associated with high-status bivallate and trivallate ringforts [180].

There are no indications in the results of the current research that this social custom was closely followed in the three case study areas. The empirical evidence instead suggests that the verse from the poem provides a general description, rather than strict social or legal custom. Abrupt boundaries between the different ringfort typologies are not evident in the morphological variables examined in the three study
areas (See Table 7.20). Instead, the morphological characteristics of ringforts display a gradual progression of social status through different sizes, shapes and complexities in the remaining earthworks. The differences in ringfort size and complexity may link with the potential sources of wealth locally available within each of the three study areas. The low-status, upland ringforts (Table 7.19 and 7.20), for example, feature the smallest maximum internal and overall diameters of all ringfort groups both in Stout’s research and the current research (See Table 7.19). The environment where these upland ringforts are located offers marginal agricultural potential. Typical ringforts compared with the low-status, upland ringforts (see Table 7.19 and 7.20) are slightly larger, in terms of internal and overall diameter and are located at lower elevations which offer good agricultural potential. More evidence of the size of a ringfort and its surrounding environment is apparent in the bivallate ringforts in the Blackwater valley (cluster number V, BWV, Table 7.3). This cluster of bivallate ringforts features mean internal and overall diameters measuring 52m and 81m, respectively. These dimensions are much larger in size, compared with the majority of bivallate ringforts in the remaining two study areas (Table 7.20). The substantial size of the Blackwater valley’s bivallate ringforts signifies that they will probably have required a large number of labourers/clients for their construction. This substantial size of these features potentially links with good quality fertile land in the Blackwater valley study area providing the means to attract and support these clients.

Ringfort morphology symbolised several societal norms. Individuals outside of a túath would likely have judged the potential military prowess of a particular tribal group, in part, by the morphology of its ringforts. For individuals living within the túath, the overall structure of a ringfort advertised the occupant’s wealth, power and social standing [191], [151]. The ringfort structure also advertised the economic risk associated with the occupant [117]. The loan of cattle from a lord or king was repaid by a client through labour (e.g., military duties and repairs to a lord’s dwelling)
and agricultural products [95]. The increased size and complexity of earthworks and defences (e.g., wooden palisade) forming a ringfort required increased levels of labour to construct and maintain. Thus, larger more elaborate ringforts conveyed continuous and successful relationships between lords and clients. Larger and more elaborate ringforts also indicated that the occupant could organise a sizable military defence, and ensure that a client received increased levels of protection in legal disputes [95], cattle raids [20], and warfare. In a non-egalitarian society, such as is believed to have existed in the Early Medieval period in Ireland, both individuals (particularly those of similar ranking and lineage) and communities would have endeavoured to advertise their wealth and status. By advertising their wealth and status, individuals were in a better position to attract and secure more clients, which would then lead to a gain in social standing. In these circumstances, the hierarchical nature of status in society was conveyed through differing sizes and complexity of ringforts. A wide variation of size and complexity exists in the ringforts investigated in the current research.

The rapid increase in the construction of ringforts (600–900 AD) has been suggested to indicate a population explosion [180]. Additional food supplies, attributable to advancements in agricultural technology and climatic improvement (see Section 3.2.1), provided the support for this population explosion. Indeed, the existence of increased food supplies and agricultural production is confirmed by palaeoenvironmental records indicating an upsurge in arable cropping [128] and woodland clearance [165] dating to the Early Medieval period. The arrival of monastic settlements (around c. 500AD) is linked to the advancement in agricultural technology. Monastic settlements had more contact with the technologically advanced Roman British world and imported its agricultural technology (e.g., watermills [6], mouldboard and later in the tenth century, ploughs with shares\(^1\) and coulters\(^2\)[30]) to sustain ecclesiastical communities in Ireland.

\(^1\)Shares are fixed onto the base of the plough where they serve as a sharp steel wedge that cuts free the top layer of soil.

\(^2\)Coulters are sharp steel wedges which come before the plough to vertically cut through the topsoil.
Both the new technologies and increase in food supplies disseminated across Ireland and led to an increase in population as well as an increase in material wealth, which is reflected in the widespread construction of ringforts during the second half of the first millennium AD.

Furthermore, each of the three study areas includes ringforts with different morphological characteristics. For example, ringforts in the Inny River catchment and the Blackwater valley have maximum internal diameters that, on average, are 2m larger in size than those in the Lough Ramor catchment. These differences may be due to social organisation, the success of the individuals in the area, land quality and trade relationships (e.g., with the monastic settlements). The superior soils, lower elevation ranges and large numbers of Early Christian ecclesiastical centres within the Blackwater valley, for example, are likely to have generated more arable cropping, and therefore more potential for trade relationships and increased levels of wealth. Direct access to food supplies may have correlated with wealth and therefore larger and more elaborate ringforts. The Lough Ramor catchment, on the other hand, did not provide the same opportunities, and wealth was not concentrated to the same degree as reflected in the smaller and less elaborate ringforts, particularly those low-status, upland ringforts (Table 7.19 and 7.20). The broad range of ringfort typology is perhaps evidence that Early Medieval society in Ireland was not tied to strict rules dictating the morphology and location of the habitations and instead responded, in part, to local conditions.

There is no evidence in the current research for a link between specific morphological characteristics (such as the circularity of ringforts) and the status of the original occupant, as implied an ancient Irish poem, Críth Gablach [19]. High-status ringforts (bivallate and trivallate) among the three study areas have a range of circularity index values (oval to circular). It would appear that ringforts which deviate from perfectly circular were not built by lesser status individuals than those with perfectly circular dimensions. Instead, the degree of circularity may relate to the skill of the builder and
the environment where the ringfort is constructed.

The most substantial measurements of bank height and fosse depth occur on trivallate and bivallate ringforts. These findings are indicative of both their original construction and also of a greater degree of preservation after they were abandoned. Bivallate and trivallate ringforts were likely to have been revered more by local people and therefore were less likely to be damaged than univallate ringforts.

9.4 Location

The current research examined the location of ringforts according to local territory and environmental conditions (e.g., townland size, parish size, altitude and slope). The origins of many townlands in Ireland date from the Early Medieval period [119]; however, a consistent pattern was not found between townland size and any of the ringfort clusters and types identified in the current case study areas. The complexity in origin and evolution of individual townlands appear to complicate any relationships that may be apparent in the results of the cluster analysis. In addition, evidence linking certain parish sizes to different ringfort types in the case study areas is not apparent, with the exception of those low-status, upland ringforts in the Lough Ramor catchment (cluster number II, LRC, Table 7.3) and the small sample of trivallate ringforts (Table 7.20). Trivallate ringforts occur in such small numbers (in the current research, five sites out of a total of 1,314) that their linking with larger parishes (calculated to a mean value of 115km²) is not significant. The low-status, upland univallate ringforts, on the other hand, are associated with larger parish sizes (on average approximately 110km² in size). The linking of these sites with larger parish sizes relates to how parishes were organised in the past with a tendency for larger parishes to occur in remote and upland areas.

A parcel of land today in Ireland is likely to have a similar elevation and slope as
in the Early Medieval period. Vertical stratification, with respect to elevation AMSL, exists in the different types of ringforts identified in the current research. This pattern is similar to that described in Stout’s model [180] (see Section 3.6). Upland univallate ringforts, for example, with the smallest internal diameters of all ringfort types, are found at the highest average elevations (155m ±19, AMSL Table 7.20) compared to any other ringfort types. It is assumed that some of these upland univallate ringforts may not have contained houses [156], [191], and instead may have had a seasonal functionality as summer enclosures for grazing cattle in the upland environments [126]. High-status, bivallate ringforts were situated, on average, at elevations of 117m ±32 AMSL. The location of these high-status ringforts, in terms of their elevation, suggests they are situated at visible, slightly elevated sites, in comparison with the majority of ringfort sites in the three study areas. Typical univallate ringforts were located at elevations of 113m ±24 AMSL indicating that the majority of univallate ringforts were positioned in lower less visible elevations than the high-status bivallate ringforts. The clusters of large multi-functional, univallate enclosures, on average, were located at elevations below typical univallate sites with a mean value of 96m ±28 AMSL. In terms of elevation, the ringfort types identified in the case study areas support the pattern illustrated in Stout’s hypothetical model (see Figure 3.3).

Patterns associated with the degree of slope and the different ringfort clusters (Table 7.3) and ringfort types (Table 7.20) were not apparent in the different clusters and ringfort types identified in the current research.

9.5 Distribution

In this research, the distribution of ringforts was analysed in terms of their proximity to neighbouring ringforts, position within the local townland and proximity to Early Medieval ecclesiastical centres. The distribution of ringforts is markedly different
within each of the three study areas. For instance, the nearest neighbour overall mean
values range from 900m in the Blackwater valley to 460m in the Inny River catchment
(see Table 7.3). Because of these markedly different ringfort distributions, ringfort
clusters were compared with others in the same study area (see Table 7.3), as well as
between the different types listed in Table 7.20.

The placement of the low-status upland univallate ringforts in the Lough Ramor
catchment may demonstrate a recurring pattern for upland univallate ringfort sites,
which is that they are located closer together. The same pattern is evident in ringforts
in cluster number IV from the Inny River catchment. This cluster, although labelled
as a typical univallate ringfort (Table 7.19), comprises ringforts with the highest mean
elevation values in the Inny River catchment (Table 7.3). These sites were located
closer together than any of the remaining clusters in the Inny River catchment. Rather
than suggesting these upland locations were used exclusively as seasonal dwellings for
the summer grazing of cattle [180], it is also possible that during the main phase of
construction and occupation of ringforts (600–900 AD) some of these upland locations
may have offered available land for a growing population. Ringforts in these areas may
be the most recently constructed of all ringfort types, and represent the habitations of
people in a situation where there was little vacant space in lower elevations.

With the exception of the large multi-functional, univallate ringforts, a consistent
pattern for ringfort types and position within townlands was not evident in the different
types of ringforts identified in the three study areas. Large, univallate, multi-functional
sites, however, tend to be located nearer the townland boundaries than any of the
ringfort types analysed in the current research (Table 7.20). The close proximity
of these large multi-functional, univallate ringforts to townland boundaries provides
evidence supporting the pattern identified in Stout’s research. The consistent size,
location and distribution of these sites, both within the current study areas and in
Stout’s research, suggest these ringforts served a particular role in the Early Medieval
society. Potentially they were military enclosures or used as stockades for seized cattle [180]. Alternatively, these sites may have served a communal role for community functions such as, fairs, and sporting competitions [151] held within the local areas.

Distances between ringforts and the nearest Early Medieval ecclesiastical centres vary within and between the three study areas. This finding is in part because of the differences in the numbers of Early Medieval ecclesiastical centres within the different study areas. The Lough Ramor catchment study area, for example, features one Early Medieval ecclesiastical centre 73km$^{-2}$, while the Blackwater valley study area features one Early Medieval ecclesiastical centre 11km$^{-2}$. By comparison, the Lough Ramor catchment study area features ringforts at a density of one site 1.2km$^{-2}$ and the Blackwater valley study area features ringforts at a density of one site 5.8km$^{-2}$.

The most probable explanation for this distribution of Early Medieval ecclesiastical centres relates to environment and agricultural land potential. According to the CLC 2000 data (Table 5.5), 22.7% of the Blackwater valley study area is occupied by arable agriculture, compared with 0.1% of the Lough Ramor catchment study area. If such differences in agricultural potential also characterised the two study areas in the Early Medieval period, and it seems reasonable to assume they did, it would appear that ecclesiastical centres were sited more frequently on land with the greatest capability for arable farming and this high density of ecclesiastical centres in some precluded the construction of ringforts at high densities.

Higher elevations were settled with relatively few ecclesiastical centres, which were instead located within lower lying elevations along major routes [115]. The siting of ecclesiastical centres in lowland fertile environments enabled the arable farming practiced within these communities.

Empirical evidence put forth by researchers such as Simms [170], Warner [191] and Stout [180] suggest that higher status ringforts were situated closer to ecclesiastical sites than the lower status ringforts. In the three study areas examined in the current
research, the locations of higher status ringforts –bivallate and trivallate– do not appear to be influenced by the presence of monastic settlements. The proximity of ringforts and ecclesiastical centres varies regionally and none of the ringfort types display a tendency to be located closer to Early Medieval ecclesiastical centres than any of the other types.
Chapter 10

Research Conclusions

10.1 Introduction

Ringforts, in the context of their time period, Celtic Europe and the British Isles, are a unique habitation form constructed by tribal societies inhabiting all parts of Ireland. The Early Medieval period in Irish history is characterised by relative prosperity that led to the rapid increase in ringfort numbers. This prosperity was generated through the spread of Christianity, expansion of monastic settlement – regarded highly throughout Early Medieval Europe –, widespread raiding of post-Roman Britain, trade relationships with Celtic Europe and the British Isles [40], climatic amelioration and the introduction of new farming practices and food sources. These factors led to an explosion in both population and static material culture. Analysis of the remains and locations of these earthwork habitations shed light on this period in Irish history and the culture that developed them.

This study examined a sample of 1,314 ringforts in the central midlands of Ireland out of a country-wide total of approximately 45,000. Additional case study areas from other locations in Ireland combined with improving GIS capacities and other types of spatial data (e.g., soils and elevation), may further improve understanding of the
societies responsible for the construction of ringforts in Ireland. The research aims of
this study were twofold: the first aim was to model the current locations of ringforts in
selected parts of Ireland in order to deepen understanding of the societies responsible for
their construction and the possible role of environmental conditions in influencing their
distribution. The second aim was to identify the typology, location and distributional
settlement patterns associated with ringforts.

To address the first research aim, a predictive archaeological model using stepwise
logistic regression was developed to examine the locations of ringforts in selected parts
of Ireland. Three case study areas were selected: the Blackwater valley; the Inny
River catchment and Lough Ramor catchment. Each of these contiguous case study
areas has unique physiographic, socio-historical settings enabling comparative analysis
of ringforts between the different study areas. Environmental data such as elevation,
slope and soil type were also assembled for these case study areas, using the data
handling capabilities of GIS. Stepwise logistic regression was used as an analytical
tool for quantifying the various environmental conditions influencing the locations of
ringforts in Ireland [102].

For the second research aim, a large archaeological dataset on ringforts was
assembled for the three selected study areas. Variables collected for this dataset enabled
analysis of the morphology, location and distributional patterns of ringforts. Statistical
analysis of this dataset established clusters of ringfort sites. These were based on the
similarities and differences among their distinctive attributes (morphology, location
and distribution). Separate clusters were generated for each of the selected study
areas. These different clusters enabled comparison between the ringforts in the different
case study areas. In addition, the ringfort clusters were compared with an existing
settlement model developed by Stout in an earlier study [180].

The predictive archaeological model developed for the Inny River catchment and
its application to the remaining study areas (Blackwater valley and Lough Ramor
catchment) revealed the following:

- Ringforts tended to be sited on moderately fertile, well-drained soils on gently sloping land (slopes of 4-9%) between 80m and 150m AMSL.

- Landscapes favourable to arable farming were not as intensively settled by the population who constructed and occupied ringforts.

- Arable areas were inhabited to a greater extent by ecclesiastical communities and those who were associated with ringforts tended instead to settle in upland areas that were predominantly suited to pasture-based agriculture.

- A dichotomy between activities of ecclesiastical communities and the secular agricultural habitations occurring during the Early Medieval period in Ireland.

The pattern of settlement identified by the predictive archaeological model corresponds with events that occurred during the Early Medieval period in Ireland. For example, the ecclesiastical communities that arrived at the outset of the Early Medieval period (c. 500 AD) settled initially in areas such as the Blackwater valley [183]. With the arrival of these ecclesiastical communities came improvements in agricultural technologies and increased food supplies. Increased food supplies disseminated across Ireland and facilitated a population growth and increased numbers of secular settlements (ringforts). The ecclesiastical communities expanded their agriculture activities in areas that could best support tillage-based agriculture. Those inhabiting ringforts were largely excluded from environments that could support arable farming and instead settled in large numbers in marginal upland areas.

Using cluster analysis and datasets assembled for the selected study areas, morphological variables revealed ringforts typology exhibits a progression in size, shape and complexity. This progression can be seen to communicate social status within the non-egalitarian hierarchical society described in ancient Irish Law tracts [95]. The
examination of ringforts suggests that their morphology and typology may be linked with available concentrated food supplies, such as cereals, that are ideally suited for long term storage. For example, the Blackwater valley, an environment with superior arable agricultural potential contains on average larger, more elaborate ringforts than either the Inny River or Lough Ramor catchments. The locations of high-status sites (e.g., bivallate and trivallate) are not, however, limited to these agriculturally superior areas.

In terms of location, ringforts are found in more conspicuous and defensive settings. These settings were most likely chosen for a variety of reasons to maintain defensive postures and visibility from site to site. In addition, a visible location was a means to advertise power and social status, both to inhabitants within the local community and to those outside. Defensive ringforts, such as bivallate and trivallate forms; occur in higher elevations, affording more commanding views and conspicuous locations, than the majority of univallate ringforts. The location patterns of different ringfort types identified in the current study areas largely support those identified by Stout in an earlier study [180].

The distribution of ringforts varies within and between the case study areas. For example, the nearest neighbour distances between ringforts vary from 900m in the Blackwater valley to 460m in the Inny River catchment. This variation is due to the higher numbers of Early Medieval ecclesiastical centres found on land with greater agricultural potential (e.g., the majority of the Blackwater Valley). Higher status bivallate and trivallate ringforts are found in all three case study areas. Their presence does not appear to be correlated to the locations of Early Medieval ecclesiastical centres.

To conclude, primary aim of this research was to investigate the locations, typology and distributions of ringforts among the selected study areas in the Blackwater valley, the Inny River catchment and Lough Ramor catchment. While it is largely agreed ringforts date to the Early Medieval period in Ireland, little evidence exists as to when
and where the different settlements were established. Dating evidence from a range of different ringfort types and locations across Ireland will provide a means to examine the population growth and migratory trends which occurred during the Early Medieval period in Ireland. For example, it may be possible to determine whether certain types of locations were settled in preference to others. This in turn may help researchers to trace migration and settlement patterns of secular communities throughout the Early Medieval period in Ireland.
Bibliography


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Appendix A

Arc Macro Language Scripts and Variable Summaries

A.1 Introduction

The appendix contains three Arc Macro Language (AML) scripts used to generate several of the ringfort variables in this research. In addition summary plots of the data used within the cluster analysis have also been included.

The AML scripts were applied to ArcInfo version 9.0. Further information about these procedures is available in the ArcInfo Help and AML [53] manual. All scripts were written as ASCII text files and saved as *.AML files. Within the AML code all text to the left of the ‘/*’ characters, represent comments written when drafting the code.
A.2 Scripts

A.2.1 Nearest neighbour (NearestNeighbour.AML)

The nearest neighbour script calculates the distance from an individual ringfort to its closest neighbouring ringfort site.

```aml
&sv id = 0
&do &until %id% = 58 /* Initiate a loop to iterate through all ringforts in BWV dataset
 &sv id = %id% + 1
 ae /* Begin ArcEdit to create two new coverages
 ec ringforts /* Select ringforts
 ef point /* Initiate the edit point environment
 select ringforts-id = %id% /* Isolate ringforts by the current ID value
 &if %id% = 1 &then; &do; /* Condition
 &sys arc kill snglefort_tmp all /* delete any temporary coverages
 &sys arc kill singlefort_tmp all
 put singlefort_tmp /* Create a single coverage with the point currently selected
 &end
 &if %id% > 1 &then; &do; /* Condition
 &sys arc kill singlefort_tmp all /* Delete and unnecessary temporary coverages
 put singlefort_tmp /* Create a single coverage with the point currently selected
 &end
 select all
 unselect ringforts-id = %id%
 &if %id% = 1 &then; &do; /* Isolate the current value
 put nneigh Cov /* Place this coverage in a nearest neighbour cover
 &type 'in the if then statement id val = ' %id% /* interactive comment
 &end
 &if %id% > 1 &then; &do
 &sys arc kill Mlt_fort_TMP all /* Delete redundant coverages
 &type 'at else' %id%
 put Mlt_fort_TMP /* Create a coverage with all points except values with current ID
 &end
 quit
dropitem Mlt_fort_TMP.pat Mlt_fort_TMP.pat distance /* remove conflicting database items (i.e., distance)
dropitem singlefort_tmp.pat singlefort_tmp.pat distance
near singlefort_tmp Mlt_fort_TMP point 10000 tmp_nr_cov */ Use the Near command to identify distances
build tmp_nr_cov point */ Create topology
ae
ec tmp_nr_cov /* Use ArcEdit to create a new coverage assembling all nearest neighbour points
ef point
select all
 &if %id% = 1 &then; &do; /* Isolate the current value
 put nneigh_cov /* Place this coverage in a nearest neighbour cover
 &type 'in the if then statement id val = ' %id% /* interactive comment
 &if %id% > 1 &then; &do;
 &type 'at else' %id%
 put nneigh_cov
 y
 &end
 quit
```

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A.2.2 Centrality index (CentralityIndex.AML)

This AML calculates a centrality index value for each ringfort with respect to its townland boundaries.

```aml
ae /* clear any redundant coverages
&sys arc kill bndry_dist all quit
&do #until %id% = 58
  &sv id = %id% + 1
  ae /* Begin calculating by clearing redundant coverages
  &sys arc kill tmpbnd_Dst all
  &sys arc kill bnd_point all
  &sys arc kill tmppoly all
  &sys arc kill tmp-ring all
  ec ringtown /* Create a coverage containing ringforts with a townland database item.
  ef point
  select ringforts# = %id% /* Isolate a single ringfort
  put ringtemp /* Put into a temporary coverage
  &sv id2 = [show select 1] /* Label a variable by the current ID
  &sv TownLand = [show point %id2% item Townlands-ID] /* Label a variable with the townland’s name
  ec townlands
  ef poly
  &type 'the townland is now listed as %id2%' /* Comments to identify the current progress
  select Townlands-id = %Townland% /* Select the current townland variable from the overall dataset
  put polytemp /* Create temp polygon cover
  ec polytemp /* Cleanup the townland topology
  grain 100
  ef arc
  select all
  unsplit none
  spline
  clean
  &sys arc kill temp_point all quit

y; y
additem polytemp.aat polytemp.aat SPOT 4 4 I /* Add and remove items
arcpoint polytemp bnd_point line SPOT /* Create a new point coverage
dropitem ringtemp.pat ringtemp.pat.distance
dropitem bnd_point.pat bnd_point.pat.distance
```
near ringtemp bnd_point point 10000 tmphbd_Dst /* calculate distances to townland boundaries
ae; ec tmphbd_Dst
ef point
select all
&if %id% = 1 &then; &do; put bndry_dist /* Create a new boundary distance file
&end
&if %id% > 1 &then; &do; put bndry_dist; y
&end
quit
&end
additem bndry_dist.pat bndry_dist.pat Bndry_Dist 8 8 F 2 /* Assemble items in the database tables
select bndry_dist.pat
calculate Bndry_Dist = distance quit
kill tmphbd_Dst all kill bnd_point all kill polytemp all kill /* Remove any redundant coverages
ringtemp all
build bndry_dist point /* Create the topology
&type THE BOUNDARY DISTANCE CALCULATIONS ARE FINISHED
-----------------------------------------------------------------------
/* CALCULATE DISTANCE TO TOWNLAND CENTROID VALUES
&sv id = 0 /* 1 ae &sys arc kill centroid_dist all quit /* Initialise variables
&do until %id% = 58
&sv id = %id% + 1 /* Initialise variables
ae
&sys arc kill in_cover all /* Remove any redundant coverages
&sys arc kill near_cover all
&sys arc kill near_tmp all
ec ringtown /* Edit a ringfort coverage with townland labels
ef point
select ringtown# = %id%
put in_cover
&sv twnpoint = [show point %id% item Townlands-ID] /* Identify ringforts one by one
&type; &type; &type At stage: %id%; &type /* State current progress
ec towncntr
&sys arc cls
type 'The value of townlands is' %twnpoint%
&if %twnpoint% = 0 &then; &do /* Correct some variable IDs
&sv twnpoint = 65; &end
&if %twnpoint% = 340 &then; &do
&sv twnpoint = 65; &end
&sv twnpoint = 65; &end
ef point
select TOWNCNTR-ID = %twnpoint% /* Isolate the townland centroid
put near_cover /* Create a point file with the centroid
quit
near in_cover near_cover point 10000 near_tmp /* Calculate dist. between the ringfort and the centroid
build near_tmp point /* Create point topology in the new coverage
ae
ec near_tmp /* Edit the point distance coverage
ef point
select all
type 'almost at the if then statement'
A.2.3 Church distance (Church-Dist.AML)

This short AML script calculates the distance from a ringfort to its closest ecclesiastical site.

```aml
/* FINISHED CALCULATING THE DISTANCE TO CENTROID'S */

/* Now Creating the Centrality Index Cover */ Create the centrality index coverage
```
put CHURCH_SITE  /* Create a point coverage featuring these sites */
quit
/* Calculate the distance between a ringfort and the nearest early medieval church site */
NEAR RINGFORTS CHURCH_SITE POINT 200000 CHUR_DIST
&cov COVERAGE = CHUR_DIST
&type 'All FINISHED CALCULATING THE DISTANCE TO CHURCHES'

A.3 Summary graphs of ringfort variables used in the current cluster analysis procedures
Fig. A.1: Histograms summarising the variables that were used in the cluster analysis for the Blackwater valley. These charts include both variables entered into the statistical algorithms and those used specifically for interpretation of the clusters.
Fig. A.2: Histograms summarising the variables that were used in the cluster analysis for the Inny River catchment. These charts include both variables entered into the statistical algorithms and those used specifically for interpretation of the clusters.
Fig. A.3: Histograms summarising the variables that were used in the cluster analysis for the Lough Ramor catchment. These charts include both variables entered into the statistical algorithms and those used specifically for interpretation of the clusters.