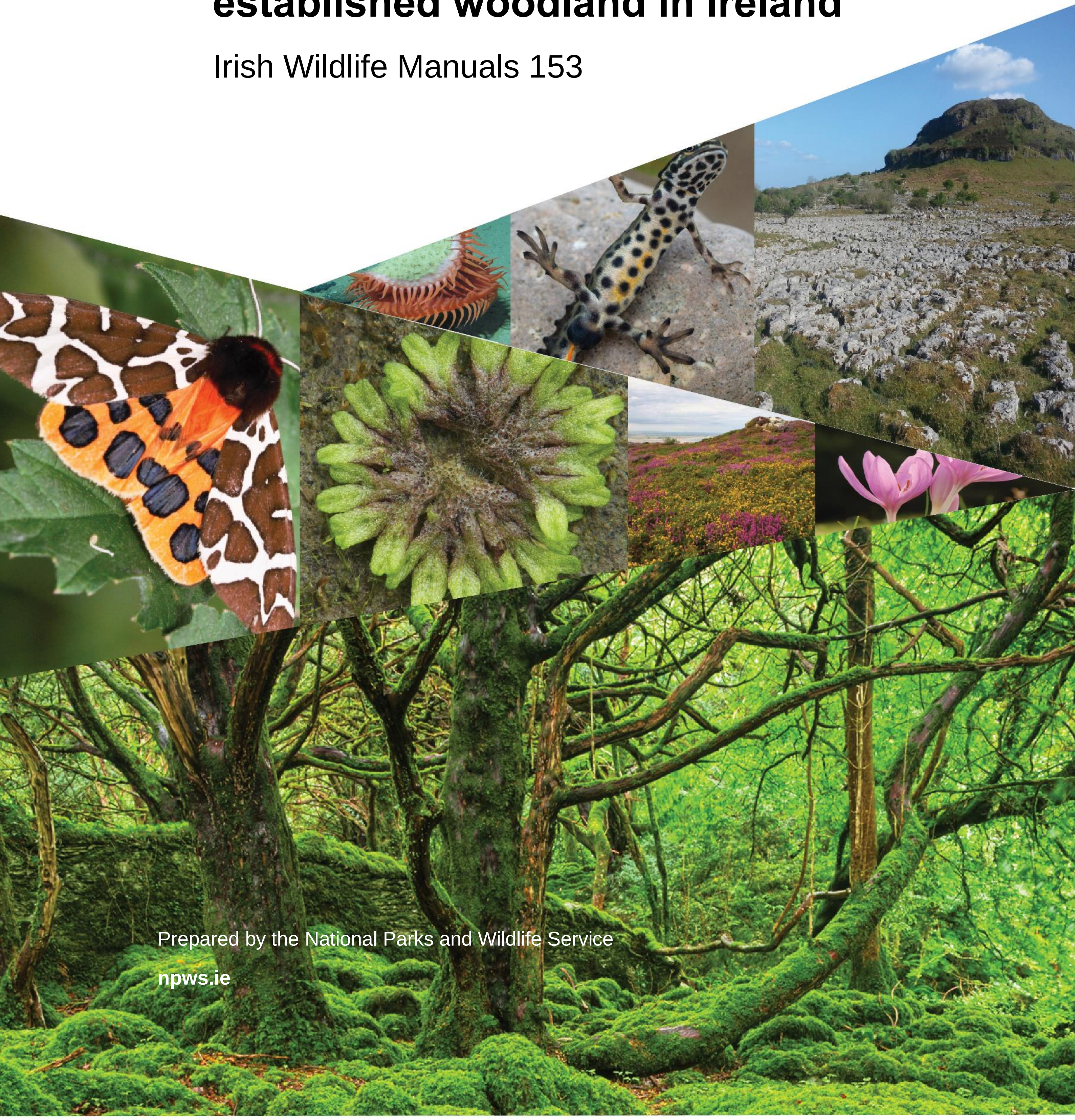
An tSeirbhís Páirceanna Náisiúnta
agus Fiadhúlra
National Parks and Wildlife Service

Mapping, monitoring, and protecting ancient and long-established woodland in Ireland

Irish Wildlife Manuals 153



Prepared by the National Parks and Wildlife Service

npws.ie

Citation: Devaney, J., Shaw, H., Leniston, T., Mitchell, F.J.G., Darcy, E. & Roche, J. (2024). Mapping, monitoring, and protecting ancient and long-established woodland in Ireland. Irish Wildlife Manuals, No. 153. National Parks and Wildlife Service, Department of Housing, Local Government and Heritage, Ireland.

Keywords: Ancient woodland, Ireland, historical ecology, forest conservation, palaeoecology, palynology

Front cover, small photographs from top row:

A deep water fly trap anemone *Phelliactis* sp., Yvonne Leahy; **Common Newt** *Lissotriton vulgaris,* Brian Nelson; **Limestone pavement**, Bricklieve Mountains, Co. Sligo, Andy Bleasdale; **Garden Tiger** *Arctia caja,* Brian Nelson; **Violet Crystalwort** *Riccia huebeneriana*, Robert Thompson; **Coastal heath**, Howth Head, Co. Dublin, Maurice Eakin; **Meadow Saffron** *Colchicum autumnale*, Lorcan Scott

Bottom photograph: **Yew trees at Reenadinna, an ancient woodland in Killarney National Park**, Nicolas Raymond CC-BY-SA-3.0

Mapping, monitoring, and protecting ancient and long-established woodland in Ireland

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This IWM was edited by Domhnall Finch and Sue Wilson

ISSN 1393 – 6670

An Roinn Tithíochta, Rialtais Áitiúil agus Oidhreachta, 90 Sráid an Rí Thuaidh, Baile Átha Cliath 7, D07 N7CV

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Executive Summary

Ireland's ancient woodlands (areas believed to have remained continuously wooded since at least 1660) are irreplaceable habitats of high biodiversity value. These woodlands can also provide additional ecosystem services (*e.g*. long-term carbon storage) and often contain features of historical and cultural significance. However, ancient woodlands and long-established woodlands (LEWs - areas that have remained continuously wooded since the first edition Ordnance Survey maps of the 1830s) are now a rare and fragmented feature of the Irish landscape. The provisional inventory of ancient and long-established woodland in Ireland (Perrin & Daly, 2010) used historic map and text sources in combination with other contextual evidence to assign ancient or possible ancient status to 123 woodland sites across Ireland. However, the provisional inventory focused primarily on relatively large woodlands (>5 ha). Given the small and fragmentary nature of Irish woodlands, it is likely that many ancient and long-established woodlands (ALEWs) are not included in the provisional inventory. In addition, the current conservation status of ALEWs in Ireland has yet to be evaluated. In this report, the results of a desk-based study on the current state-of-knowledge of ALEWs in Ireland are presented. The overall objective of the study was to assess current conservation status of known ALEWs and to outline the steps necessary for the completion of a national inventory of ALEW in Ireland that includes smaller (<5 ha) woodlands.

A review of the provisional inventory of ancient and long-established woodland (Perrin & Daly, 2010) revealed that only 32% of the area of mapped ALEWs occurs within the current network of protected areas. Conservation assessment information for 75 ALEW sites listed in the provisional inventory is available through Habitats Directive Article 17 monitoring data for Annex I habitats. Forty-six percent of these ALEW sites received an Unfavourable-Bad conservation assessment. The most common negative impacts on the conservation status of ALEWs come from invasive non-native species and overgrazing.

A case study of 1830s woodland cover in Co. Leitrim and Co. Kilkenny was completed. To identify and map historic woodland cover at a finer scale than the provisional inventory, all woodlands >0.1 ha in OS first edition maps were digitised in a GIS database. Based on first edition maps, forests covered 1.3% (2,077 ha) of Leitrim in c. 1830, compared to 20.1% today. 1102 ha (53%) of c. 1830s woodland in Leitrim remains wooded today. In Kilkenny, 3.8% (7,860 ha) of the area of the county was wooded compared with a current forest cover of 10%. Only 44% (3487 ha) of the wooded area in c. 1830s remains wooded today. Despite the widespread loss of old woodlands, the overall forest area in Leitrim and Kilkenny has dramatically expanded since the c. 1830s largely due to establishment of non-native conifer plantations.

As part of the case study, Down Survey maps (1656-1658) and other 17th and 18th century sources were used to assign ancient status to extant c. 1830s woodlands >0.25 ha in size. In Leitrim and Kilkenny, 120 and 145 ancient or possible ancient woodland polygons were identified, a total of 270 ha and 877 ha, respectively.

A review of current palaeoecological knowledge of ALEWs in Ireland was also conducted to assess the utility of palaeoecological data analysis as a tool for determining woodland ancientness. Palaeoecological evidence can be used to clarify the classification of ancient woodlands and can extend our temporal perspective of these woodlands. However, palaeoecological data are an underused resource and currently provide limited understanding across sites, with only 18 local stand-scale palaeoecological studies conducted in ALEW in Ireland.

Despite their ecological, historical, and cultural significance, undesignated ALEWs are at risk of degradation and even deforestation. A formalised approach for the protection, monitoring, and restoration of ALEWs in Ireland is required. Based on the results of a case study in Leitrim and Kilkenny, the majority of ALEWs in Ireland are not recorded in the provisional inventory of

ancient and long-established woodland. A full national inventory of ancient and long-established woodland in Ireland is required. The inventory should be designed to allow for periodic updates based on best available information. A consistent and repeatable approach to identifying ALEWs in Ireland is proposed in this report.

The attribution of ancient woodland status is best supported by multiple lines of evidence. In addition to the interpretation of historic documents and maps, toponymical research, ancient woodland indicator species, palaeoecological data and woodland archaeology should be used to support the assessment of woodland antiquity. As part of a National Inventory of Ancient Woodland, a consistent methodology for assessing sites in the field should be developed.

Acknowledgements

The authors gratefully acknowledge the assistance of a number of people who have helped in the preparation of this report. Many thanks to Orla Daly and Dr Phillip Perrin (BEC Consultants) for providing guidance on the provisional inventory of ancient and long-established woodland in Ireland. We also thank BEC Consultants for the use of a number of photographs of ancient and long-established woodland sites in this report. We thank Ordnance Survey Ireland (OSi) for access to aerial photography and historic maps (Licence No. MP008021). We thank Tom Broderick at OSi for guidance on interpretation of OS first edition maps. We are grateful to Coillte for providing spatial data for “old woodland sites”. We thank John Redmond at the Forest Service, Department of Agriculture, Food, and the Marine for providing National Forest Inventory data. We also thank David Smyth and the Native Woodland Trust for providing information on a citizen science project that sought to identify ALEW in a number of counties. We thank Dr Ronan Foley (Maynooth University) for assistance with GIS.

Special thanks to a number of experts who provided additional guidance on the interpretation of historic map and text sources relevant to the identification of ancient woodlands, namely Paul Ferguson, Dr David Brown, Professor Micheál Ó Siochrú (Trinity College Dublin), Dr Annaleigh Margey (Dundalk Institute of Technology) and Professor Ian Rotherham (Sheffield Hallam University).

List of Abbreviations

ALEW	Ancient and Long-established woodland
AW	Ancient woodland
CNN	Convolutional neural network
EPD	European pollen database
EU	European Union
GIS	Geographical Information System
HD	Habitats Directive
IPOL	Irish pollen site database
LEW	Long-established woodland
NFI	National Forest Inventory
NHA	Natural Heritage Area
NLI	National Library of Ireland
NPP	Non-Pollen Palynomorphs
NPWS	National Parks and Wildlife Service
NSNW	National Survey of Native Woodland
OS	Ordnance Survey
OSi	Ordnance Survey Ireland
PAW	Possible Ancient Woodland
pNHA	Proposed Natural Heritage Area
SAC	Special Area of Conservation
SPA	Special Protection Area
XRF	X-ray fluorescence

1. Introduction

1.1 Background and rationale

In an Irish context, ancient woodlands (AW) have been defined as areas believed to have remained continuously wooded since 1660[1] (Perrin & Daly, 2010). Possible ancient woodlands (PAWs) are woodlands thought to have remained wooded since 1660, but for which evidence is less strong. Long-established woodland (LEW) is defined as woodland that has remained continuously wooded since the first edition OS maps of 1829-1842 (Perrin & Daly, 2010). Internationally, the ecological and cultural value of old woodlands has long been recognised (Honnay *et al.,* 1998; Peterken, 1977; Rackham, 1980). For example, ancient woodlands can support higher levels of biodiversity compared to woodlands of recent origin, including rare species and woodland specialists (Paillet *et al.,* 2015; Peterken, 1983). Ancient and long-established woodlands (ALEWs) can provide other valuable ecosystem services such as long-term carbon storage and the maintenance of human health (Glatthorn *et al.,* 2018; Luyssaert *et al.,* 2008; Watson *et al.,* 2018). In addition, ALEWs often contain features of significant historical and/or cultural value (Perrin & Daly, 2010).

The EU Biodiversity Strategy for 2030 (European Commission, 2021a) outlines a commitment to strictly protect all remaining EU old-growth forests[2]. However, a recent report by Barredo *et al.* (2021) highlighted significant gaps in our knowledge of the extent of old-growth forests in Europe. Improved mapping of primary and old-growth forests has been identified as a key priority, and the European Commission has published guidelines for the definition, mapping, monitoring and strict protection of all the EU's remaining primary and old-growth forests[2]. Though this definition of old-growth forests emphasises high levels of naturalness rather than long temporal continuity of forest cover, some overlap is likely to occur between old-growth forests and ALEWs in the Irish context.

In Ireland, ancient woodlands are a rare and fragmented feature of the landscape. Given the near-complete deforestation of old-growth forests in Ireland, fragments of ancient woods represent a critically important ecological and cultural resource that provides a tangible link to a prehistoric wooded past. They include some of the most natural and least disturbed examples of woodland habitat remaining in Ireland. A sizeable body of research has explored the history of woodland cover in Ireland, including the work of McCracken (1971), Mitchell (1988), O'Connell *et al.* (1988), Bohan (1997), Nicholls (2001), Everett, (2014), and others (see Perrin & Daly, 2010, for a full summary of previous research on ancient woodland in Ireland). However, prior to 2010, no inventory of ancient woodland in Ireland existed. In comparison, detailed inventories of ancient woodlands in Britain since the 1980s have become established tools in planning and conservation policy (Goldberg *et al.,* 2007). This has highlighted the need for a comprehensive review of the current state of knowledge of ALEWs in Ireland to support evidence-based decision-making and inform future work.

The publication of the provisional inventory of ancient and long-established woodland in Ireland (Perrin & Daly, 2010) marked a major advance in our understanding of the distribution of ancient woodland in Ireland. After identifying long-established woodlands using Ordnance Survey (OS) first edition maps, Perrin & Daly (2010) used 17th and 18th century maps and historical texts, in combination with vegetation data, palaeoecological evidence, archaeological

[1] This date was used because the Down Survey and the Civil Survey were conducted during the 1650s - these are the two most useful historical resources available. In Northern Ireland, ancient woodland is defined as land continuously wooded since at least 1600 (Anon, 2007).

[2] A forest stand or area consisting of native tree species that have developed, predominantly through natural processes, structures and dynamics normally associated with late-seral developmental phases in primary or undisturbed forests of the same type. Signs of former human activities may be visible, but they are gradually disappearing or too limited to significantly disturb natural processes. https://ec.europa.eu/transparency/documents-register/detail?ref=SWD(2023)62&lang=en

features and other contextual information, to assign ancient or possible ancient status to 123 woodland sites. However, the limited scope of the project meant that evaluation of woodland antiquity was largely restricted to relatively large stands (>5 ha). Given the small and fragmentary nature of Irish woodlands, it is likely that many ancient woodlands were not included in the provisional inventory. Additionally, because data from the National Survey of Native Woodlands (NSNW; Perrin *et al.,* 2008) was used as the primary dataset for ancient woodland identification and mapping, some ALEW sites now dominated by planted conifers or non-native broadleaves may have been omitted. Indeed, preliminary evidence from a recent Citizen Science project[3] (Smyth, 2020) indicates that smaller sites, non-native woodlands, and privately-owned sites may be under-represented in the provisional inventory of ALEWs in Ireland. Ancient woodlands in Ireland are irreplaceable and are of extremely high conservation value. Yet, major gaps remain in our understanding of ancient woodlands in Ireland and their conservation status.

The provisional inventory of ancient and long-established woodland (Perrin & Daly, 2010) emphasises that "the provisional nature adopted by the inventory leaves it open to systematic revisions, should new information emerge". In the fourteen years since the publication of the provisional inventory, numerous new or previously unavailable resources relevant to ALEW in Ireland have become available. Multiple recent publications and datasets may provide additional evidence regarding the distribution and status of ALEWs in Ireland (*e.g*. Cooper & McCann, 2013; Cudmore, 2012; Devaney *et al.,* 2017; Mitchell *et al.,* 2013; Roche *et al.,* 2018; Roche & Doherty, 2023, see Appendix 1 for a list of relevant studies that have been published since 2010). Moreover, historical texts and archival maps that can be used to determine woodland age are becoming increasingly accessible, with many now available online through digital libraries (*e.g.* The Down Survey Project https://downsurvey.tcd.ie/). Given the availability of new information on woodland ancientness, and increased emphasis on the protection of old-growth forests in EU forest policy, there is now a timely opportunity to enhance the identification, mapping, and conservation of remaining ALEWs in Ireland.

1.2 Project aims

There is a pressing need to examine the feasibility of integrating existing datasets, identify remaining knowledge gaps, and set out the necessary steps to complete a national inventory of ALEWs in Ireland. As there is currently no specific protection or monitoring of ALEWs in Ireland, the adequacy of protection afforded to ALEW sites in Ireland, and their conservation status, requires evaluation. In this report, the results of a desk-based study on the current state-of-knowledge of ALEW in Ireland are presented. The results described herein will inform future work and support evidence-based decision-making regarding the identification, mapping, monitoring, and protection of ALEW. While it is recognised that detailed studies of ancient woodland require a field assessment component (*e.g*. indicator species and/or interpreting archaeological and landscape features), as this is a desk-based study, focus is placed on existing datasets, mapping resources, historic maps and texts, and published palaeoecological data. The specific objectives of this project were:

- To use existing datasets to evaluate the current conservation status of known ALEWs (after Perrin & Daly, 2010) in Ireland.
- To utilise historic OS maps and contemporary aerial imagery to digitise c. 1830s woodland cover in two case-study counties (Co. Leitrim and Co. Kilkenny). This digitisation was completed at a much finer scale (woodlands >0.1 ha) than the Provisional Inventory of Ancient and Long-established Woodlands.
- To use historic text and/or archival map evidence to evaluate the ancientness of all extant c. 1830s woodlands (>0.25 ha) cover in Leitrim and Kilkenny.

[3] A volunteer Citizen Science sought to map LEW sites in Ireland, with support from the Native Woodland Trust. Determinations are based on the 6-inch and 25-inch OS maps, using OSI's Geohive website (Smyth, 2020).

- To review all available palaeoecological data relevant to the study of ancient woodlands in Ireland.
- To outline the steps necessary for the completion of a National Inventory of ALEW in Ireland.

2. Conservation status of ancient and long-established woodlands in Ireland

2.1 Introduction

A recent EU report has outlined the urgent need to strictly protect all primary and old-growth forests in Europe (Barredo *et al.,* 2021). The report also emphasises that a comprehensive monitoring system for primary and old-growth forests in Europe is required to safeguard their long-term integrity. Despite their national importance, no specific protection is afforded to Ireland's ALEWs. While some ALEW sites occur within Ireland's network of Natura 2000 protected areas, the adequacy of the overall protection afforded to ALEWs requires evaluation. In addition, currently, there is no monitoring programme for ALEWs in Ireland. However, as required under Article 17 of the EU Habitats Directive, systematic ecological assessment occurs every six years in a subset of Ireland's Annex I woodland sites (*i.e.* 91A0 Old sessile oak woodland, 91D0 Bog woodland, 91E0 Alluvial woodland, 91J0 Yew woodland). Some ALEWs occur within these Annex I woodland habitats and consequently, data on the conservation status of some ALEWs are available (NPWS, 2019). To date, however, the proportion of ALEWs that occur within Annex I habitats, and their conservation status, has not been evaluated.

In this chapter, the adequacy of the current protected area network for ALEWs (after Perrin & Daly, 2010) is assessed. An analysis of existing Article 17 spatial and monitoring data for ALEW sites is also presented.

2.2 Methods

2.2.1 Evaluating the current level of protection of ALEWs in Ireland

In ArcGIS Pro® (V2.8), the provisional inventory of ALEWs was intersected with spatial data for Ireland's protected area network (*i.e*. Special Areas of Conservation (SACs), Special Protection Areas (SPAs), Natural Heritage Areas (NHAs)) (NPWS, 2022, https://www.npws.ie/maps-and-data/designated-site-data). The area of ALEW occurring in proposed NHAs[4] (pNHAs) was also documented. The coverage of the ALEW Annex I habitat types occurring inside and outside protected areas and pNHAs was also summarised.

Instances where ALEW is located within an SAC and assigned to an Annex I habitat which is not listed as a qualifying interest for that site were documented. Next, for ALEWs outside of the protected area network, the relationship between ALEW size and distance to nearest protected area (using 50 m, 100 m, 200 m, and 500 m buffers around ALEW sites) was assessed.

The National Survey of Native Woodlands (NSNW; Perrin et al., 2008) was undertaken from 2003-2008. Covering 1,217 sites, it is a representative sample of the range of native woodland diversity in Ireland. As part of the survey, sites were surveyed, described and classified, and their boundaries and habitats were mapped using Fossitt (2000). By intersecting the provisional ALEW inventory data with spatial data from the NSNW (Perrin *et al.,* 2008, NPWS, 2022, https://www.npws.ie/maps-and-data/habitat-and-species-data), the occurrence of ALEWs in different native woodland habitat types (Fossitt, 2000) was summarised, paying particular attention to WN2 Oak-ash-hazel woodland, as this habitat is of high conservation importance nationally, but is not directly aligned to an Annex I habitat.

[4] Proposed Natural Heritage Areas (pNHA) were published on a non-statutory basis in 1995. They have not since been statutorily proposed or designated. These sites are of significance for wildlife and habitats. A process is underway to resurvey and formally designate some pNHAs as NHAs. Prior to statutory designation, woodland pNHAs are subject to some limited protection as follows: (i) The Forest Service is obliged to refer all applications for proposed forestry developments within pNHAs to NPWS for comment. (ii) Recognition of the ecological value of pNHAs by Planning and Licencing Authorities. https://www.npws.ie/protected-sites/nha

2.2.2 Monitoring of ALEWs in Ireland

ALEW spatial data in Perrin & Daly (2010) (NPWS, 2022, https://www.npws.ie/maps-and-data/habitat-and-species-data) was intersected with existing Article 17 woodland monitoring site data (91A0 Old sessile oak woodland, 91D0 Bog woodland, 91E0 Alluvial woodland, 91J0 Yew woodland). Using Article 17 monitoring data extracted from ALEW sites, the conservation status and current pressures (*e.g*. invasive species, overgrazing) for ALEW sites in Ireland were summarised.

Devaney *et al.* (2017) reported 52 deforestation events occurring between 2000-2012 in ALEWs identified by Perrin & Daly (2010). Using more recent Ordnance Survey Ireland (OSi) aerial imagery (2017), this assessment of permanent deforestation in ALEWs over the last two decades was updated. A breakdown of land-use transitions and woodland type is provided. Land-use types are based on land-use types recorded in Ireland's National Forest Inventory (Forest Service, 2023a).

2.3 Results

2.3.1 Evaluating the current level of protection of ALEWs in Ireland

Of the 19,672 ha of ALEW identified by Perrin & Daly (2010), 6300 ha (32%) occurs within protected areas (Figure 1, 2). Twenty eight percent (5,596 ha) of the total area of ALEWs occur within Ireland's network of SACs. A relatively small area (598 ha, 3% of total ALEW area) occurs within SPAs but outside of SACs. 106 ha (0.5%) of ALEW is outside of Ireland's Natura 2000 network but within NHAs. Of the remaining undesignated ALEWs, 1,227 ha (9%) falls within 100 m of a protected area. 2,861 ha (15%) of ALEWs are not currently protected but occur within as yet undesignated pNHAs.

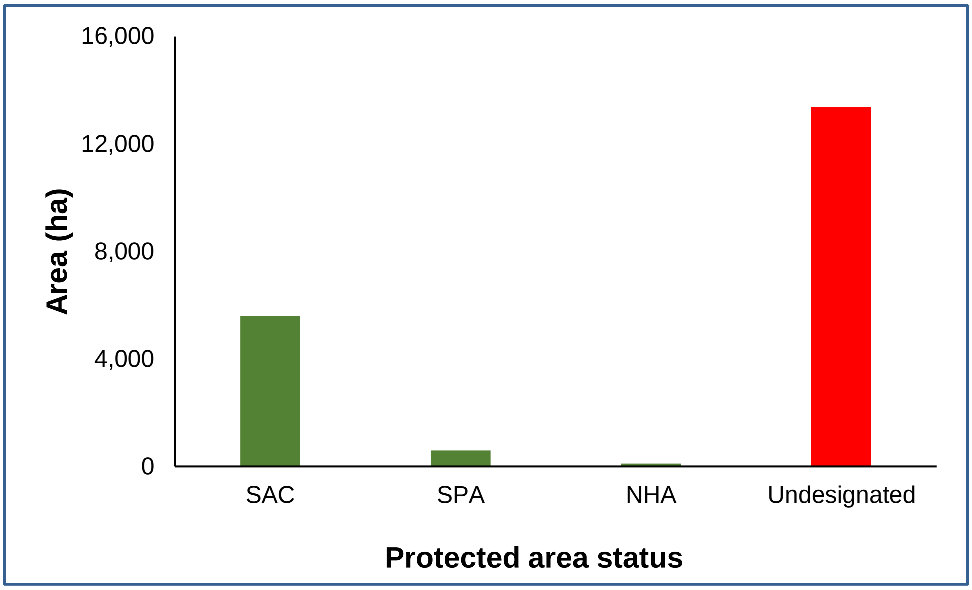

Figure 1 The area (ha) of mapped ALEWs (data from Perrin & Daly, 2010) protected/undesignated under different protected area categories (SAC Special Area of Conservation, SPA Special Protection Area, NHA Natural Heritage Area).

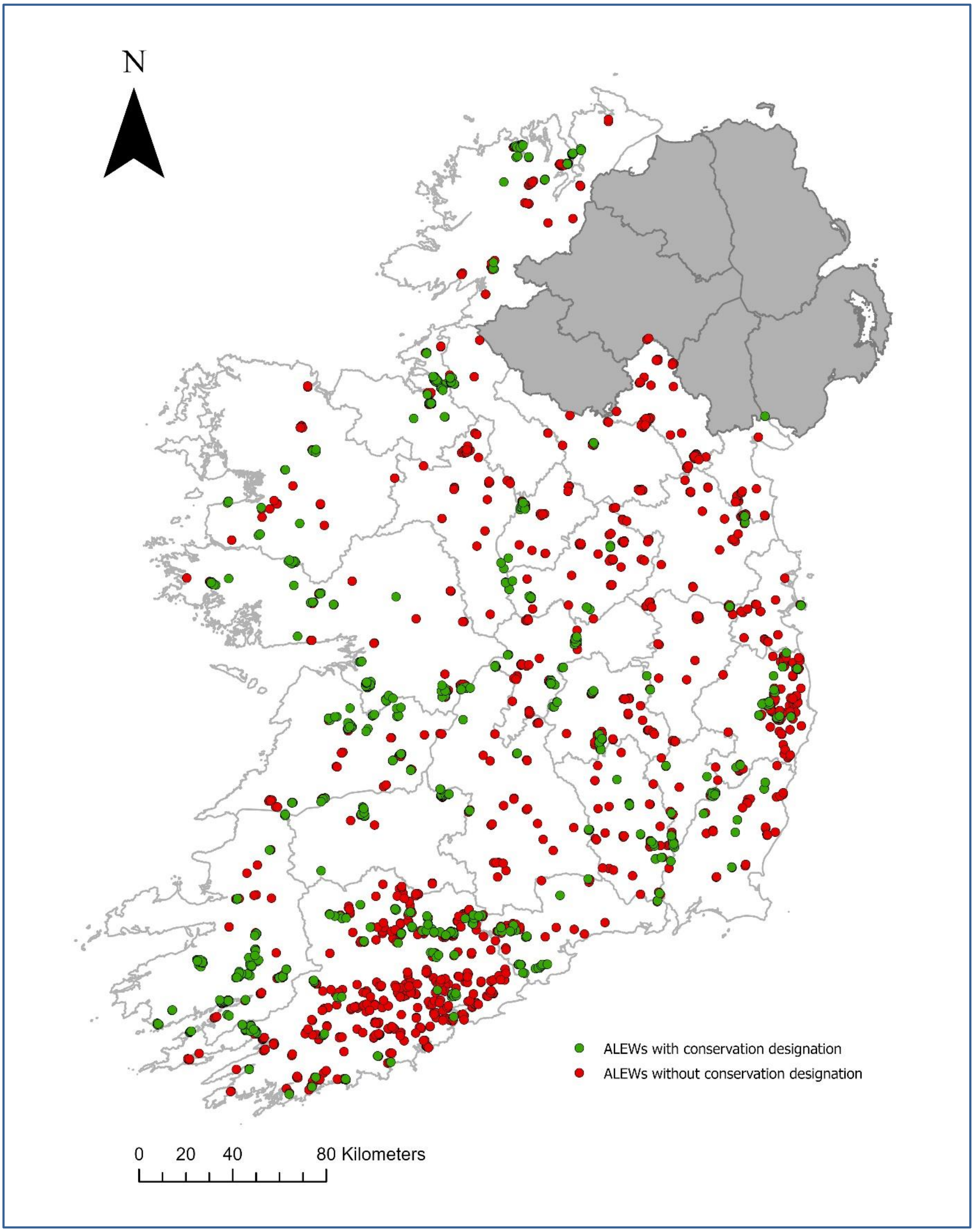

Figure 2 The distribution of mapped ALEWs (data from Perrin & Daly, 2010) with conservation designation (green) and ALEWs without conservation designation (red) in Ireland. The high density of ALEWs in Co. Cork is due to the inclusion of ALEW sites from an unpublished report "The Ancient and Long--established Woodlands of County Cork" (Daly & Perrin, 2010).

Based on available spatial data (NPWS, 2019, https://www.npws.ie/maps-and-data/habitat-and-species-data/article-17/2019), 3,948 ha (20%) of ALEW occurs within mapped Annex I habitat (91A0 Old sessile oak woodland, 91E0 Alluvial woodland, 91J0 Yew woodland, and woodland occurring on 8240 Limestone Pavement). No ALEW was recorded within mapped 91D0 Bog woodland. Fifty-nine percent of Annex I type ALEWs occur within protected areas

(Figure 3). In cases where Annex I ALEWs occur within an SAC, that Annex I woodland habitat type is usually listed as an SAC qualifying interest. In a small number of cases however, Annex I ALEWs occur within an SAC, but the Annex I woodland habitat is not listed as a qualifying interest (Table 1).

Figure 3 The area (ha) of protected and undesignated ALEWs (data from Perrin & Daly, 2010) that fall under mapped Annex I woodland habitat types (NPWS, 2019, https://www.npws.ie/maps-and-data/habitat-and-species-data/article-17/2019).

Thirty-one percent (6,165 ha) of the area of ALEWs mapped by Perrin & Daly (2010) fall within the boundary of sites mapped by the NSNW (Perrin *et al.,* 2008, NPWS, 2012, https://www.npws.ie/maps-and-data/habitat-and-species-data). Using this dataset, the occurrence of ALEWs and their protection status with respect to mapped Fossitt (2000) woodland habitat types was documented (Figure 4). The most common ALEW woodland type in the NSNW dataset is WN1 Oak-birch-holly woodland (2320 ha). This habitat broadly aligns with the Annex I habitat 91A0 Old sessile oak woodland and consequently, a large proportion (67%) of the area of WN1 ALEW is afforded protection through the protected area network (Figure 4). WN2 Oak-ash-hazel woodland is also a common habitat type for ALEWs in the NSNW dataset (1569 ha). Unlike WN1 Oak-birch-holly woodland, WN2 Oak-ash-hazel woodland has no analogous Annex I designation and, despite its national importance, WN2 Oak-ash-hazel woodland is not afforded the same level of protection through the Natura 2000 network. Indeed, this analysis indicates that only 47% of the area of WN2 ALEW occurs within a protected area.

Table 1 List of mapped ALEW sites (data from Perrin & Daly, 2010) that have Annex I woodland (NPWS, 2019, https://www.npws.ie/maps-and-data/habitat-and-species-data/article-17/2019), and occur within an SAC, but their Annex I woodland is not listed as a qualifying interest for that SAC.

Site Name	County	Overall Area (ha)	Area of ALEW	ALEW habitat not listed as qualifying interest
Castlemaine Harbour SAC	Kerry	8683	1.5	91A0 Old sessile oak woodland
Mweelrea/Sheeffry/ Erriff Complex SAC	Mayo	20974	12.2	91A0 Old sessile oak woodland
The Twelve Bens/Garraun Complex SAC	Galway	16163	8.4	91E0 Alluvial woodland
Lower River Shannon SAC	Clare, Cork, Kerry, Limerick, Tipperary	37394	6.5	91A0 Old sessile oak woodland
Pollnaknockaun Wood Nature Reserve SAC	Galway	6094	69.23	91J0 Yew woodland
Glenomra Wood SAC	Clare	5098	42.9	91E0 Alluvial woodland
Castletownshend SAC	Cork	17	15.8	91A0 Old sessile oak woodland
Kenmare River SAC	Cork, Kerry	22880	11.8	91A0 Old sessile oak woodland
Glenstal Wood SAC	Limerick	8.08	7	91A0 Old sessile oak woodland
Blackstairs Mountains SAC	Carlow, Wexford	5046	6	91A0 Old sessile oak woodland
Courtmacsherry Estuary SAC	Cork	741	9.74	91A0 Old sessile oak woodland
Lough Hyne Nature Reserve and Environs SAC	Cork	451	21.5	91A0 Old sessile oak woodland

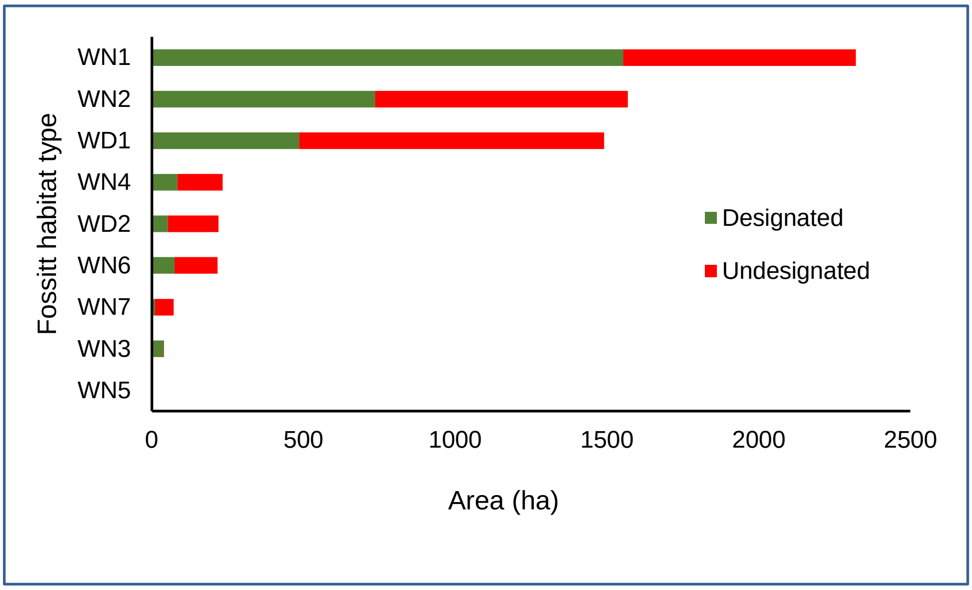

Figure 4 The area (ha) of protected and undesignated ALEWs (after Perrin & Daly) that fall under Fossitt (2000) woodland habitat types (WN1 Oak-birch-holly woodland, WN2 Oak-ash-hazel woodland, WN3 Yew woodland, WN4 Wet pedunculate oak-ash woodland, WN5 Riparian woodland, WN6 Wet willow-alder-ash woodland, WN7 Bog woodland, WD1 (Mixed) broadleaved woodland, WD2 Mixed broadleaved/conifer). Data from the National Survey and Native Woodlands (NPWS, 2012, https://www.npws.ie/maps-and-data/habitat-and-species-data).

2.3.2 Evaluating current monitoring and conservation status of ALEWs in Ireland

A total of 492 plots across 128 woodland sites are currently included in Ireland's Annex I woodland monitoring network (Daly *et al.,* 2023). Annex I woodland monitoring gathers data on three main parameters – habitat area, Structure and Functions, and Future Prospects (Daly *et al.,* 2023). Each site receives a rating of Favourable (green), Unfavourable-Inadequate (amber) or Unfavourable-Bad (red) for these parameters. Pressures and threats that are impacting sites are also evaluated. The results of these appraisals are used to obtain an overall assessment of conservation status at each site.

Conservation assessment information for 75 (11%) of ALEW stands mapped by Perrin & Daly, (2010) are available through the Annex I woodland monitoring data (Figure 5, Appendix 2). The majority of ALEWs with conservation assessment data are from 91A0 Old sessile oak woodland (59 stands) with twelve 91E0 Alluvial woodland sites, and four 91J0 Yew woodland stands also being part of the Annex I monitoring network (Figure 5).

The most recent available monitoring data were recorded in 2017-2018 (Daly *et al.* 2023). For the "Area" assessment, all ALEW stands with Annex I monitoring data received a Favourable (green) score *i.e*. no habitat loss was recorded from monitoring sites. In terms of their Structure and Functions, only seven AW and PAW ALEW sites (23%) received a Favourable (green) assessment (Appendix 2, Figure 6). In contrast, 32% of LEW sites received a Favourable assessment for Structure and Function. In a similar trend, only 22% of AW and PAW sites received a Favourable assessment for Future Prospects, whereas 32% of LEW sites received a Favourable assessment for Future Prospects (Appendix 2, Figure 6). The most common negative impact on the conservation status of ALEWs comes from invasive non-native species – problematic invasive species were recorded in 68 (90%) of all ALEW Annex I monitoring sites. Many sites (n=28) were also negatively impacted by overgrazing (Appendix 2, Figures 7 and 8). Less frequently occurring negative impacts at ALEW Annex I monitoring sites included the dumping of garbage and solid waste, the presence of paths, tracks, cycling tracks through woodland, and problematic native species (Appendix 2). For AW and PAW sites with Annex I monitoring data, 23% received a Favourable assessment for Overall Conservation Status, 32% received an amber assessment and 45% received a red assessment. For LEWs with Annex I monitoring data, 32% received a Favourable assessment for Overall Conservation Status, 27% received an amber assessment and 41% received a red assessment.

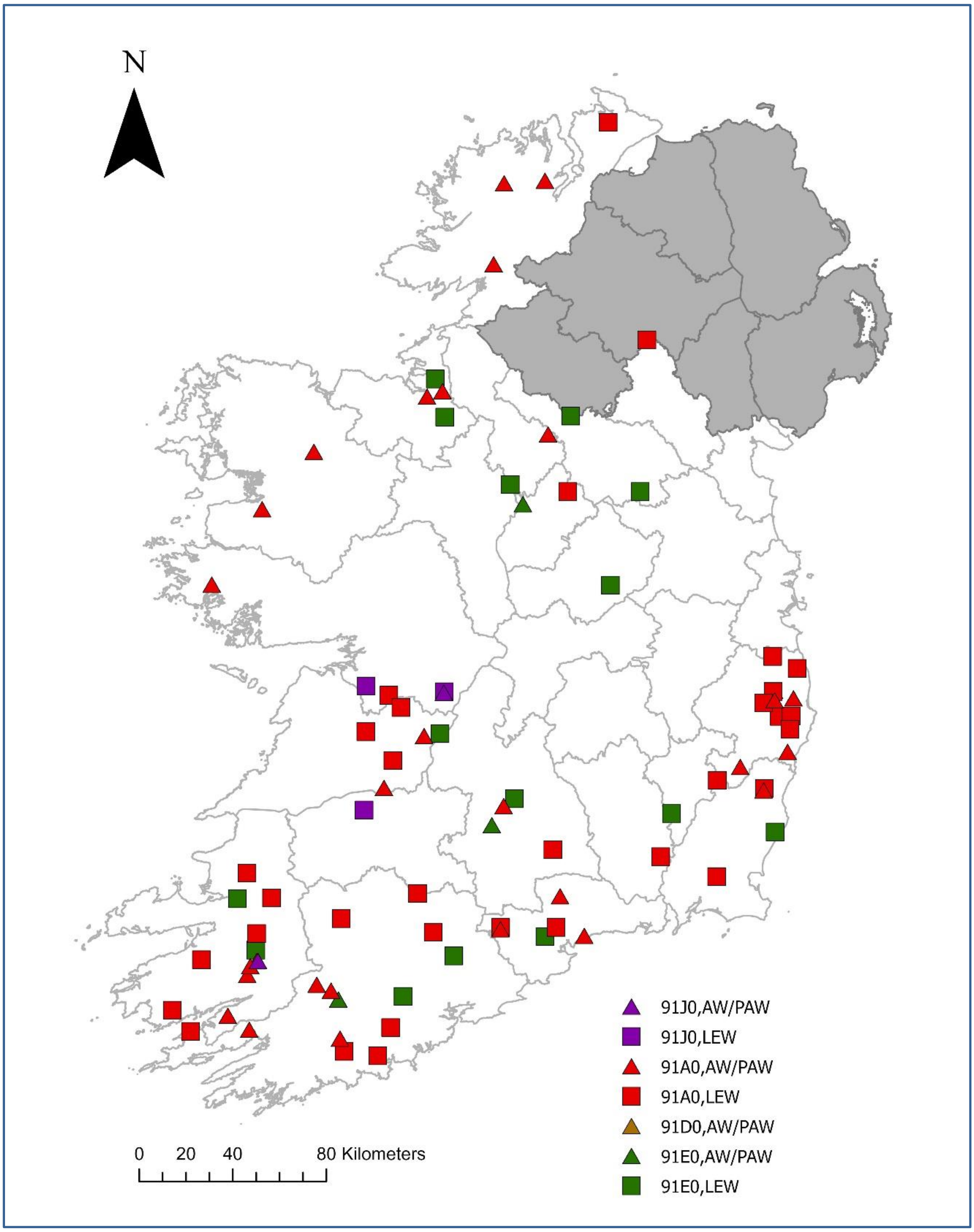

Figure 5 Distribution of ALEWs (after Perrin & Daly, 2010) with Annex I woodland monitoring data (red; 91A0 Old sessile oak woodland, green; 91E0 Alluvial woodland, purple; 91J0 Yew woodland). Triangles indicate ancient or possible ancient woodlands and squares indicate long-established woodland.

Of the ALEW 91E0 Alluvial woodland sites monitored, 30% received a red conservation status assessment, 45% an amber assessment, and 25% a green assessment. All (100%) of the ALEW 91J0 Yew woodland sites monitored received a red conservation status assessment; the pressures and threats affecting these sites are further described by Roche *et al*. (2023). Of the ALEW 91A0 Old sessile oak woodland sites monitored, 41% received a red conservation status assessment, 29% an amber assessment, and 31% a green assessment.

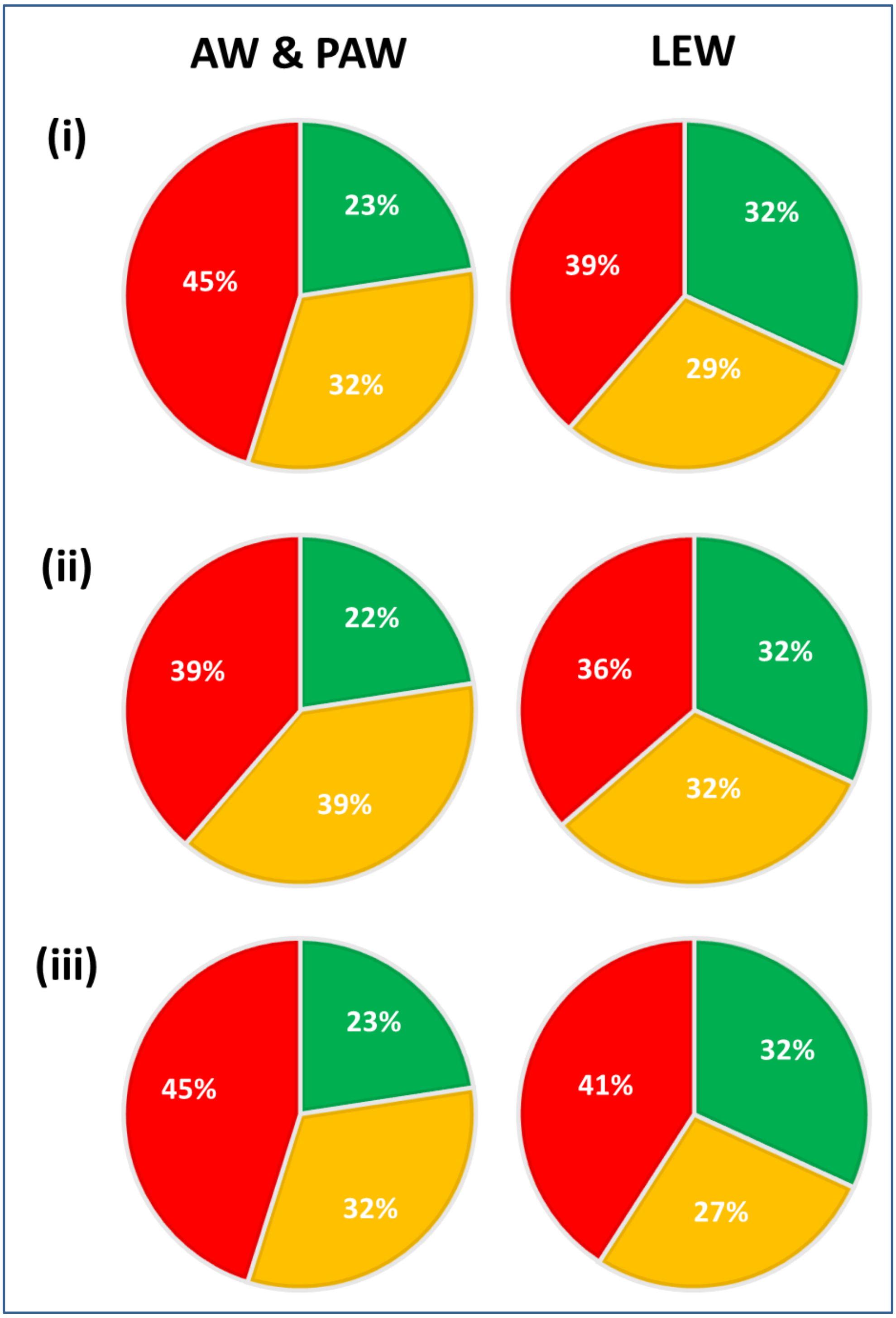

Figure 6 The percentage of AW and PAW (left) and LEW (right) (after Perrin & Daly, 2010) that were rated as Favourable (green), Unfavourable-Inadequate (amber), or Unfavourable-Bad (red) in the Structure and Functions (i), Future Prospects (ii), and Overall Conservation Status (iii) categories.

Figure 7 Derrycunihy Wood, part of Killarney National Park, Co. Kerry, is categorised as AW (Perrin & Daly, 2010) based on palynological, cartographical, and written evidence of woodland antiquity. The current conservation status of Derrycunihy Wood is Unfavourable-Bad, primarily due to heavy deer grazing (note lack of developed understorey vegetation) and invasive non-native plant species (Daly et al., 2023). Photograph Orla Daly.

Figure 8 Glengarriff Wood, Co. Cork, is categorised as AW (Perrin & Daly, 2010) due to historic cartography and written evidence of woodland antiquity. The current Overall Conservation Status of Glengarriff Wood is Favourable, owing to large scale removal of invasive non-native shrubs. This, coupled with lower deer browsing pressure than some comparable sites in the southwest, has facilitated the development of understorey vegetation, including the natural regeneration of native tree species (Daly *et al.,* 2023). Photograph Oisín Duffy.

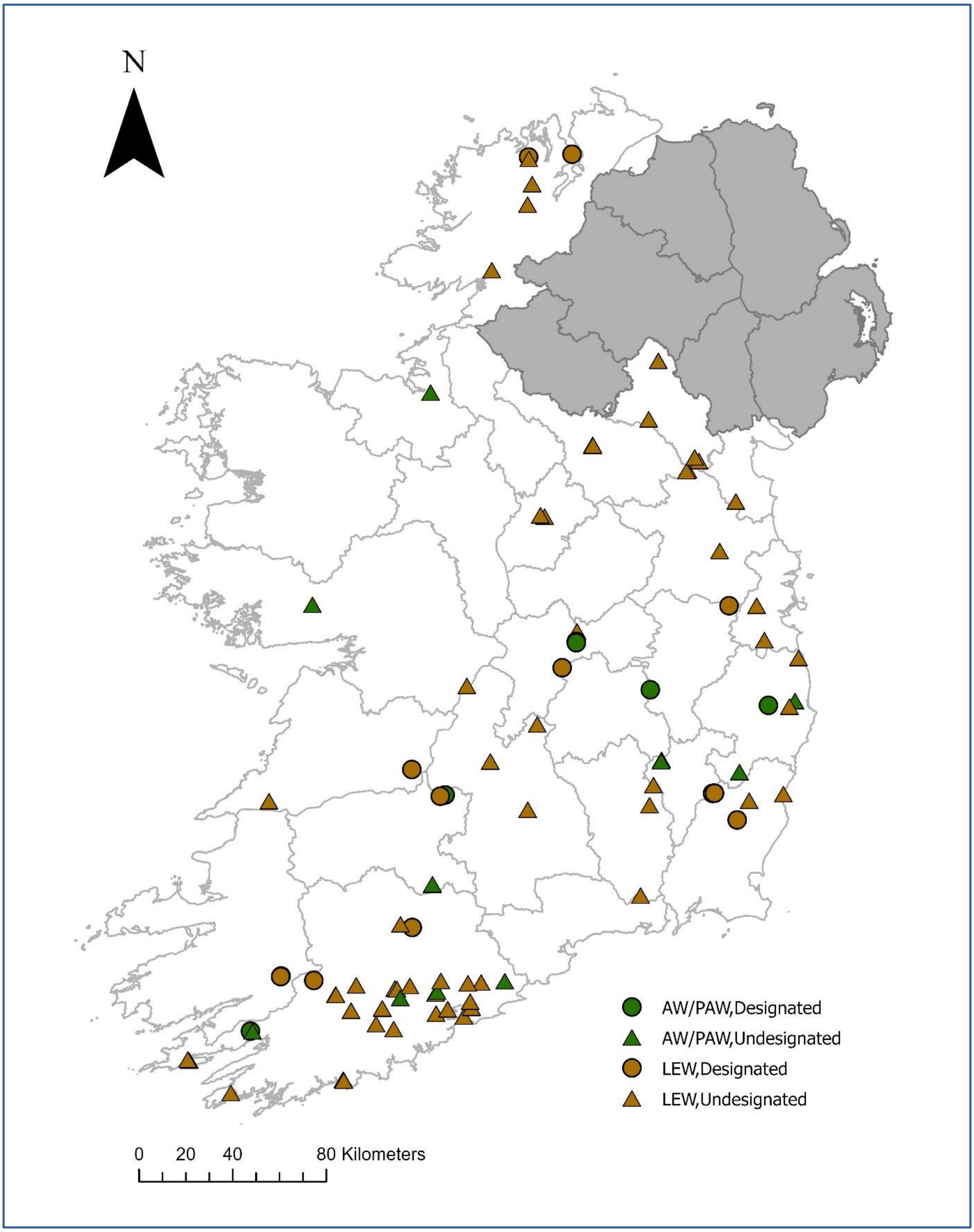

Figure 9 Distribution of deforestation events recorded at ALEWs (after Perrin & Daly, 2010) between 2000-2018 using aerial imagery interpretation (green: ancient and possible ancient woodland, brown: long-established woodland). Deforestation occurred mostly in ALEWs with no protected area designation (73 sites, triangles). Twenty ALEW deforestation events occurred in SACs (circles).

No losses of ALEW area were detected by Daly *et al.* (2023) within the Annex I woodland sites monitored for Article 17 reporting. However, a wider-scale analysis of deforestation in Ireland, utilising aerial imagery, has identified instances of area loss of ALEW. Devaney *et al.* (2017) reported 52 deforestation events occurring in ALEWs identified by Perrin & Daly (2010) between 2000 and 2012. Using more recent (2017) OSI aerial imagery, the level of permanent deforestation in ALEWs over the last two decades (since 2000) was re-assessed. An additional 41 permanent deforestation events in ALEWs were identified (total of 93 since 2000, Figure 9). Four permanent deforestation events were identified in AWs, 14 in PAWs, and 75 in LEWs. By far the most frequent land-use transition was forest to built land (rural). Examples included conversion of ALEW to one off houses, larger housing developments, and expansion of industrial sites (Figure 10, 11). Deforestation of ALEW to agricultural grassland was also relatively frequent (n=18). In both built land and grassland land-use transitions, deforestation was more common for semi-natural broadleaf ALEWs in comparison to ALEWs that are now dominated by conifer, mixed (conifer and broadleaf), or non-native broadleaves (Figure 10). The third most frequent post deforestation land use was green space (rural) – examples included conversion of ALEWs to amenity grassland, golf courses, and playing pitches (Figure 10, 11). Of the 93 documented cases of permanent deforestation of ALEWs since 2000, 20 occurred within protected areas (all SACs), with the remaining 73 deforestation events occurring in woodland sites with no statutory conservation designation. Two cases of deforestation were recorded in Annex I habitat (both 91E0 Alluvial woodland).

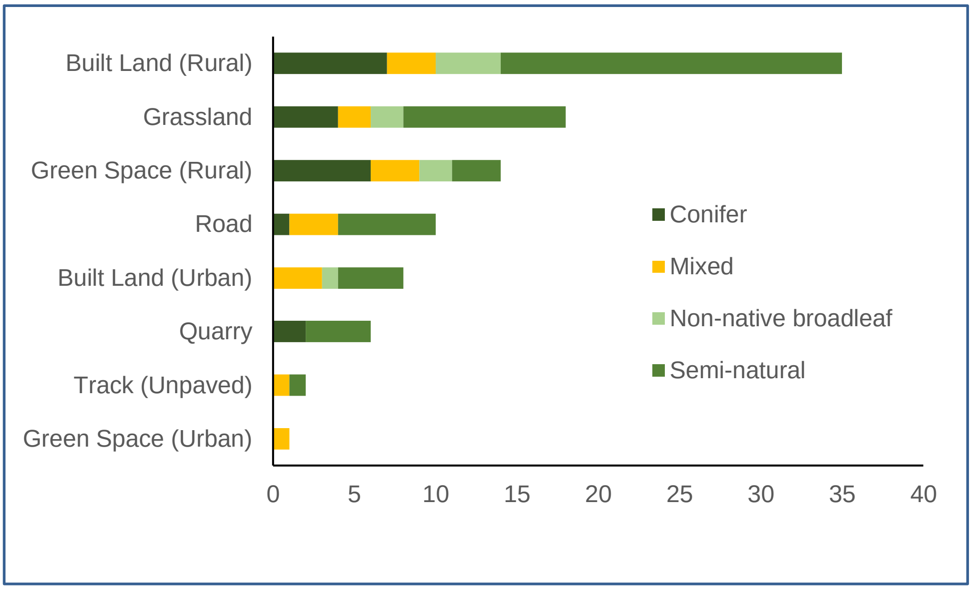

Figure 10 Number of deforestation events in ALEWs (after Perrin & Daly, 2010) in different land-use transition and woodland (conifer plantation, mixed woodland, non-native broadleaf, semi natural broadleaves) categories.

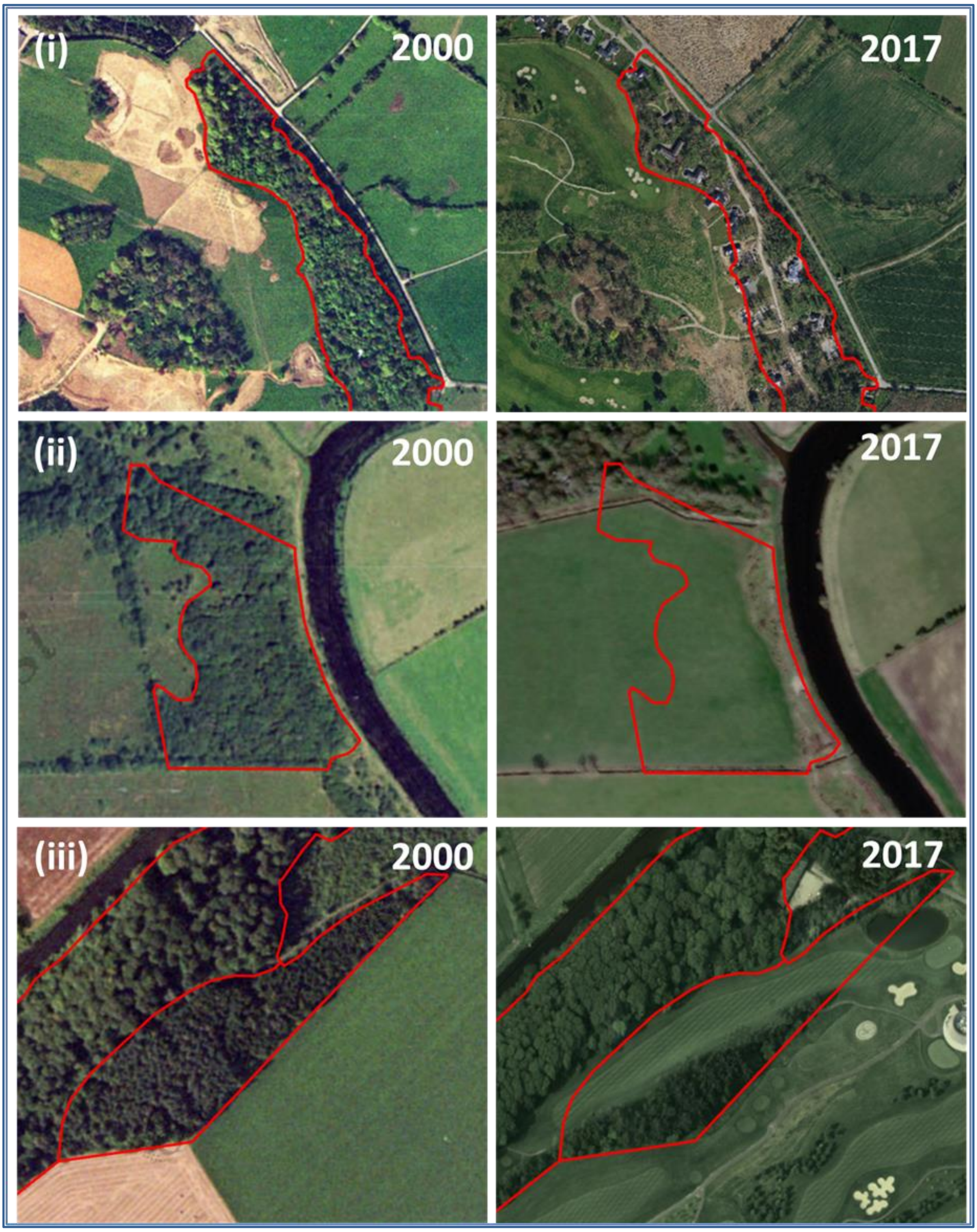

Figure 11 Examples of deforestation of ALEWs (after Perrin & Daly, 2010) in Ireland. Deforestation of semi-natural woodland for housing developments (i), deforestation of semi-natural woodland for agricultural grassland (ii) and felling of conifer plantation on old woodland for golf course (iii). Red lines indicate forest or forest compartment boundaries. OSi aerial imagery is reproduced under Licence No. MP008021.

2.4 Discussion

Currently, almost 70% of the total area of ALEWs identified in Perrin & Daly (2010) have no statutory protection. Despite their ecological, historical, and cultural significance, undesignated ALEWs are at increased risk of degradation and even deforestation. As the system of habitat protection in Ireland is largely based around habitats and species listed in the EU Habitats Directive (1992), ALEWs that fall outside those habitat types are more likely to be undesignated. The analysis shows that 59% of the total area of ALEW that occurs on mapped Annex I habitat are afforded legal protection (mainly SACs), yet only 32% of the total area of ALEWs occur within protected areas. A disproportionate number of non-Annex ALEWs have no protection. Examples of undesignated ALEWs include small fragments of woodland that tend to fall outside the Natura 2000 network and old woodlands that are now dominated by planted conifers. While the ecological integrity of these sites is much diminished relative to our best examples of semi-natural ancient woodland, ALEWs in planted conifer sites can retain some features of ancient woodland such as soils, ground flora, and woodland archaeology, and have restoration potential.

For ALEWs that are designated as SACs and fall within Annex I woodland habitat types, in a small number of cases, the ALEW woodland habitat is not listed as a qualifying interest (Table 1). For each SAC, qualifying interest habitats are afforded specific additional protection. Therefore, it is recommended that all ALEWs in SACs should be reviewed and where applicable, the Annex I woodland habitat type should be listed as a qualifying interest for that site. An additional 598 ha of mapped ALEW occurs outside of SACs but within SPAs. However, SPA designation offers limited protection to woodlands, except where the qualifying interest is a bird of woodland habitats.

Improved identification and mapping of ALEW sites provides an opportunity to increase the level of protection of ALEWs nationally. Data from this scoping study show that 1,227 ha of undesignated ALEWs fall within 100 m of an existing protected area boundary. To protect these last vestiges of our ancient, wooded past, the expansion of current protected areas to encompass these ALEWs is required.

The assessment of the conservation status of ALEW sites revealed that 68% of ALEW sites received an Unfavourable conservation evaluation. The majority of ALEWs that have been monitored are being impacted by multiple negative pressures. The negative impacts of invasive species and overgrazing are pervasive in Irish woodlands - this analysis shows that 90% of ALEWs are impacted by invasive species (mostly *Rhododendron ponticum* and *Prunus laurocerasus*), and 33% are impacted by overgrazing, mostly by deer.

The analysis of the Conservation Status of ALEWs comes from Annex I woodland monitoring data. Limited data on the conservation status of ALEWs outside of this network are available, but given that they are largely composed of unprotected, highly fragmented pockets of small woodland and ALEWs now dominated by planted conifers, their ecological integrity and conservation status may be further diminished. Further, limited monitoring data are available from ALEW sites which are assigned to the WN2 Oak-ash-hazel woodland type (Fossitt, 2000), as it is not listed as an Annex I habitat. Despite its lack of protection, Oak-ash-hazel woodland is of high conservation importance nationally. These woodlands are under severe threat from the spread of the disease ash dieback caused by the fungus *Hymenoscyphus fraxineus* (Mitchell *et al.,* 2014; Short & Hawe, 2018) and further conservation monitoring data is required.

Perhaps most concerningly, 93 instances of permanent deforestation events in ALEWs have been identified by this study. Despite increasing awareness of the value and significance of ancient woodlands, their deforestation continues. Deforestation of semi-natural woodlands was more common than deforestation of conifer stands. Further study on this issue is needed to inform policy, planning and licensing decisions, and enforcement aimed at reducing deforestation in Ireland's ALEWs.

The result of this study highlights the pressing need for the establishment of an ALEW monitoring network. As a starting point, the Annex I woodland monitoring network can be used to assess the conservation status of ALEWs, however, many sites fall outside this network. The largest systematic repeated monitoring of forest in Ireland is the National Forest Inventory (NFI). On a five-year cycle, the Department of Agriculture, Food & the Marine records site and tree data on >1800 permanent sample forest plots (Forest Service, 2023a). NFI plot data contains detailed information on forest structure and condition, including tree size and vascular plant diversity – this information may be useful for confirming ALEW status and assessing conservation status. A spatial analysis indicated that 52 NFI plots are located within sites identified as ALEWs by Perrin & Daly (2010). In the short term, harmonising various woodland monitoring networks to provide useful information on ALEWs should be considered. However, additional field survey data are required. The establishment of a systematic ALEW monitoring network will ultimately provide a sound evidence base for the effective conservation and protection of Ireland's ALEWs.

3. Mapping c. 1830s forest cover in Ireland: a case study of Co. Leitrim and Co. Kilkenny

3.1 Introduction

A common approach to identifying ancient woodlands in Ireland and Britain has been to utilise detailed Ordnance Survey (OS) maps from the 19th century to first identify the occurrence of LEW. In both Ireland and Northern Ireland, a provisional GIS-based database of LEW has been created using first edition OS maps (1829-1842) in conjunction with contemporary high-resolution aerial imagery and forest cover datasets (Anon, 2007; Perrin & Daly, 2010). Similarly, the Ancient Woodland Inventory for England (Sansum & Bannister, 2018) uses 19th century OS maps (1846-1899) in combination with contemporary aerial imagery to create a detailed base map of old woodland sites. This base map is then used as a starting point for investigating whether stands are ancient (continuously wooded since the 1600s) using older historic sources of information (*e.g*. enclosure maps, estate maps and county maps from the 16th, 17th, and 18th century).

However, most of these previous efforts to identify historic woodland cover have taken a "top-down" approach – systematically searching through contemporary forest cover datasets, then referencing archival maps to determine woodland antiquity. While this approach identifies extant LEWs, it does not provide any information on woodlands that have been lost in the relatively recent past, so called "shadow" and "ghost" woods (Rotherham, 2017a,b).

A map of 19th century forest cover in Ireland would not only support the conservation of extant LEWs, but by also identifying "shadow" and "ghost" woods, it could provide insight into land cover changes, potentially informing future forest restoration efforts. The highly accurate and detailed representation of tree cover in first edition OS maps for Ireland offers a valuable opportunity to generate a complete map of c. 1830s woodland cover. In this chapter, the results of a scoping study which set out to develop a consistent and repeatable methodology for mapping c. 1830s woodland cover in Ireland are reported, using two case-study counties - Co. Leitrim and Co. Kilkenny - as an example. The size, area, and type of historic (c. 1830s) woodlands identified in Leitrim and Kilkenny is summarised herein.

3.2 Methods

3.2.1 Digitising c. 1830s woodland cover

In the provisional inventory of ancient and long-established woodland (Perrin & Daly, 2010) in Ireland, evaluation of woodland ancientness was mostly limited to large (>5 ha) native woodlands. Given the small and fragmentary nature of Irish woodlands, it is likely that many ancient woodlands were not included in the provisional inventory. The aim was to identify c. 1830s woodlands at a much finer resolution (areas >0.1 ha, based on the forest definition from Ireland's NFI (Forest Service, 2023a)). However, it was beyond the scope of this project to digitise all wooded areas >0.1 ha identified in OS first edition maps for the entire country. Therefore, a digitisation procedure on two case-study counties was conducted. Leitrim and Kilkenny were deemed to be suitable counties based on a set of criteria (Appendix 3), including overall size, land-cover histories, and the availability of historic evidence.

To systematically map c. 1830s woodland cover in Leitrim and Kilkenny, a wall-to-wall GIS photointerpretation approach was used. A similar approach has recently been adopted by the Ancient Woodland Inventory for England (Sansum & Bannister, 2018) and in the Glenveagh National Park Woodland Management Strategy (O'Neill *et al.,* 2024).

For this project, a fishnet grid of 1 km x 1 km "photo-plots" was overlaid on Leitrim and Kilkenny using ArcGIS Pro® (Figure 12). Two main data layers were used in the digitisation process – OS first edition maps and OSI high resolution contemporary aerial imagery (2017) (Licence

No. MP008021). Additional layers such as OS third edition maps, 25” maps (1897-1913), and contemporary forest cover vector datasets (NSNW, Private Forest Cover map, Coillte forest map) were also used to aid interpretation. Photo-plots were visually assessed at a scale of 1:8000 for presence of wooded areas in OS first edition maps and then marked when complete. This enables the interpreter to work through a study area and record and monitor progress (Figure 12). For digitising, a “bottom-up” approach was taken, whereby each photo-plot was interpreted and all wooded areas >0.1 ha mapped in OS first edition maps were digitised, regardless of whether they are still present today. The minimum mapping area threshold of >0.1 ha aligns with the current definition of forest outlined in Ireland’s NFI (land with a minimum area of 0.1 ha, a minimum width of 20 m, trees higher than 5 m and a canopy cover of more than 20% within the forest boundary, or trees able to reach these thresholds in situ (Forest Service, 2023a)) thus facilitating comparison between c. 1830s and contemporary forest cover.

For each digitised polygon, details of the type of woodland indicated in first edition maps (*i.e*. coniferous, deciduous, mixed, brushwood, osiers, see Figure 13) were recorded in an attribute table. The area (ha) and whether the woodland is present today in full, in part or entirely deforested was also recorded (Figure 14).

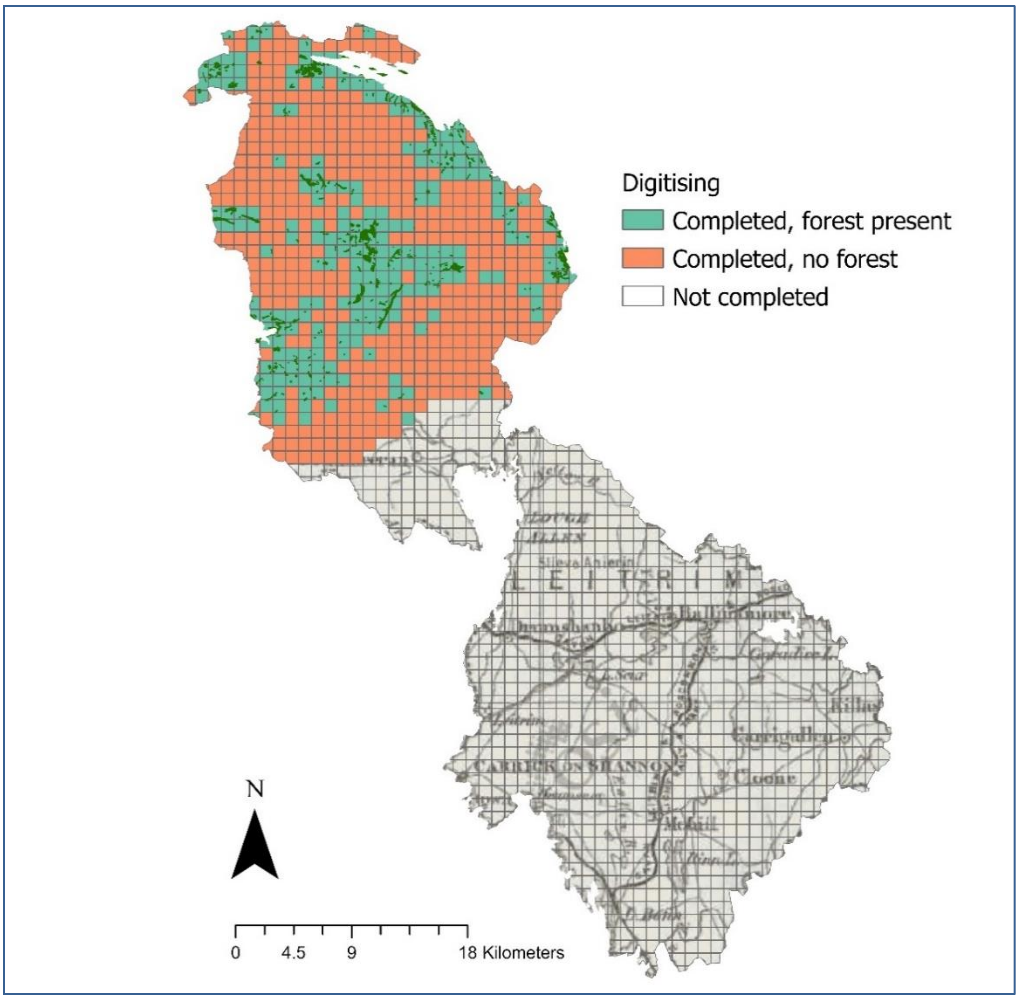

Figure 12 Example of fishnet grid of 1762 1 km x 1 km photo-plots overlaid on Co. Leitrim (with OS first edition maps shown), showing progress part-way through the digitisation process. Completed photo-plots with no wooded areas are marked orange and completed photo-plots with digitised wooded areas marked in green. OS first edition woodland also shown.

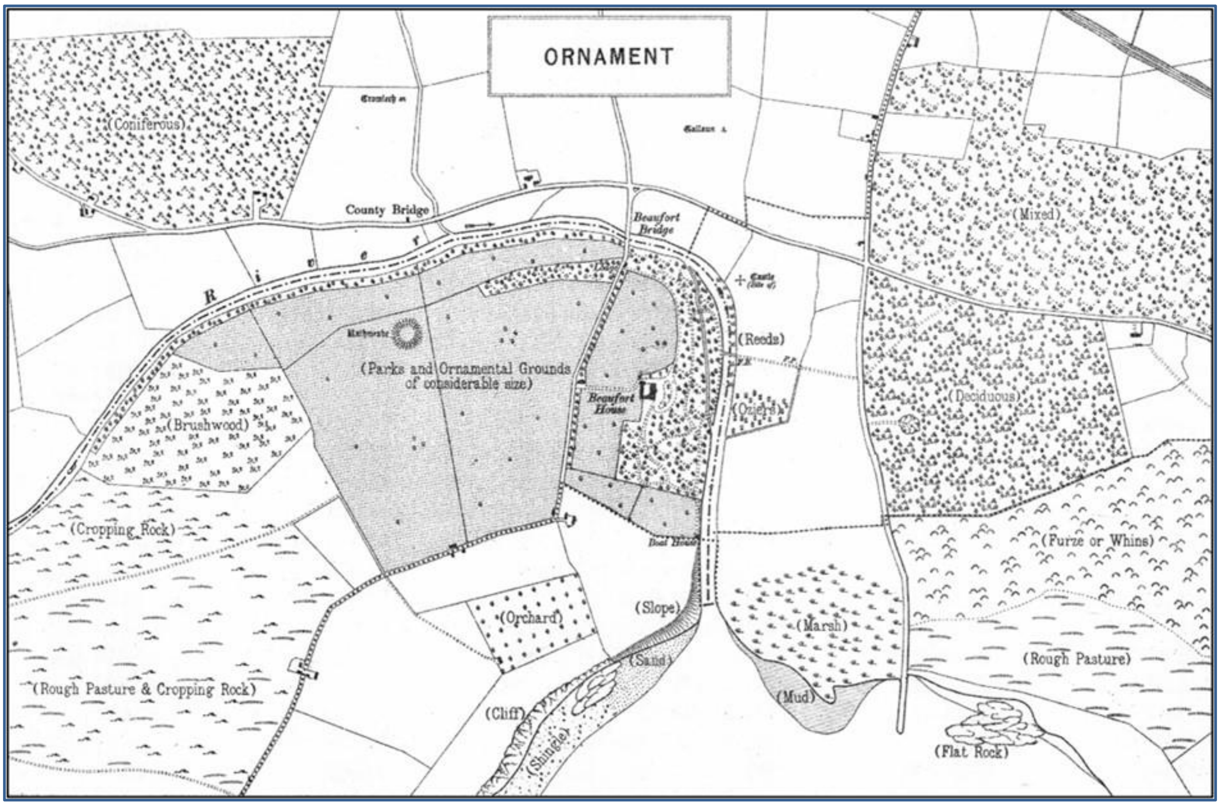

Figure 13 Legend for OS first edition maps. Wooded areas described as either coniferous, deciduous, mixed, brushwood *(i.e.* scrub woodland), or osiers (willow coppice).

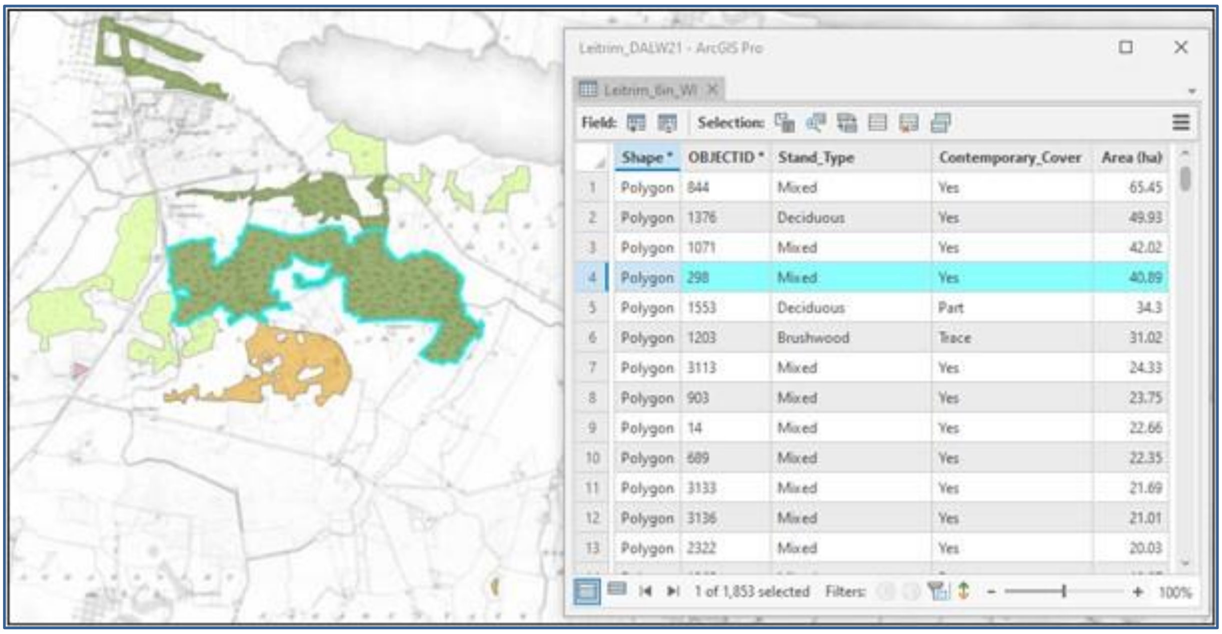

Figure 14 Example of GIS attribute table (right) with large mixed woodland stand highlighted (left). OS first edition basemap also shown.

3.3 Results

In total, 1498 woodland polygons were digitised from OS first edition maps for Co. Leitrim, covering 2,077.1 ha (Figure 15). Thus, based on first edition maps, forests covered 1.3% of Co. Leitrim in c. 1830, compared to 20.1% today (Forest Service, 2023b). c. 1830s woodland was well distributed across the county (Figure 15). It is largely absent from upland areas while occurring in high density around lake shores, particularly the western shore of Lough Melvin, the eastern and northern shores of Lough Allen, and the eastern shore of Lough Bofin.

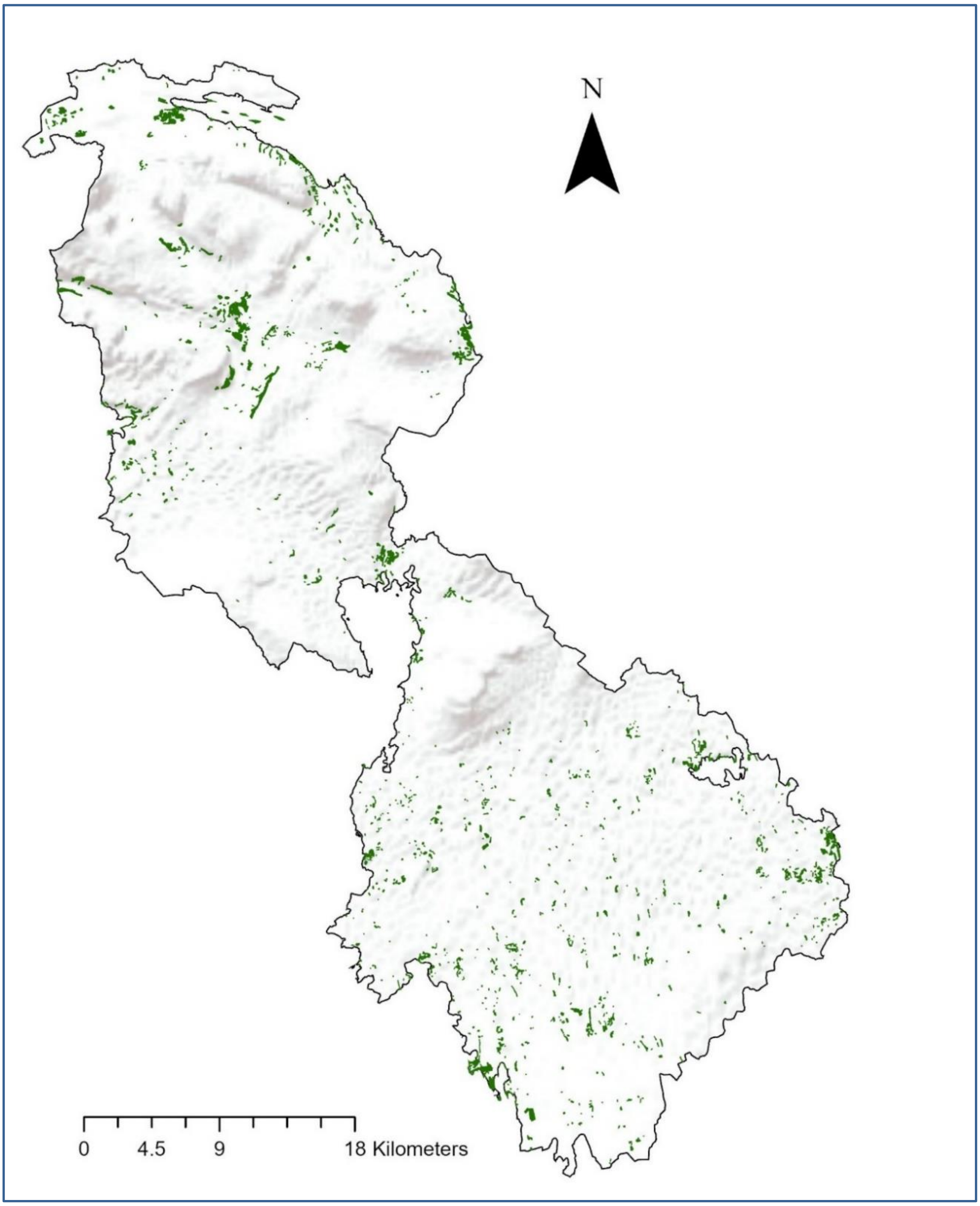

Figure 15 Map showing the distribution of c. 1830s forest cover in Co. Leitrim. Also shown is shaded relief terrain basemap (ESRI) indicating upland areas in northern and central Leitrim.

In c. 1830, forest cover in Leitrim was composed of 50% mixed woodland, 24% deciduous, 23% brushwood (*i.e*. scrub woodland), and 3% conifer stands. In contrast, contemporary tree cover in Leitrim is 23% broadleaf, 13% mixed, and 64% conifer (Table 2).

Of the 2,077.1 ha of c. 1830s woodland in Leitrim, 1102 ha (53%) remains today, although the preservation of c. 1830s woodland varied depending on woodland type. For example, 70% of digitised mixed woodland remains intact or partly intact, whereas only 28% of brushwood remains intact or partly intact (Figure 16).

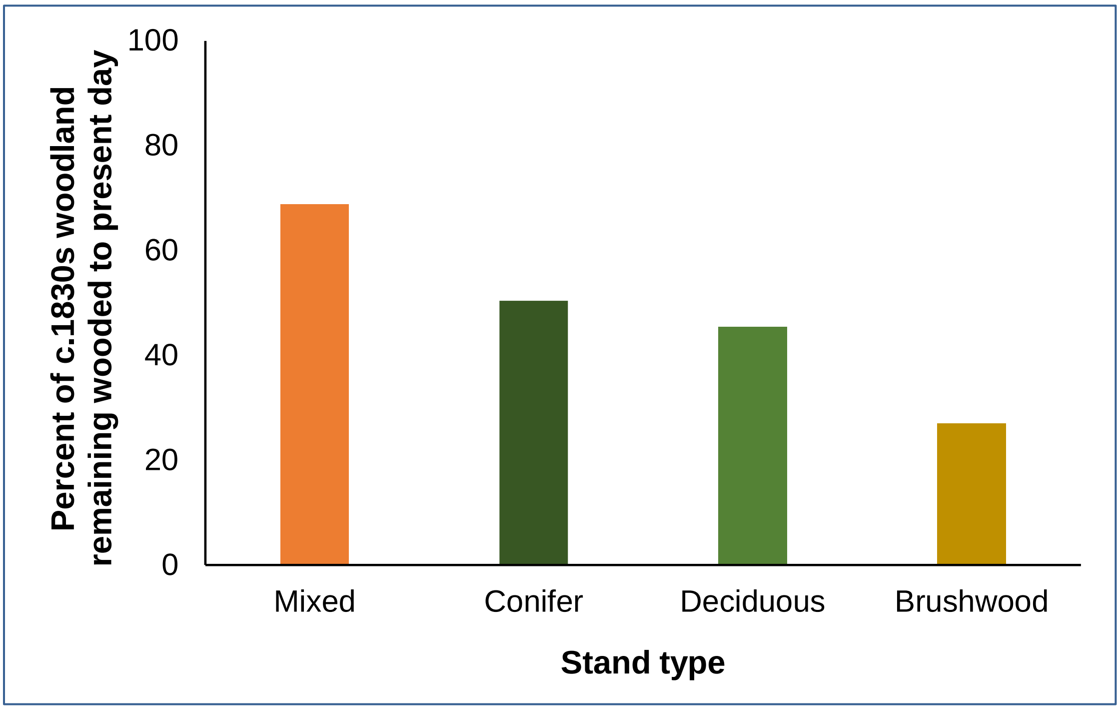

Figure 16 Percentage area of mapped c. 1830s mixed, deciduous, brushwood and conifer woodland in Co. Leitrim that remains to the present day.

The average size of digitised first edition woodland polygons in Leitrim was 1.4 ha and ranged from 0.1 ha (the minimum mapping unit) to 65.4 ha. The average size of c. 1830s woodland that remains intact or partly intact today was 2.1 ha. The average size of c. 1830 woodland that has been completely deforested was 0.63 ha.

In Kilkenny, 5235 woodland polygons were digitised from OS first edition maps (Figure 17). The total area of c. 1830s woodland in Co. Kilkenny based on first edition maps was 7,860 ha. This accounts for 3.8% of the area of the county compared with a current forest cover of 10% (Forest Service, 2023b). c. 1830s woodland is relatively evenly distributed across the county (Figure 17), with particularly high densities of riparian woodlands present along the River Barrow.

In c. 1830, wooded areas in Kilkenny were composed of 40% brushwood, 49% mixed woodland, 7% deciduous, and 3% conifer stands (Table 2). In addition, there were 61.3 ha of osiers (willow coppice). For comparison, contemporary tree cover in Kilkenny is approximately 23% broadleaf, 9% mixed, and 67% conifer (Forest Service, 2023b).

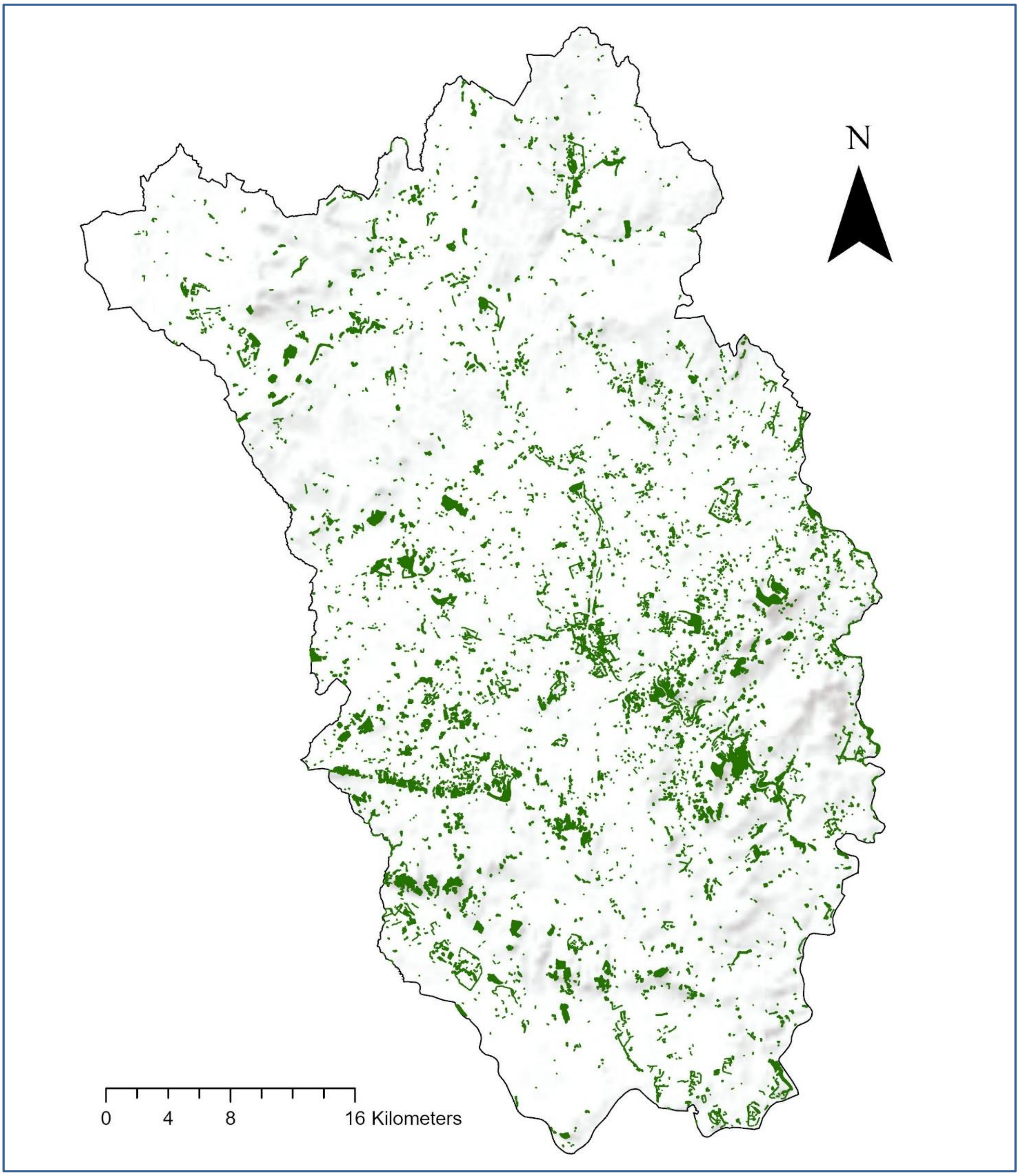

Figure 17 Map showing the distribution of c. 1830s forest cover in Co. Kilkenny. Also shown is shaded relief terrain basemap (ESRI).

Of the 8,595 ha of mapped c. 1830s woodlands in Kilkenny, 3488 ha (44%) remains today. Sixty-five percent of digitised c. 1830s conifer woodland in Kilkenny remains intact or partly intact, whereas only 22% of brushwood polygons remain intact or partly intact (Figure 18). The average size of digitised first edition woodland in Kilkenny was 1.5 ha (ranging from 0.1 ha to 153.9 ha). As with Leitrim, the average size of woodlands in Kilkenny that have been deforested (0.9 ha) was considerably smaller than woodlands that remain today (3.14 ha).

Table 2 Comparison between contemporary and c. 1830s forest area and composition in Leitrim and Kilkenny.

Woodland composition	Co. Leitrim	Co. Kilkenny
Contemporary forest area, ha (Forest Service, 2023b)	32,040	20,630
Contemporary forest cover % (Forest Service, 2023b)	20.1	10.0
Contemporary forest composition % (Forest Service, 2023b)		
Broadleaf	23	23
Mixed	13	9
Conifer	64	68
c. 1830s forest cover (ha)	2,077	7,860
c. 1830s forest cover (%)	1.3	3.8
c. 1830s forest that remains forested (ha)	1,102	3,487
c. 1830s forest that remains forested (% of county area)	0.7	1.7
c. 1830s forest composition (%)		
Deciduous	24	7
Mixed	50	49
Conifer	3	3
Brushwood	23	40
Osier	0	1

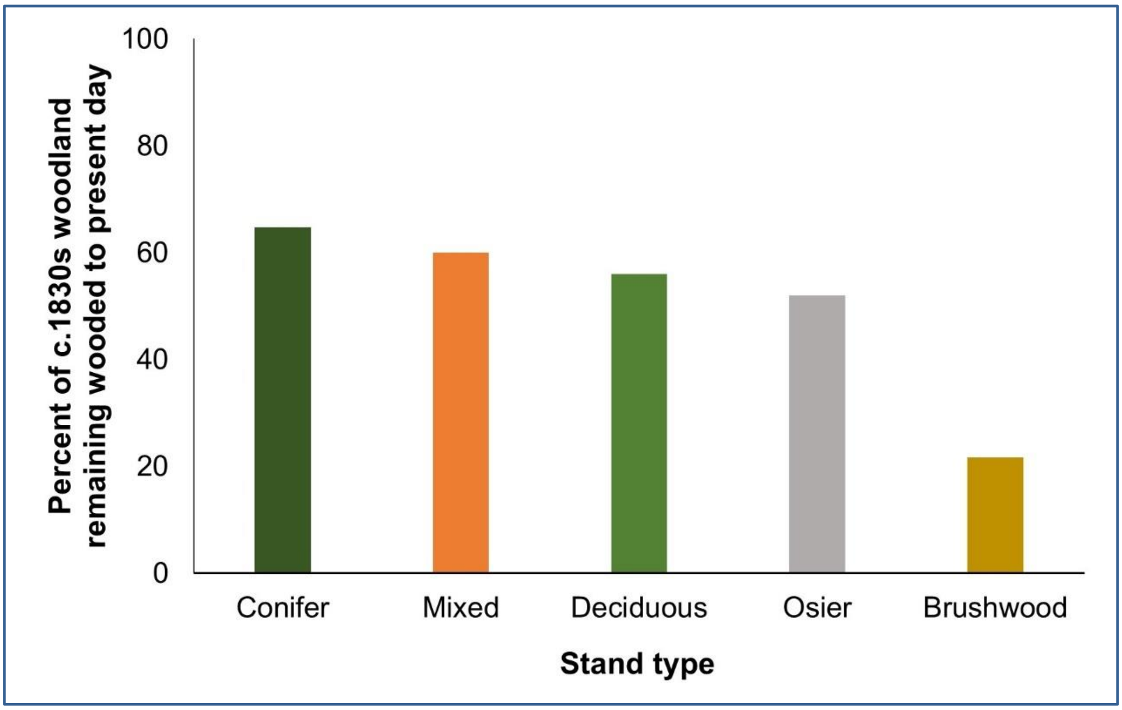

Figure 18 Proportional area of mapped c. 1830s brushwood, conifer, deciduous, mixed, and osier woodland in Co. Kilkenny that remains to the present day.

3.4 Discussion

Prior to large-scale afforestation in the 20th century, the Irish landscape was largely denuded of its forest cover. Forest cover reduced from c. 45-80% in the mid Holocene, with a gradual decline since then, and speeding up in the last c.1000 years (Fyfe *et al.*, 2013). Estimates suggest that by the late 1800s, forests covered as little as 1% of the island of Ireland (Mitchell, 2000). Perrin & Daly (2010) identified almost 20,000 ha (0.3% of the area of Ireland) of ALEW from c. 1830s OS maps. However, this figure only includes woodlands that survive to the present day, and it excludes many small woodlands that are below 5 ha in size. There are few robust estimates of early 19th century woodland cover at either the national, provincial, or county level.

To the authors' knowledge, this case study from Leitrim and Kilkenny is the first to fully map 19th century forest cover for any county. We identified 2,077 ha of woodland in Leitrim and 7,860 ha of woodland in Kilkenny. This indicates that c. 1830s forest cover in Leitrim and Kilkenny was 1.3% and 3.8% respectively. It should be emphasised that this figure includes all forest areas (>0.1 ha, >20 m wide) present at that time, including stands not of ancient origin and many woodlands that have now been cleared. Tree cover features were included in the inventory, including brushwood (Figure 12). Brushwood indicated scrub woodland types, likely small or stunted trees and/or areas dominated by early successional species such as birch and willow. Brushwood areas contributed a large proportion of the overall c. 1830s woodland cover, especially in Kilkenny (45% of all c. 1830s woodlands in Kilkenny were brushwood). Removing brushwood from the dataset would reduce c. 1830s forest area in Leitrim and Kilkenny to 1% and 2.2% respectively. However, brushwood/scrub woodland is an important habitat type in Ireland because it represents early successional woodland, an important seral stage in woodland development. It is recommended that OS first edition brushwood is considered as forest for the purpose of any future national inventory of ancient and long-established woodland. In fact, multiple extant long-established and even ancient woodlands occurred on brushwood sites (Chapter 4), further highlighting their importance.

While OS first edition maps are renowned for their accuracy, it is likely that they under-represent woodland area in mountainous and steep-sided valleys due to issues representing vertical features on a horizontal plane (Bohan, 1997, Perrin & Daly, 2010). Consequently, it is likely that c.1830s woodland cover in Leitrim and Kilkenny was greater than what is estimated in this study.

A complete map of c. 1830s woodland for Leitrim and Kilkenny reveals interesting differences in land cover dynamics between the two counties. In the past c. 190 years, Leitrim has transitioned from having a relatively low level of forest cover (1.3%) to now being the most forested county in Ireland (c. 20%). This shift has been driven by widespread planting of conifer forests in the later part of the 20th century. In contrast, from a forest cover of 3.8% in c. 1830s, Co. Kilkenny now has a forest cover of 10% of the county (Forest Service, 2023b). Thus, a sizeable proportion of Co. Kilkenny's extant woodlands are ancient or long established in origin.

Unsurprisingly, a large number of c. 1830s woodlands are no longer present today. c. 1830s brushwood in particular has been widely cleared, with only 19% of digitised brushwood polygons remaining in full or in part.

For digitising, a "bottom-up" approach was used, digitising all wooded areas >0.1 ha mapped in OS first edition maps regardless of whether they remain today. An alternative "top-down" approach would be to use contemporary forest cover vector datasets to only examine polygons of extant woodlands and use OS first edition maps to determine whether they are long-established or recent in origin. This approach has the advantage of being more time and resource efficient, but no additional understanding of forest loss will be gained. An awareness of long-term environmental change is crucial for our understanding of woodland ecology and dynamics. In addition, some woodlands (particularly small, privately owned broadleaf woodlands) may not be included in national forest cover vector datasets and will therefore not be evaluated. This may lead to biases in the data and an underestimation of ALEW cover.

Despite the substantial effort involved in digitising all woodlands on OS first edition maps, this approach will improve our understanding of spatial and temporal changes in forest cover in Ireland. A spatially explicit map of 19th century forest cover in Ireland would not only support the conservation of extant LEWs, but by also identifying "shadow" or "ghost" woods, future native woodland reforestation/rewilding schemes could be targeted at sites that have supported woodland in the relatively recent past.

Recent advances in image segmentation and machine learning approaches have indicated that accurate classification of features in historic maps may be automated (Auffrett *et al.,* 2017, Gobbi *et al.,* 2019). For example, a recent study by O'Hara *et al.* (2022) used a fully convolutional neural network (CNN) to map historic wetland over in Ireland using OS first edition maps to an overall thematic accuracy of 81%. If acceptable levels of accuracy were obtained, automated approaches to mapping c. 1830s woodland cover in Ireland would drastically reduce the overall time requirement for the exercise, and this topic warrants further investigation.

4. Identifying long-established and ancient woodlands in Ireland: a case study from Co. Leitrim and Co. Kilkenny

4.1 Introduction

After identifying LEWs using OS first edition maps, Perrin & Daly (2010) used 16th, 17th and 18th century maps and historic texts to assign ancient or possible ancient status to 123 woodland sites (in combination with vegetation data, archaeological features and other contextual evidence). This approach has also been applied in the UK (Anon, 2007, Sansum & Bannister, 2018), and elsewhere in Europe (Kervyn *et al.,* 2018).

Compared to other regions, Ireland is relatively well served by the availability of 16th, 17th and 18th century maps and texts that provide evidence for historic forest cover. For example, while inventories of ancient woodlands in England (Sansum & Bannister, 2018), Scotland Wales, and Belgium rely mainly on 18th and 19th maps (*e.g*. Roy maps (1750), Tithe maps and early OS maps (1800s)), the comprehensive map and text evidence from the 17th century Down Survey (Ó Siochrú & Brown, 2018; Ó Siochrú, 2019) in Ireland is a hugely valuable resource for identifying ancient woodlands. Directed by the surgeon-general of the English army, William Petty, the Down Survey (1656-1658) of Ireland is the first detailed land survey on a national scale anywhere in the world. The Down Survey includes County, Barony, and Parish maps as well as Terriers - written descriptions of baronies and parishes that accompany the original maps. The Down Survey served as a key reference for assigning ancient status to woodlands as part of the Provisional Inventory of Ancient and Long-Established Woodland in Ireland (2010). Since that publication, a major research project led by Trinity College Dublin has collated and digitised all surviving Down Survey maps and made them publicly available on an easily accessible, interactive website (http://downsurvey.tcd.ie/down-survey-maps.php). In recent years, other previously unavailable or unknown historical texts and archival maps relevant to the study of ancient woodlands in Ireland have also become available, often in easily accessible and searchable online digital formats. Given this increased availability and accessibility of historic evidence on woodland cover, there is now an opportunity to refine the methodology of Perrin & Daly (2010) and develop a consistent and repeatable approach to identifying ancient woodlands in Ireland using historical map and text evidence.

The aims of this chapter were twofold. Firstly, to collate archival map and historic text sources on woodland cover in Ireland and review their suitability for use in a national inventory of long-established and ancient woodlands. Secondly, to identify extant ancient woodlands in Leitrim and Kilkenny using the map of c. 1830s woodland cover (Chapter 3) and historic map and text sources.

4.2 Methods

4.2.1 Documenting available archival map and text evidence relevant to ancient woodlands in Ireland

As a starting point, Perrin & Daly (2010) and references therein were reviewed to collate 16th, 17th and 18th century archival map and text evidence for woodland cover. A literature search was conducted and relevant institutions and experts were consulted to gather evidence relevant to the study of ancient woodlands in Ireland. The online catalogues of the Irish Manuscripts Commission, the National Archives of Ireland, the TCD Library Digital Collections, UCD Map Collection, Queen's University Belfast Digital Special Collections & Archives, Yale University Library Digital Collection, the UK National Archives, the West Sussex Records Office, the L Brown Map Collection, and the David Rumsey Map Collection were reviewed. The National Library of Ireland (NLI) online catalogue was also reviewed, paying particular attention to Estate Records collections. All estate records and documented cases where pre-

1800 estate maps or other potentially relevant information were contained in the collection were reviewed.

A detailed assessment of the occurrence of ancient woodlands in two case-study counties – Leitrim and Kilkenny was conducted. Any NLI maps or other manuscripts relating to Leitrim and Kilkenny (pre-1800) were reviewed in the NLI reading room. Relevant material in the Maynooth University Andrews' Map Collection and the National Archives were also reviewed. All archival maps were categorised as general maps of Ireland, provincial maps, county maps, or local maps.

4.2.2 Defining long-established and ancient woodland in Ireland

Largely based on the accuracy and availability of map evidence, previous studies of old woodlands in Ireland (Perrin & Daly, 2010, Anon, 2007) have defined long-established woodland as areas that have remained continuously wooded since c. 1830 (coinciding with the publication of OS first edition maps of 1829-1841). Ireland's ancient woodlands have been defined as areas of woodland believed to have remained continuously wooded since the 17th century (Anon, 2007, Perrin & Daly, 2010).

It is recommended that future inventories of ancient woodland heed the authors' reservations about the problematic nature of pre-modern descriptions of woodlands in the Irish landscape. Perrin & Daly (2010) included two categories of Long-Established Woodland in their definitions – "LEW (I) is defined as woodland that has remained continuously wooded since the first edition OS maps of 1829-41, but for which no positive evidence of antiquity has been found in older documentation. These woodlands may however have ancient origins." In contrast, "LEW (II) is defined as woodland that has remained continuously wooded since the first edition OS maps of 1829-41, but for which there is positive evidence in older documentation that it is not ancient in origin." In Perrin & Daly (2010), stands were classed as LEW (II) when pre first edition historic sources of information were available for a site but did not contain any specific reference to woodland. Following consultation with historic geographers and the authors' own research, it is clear that 17th century mapmakers did not depict Irish woodlands in a consistent way; some chose not to depict woodlands at all while others misrepresented the amount of coverage. Such evidence needs to be used tentatively and corroborated, where possible, with other map-based, textual, or palaeoecological sources. Therefore, the accuracy and quality of historic map and text sources is not considered to be appropriate for attributing positive evidence that stands are *not* ancient in origin, especially for small, fragmented forest stands. Consequently, it is proposed that the differentiation between LEW (I) and LEW (II) should be removed from future inventories.

It is important to note that existing surveys in Ireland, Northern Ireland and elsewhere have different size thresholds or minimum mapping units for ALEWs. In Northern Ireland, the Back on the Map project (Anon, 2007) used a size threshold of 0.5 ha (or woodland contiguous with larger wooded areas totalling >0.5 ha) for digitising LEW, resulting in the identification of 2,617 areas of woodland dating back at least 170 years. The Ancient Woodland Inventory for England recently reduced its minimum size threshold from 2 ha to 0.25 ha, resulting in the inclusion of many smaller parcels of ancient woodlands (Sansum & Bannister, 2018). In the context of potential future surveys in Ireland, it is important to establish a minimum size threshold for mapping, conserving, and protecting ALEWs.

In Chapter 3, c. 1830s woodland cover including all woodland areas >0.1 ha were mapped. However, in the context of ancient woodlands, such a small size threshold would make it challenging to link small fragments of wooded areas with woodlands depicted on even the most detailed archival maps and texts. For example, some of the most detailed local-scale map and text evidence available comes from Down Survey parish maps (Andrews, 1997). In parish maps, woodland symbols or a reference to woodland cover is often given for individual townlands. However, it would be challenging to associate woodlands depicted in 17th century parish maps with tiny fragments of 0.1 ha woodland that exist today. To assign woodlands as ancient from historic map sources with reasonable confidence, a minimum size threshold for ancient woodlands of 0.25 ha is proposed. Consequently, modified definitions for ALEWs are proposed.

***Ancient woodland** – areas of woodland (>0.25 ha) that are believed to have remained continuously wooded since 1660.*

***Possible ancient woodland** – areas of woodland (>0.25 ha) that are thought to have remained continuously wooded since 1660, but for which evidence is not so strong, due typically to the somewhat ambiguous nature of names and locations in much of the 17th century literature.*

***Long-established woodland** – areas of woodland (>0.25 ha) believed to have remained continuously wooded since the first edition OS maps of 1829-1841.*

This size threshold is comparable with the threshold used for mapping woodlands in the Ancient Woodland Inventory for England (Sansum & Bannister, 2018).

Additionally, it should be noted that these definitions are independent of past and current management. No distinction is made between the stand type (semi-natural broadleaf, non-native broadleaf, mixed, conifer plantation) at different points in history, including the present day. Current stand type is however recorded in the GIS attribute table when c. 1830s polygons are digitised. Clear-felling (provided that replanting or natural regeneration has occurred shortly thereafter) or coppicing is not regarded as a discontinuation of woodland cover.

4.2.3 Assigning ancient woodland status in Co. Leitrim and Co. Kilkenny

Firstly, mapped c. 1830's woodland <0.25 ha was removed from the dataset. Next, areas which were mapped as woodland in c. 1830s but are no longer present today were removed. Additionally, polygons where there was positive evidence that woodland cover was discontinuous (*i.e*. forest in OS first edition maps, currently forest, but evidence indicating non-forest land use/land cover in the intervening time period) were removed from the dataset.

Due to a difference in map projections and local fitting of OS map sheets, there is frequently a spatial offset (c. 0-30 m) between OS first edition maps and recent aerial imagery. Consequently, mapped LEW that are extant today may be positioned up to 30 m from their known location on modern maps. To address this issue, ALEW polygons were edited so they aligned with contemporary aerial imagery. Existing contemporary forest cover datasets (NSNW, Article 17, the Forest Service Private Forest Cover layer, Prime2, and the new National Land Cover dataset) were used to aid redigitising (*i.e*. tracing/snapping to existing forest cover vector data where appropriate).

A consistent and repeatable process for assigning PAW status in Leitrim and Kilkenny based on historical map and text evidence was developed. In the GIS dataset of c. 1830s woodland, columns were added to the attribute table for each relevant historic map and text. Next, each digitised woodland polygon was reviewed and evidence for woodland presence in historic map and/or text sources was noted (indicated by a yes/no in each attribute field). In the Down Survey, woods are referred to in a number of ways, including “woods”, “timberwood”, “copps”, “underwood”, “shrubby woods”, and tree symbols on maps. A dichotomous key was developed (Figure 19) to assign ancient, possibly ancient, or long-established status to woodlands. Briefly, if woodland was indicated in its current location (with identifiable geographic feature such as woodland occurring along townland or parish border, lake edge, *etc*.) in a local map or text source (Down Survey parish and/or barony map, or other local map/text source), sites were assigned ancient status. If woodland was indicated (on map or text) in a general location in a local map or text source (*e.g*. reference to woodland in Parish Terrier, or “much wood” indicated in townland map), sites were assigned PAW status. If no local evidence of woodland presence was found, an assessment was made on whether the cumulative evidence from county, provincial, and general Irish maps support the designation of the site as a PAW. In the absence of any local source information, PAW status could only be assigned if more than one county, provincial, and general Irish map or text source indicates woodland presence in the same location. In practice, this requires multiple lines of evidence to indicate the presence of woodland in a consistent location associated with an identifiable geographic feature (*e.g.* woodland occurring along county boundary, lake edge, adjacent to a settlement, *etc*.). All sites not assigned as PAW were assigned LEW status. Finally, for all ALEW polygons data on ownership (Coillte, NPWS, private grant aided, private non-grant aided) and contemporary woodland type (conifer, broadleaf, mixed) were recorded.

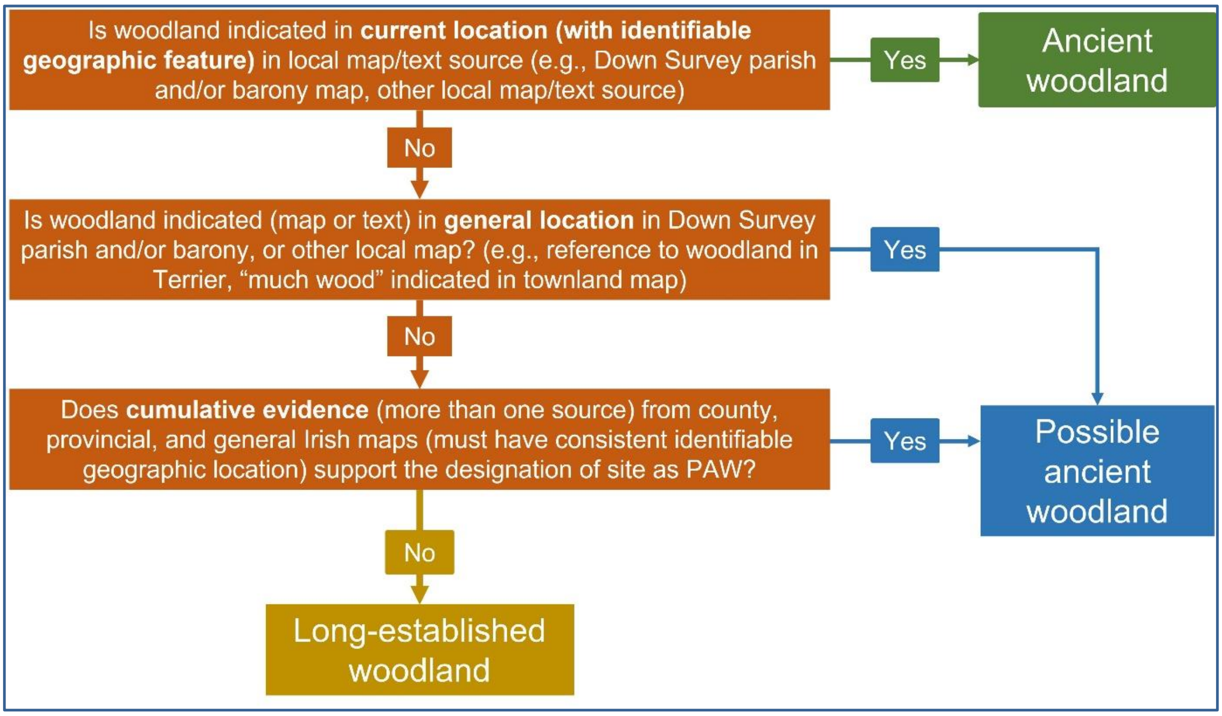

Figure 19 Key used to assign ancient, possible ancient, or long-established status to digitised woodland polygons.

Table 3 Historical sources of information used to assign ancient status to woodlands in Co. Leitrim and Co. Kilkenny.

County	Scale	Name	Author	Year	Online	Comment
Leitrim & Kilkenny	Ireland	A General Map of Ireland	Petty	1660	Yes	Woodland depicted, particularly around lake shores
Leitrim & Kilkenny	Ireland	Le Royaume d'Irlande divisé en ses Provinces	Jaillot	1693	Yes	Woodland eastern shore of L. Allen, western L. Melvin
Leitrim	Provincial	Brown's map of Connaught	Brown	1591	Yes	Accurate detail aiding placement of woodlands
Leitrim	Provincial	John Speed’s map of Connacht	Speed	1616	Yes	Coarse, abundant woodland, geographical inaccuracies
Leitrim	County	Maps of the escheated counties of Ireland	Bartlett	1609	Yes	Forest depicted northern shore of Glencar Lough
Leitrim	County	Down Survey County Map	Petty	1658	Yes	Woodland presence indicated throughout county
Leitrim	Local	Down Survey Barony Map and Terrier	Petty	1658	Yes	Woodland infrequently indicated on map or terriers
Leitrim	Local	Down Survey Parish Map and Terrier	Petty	1658	Yes	Woodland frequently indicated on map or terriers
Leitrim	Local	Map of Lough Muckruske	Bartlett	1603	Yes	Heavily wooded around shores of Lough Boderg
Leitrim	Local	Book containing 33 estate maps	Wogan	1776	NLI Only	Detailed land cover maps, including woodland
Kilkenny	Provincial	John Speed’s map of Leinster	Speed	1616	Yes	Coarse, abundant woodland, geographical inaccuracies
Kilkenny	Provincial	Leinster	Janssonius	1659	Yes	Heavily based on Speed's Map, some additional info
Kilkenny	Provincial	Province of Leinster	Blaeu	1654	Yes	Heavily based on Speed's Map, some additional info
Kilkenny	County	Down Survey County Map	Petty	1658	Yes	Woodland presence indicated throughout county
Kilkenny	Local	Down Survey Barony Map and Terrier	Petty	1658	Yes	Woodland frequently indicated on map or terriers
Kilkenny	Local	Down Survey Parish Map and Terrier	Petty	1658	Yes	Woodland infrequently indicated on map or terriers
Kilkenny	Local	Map of the demesne at the Kilmurry estate	Patsull	1757	NLI Only	Depicts large orchard, some woodland

4.3 Results

4.3.1 Documenting available archival map and text evidence relevant to ancient woodlands in Ireland.

Following the literature review, examination of archive catalogues, and consultation with experts, a complete list of 91 potentially relevant historic sources of information on ancient woodlands in Ireland was compiled (Appendix 4). Sources of information used in this case study of ancient woodlands in Leitrim and Kilkenny are listed in Table 3 and included general maps of Ireland (*e.g.* Royaume D'Irlande, 1693, Alexis Hubert Jaillot, Nicolas Sanson, Figure 20), provincial maps (*e.g*. John Speed's map of Leinster, 1616, Figure 21), county maps (Bartlett's map of Tyrconnell, 1609, Figure 22), and local maps (*e.g*. Down Survey Barony maps, (Figure 23, Figure 24)).

Figure 20 Jaillot's Le Royaume d'Irlande divisé en ses Provinces, (1693) depicting tree cover along eastern shore of "Lac Allyne" (Lough Allen) (above left) and southwest of "L. Melvie" (Lough Melvin) (above right). From the David Rumsey Map Collection, David Rumsey Map Center, Stanford Libraries.

Figure 21 John Speed's map of Leinster (1616) indicating woodland in southwest Kilkenny. John Speed, Public domain, via Wikimedia Commons.

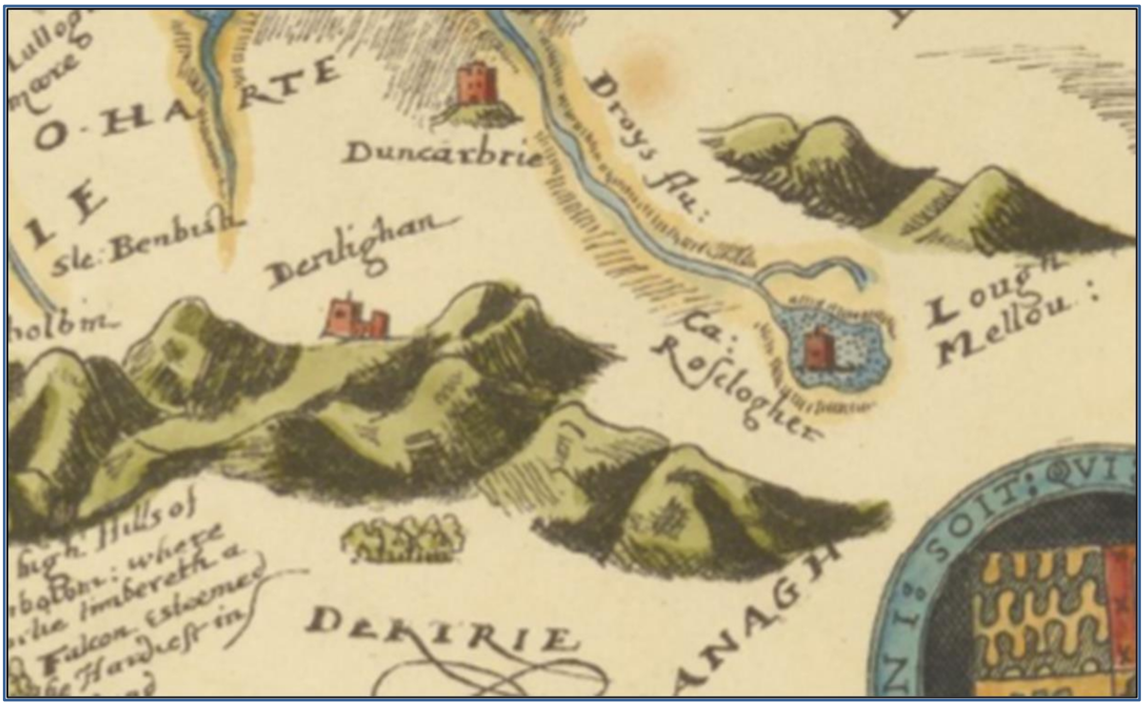

Figure 22 Bartlett's map of Tyrconnell (1609) indicating woodland to the south of Dartry Mountains. Special Collections, Queen's University Belfast, MS reference G5783.U4 BART.

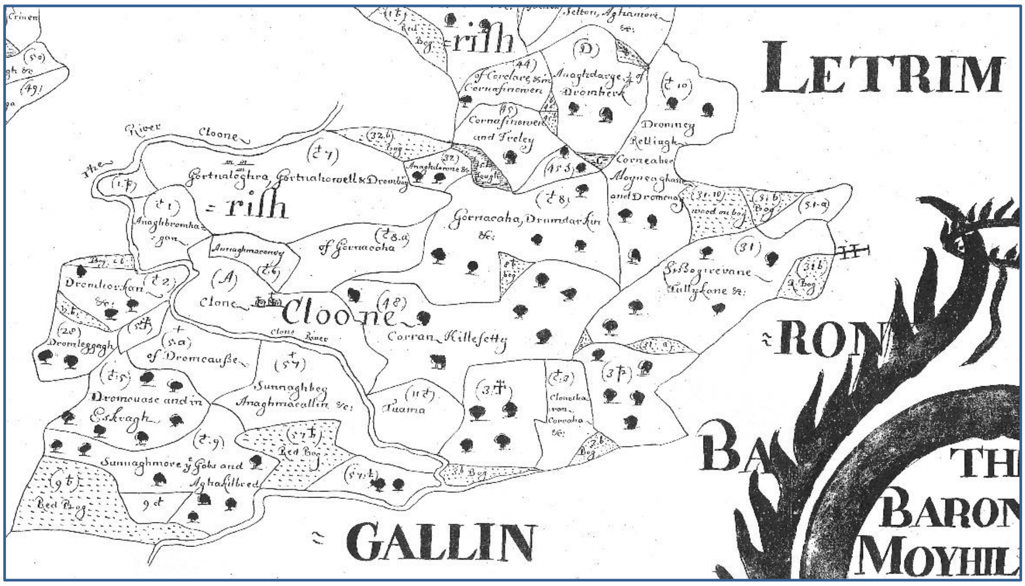

Figure 23 Down Survey map of part of Mohill barony, Co. Leitrim (1658). Map details a high level of tree cover for the parish of Cloone. Reproduced from a map in Trinity College Library, Dublin, with the permission of the Board of Trinity College.

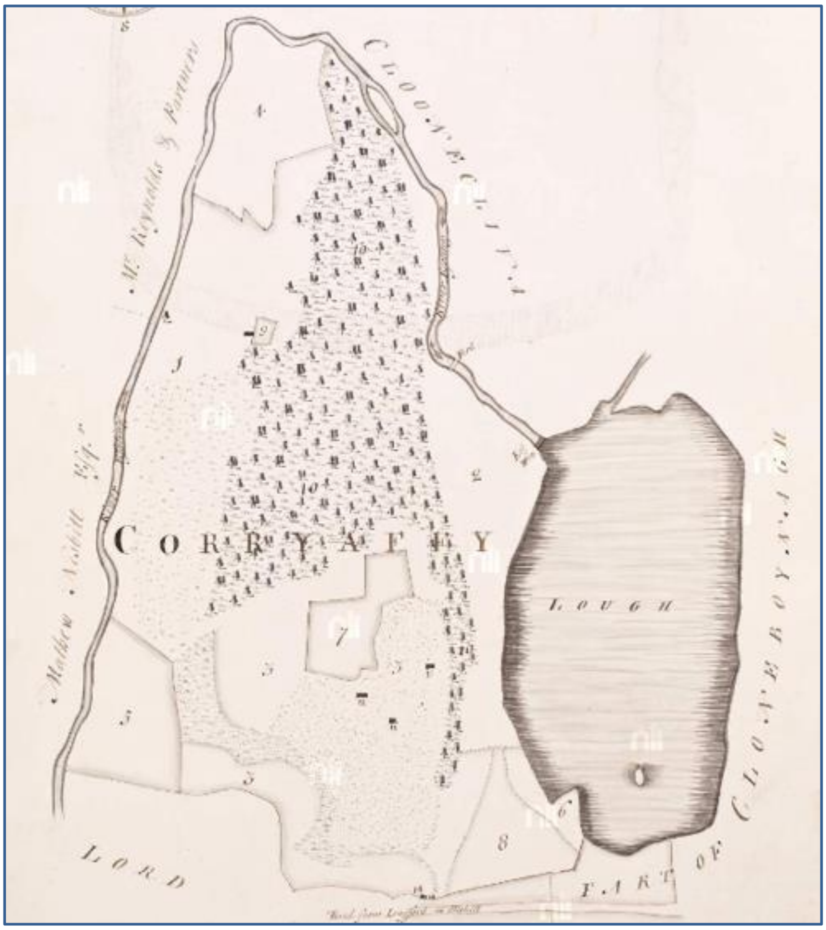

Figure 24 Map of “Corryaffy” townland, Co. Leitrim. From “A Book of Maps of the Estates Belonging to Nathaniel Clements Esquire In the Parishes of Mohill & Clune In the County of Leitrim”. 1776. Courtesy of the National Library of Ireland.

4.3.2 Assigning ancient woodland status in Co. Leitrim and Co. Kilkenny.

As a first step, all digitised c. 1830s woodland polygons (Chapter 3) in Leitrim and Kilkenny that were <0.25 ha in size, and/or no longer present were filtered from the dataset. Polygons where there was positive evidence that woodland cover was discontinuous were also removed. Following this process, the dataset for Leitrim was reduced from 1499 woodland polygons in first edition maps to 488 extant long-established and ancient woodland polygons (>0.25 ha). After review, ancient woodland status was assigned to 18 (4%) of these polygons in Leitrim. Twelve of these polygons were assigned AW status due to local-scale information in the Down Survey for Leitrim, whereas the remaining six were assigned AW status based on evidence from non-Down Survey local source information – in this case the "Map of Lough Muckruske and Shannon River, Co. Leitrim", c. 1602, NLI MS 2656 (12). A further 102 polygons were assigned PAW status, either due to information from the Down Survey (71 polygons) or the cumulative evidence from other non-local sources. The remaining 368 polygons were assigned LEW status (Figure 25, Figure 26).

The combined area of ALEW in Leitrim was 1,095 ha, accounting for 3.5% of the forest area in the county, and 0.7% of the total area of the county. The overall area of AW, PAW, and LEW in Leitrim was 54 ha, 216 ha and 826 ha respectively (Table 4). The average size of AW and PAW in Leitrim was 3 ha and 2.1 ha respectively, while the average size of LEW was 2.2 ha.

In terms of ownership, 59% of ALEWs in Co. Leitrim occur in privately owned woodlands, with the remaining 41% occurring in state-owned forests (Figure 27, Table 4). Most ALEWs in Leitrim are dominated by broadleaf tree species (619 ha, 56% of the total area). However, a sizeable proportion of ALEWs in Leitrim occur in woodlands now dominated by conifers (240 ha, 22% of total area) (Figure 27).

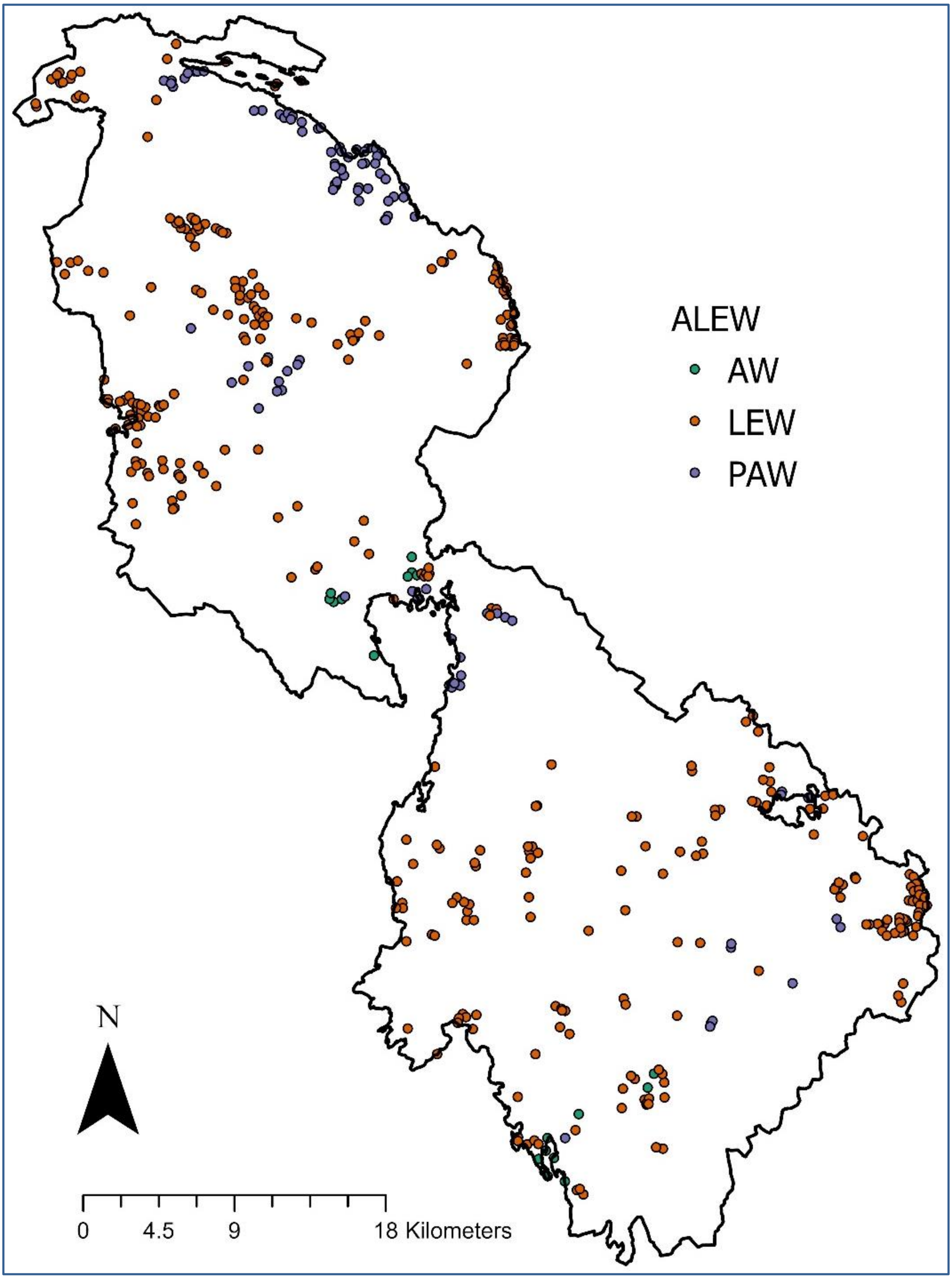

Figure 25 Distribution of extant ancient woodland (AW - green), possible ancient woodland (PAW - purple) and long-established woodland (LEW - brown) in Co. Leitrim.

Figure 26 Woodland at Garadice Lough Peninsula SAC, Co. Leitrim. Garadice was the only PAW recorded in Leitrim in the Provisional Inventory of Ancient and Long-established Woodlands in Ireland (Perrin & Daly, 2010). Photograph Orla Daly.

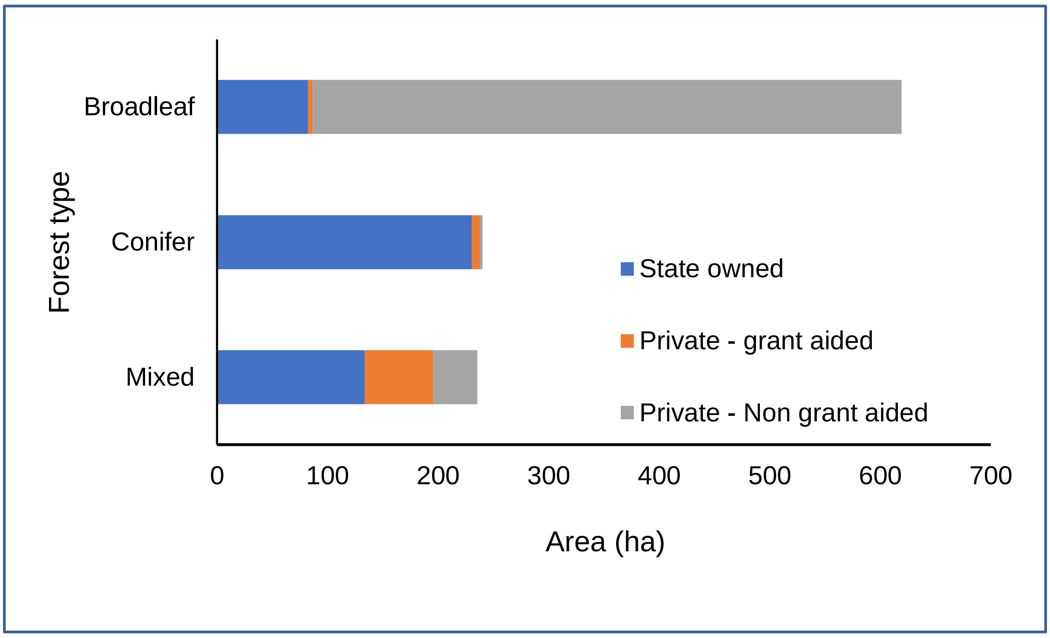

Figure 27 Total area of ALEW (>0.25 ha) in Co. Leitrim by contemporary cover type (broadleaf, conifer, mixed) and ownership.

From the original Kilkenny dataset of 5235 c. 1830s woodland polygons (Chapter 3), 1109 extant ALEW polygons were identified. Of these, 76 were assigned ancient woodland status, primarily due to their geographic location being identifiable on Down Survey parish or barony maps. An additional 69 polygons were assigned PAW status. The remaining 964 polygons were assigned LEW status (Figure 28).

The area of identified ALEW in Kilkenny was 3,482 ha. This accounts for 17% of the forest area in the county, and 1.7% of the total area of the county. The total areas of AW, PAW, and LEW in Co. Kilkenny were 473 ha, 404 ha and 2,606 ha respectively (Table 4). The average size of AW and PAW in Kilkenny was 6.2 ha and 5.9 ha respectively, while the average size of LEW was 2.7 ha.

In terms of ownership, 58% of ALEWs in Kilkenny are managed by Coillte or NPWS, with the remainder either privately-owned forests in receipt of grant/premium payment for afforestation (5%) or privately-owned non-grant aided woodlands (37%). A large proportion of ALEWs in Kilkenny occur in Coillte-managed mixed woodlands (1,108 ha, 32% of total ALEW area in Kilkenny). The majority of ALEWs in privately-owned woodlands in Kilkenny are dominated by broadleaf tree species (Figure 29).

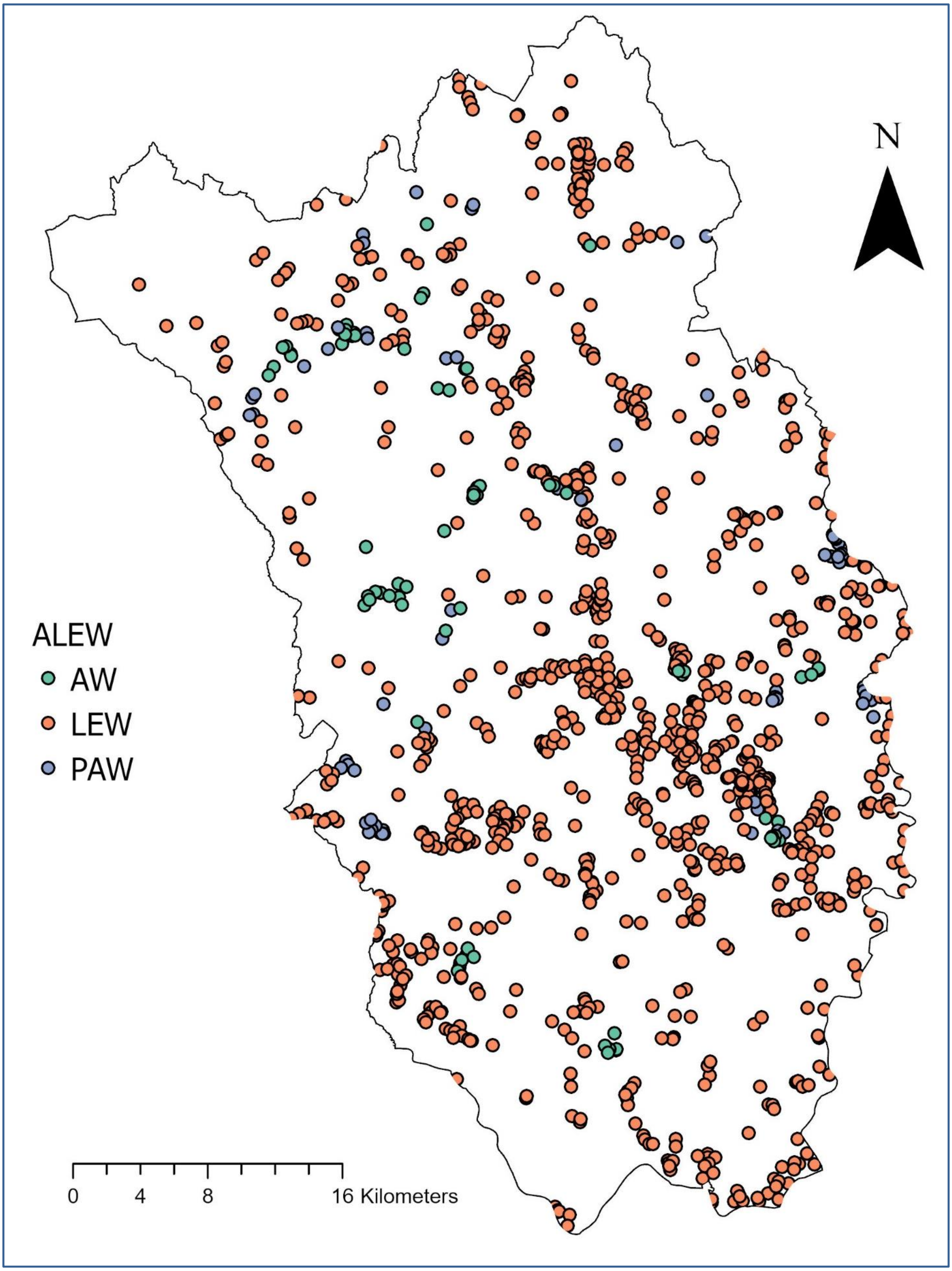

Figure 28 Distribution of extant ancient woodland (AW - green), possible ancient woodland (PAW - purple) and long-established woodland (LEW - brown) in Co. Kilkenny.

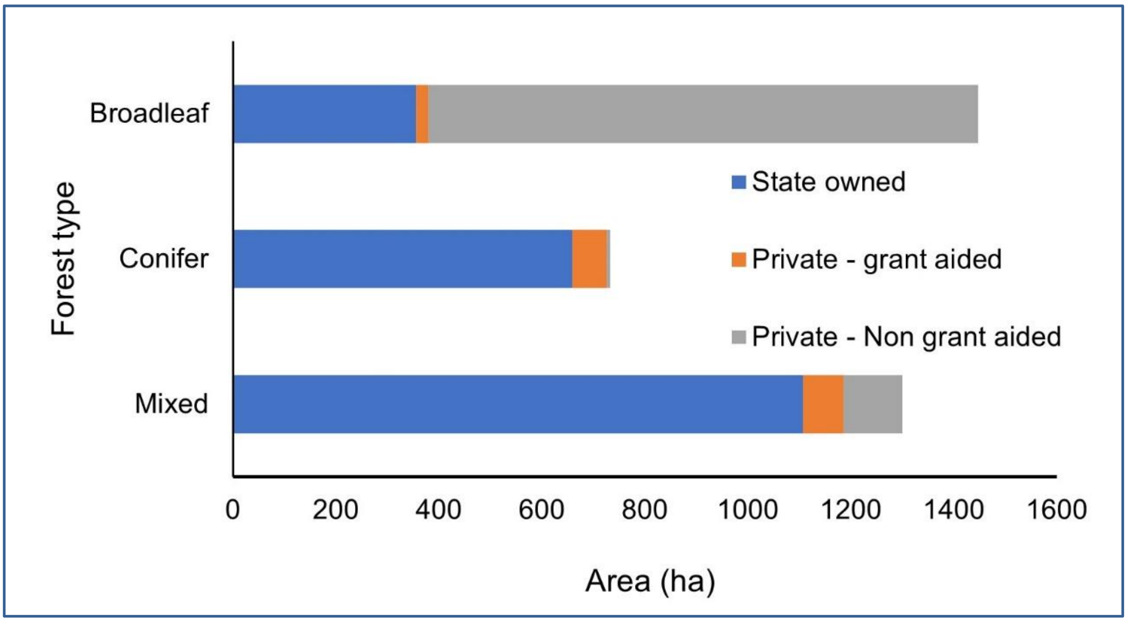

Figure 29 Total area of ALEW (>0.25 ha) in Co. Kilkenny by contemporary cover type (broadleaf, conifer, mixed) and ownership.

Table 4 Summary of extant ALEW area and composition in Leitrim and Kilkenny.

Common name	**Co. Leitrim**	**Co. Kilkenny**
Extant ALEW area (ha)	1095	3482
Ancient woodland (ha)	54	473
Possible ancient woodland (ha)	216	404
Long-established woodland (ha)	826	2606
ALEW percent cover of county area	0.7	1.7
ALEW ownership (%)		
State-owned	41	58
Private	59	42
ALEW contemporary forest type (%)		
Broadleaf	56	30
Mixed	22	66
Conifer	22	4

4.4 Discussion

Based on this analysis of historic map and text evidence, 270 ha of ancient and possible ancient woodland in Leitrim, and 877 ha of ancient and possible ancient woodland in Kilkenny were identified. This corresponds to 0.17% of land cover in Leitrim and 0.42% of land cover in Kilkenny. However, a conservative approach was taken, whereby ancient status was only assigned to stands that had historical evidence to support their antiquity. Consequently, it is likely that many more stands are in fact ancient in origin, but historical evidence has not been identified, and the estimates of ancient woodland cover in Leitrim and Kilkenny presented are likely to be underestimates.

This is the first study to conduct an assessment of ancientness on small (>0.25 ha) stands of putatively ancient woodland in Ireland. The distribution of woodlands in OS first edition maps indicates that Ireland's forests were already small and highly fragmented by the early part of the 19th century (Chapter 3). Clearly, to overlook small woodlands from an inventory of ALEWs would omit a sizeable proportion of sites from the inventory. Indeed, although this case study examined only two counties, it has already greatly increased the number of AW sites identified compared to the number in the provisional national inventory (Perrin & Daly, 2010). However, using historic documents to assign ancientness to small fragments of woodlands presents challenges compared to associating large extant woodlands (*e.g*. woodlands >5 ha in size classified by Perrin & Daly, 2010) with woods indicated in historic maps or texts. For example, depending on the type of historic evidence available, the level of confidence in assigning ancient status may be diminished for smaller extant woodlands. For any future complete inventory, careful consideration needs to be given to defining an ALEW minimum mapping threshold. Based on the spatial resolution of historic map and text evidence, a minimum size threshold for ancient woodlands of 0.25 ha has been proposed. Smaller patches of LEWs <0.25 ha in size may nonetheless retain important ecological, cultural, and historical features and should be valued, but systematically determining their ancient status is likely to prove extremely challenging.

In Chapter 2, it was reported that 32% of the area of large (>5 ha) ALEWs (after Perrin & Daly, 2010) occur within the national protected areas network. Mapped at a finer resolution, only 27% of the area of the identified ALEWs in Leitrim had any form of legal protection. Similarly, only 20% of the area of ALEWs (>0.25 ha) identified in Kilkenny occur within protected areas. This lack of protection, primarily of small ALEW stands, places them at increased risk, borne out by the fact that evidence of permanent deforestation was recorded at 18 of the additional ALEWs identified in Leitrim and 26 in Kilkenny.

While it is recognised that robust national inventories of ancient woodland require additional field surveys to support woodland ancientness assessments, as a desk-based study, focus was placed on historic map and text evidence, and existing palaeoecological data. The challenges in interpreting historical documents are discussed in Perrin & Daly (2010). A particular challenge is the fragmentary nature of historic documents and piecemeal spatial coverage of maps. For example, while the case-study counties of Leitrim and Kilkenny are well covered by Down Survey maps and Terriers, other counties may be missing entire sets of Down Survey barony and/or parish maps. Similarly, although the Civil Survey contains some useful information on 17th century woodland cover, it is only available for nine counties (neither Leitrim nor Kilkenny have survived). The Books of Survey and Distribution, despite covering almost all counties, have useful woodland information for only a handful of counties.

Nonetheless, archival maps and manuscripts represent key sources of information that can help build a picture of land-cover history at individual sites. For example, in a separate study, recent re-evaluation of historic maps and texts for the nationally important Glen of the Downs SAC has contributed to its recognition as AW (Roche & Doherty, 2023, Figure 30). Similarly, detailed examination of historic maps and texts has provided strong evidence to upgrade Mullangore Wood in Glenveagh National Park from a PAW to an AW (O'Neill *et al*., 2024). Casual observation of historic maps also highlighted evidence to support the upgrade of sites in Durrow (Co. Laois) and Rostellen (Co. Cork) to AW. Interrogating relevant historical sources in an efficient and systematic manner represents a key challenge for completing a full national inventory of ancient woodland. While sources such as the Down Survey, Civil Survey, and Books of Distribution have wide (albeit incomplete) coverage and are easily accessed, to gather all available historic sources of information for every candidate ancient woodland would require considerable research effort. There may be many local historical accounts (including written surveys, diaries, travelogues, pictorial evidence) for individual sites, but to locate, access, and interpret these for all sites nationally would be logistically challenging.

Ultimately, the level of confidence to which ALEW status can be assigned reflects the quality and availability of historic map and text sources. It should be noted that the designation of a site's ancientness using historical sources does not imply absolute certainty but should be considered as the best assessment at the time made by examining all the currently available evidence.

Figure 30 Oak canopy at Glen of the Downs SAC. Originally categorised as LEW by Perrin & Daly (2010), a more detailed examination of archival map and written records has led to its recognition as Ancient Woodland (Roche & Doherty, 2023). Photograph Orla Daly.

A well-researched reference database of historic sources of information is essential for the efficient completion of a full national inventory of ancient woodlands in Ireland. A preliminary list of 91 map and text sources of information on 17th and 18th century woodland cover is provided (Appendix 4). This reference catalogue should be regarded as a starting point – more evidence is likely to come to light if individual counties and putative ALEW stands are assessed further. Indeed, during the literature search, “Mapping during the Irish Plantations, 1550-1636” (Margey, 2003) was reviewed. This thesis contains a catalogue of maps from Ulster and Munster from 1550 – 1636, many of which contain detail on forest cover. Following consultation with the author, this catalogue has now expanded to cover >700 maps from the period across all four provinces (Margey, in press). A search of the catalogue revealed 283 references to “woods”, 54 references to “trees” and one reference to “underwood”. This catalogue will likely serve as a key reference for gathering historical map evidence for any future national inventory of ancient woodlands in Ireland.

5. Review of palaeoecology in ancient woodlands in Ireland

5.1 Introduction

Holocene palaeoecology, mainly the use of pollen analysis, whereby pollen is extracted from stratigraphical deposits and used as a proxy for past vegetation presence, is pivotal to a baseline understanding of ancient and old growth woodland. Without numerous influential palaeoecological studies conducted over the last c.100 years, the past forest cover of Ireland would simply not be known, or the millennial timescale over which losses of woodland have occurred. Palaeoecology can also contribute to ecological theory and conservation paradigms (as reviewed in Birks, 2019), quite literally “transforming” ecology (Edwards *et al.,* 2017). Palaeoecology can be used to assist land managers in defining baseline ecological conditions, understanding a range of ecological processes across ecosystems and biomes (Mitchell, 2011) and, using this knowledge, selecting resilient woodland management options (Stobbe & Gumnior, 2021).

Airborne pollen disperses readily over great distances so that many early studies depict regional forest cover. Syntheses of these studies have been used to inform on the post-glacial succession of woodland across Ireland, Britain (*e.g*. Birks, 1989) and Europe (Giesecke & Brewer, 2018), and have been used to provide informative reviews of past woodland cover in Ireland (*e.g*. Birks, 1989; Mitchell, 2006; Mitchell, 2011). Furthermore, carefully selected individual palynological study sites can be used to determine historical dynamics of woodland at the stand scale (Section 5.1.1).

Sometimes stand-scale palaeoecology can provide unexpected results; for example, some studies show former clearance in putative ancient woodland (*e.g*. Segerstrom *et al.,* 1996), recent forest regeneration on previously open land (*e.g*. Shaw & Tipping, 2006), or species turnover (*e.g*. Mitchell 1988, 1990a; Webb & Goodenough, 2021). There have been a series of calls to integrate palaeoecology into conservation, spanning more than 50 years (*e.g*. Barber, 1993; Birks, 2012; Davis, 1994; Flessa & Jackson, 2005; Oldfield, 1970; Willis & Birks, 2006). Palaeoecology and paleoenvironmental records from lakes are particularly well integrated with modern ecological monitoring in some regions such as the UK and Australia (*e.g*. Bennion & Battarbee, 2007), however, in general, integration with terrestrial ecology and conservation is poor (Groff *et al*., 2023). Integration with woodland conservation has tended to be via single site-based studies, rather than routine application to monitoring to inform policy.

In defining ancient woodland status, Perrin & Daly (2010) list some palaeoecological evidence, but rely on historic map and text evidence, whilst in the UK the Ancient Woodland Inventory Handbook (Sansum & Bannister, 2018) does not reference palaeoecology at all. Documentary sources are temporally limited with widespread records of woodlands depicted only from the 1830s onward when OS mapping became widespread (Chapter 3). The limited records extending back to the 18th, 17th and 16th centuries have a considerable lack of spatial accuracy (Chapter 4), lack widespread systematic coverage, and provide only snapshots in time. Some tree species have lifespans of several centuries, so that species turnover and regeneration is a slow process. Therefore, an ancient woodland inventory would benefit from fuller integration of palaeoecology to provide a longer-term perspective than available from historic map sources (Mitchell, 2011; Shaw, 2006).

Palaeoecological investigation of ancient woodland has three potential advantages for inventory; 1. It can confirm a much longer-term presence of woodland cover; 2. It can provide a continuous, or regularly sequenced, record of changes in woodland cover through time; 3. Since palaeoecologists can identify and distinguish pollen taxonomically between many tree species, palaeoecological data can help define the composition and diversity of woodlands, as well as species turnover—detail of which is usually missing from maps and written records.

In the provisional inventory of ALEW in Ireland, Perrin & Daly (2010) note that several palynological studies assist in the determination of ancient woodland; however, they list just a handful of sites where continuous woodland cover is affirmed by such studies - "Killarney woods (Mitchell 1988, 1990a), Uragh Wood (Little *et al.,* 1996, Figure 31), Slish Wood (Dodson & Bradshaw, 1987) and Old Head Wood (Ní Ghráinne, 1988)". Perrin & Daly (2010) list several additional sites where palynological studies are found correlated with sites listed in the NSNW (Perrin *et al.,* 2008).

The small number of sites listed in Perrin & Daly (2010) requires further investigation. Is it possible to make more use of the palaeoecological record in the interpretation of ancient woodland in Ireland, especially to corroborate, and extend temporally, the evidence from maps and written sources? How much information can be gleaned from existing palynological studies additional to, and including, the ones noted by Perrin & Daly, given that there are 507 sites listed in The Irish Pollen Site Database (IPOL, Mitchell *et al.,* 2013)? Are there potentials for further studies, how should these be carried out, and what are the barriers and limitations?

This chapter aims to investigate these questions via a review of existing palaeoecological data in Ireland and reference to exemplars from elsewhere. It will review palaeoecological sites listed in the updated (2019) IPOL database selecting those which can assist inventory mapping by depicting local scale presence of woodland over time, as well as continuity, composition and change. In addition, the chapter will reflect on the use of other aligned methods such as macrofossils, charcoal records, and archaeology to add detail and corroborative evidence of woodland continuity beyond the written record. The collated information aims to provide a deeper understanding for the improved use of these methods as integrated tools for ancient woodland assessment, inventory, mapping and monitoring in Ireland.

Figure 31 Bracken-dominated understorey at Uragh Wood, Co. Cork. The Provisional Inventory of Ancient and Long-established Woodland (Perrin & Daly, 2010) used palynological evidence from Little *et al.* (1996) to assist in the determination of ancient woodland status for Uragh Wood. Photograph Oisín Duffy.

5.1.1 Potentials and problems in palynological interpretation

Three interrelated issues require consideration when interpreting pollen data and the accuracy of reconstructing vegetation cover from it. 1. the source area from which the pollen travelled into the basin from which the studied material is extracted. 2. the correlation between the abundance of pollen and the cover of plants, as this is not a linear relationship. 3. the chronology of the stratigraphy. These are discussed briefly below to define the rationale for the selection of relevant sites for review.

Pollen can travel large distances before settling into palaeoecological deposits, this makes interpretation of local features such as individual woodlands problematic. However, palaeoecologists have, via careful modelling and testing, established that pollen deposited in small diameter basins under a woodland canopy tended to come from local sources (Calcote, 1995; Jacobsen & Bradshaw, 1981; Sugita, 1994). Selecting such basins for local scale vegetation reconstructions from palaeoecology is now widely accepted (Overballe-Petersen & Bradshaw, 2011). This approach has been utilised in several palaeoecological studies to determine woodland history at the stand scale (*e.g*. Brown, 2010; Hannon *et al.,* 2000; Novák *et al.,* 2019; Pędziszewska & Latałowa, 2016; Petr *et al.,* 2020; Sansum, 2005; Shaw & Tipping, 2006) and in Ireland, notably by Mitchell (1988, 1990a,b).

The relationship between plant abundance and pollen abundance is not linear. The dominant tree taxa in many temperate woodlands are anemophilous (wind-pollinated), therefore pollen may be transported in great quantities. Other taxa, *e.g*. *Ilex aquifolium* (Holly), are insect pollinated, this evolutionary strategy leads to production of fewer larger pollen grains that do not release easily from the anther. The dispersal of pollen from insect-pollinated plant types into sedimentary basins can be limited and stochastic (*e.g.* Shaw & Whyte, 2020). This can lead to underestimation of canopy cover of some species. Numerous studies have built up important models relating pollen productivity to plant abundance, a review in 2008 by Gaillard *et al.* provides some background to the methods this complex modelling work is progressing. In its simplest form correlations between plant cover or tree basal area and pollen sampled from moss polsters (clumps of fresh moss) have been made, leading to correction factors which can be used for palaeoecological calibrations (*e.g*. Anderson, 1970; Bradshaw, 1981; Mitchell, 1988). Recent studies have used this knowledge to propose missing species in pollen-based reconstructions (*e.g*. Stolze & Monecke, 2017). Even for highly-dispersed pollen types, modern re-analyses are detecting former persistence of small populations into more recent times *e.g*. relict *Pinus sylvestris* (Scots Pine) in Ireland (Roche *et al*., 2018).

The main method of dating sediments is via radiocarbon dating. This method calibrates the proportion of the radiocarbon 14 isotope in a sample to an age based on the half-life of the isotope. Though this method has been available since the 1950s, in reality radiocarbon dating was subject to large errors and was not generally calibrated until the 1990s. The calibration relies on a series of assumptions of, rate of supply of Carbon-14 to the atmosphere, duration of half-life, and precision of measurement in the sample. Each calibrated age comprises a relatively wide age range probability. Intensive effort to match radiocarbon ages with artefacts of known age has allowed development of an international calibration curve for radiocarbon, the latest of which for the northern hemisphere is IntCal20 (Reimer *et al.,* 2020). However, this still results in a wide age range rather than a specific date. Earlier studies tend to have few dates per stratigraphy. Two or three radiocarbon dates across a stratigraphy of multi-centennial or millennial timescales is simply not sufficient to determine a secure chronology, especially when considering potential for accumulation changes and hiatuses. Multiple date approaches are generally limited to very recent palaeoecological studies. Older reported radiocarbon dates require recalibration to adjust to a more accurate age range.

Additional tools for establishing chronologies of sediments are the Lead-210 isotope, which, with a half-life of 22 years is useful for dating the most recent 150 years of a stratigraphy; influxes of exotic marker pollen, *e.g*. *Picea* (Spruce), where there are known dates for planting; spheroidal carbonaceous particles from fossil fuel combustion (Swindles, 2010); and tephra (volcanic ash) analysis. The former two are temporally limited to the historical period. The latter can be extremely useful in dating precisely some of the layers of peat, but only for known dates of eruptions (*e.g*. Plunkett *et al.,* 2004).

The interpretive limitations and potentials of different site types, chronological controls and calibrations of pollen abundance provide some parameters to filter existing studies for those relevant to informing a long-term stand-scale ancient woodland inventory.

Pollen data from small basins, forest hollows, and ponds, *etc*. from within woodlands of interest are the most useful, as they are spatially constrained and depict local woodland. Datasets from large peat basins and lakes provide a regional picture and are generally of little use in determining continuity or change in specific ancient woodland stands as the pollen source is too diffuse to determine the precise locality of the arboreal component.

Studies that lack palynological data covering at least some of the last 600 years are of limited use to modern inventory. Early Holocene records of woodland presence, whilst interesting, cannot provide information over recent centuries to connect with map data in order to elucidate information on continuity and dynamics. It must be possible to interpret changes in woodland, in regular temporal sequence, alongside and beyond the historic record, at least over centuries and, if possible, continuously over millennia. Secure chronological controls are required.

5.1.2 Other considerations

Whilst pollen-based palaeoecological analysis is key to our understanding of past ecology, it can tell us only about the changes in the composition and relative abundance of trees and flowering plants. The palaeoecologist can interpret site changes in composition and canopy openness and infer anthropogenic indicators as drivers of change; however, independent corroboration of the wider anthropogenic, environmental and climatic drivers of change requires a suite of other proxies. Additional searches for material using non-pollen approaches such as charcoal, non-pollen palynomorphs (NPPs) *e.g*. spores (*e.g*. Latałowa *et al.,* 2013), plant macrofossils, insect remains *e.g*. fossil beetles (*e.g*. Olsson, 2006), have had some use in Ireland, and can also be informative. A short review of their utility from exemplar sites in Europe is also provided to demonstrate how a multi-proxy approach might add to a toolbox of palaeoecological approaches to integrate with future woodland inventory.

5.2 Methods

To determine the current state of knowledge of ALEW sites from palaeoecology, IPOL was downloaded into a Microsoft Office Access database. Data were interrogated for relevant sites in the Republic of Ireland based on filter parameters determined by methodological considerations discussed above.

Sites with ‘Top Date’ equal to or under 600 years were selected via database query; this ensures at least some temporal proximity or overlap with the oldest map data. Sites entered in IPOL with ‘unknown’ dates were also selected for further checking.

A further filtering of these sites for site types likely to produce a local pollen record, was implemented by querying the database for the ‘Site Type’ terms; “woodland hollow" “forest hollow", OR "small hollow", OR "heath", OR "grykes", OR "wood peat", OR "mor humus", OR "kettle hole", OR "peaty basin", OR "artificial pond", OR "pond", OR "peat filled kettle hole", OR “kettle hole”, OR “peat monolith”.

Sites listed as “multiple cores” were also reviewed as these studies may also have local scale data. Following this, a query of sites of any type with ‘wood’ and or with ‘fine’ anywhere in the title was implemented to retain any potentially relevant sites that may have been lost during the filtering process.

IPOL lists study sites up to 2019, with some sites being prepared for publication in 2019 included as unpublished sites. Therefore, Google Scholar was used in a systematic search of studies published since 2019. Two searches with combined Boolean terms were used: 1. (palaeoecology OR paleoecology) AND (wood* OR forest*) AND (Ireland OR Irish)” since 2019, and 2. “(small hollow OR small basin) AND (palaeoecology OR paleoecology) AND

(Ireland OR Irish)" since 2019. This returned several thousand results and was modified subsequently using the terms "-Eocene -Triassic -Cretaceous -Ordovician -Jurassic" to filter out unwanted age ranges. This returned c. 1730 results on 31/01/23. A search of "(small hollow OR small basin OR fine spatial) AND (palaeoecology OR paleoecology) AND (Ireland OR Irish) -Eocene -Triassic -Cretaceous -Ordovician -Jurassic" was also carried out.

A scan of the returned recently published studies was implemented to determine: 1. If these were re-analyses of previous studies; 2. If new study sites were of local-scale or had information on Irish woodlands; 3. If new sites had suitable chronologies. In ArcGIS, all sites in IPOL were intersected with existing ALEWs from Perrin & Daly (2010) using the shape files ALEW09_woodland_inventory.shp and the NSNW_Woodland_Habitats.shp available online (NPWS, 2008, 2010). Local sites selected from IPOL using the filters, post 2019 studies, and sites intersecting with ALEW were reviewed individually where available. Several undergraduate or post-graduate theses were unavailable. Summary descriptions of woodland composition, cover and dynamics are provided for each site.

Sites with radiocarbon dates presented as radiocarbon years (BP) were recalibrated (cal BP), where appropriate, using Bacon in R (Blaauw *et al.,* 2020, 2022) based on the IntCal20 radiocarbon calibration curve (Reimer *et al.,* 2020), before reviewing the data to attain the most accurate assessment of the timing of any shifts in woodland.

A brief non-systematic review of exemplar studies using other paleoenvironmental methods was included to illustrate the breadth of palaeoecological analysis and to consider the ways that additional proxies and data might be used to improve information for an ancient woodland inventory in Ireland.

5.3 Results

5.3.1 Summary data for relevant palaeoecological studies

Of the 507 sites listed in IPOL, 370 are from the Republic of Ireland. Sites from Northern Ireland are not included here. After selection of sites with top date equal to or under 600 years, 189 sites listed in IPOL have a suitable temporal span to link with historical mapping of extant woodland and another 14 sites have unknown chronologies. However, many of these are from larger lakes or raised mires. After filtering for site type, as well as keywords 'wood' and 'fine' in the titles of publications associated with the 189 remaining sites, 66 sites in IPOL likely depict local or extra-local scale vegetation. A further two sites from the fourteen sites listed as unknown date—Charleville (Stefanini, 2003) and Brackloon Hollow B (von Engelbrechten *et al*., 2000)—may be of interest due to being listed as from woodland or forest hollows.

The 68 sites, including undated and the two local sites of unknown date, are reviewed in Appendix 5. Of these, 45 had at least one radiocarbon date, 38 had at least two radiocarbon dates and 1 used Lead-210 dating. After a review of the published studies, 41 sites depicted local or extra-local vegetation around the sites, with 29 sites with at least one radiocarbon date. Of these dated sites, 21 are stand-scale woodland sites.

Nineteen local-scale palaeoecological study sites intersect with ALEW woodlands (Figure 32). Thirteen of these are ALEW AW sites, four are PAW sites and two are LEW sites. An additional site at Union wood lake (in PAW) is included in Appendix 6, but palaeoecological evidence is not strictly local in scale at this site. Of the 19 local-scale sites plus Union wood lake intersecting ALEW, seven lack radiocarbon dating and three have only one radiocarbon date. In addition to the 20 palaeoecological study sites in ALEW, four sites with local-scale palaeoecology are currently wooded (as determined by visual inspection of aerial images) but not in NSNW woodland or ALEW. Nine local scale palaeoecological studies in currently open areas indicate the existence of recently lost woodlands or recent decreases in local woodland cover (Appendix 7). The remaining sites in the list of 68 reviewed studies lacked relevance to woodland studies or, on inspection depicted regional vegetation.

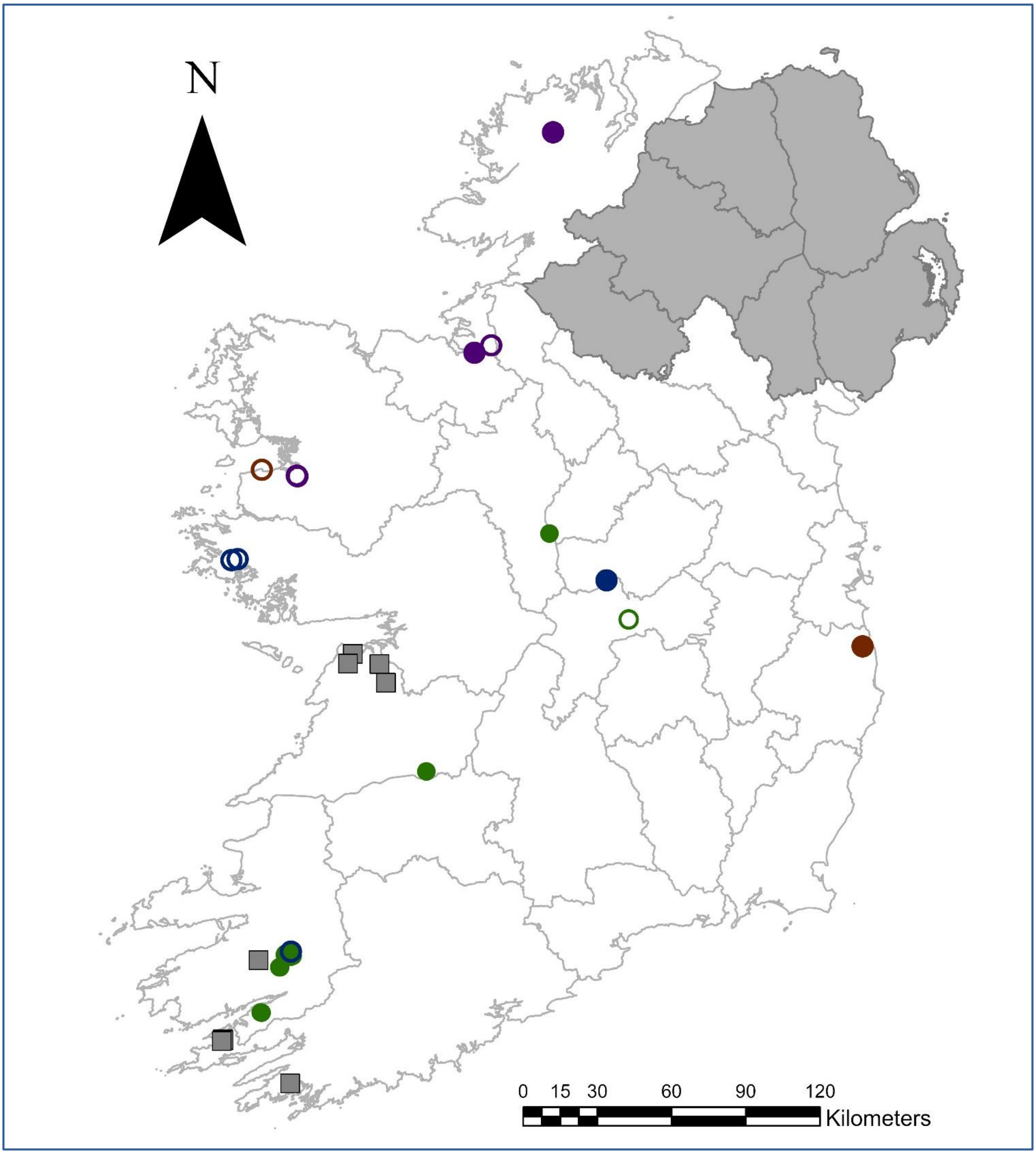

Figure 32 Distribution of IPOL sites containing pollen data that depict local-scale woodland histories. Sites that intersect with the Provisional Inventory of Ancient and Long-Established Woodland (Perrin & Daly, 2010) are shown as circles. AWs (from Perrin & Daly, 2010) are shown in green, PAWs in purple, LEWs in brown. Where palaeoecological evidence confirms AW status, circles are filled, and where palaeoecological evidence does not indicate definitive AW status, circles are open. Local-scale IPOL sites in currently open landscapes where the palaeoecology shows evidence of recent woodland loss (*i.e*. potential shadow woodlands) are shown as grey squares.

Nine possibly relevant new palaeoecological studies from Irish sites published since 2019 were selected for further review. Most are from lakes and large bogs and were discarded from detailed review due to a regional pollen signal. Three sites returned potentially relevant information pertaining to local woodland histories (Section 5.3.1 and Appendix 5).

No suitable sites (with ideal chronology and local-scale) were found in Leitrim or Kilkenny (although see brief discussion of the results from the regional scale study from Lough Cullin in section 5.3.1), therefore it was impossible to corroborate woodland longevity of new potential ALEW found in Chapters 3 and 4. This chapter therefore scopes the utility of palaeoecology in our understanding of ancient woodland across Ireland.

5.3.2 Corroboration of ALEW categorisations using existing palaeoecology

A brief review of the palaeoecological research for each site filtered from IPOL is provided in Appendix 5. Appendix 6 lists relevant sites in ALEW, or under current woodland and Appendix 7 lists sites in areas of potential shadow woodland. The ALEW site number and woodland status (AW, PAW or LEW) is included in the site summary along with a citation to the relevant publication. Appendix 6 also indicates where palaeoecological research corroborates or refutes ALEW status.

Local-scale palaeoecological sites studied within ALEW and categorised as AW are mainly in Co. Kerry--Reenadinna Wood, Uragh Wood (two sites), Camillan Wood, Derrycunihy1, Ross Island and Glaisín na Marbh. Other sites are in Co. Clare - Garrannon Wood and Co. Roscommon - St John’s Wood. Sites corroborated as AW according to the definitions of Perrin & Daly (2010) are noted in Appendix 6. Some sites lack suitable chronologies or details to provide secure evidence of AW status, these include sites marked as “tentative” (Appendix 6). These include Camillan 2 and Glena, with stratigraphic age spans estimated from present to 250 years, and Charleville (Co. Offaly), an unpublished study, where it is currently not possible to corroborate ancientness with existing palaeoecological analyses as it is not dated.

PAW sites include Mullangore in Donegal, Brackloon Hollow A and B in County Mayo and Slish Lake (Slish Wood) in Co. Sligo. Union Wood is also included in Appendix 6 although it is not a local scale study site. LEW sites include and Old Head Wood (LEW (I)) in Co. Mayo and Glen of the Downs (LEW (I)) in Co. Wicklow. The palaeoecological analysis of Mullangore wood spans the most recent c. 650 years and shows a continuous record of *Betula* (Birch) pollen with some *Corylus* (Hazel), but with a disturbance phase at the base of the stratigraphy transitioning from higher abundance of *Quercus* (Oak) pollen. This seems to support findings in Section 4.4 that Mullangore should be reassigned from PAW to AW, however, a more intensive sampling effort at this site with further radiocarbon dating would help to clarify this and to determine the time-span of the disturbance phase. Brackloon Hollows suffer from poor pollen preservation (site B and limited sampling (Site A). Site A may show some continuity of woodland. Old Head Wood is undated and estimated to cover just 200 years of woodland history, this does not extend past the time period of mapped evidence, whereas the palaeoecological study at Glen of the Downs, although undated, is estimated to cover perhaps 400 years of history with a steady abundance of woodland pollen types including *Quercus* (Oak) and *Fraxinus* (Ash). Glen of the Downs is likely to be AW conforming to the assigned *Quercus petraea* - *Luzula sylvatica* woodland group. This seems to support the findings of Roche and Doherty (2023) that the Glen of the Downs should be reassigned from LEW (I) to AW (Section 4.4). Whilst 12 of the 19 local scale palaeoecological studies provide reasonable confirmation of ancient woodland status (Appendix 6), the evidence is often tentative due to a lack of detailed chronology. A further five sites do not confirm with any certainty the status of the woodland, mainly due to lack of detailed chronology or lack of subsamples. In one case, Slish Wood, tentative evidence may demonstrate that the woodland is LEW rather than PAW. In some cases, limited access to older unpublished works means some studies were not consulted fully.

Most sites seem to have suffered past disturbance and change to differing extents in the past 1000 years. Camillan Wood, although meeting the definition of AW from Perrin & Daly (2010), shows clear evidence of secondary woodland forming c. 1000 years ago. In particular, a previous synthesis and review of Uragh, Derrycunihy, Camillan and Brackloon (Mitchell, 2013) provides analysis of biodiversity shifts through time, finding that biodiversity was highest from 5000-1000 years ago, presumably in the presence of some human land use, but in the last 1000 years rates of woodland change have increased as exploitation and management both opened the canopy and favoured *Quercus* (Oak) over other species. Mitchell's synthesis also highlights the role played by *Pinus sylvestris* (Scots Pine) in the former woodland until 1500 years ago as part of a much more stable mixed woodland.

Some local-scale studies are in currently wooded sites which are not mapped as ALEW (Perrin & Daly, 2010), *i.e*. Rough Island, Oak Island, Birch Island, Kilcurley, and the recent study of Derrycarhoon (Kearney & O'Brien, 2021), a clearing in conifer plantation. Oak Island, Lough Anessaundoo and Birch Island, Lough Derrycunlaghmore are undated, but Hannon and Bradshaw (1989) estimate these sites span the most recent 1000 years and both show evidence of woodland regeneration on heathland c. 250-300 years ago. This may suggest a categorisation of LEW (II) according to Perrin & Daly (2010). Kilcurley in Co. Offally (O Carroll, 2012) is also a small area of extant wet woodland with some evidence of continuity and change over the last 2000 years, perhaps indicating a small ancient woodland area; however, a period of erosion leading to inwash of material into the core leaves considerable uncertainty.

Further sites are in currently open landscapes. The Co. Clare sites Cappanawalla, Gortaclare and RUA (Feeser & O'Connell, 2009), all demonstrate some open woodland until the 17th century and a low-point in woodland cover, with high levels of sheep grazing in the following 100 years. There is a similar recent-centuries decline of remaining pockets of woodland on the Aran Islands (Molloy & O'Connell 2004; O'Connell & Molloy, 2019). Nine sites show possible shadow woodland status (Appendix 7).

Studies published since 2019 include a new analysis of Lough Mám Éan (O'Connell, 2021) formerly examined by Huang (2002), a study at Derrycarhoon (Kearney & O'Brien, 2021) and a small lake study site (Lough Cullin) in Co. Kilkenny (Kearney *et al.,* 2022).

At Lough Mám Éan there is evidence of widespread deforestation in the Connemara uplands, a now treeless and eroded landscape impacted by heavy grazing shows evidence of *Corylus* and *Alnus* persisting into late prehistory. Derrycarhoon (Kearney & O'Brien, 2021) provides palaeoecological analysis linked to an archaeological setting, in an infill of a copper mine working, the pollen signal is local, but the record is truncated at the top, revealing earlier woodland history but with no evidence of a continuous chronological link to extant woodland. The study at Lough Cullin, Co. Kilkenny provides a record from a small lake. Arboreal pollen at the top of the core in the period 780-1035 AD suggests sizable areas of woodland remained locally (Kearney *et al.,* 2022). Prior to that there had been periods of clearance for pastoral land followed by the resurgence of woodland from the Neolithic, with the last resurgence c. 2400-1500 years ago. Although this pollen diagram does not extend to the time period covered by mapping, the findings may tentatively indicate that Kilkenny has always contained a sizeable area of woodland, as found in Chapter 3, thus providing woodland continuity over a long time period. However, none of these more recent studies elucidates stand-scale history within ALEW.

5.3.3 Potential contributions from other palaeoenvironmental and archaeological sources beyond pollen and the written record

Other studies provide a variety of data increasing the scope of palaeoecology by using plant macrofossils, charcoal, non-pollen palynomorphs (NPP), beetle and insect remains and archaeological datasets, as well as soil and isotope studies. A brief review to demonstrate potential is provided here. Examples include European examples demonstrating potential for application in Ireland.

Plant and insect macrofossils

Macrofossils comprise parts of plants, insects, *etc*. The size range varies but they are usually larger than pollen. Leaf fragments can include the microscopic stomatal guard cells, which are extremely resistant to decay. Roche *et al*. (2018) determine, based on pollen and macrofossil evidence, that *Pinus sylvestris* persisted in Ireland around Rockforest contradicting prior assumptions that *Pinus* had died out earlier in the Holocene and that all *Pinus* is Ireland is the result of recent planting. Little use has been made of stomata in Ireland (Roche, 2010) and indeed none were found in the Rockforest samples (lake core), however, in Scotland, Shaw (2006) found that *Pinus* stomata were present when trees were within 20 metres of small hollow deposits. Given that these and other macrofossils indicate local presence more securely than pollen, more widespread use of macrofossils would be helpful.

Insect remains can also be important indicators of forest structure, beetle remains in particular can assist in determining woodland openness and the senescence stage when used as a proxy for the presence of dead and rotting wood (*e.g.* Whitehouse & Smith, 2010). In the Tatras, beetle remains have recently been used to determine ecological changes and infer greater human activity, via the analysis of insects associated with domesticated livestock (Schafstall *et al*., 2020).

Non Pollen Palynomorphs (NPPs)

NPPs encompass a range of micro-fossils of plant, fungi and animal remains (Miola, 2012). The variety of these types and their differing abundance across layers of stratigraphy can be used to infer environmental and ecological changes. The best known and utilised of these are coprophilous or dung fungal spores, which tend to be found in greater abundance with grazing herbivore abundance (van Asperen *et al.,* 2020). However, a range of other environmental inferences can be made, for example Prager *et al.* (2006) examine the NPPs of Alder carr and find useful types to confirm the presence of this vegetation type, whilst Innes *et al.* (2006, 2010) find *Kretzschmaria deusta*, a wood rot fungus, associated with the Elm decline at two sites in the UK. Marret *et al*. (2021) and Enevold *et al*. (2019) establish a connection between several NPP types and openness or erosion. The range of NPPs is vast and their utility is just beginning to be explored more widely from the pioneering work of van Geel (*e.g*. Shumilovskikh & van Geel, 2020; van Geel, 2002).

In Ireland, O'Sullivan (1991) uses *Gelasinospora* to indicate erosional disturbance c. 8500 cal BP in Glaisín na Marbh small hollow. Several studies in the west of Ireland have used NPPs, including a study which examines woodland around a small lough, with possibly an extra local rather than regional pollen signal (Ghilardi & O'Connell, 2013). Similarly, research at Kilbegly (Overland & O'Connell, 2011) utilised NPPs to clarify woodland dynamics. Not all of these studies meet the selection criteria for this study; however, they demonstrate utility of NPPs in Ireland for developing a clearer understanding of woodland dynamics and clearance phases.

Charcoal

Charcoal from both palaeoecological and archaeological sites hints at the availability, or at least exploitation, of woodland resources through time. Peaks can indicate increased fire activity in the landscape. In Ireland Mitchell (2013) reviews four sites in Atlantic oakwoods (Uragh, Camillan, Derrycunihy and Brackloon), finding that high charcoal levels are associated with tree cover reduction over centuries in the last millennium, when rates of change were higher than in the preceding five millennia.

Charcoal can also be present as macro-fragments or charred archaeological remains. A benefit of larger fragments of charcoal from archaeological sources, such as fire pits, or charred remains, is that the cellular structure is often maintained and can sometimes be identified to species. O'Donnell (2018) finds increased evidence of *Quercus* (Oak) during the Late Iron Age Lull from charcoal found in Tipperary and Cork, and records 14 species of tree. Similarly, a major review in the Midlands illustrates shifting resource use as well as showing presence of a number of taxa not well represented by pollen analysis due to insect pollination strategies, including Maloidae, *Prunus* sp. and shrubs such as *Ulex europaeus* (Gorse), *Cornus sanguinea* (Dogwood), *Euonymus europaeus* (Spindle) and *Viburnum opulus* (Guelder Rose) (O Carroll & Mitchell, 2017). Lyons (2018) also examines charcoal use throughout the south-Midlands in counties Tipperary, Kilkenny and Carlow. This work demonstrates changing resource use through time, driven by changes in the availability of timber and woodland resources, both from using-up, and managing, species in the woodland landscape. The increase in *Quercus* (Oak) after the 10th century is notable, as is the widespread and frequent presence of fruitwoods in prior centuries.

Environmental DNA

Emerging methods of DNA barcoding can allow for sedDNA (DNA fragments from sediments) or aDNA (ancient DNA) to contribute to palaeoecological studies. This can help detect species present in the environment that are not recorded in other data. Giguet-Covex *et al*. (2014) successfully demonstrate the utility of this technique, in Lake Anterne in France. They link loss of arboreal taxa with erosional events and both of these with DNA evidence for increased numbers of sheep and cattle, establishing a link between Roman and post-Roman pastoral activity, loss of trees, and the highest rates of erosive events for the last 10,000 years. In Ireland, modern DNA has been used with palaeoecology to determine provenance of subspecies or Lusitanian species (Sheehy Skeffington & Scott, 2021).

Archaeology

This broad field of study can add a wide range of detail, indicating human activity, manipulation of landscape *etc*. important for a fuller understanding of woodland history. For example, the PhD study by Budd (1998) usefully links various archaeological clues to woodland history in Ireland. In terms of woodland presence and structure, two examples of the possible use of archaeological resources are provided here.

Many “Togher” roads are recorded in Ireland on the Sites and Monuments Record and mapped on the Historic Environment Viewer (https://maps.archaeology.ie/HistoricEnvironment/). Most are constructed of wood. Chronologies are varied. The construction indicates the use of local timber resources and the tree species used can be identified. In addition, since some are constructed of brushwood and pole wood and some of larger split timbers or plank wood, it may be possible to derive some further information on the type, structure and age of woodland around these sites from further analysis of the trackway timbers, where they still exist. This approach has been taken in other archaeological contexts with recent papers by Out *et al.* (2018, 2020) describing methods of establishing ancient forms of woodland management through branch age and diameter.

Other wooden archaeological items can also add information relevant to woodland ecology. For example, preserved dugout canoes can give an indication of the species and minimum dimensions of individual large trees. Lanting & Brindley (1996) review canoe finds in Ireland, presenting a study of the age range of all dated finds. A large proportion date to the last c. 1000 years, up until the 18th century, indicating continued availability of large trees. Subsequent finds and better radiocarbon calibration might assist in a new review. Lanting & Brindley (1996) state that there is loss of outer timber, but since tree size is an important parameter, further review of this resource for minimum timber diameter may be informative.

5.4 Discussion

5.4.1 Mapping and monitoring ALEW in Ireland with the aid of palaeoecology

Section 2.4 highlights that the establishment of a systematic ALEW monitoring network will ultimately provide a sound evidence base for the effective conservation of Ireland's ALEWs. However, without the addition of palaeoecology the longer-term history of these woodlands is unclear. Paleoecology can provide corroborating evidence on ALEW status (Appendix 6). AW status is variously confirmed or challenged by palaeoecology and categorisation of PAW or LEW can be clarified. The scope for integration with inventory data is currently limited, due to few stand-scale palaeoecological studies in ALEW woodlands in Ireland. Furthermore, several existing studies lack chronological controls, or provide a limited number of subsamples. There is room for a systematic expansion of the use of palaeoecology alongside map-based inventory.

Section 3.1 takes a bottom-up approach (after Sansum & Bannister 2018) by searching historic maps for woodland and using this as a base map to establish both the longevity of cover and the losses of woodland. This may provide information relevant to maintenance, restoration and compositional change. Palaeoecological studies expand such information showing that many woodland stands have been disturbed in prehistory and are at various stages of growth and change following disturbance. Importantly, palaeoecology can also assist in identifying lost shadow woodlands, both within and beyond historically mapped woodlands, and can thus help to establish and extend information regarding woodland stand loss over centuries, or even millennia. A systematic expansion of the use of palaeoecology across a greater number of sites can contribute useful corroborating evidence to information on woodland dynamics.

There would be merit in a re-examination of several local scale palaeoecological study sites with long, seemingly uninterrupted records (Appendix 6) to gain greater insights into woodland currently categorised as LEW and PAW, as well as, to confirm AW status over a longer time period. In addition, areas now open in character may also be usefully examined to identify further shadow woodlands, corroborating and adding to those visible in historic map evidence. The most pressing problems are providing a suitable number of samples per core in these sites and developing, with the aid of radiocarbon dating, tephra and other methods, a secure and detailed chronology for the changes observed.

Several of the earlier palaeoecological studies in Ireland lack detailed presentation of the whole pollen spectra. Many early studies count a smaller number of pollen grains or focus on major arboreal taxa. Low pollen counts are determined empirically as suitable for a broad-brush inference of arboreal cover. Careful reanalyses with increased pollen counts can elucidate presence of species that are scarce in the woodland mix. Fruitwoods, for example, are visible in archaeological samples, but lacking in many pollen-based interpretations. Such painstaking studies can also provide evidence of very early species introductions, *e.g*. *Arbutus unedo* (Strawberry tree), especially if palaeoecology is combined with other palaeoenvironmental, chemical and archaeological techniques (Sheehy Skeffington & Scott, 2021).

It is difficult to establish common interpretation methods without recourse to the original raw count data and uncalibrated radiocarbon dates. In many palaeoecological studies it is difficult to access older and unpublished reports. Although there have been invaluable recent efforts to store data according to FAIR principles (*e.g*. PANGEA (https://pangaea.de/), NEOTOMA (https://www.neotomadb.org/), EPD (http://europeanpollendatabase.net/index.php)), many older datasets are not freely available and radiocarbon dating reporting can be unclear. In order to aid future reanalyses, new datasets should be stored in a standardised way, in an inventory with other woodland monitoring data. Where possible unpublished reports should also be stored to avoid future loss and ensure continued access.

5.4.2. Understanding old growth forest in the Irish context

Evidence of woodland exploitation, species turnover and clearance prior to 400 years ago in ALEW sites is common among the available palaeoecological studies. Current ALEW categories and inventories are based on mapped data. Although the palaeoecological evidence is currently limited across sites, the example from Derrycunihy, where the woodland is described as "perhaps the most natural Sessile Oak (*Quercus petraea*) wood in the country" in the SAC synopsis (Department of Arts, Heritage and the Gaeltacht, 2013) contrasts markedly with Mitchell & Cooney's (2004) evidence that the current woodland is a legacy of 19th century silvicultural practice. This confirms a requirement for a palaeoecological view of the development of individual stands to fully understand Ireland's ancient woodlands.

In other sites small woodland patches seem to have value as shadows of former woodland, this is highlighted by palaeoecology and modern biodiversity (*e.g*. Feeser & O'Connell, 2009; Overland & O'Connell, 2008), although none of these sites are linked to current ALEW woodland areas they perhaps hint at the nature of woodland recently lost.

For several sites, species turnover, increasing from the Bronze Age, and after an Iron Age Lull, seems to have removed any Mid-Holocene high forest and replaced it with scrubby vegetation. In other areas, *Taxus* (Yew) woodland dominated after clearance episodes and *Fraxinus* (Ash) has also responded to clearance (*e.g*. Mitchell, 1990a). The loss of native *Pinus sylvestris* (Scots pine) has also varied temporally and spatially, creating species turnover within our woodland communities with possible ongoing impacts on biodiversity where losses are more recent (*i.e.* hysteresis). Elsewhere in Europe disturbance and change has been linked positively with valued elements of woodland biodiversity (*e.g*. Bradshaw *et al.,* 2015; Sansum, 2005). In Scotland, Sansum (2005) found that Atlantic bryophytes (*i.e.* mosses and liverworts) and Pteridophytes (ferns) have persisted even through offtake of cash crops and local woodland use. A similar suite of ferns is listed in Uragh Wood (Cunningham *et al*., 1999), where disturbance histories also seem not to have impacted the presence of these taxa. Sansum (2005) observed that various forms of restrictions on management have been used through history to preserve the ecosystem services of the woodlands, and these management activities might provide options for the future without loss of biodiversity.

Where ancient woodland exists, this clearly does not mean unchanging, or imply a lack of human use. Past disturbance may not negate current and future biodiversity value. Inventory and protection of sites needs to take this into account. Mid Holocene and later species shifts are found in other areas of Europe in forests categorised as 'Primary' and 'Old Growth'. EU policy (non-binding) instructs member states to protect old growth forest by 2029. This does not prevent inventory as AW in the ALEW framework. Criteria for protection need to be adapted for the Irish context in the light of continuity and change in woodland history, accepting periods of past cultural use.

Although, conceptually, 'woodland' in Ireland is often associated with larger tree species such as oak and ash, the variety of species depicted in the charcoal record may indicate that our perception of woodlands could be inherited from recent social values rather than the reality of more ancient woodland structures. In Scotland, Sansum (2005) argues that more open woodland, which may have supported smaller light-demanding trees, is depicted earlier in the second Millennium by charcoal evidence. This is undoubtedly the case in Ireland too. Ireland is at the western extreme of the Atlantic woodland type and is likely to be quite different to other European areas. The EU Forest Strategy (European Commission, 2021b) urges that management strategies take "into account the differences in natural conditions, biogeographic regions and forest typology". This should be considered in the light of findings that many mapped ancient woodland fragments do not conform to Annex I woodland (Chapter 2). Wet and scrubby woodland, alluvial and bog woodland are important, as well as WN1 high forest woodland.

5.4.3. Inventorising and protecting shadow woodlands

Some currently treeless sites show that woodland loss has been relatively recent. Feeser & O'Connell (2009) demonstrate an important open *Pinus sylvestris* dominated arctic alpine woodland over much of the Burren until the Iron Age and note that "39 species of putative ectomycorrhizal fungi, normally intimately associated with pine woodland, are confined in the Burren to these upland arctic-alpine plant communities". The longevity of survival of floral and fungal elements demonstrates the important role of "shadow" and "ghost" woods (*sensu* Rotherham, 2017a,b) in defining biodiversity in currently open sites.

The ability to use small hollows and wetlands in currently open and uncategorised woodlands to elucidate site histories and identify remnants of shadow and ancient woodland is important to corroborate the extent and timing of woodland loss in the landscape. Restoration requires expansion of woodland and shadow woodland sites may prove to hold relevant biodiversity to facilitate such expansion.

5.4.4. Extending palaeoecological analyses

A number of other palaeoecological techniques have been sporadically used in Ireland, these could form a beneficial addition to a more systematic analysis of ancient woodland. The analysis of macro-charcoal, and the detailed analysis (via increased pollen counts per sample) of pollen types from rarer taxa or from insect-pollinated trees may provide a more detailed perspective on the arboreal, shrub and understorey composition, and biodiversity losses or gains, in woodlands through time. NPPs also form an underused resource in palaeoecology, especially useful in determining herbivore presence, but also in erosion episodes and indicating wood rot, whilst insect remains can assist in depicting the state of woodlands *e.g*. regenerating or senescing.

Modern whole core scanning technologies can assist greatly with a more holistic understanding of the stratigraphic profile, periods of inwash from erosion, mining, *etc*. at fine resolutions, alongside the pollen and palynomorph counts. Shifts in soil nutrient status, soil acidity, and soil biodiversity (Cudmore, 2012) as well as soil loss (Feeser & O'Connell, 2009) need to be similarly elucidated from multiproxy and environmental data and considered in site management planning. Other emerging methods such as lipid biomarkers (Jordan *et al*., 2017) and phytoliths (Osborne, 2023) can be added to the palaeo toolbox. These may allow for the enhanced detection of species with low pollen productivity and dispersal, as well as adding to the information on grazing presence in woodlands.

The use of multiple sites in the woodland landscape is important to determine spatial patterns of woodland (*e.g*. Hultberg *et al*., 2017; Shaw, 2006). Patterns may include, for example, trajectories of woodland change across different soils and at differing altitudes (Allen, 2022). This approach is particularly relevant for stand scale dynamics in suites of connected ALEW sites where PAW/LEW and AW categorisations occur across the woodland, *e.g*. in both Co. Kerry and Co. Clare. The different trajectories of different woodland areas become apparent in reviews of the woodland using comparisons across sites (*e.g*. Feeser & O'Connell, 2009; Mitchell, 2013). Although data synthesis reviews can develop after a build-up of studies through time, modern palaeoecological studies can benefit from a designed approach, so that data is collected in a consistent way and can be compared directly. A designed multiple core approach can inform stand scale dynamics (Bradshaw, 2007) as well as determine overall decreases (or increases) in woodland cover.

The ability to correlate the timings of various vegetation shifts across a landscape is essential to test for synchronous and asynchronous change in multiple core approaches. Several of the older palaeoecological analyses understandably have very limited chronological controls. To gain a secure chronology, multiple radiocarbon dates must be obtained along the depth of the core. These can now be combined with wiggle-matching statistical techniques including Bayesian modelling, to interpolate a best fit sequential chronological model for the stratigraphy (Blaauw *et al.,* 2018). Financing of sufficient radiocarbon dates and detailed multiproxy analyses continues to be a problem, especially as conservation and biodiversity science tends to be 'chronically' underfunded (Barbier, 2018; Pettorelli *et al*., 2021). The addition of tephra analysis should also be routinely applied to future palaeoecological studies from small hollows as corroborating evidence (*e.g*. Reilly & Mitchell, 2015). Establishing a clear chronology, however, may reveal discontinuities and sedimentary disturbance, which render some sites unreliable and this data redundancy risk needs to be accepted.

5.5 Conclusions for integration of palaeoecology into ALEW inventories and woodland restoration

Despite several important exemplar projects, over 500 palaeoecological sites in Ireland, and c. 100 years of pollen analysis, currently a limited number of study sites provide detailed local-scale vegetation reconstructions. However, with notable exceptions in the west, across the rest of Ireland the limited number of suitable local palaeoecological records confines to generalities our understanding of long-term histories of woodlands in Ireland, including stand-scale longevity, the impacts of disturbance, and the dynamics of woodland at the stand-scale.

The evidence from past palaeoecological studies aligned with ALEW woodland shows that many AW sites have still undergone considerable change in species composition. Habitat descriptors may need to be suitably flexible to allow for such change and previous periods of species turnover may inform process-based management. The past openness and species turnover in certain woodlands in Ireland shows the need to broaden our assumptions about woodland structure and composition. Change should be expected as neglected or abandoned woodlands develop into a future-natural state (*sensu* Peterken, 1996). Allowing space for dynamic woodland boundaries, more open areas, and diverse woodland is important. Management of protected ALEW sites should allow for species turnover, for example in response to Ash Dieback disease. We cannot expect woodlands to remain the same into the future. Cultural management of woodlands in the past has sometimes added to biodiversity, and some species have been resilient to the disruptions of resource use, disease or climate, whilst others have not.

A relevant primary and old-growth forest definition for Ireland should consider a much longer-term cultural history of Irish woodlands. The importance of a range of high forest, open forest with fruiting trees, and scrubby, small marginal woodlands in the extreme Atlantic climate of Ireland should not be overlooked. The EU definition of primary and old-growth forests may not suit Ireland well. Policies will need to be flexible towards past and continuing change. Past changes should be carefully assessed and should not necessarily preclude current woodland from designation and protection. To achieve resilient future old growth forests, management actions will need to be better informed by past structure and composition of woodland in Ireland. There may also be some currently treeless landscapes which could be prioritised for forest expansion, due to recent shadow woodland, or recent losses in proximity to ancient woodland fragments.

Some existing sites could be revisited, combining detailed palaeoecology with modern dating techniques. Increased subsampling to improve and clarify temporal resolution would be beneficial at sites such as Brackloon, The Gearagh, Charleville and St. John's Wood. New sites could be sought in other woods such as Old Head Wood and Glen of the Downs, to attempt to extend the limited chronology of existing studies. Across Ireland a range of previously unstudied sites could be investigated via palaeoecology. PAW sites are particularly ripe for palaeoecological research, as are sites in areas which are poorly covered by historic mapping. Small pockets of PAW occur in many areas, including Donadea Forest Park (Co. Kildare), and Dromore (Co. Clare), where PAW woodland occurs around lakes which could hold stratigraphic deposits. As mapping at smaller scale provides newly inventorised sites (including the newly mapped PAW sites in Kilkenny and Leitrim (Chapter 4), a systematic exploration of these sites for palaeoecological potential would also be informative.

A fully integrated strategy to include palaeoecology, wherever possible, into mapped site evaluations is proposed. Whilst pollen data are the main focus for future palaeoecological work, a multiproxy approach is recommended to develop the detailed interpretive reconstruction needed, to align with ALEW categorisation and monitoring needs. Beyond palaeoecology, linkages with holistic landscape studies including history, archaeology and present-day ecology all combine to add value to each method of analysis. In this way records from the past will contribute an important method of extending inventory and monitoring data, to provide evidence-based management options.

To adhere to best practice, the process should include:

1. Looking for suitable peat and mor humus basins (*sensu* Overballe-Peterson & Bradshaw, 2011) across ALEW sites in Ireland.
2. Extracting suitable core or monolith samples to undertake palaeoecological and palaeoenvironmental analysis.
3. After stratigraphic description of the core, undertaking XRF scanning for elemental content, including indicators of erosion, and scanning for tephra to assist with a secure chronology.
4. A rigorous application of multiple AMS radiocarbon dates to ensure a secure chronology.
5. Extraction of samples at continuous or high temporal resolution, to aim for sub-100 year timeframes.
6. Preparation of subsamples to extract pollen, NPP and micro-charcoal using established protocols.
7. Counting of samples to a high resolution (c. 800-2000 pollen grains per sample) determined by site specific questions on biodiversity.
8. Calibration of pollen against a new set of locally derived pollen productivity estimates.
9. A consideration of other methods such as aDNA, fossil beetles (*e.g*. Reilly, 2011; Whitehouse, 2006), and macrofossils.

In order to harmonise processes across mapping and palaeoecological investigation, ecology personnel implementing monitoring and site surveys could be trained to identify potentially suitable sites for pollen analysis. A database of potentially suitable sites could be developed.

6. Conclusions and Recommendations

6.1 The protection, restoration, and monitoring of ancient and long-established woodlands in Ireland

Ireland's ancient and long-established woodlands are irreplaceable habitats of significant biodiversity and cultural heritage value. Yet, the analysis of the conservation status of ALEW sites (Chapter 2) revealed that 68% of ALEWs surveyed as part of Habitats Directive Article 17 monitoring received an Unfavourable conservation status assessment, mainly due to the impacts of non-native invasive species and overgrazing. Furthermore, a large proportion of the area of ALEWs identified in the Provisional Inventory of Ancient and Long-Established Woodland in Ireland (Perrin & Daly, 2010) have no statutory conservation designation. However, 1,227 ha of undesignated ALEWs fall within 100 m of an existing protected area boundary. To protect and restore these last vestiges of our ancient, wooded past, the expansion of current protected areas to encompass and connect these ALEWs is needed. The designation of NHAs should also be considered for the protection of ALEW.

Based on the analysis of ALEWs in Leitrim and Kilkenny (Chapters 3 and 4), the work of Perrin & Daly (2010), Garrett (2001), and O'Sullivan (2004), it is clear that a sizeable proportion of ALEW sites in Ireland are now dominated by planted conifers. While the ecological integrity of these sites is much diminished relative to our best examples of semi-natural ancient woodland, ALEWs in planted conifer sites can retain some features of ancient woodland such as soils, ground flora, and woodland archaeology, and may have restoration potential. Indeed, the level of historic disturbance in Irish woods means that EU primary and old-growth forest status may not be applicable to some valuable remnants of forest recovering from or shaped by previous cultural impact. Biodiversity assessment indicates that these woodlands are no less valuable due to disturbance history in previous centuries and recovery from disturbance is possible. This has implications for overgrazed and planted ancient woodlands in Ireland. Consequently, restoration of ALEWs should be central to national forest policy. Policy on ALEWs in Ireland should consider how any future protection measures will be integrated with approaches to forest conservation under current EU Biodiversity and EU Forest Strategy, as well as the EU Nature Restoration Law.

In Chapters 3 and 4, it was shown that a sizeable proportion of ALEW sites fall below the 5 ha size threshold largely applied in the Provisional Inventory of Ancient and Long-Established Woodland in Ireland (Perrin & Daly, 2010). Although this case-study examined only two counties, it has already greatly increased the number of AW sites identified compared to the number in the provisional national inventory. This underlines the need for a full national inventory of ALEWs. An important component will be a consistent and repeatable approach to interpreting historic evidence when investigating woodland antiquity. Continued research into historical map and text sources of information for ancient woodland evaluation is required. However, map evidence has a limited temporal extent. Where possible, detailed palaeoecological analysis should be implemented to clarify the status and stand dynamics of each woodland.

In Chapter 5 the state of knowledge of ALEW sites beyond the historical record was reviewed, via palaeoecological approaches. Just 18 ALEW sites have such extended temporal records. Notwithstanding the limitations created by a lack of suitable sedimentary basins in many woodland sites, examples from Ireland and the rest of Europe demonstrate that palaeoecological data contributes usefully to ancient woodland inventory. Further research is urgently needed to clarify the biodiversity value and resilience of Irish woodlands. The valued structural biodiversity of some woodlands may be partly due to cycles of disturbance and succession over long time periods in prehistory. Palaeoecology also highlights a pressing need for more research to understand the role of long-term change, disturbance and hysteresis effects on the biodiversity of woodlands. There is clear room for expansion of knowledge of long-term processes in ALEW sites to contribute to restoration. Mapping and palaeoecological techniques can also be combined to consider the location and value of shadow woods – areas of recently lost woodland where ground flora and soil conditions may be conducive to woodland regeneration. Several areas of possible shadow woods are discussed in Chapter 5 and the recommended inventory techniques, which start with woodland present in older maps, provide opportunities to discover and map these potentially important sites (Chapter 3).

The combined results of these analyses highlight the pressing need for expanded ALEW inventory, the evidence base for ALEW restoration, and the establishment of a long-term ALEW monitoring network. We therefore make the following recommendations:

Recommendation 1. Complete a full National Inventory of Ancient and Long-established Woodland in Ireland. An overview of a proposed approach to identifying ALEWs in Ireland is outlined in Figure 33.

Recommendation 2. To ensure consistency in future inventories of ALEW in Ireland, definitions (size thresholds in particular) for ancient and long-established woodland in Ireland established in Chapter 4 should be adopted. Given the challenges associated with linking woodlands depicted in 17th century maps with tiny fragments of extant woodland, to assign woodlands as ancient from historic map sources with reasonable confidence, a minimum size threshold for ALEW of 0.25 ha is proposed.

Recommendation 3. A formalised approach for the protection of ALEWs in Ireland is required. ALEWs of high conservation value should be prioritised for designation. ALEWs that correspond to Annex I habitats, which are listed under the Habitats Directive, may receive protection under the Natura 2000 network. However, some ecologically important woodland types in Ireland (*e.g*. WN2 Oak-ash-hazel woodland) do not correspond to Annex I habitats and, where appropriate, should be protected under national legislation *i.e*. as NHAs designated under the Wildlife Acts 1976 to 2023.

Recommendation 4. The consistent, repeatable approach to the long-term monitoring of ALEWs should be continued and expanded. Given that many ALEWs in Ireland do not correspond to Annex I habitats, a network of repeated monitoring sites in addition to Annex I plots is required.

Recommendation 5. The ALEW dataset should be shared widely across land management and planning agencies and departments, and the value of these woodlands highlighted in relevant ways: *e.g*. cultural, heritage, biodiversity, and carbon sequestration. Increased awareness of ALEWs within competent authorities can help to inform planning, licensing and enforcement decisions.

Recommendation 6. Management guidelines for ALEWs are provided in Cross & Collins (2017). Further guidance and training to facilitate the restoration of ALEWs in Ireland through conservation and restoration works is required.

Recommendation 7. Restoration action should be underpinned by research and monitoring in Annex I and non-Annex I sites, as well as shadow woodland sites. The long-term dynamics and disturbance histories of Irish woodlands should be utilised to provide a full understanding of restoration potential and planning. Restoration of Annex I ALEWs with Unfavourable conservation status should be prioritised. This will be required for large proportions of Annex I ALEW under the EU Nature Restoration Law.

Recommendation 8. A digital repository of historical information on woodland cover in Ireland (archival maps, manuscripts, written surveys, diaries, travelogues, pictorial evidence) should be developed and curated. Although interpreting fragmentary historic documents and maps presents numerous challenges, these records can form a basis for ALEW mapping and targeting of more detailed inventories and field surveys. Indeed, the attribution of ancient woodland status or otherwise is best supported by multiple lines of evidence. The value of toponymical research, ancient woodland indicator species, and woodland archaeology was addressed in Perrin & Daly (2010). Further review of these was beyond the scope of this study.

Recommendation 9. Where ancientness is uncertain, sites should be visited to evaluate landscape features, archaeological evidence, and ancient woodland indicator species that may inform the assessment of antiquity for putative ALEW sites. Where suitable stratigraphic substrates are available, palaeoecological analysis should be implemented.

Recommendation 10. Implement a procedure (Chapter 5) for systematically gathering palaeoecological evidence to support woodland ancientness evaluation as part of a new inventory and monitoring system.

6.2 Recommendations for future research

In addition to the overall recommendations of the project, key areas warranting further research have also been highlighted.

- Recent advances in machine learning approaches have enabled accurate, automated classification of features in historic maps (Auffrett *et al*., 2017, Gobbi *et al*., 2019). O'Hara *et al*. (2022) used a fully convolutional network (CNN) to map historic wetland cover in Ireland using OS first edition maps to an overall thematic accuracy of 81%. The potential application of machine learning approaches to automated mapping of 1830s woodland cover from OS first edition maps should be explored.
- 93 instances of permanent deforestation events in ALEWs between 2000 and 2017 were documented. Further research on this issue is needed to inform policy aimed at reducing deforestation in Ireland's ALEWs.
- Research on the restoration of shadow or ghost woods (Rotherham, 2017a,b) – sites which are no longer wooded but were ancient woodland in the relatively recent past – is required.
- The restoration potential of ALEWs which are now dominated by managed plantations warrants further research.
- Further research on the value of ancient woodland indicator species, including non-vascular plants, lichens, fungi, and invertebrates, is required.
- Increase the use of stand-scale, pollen-based palaeoecological and palaeoenvironmental records and utilise these to test further the linkages between woodland ancientness, biodiversity value and carbon sequestration.

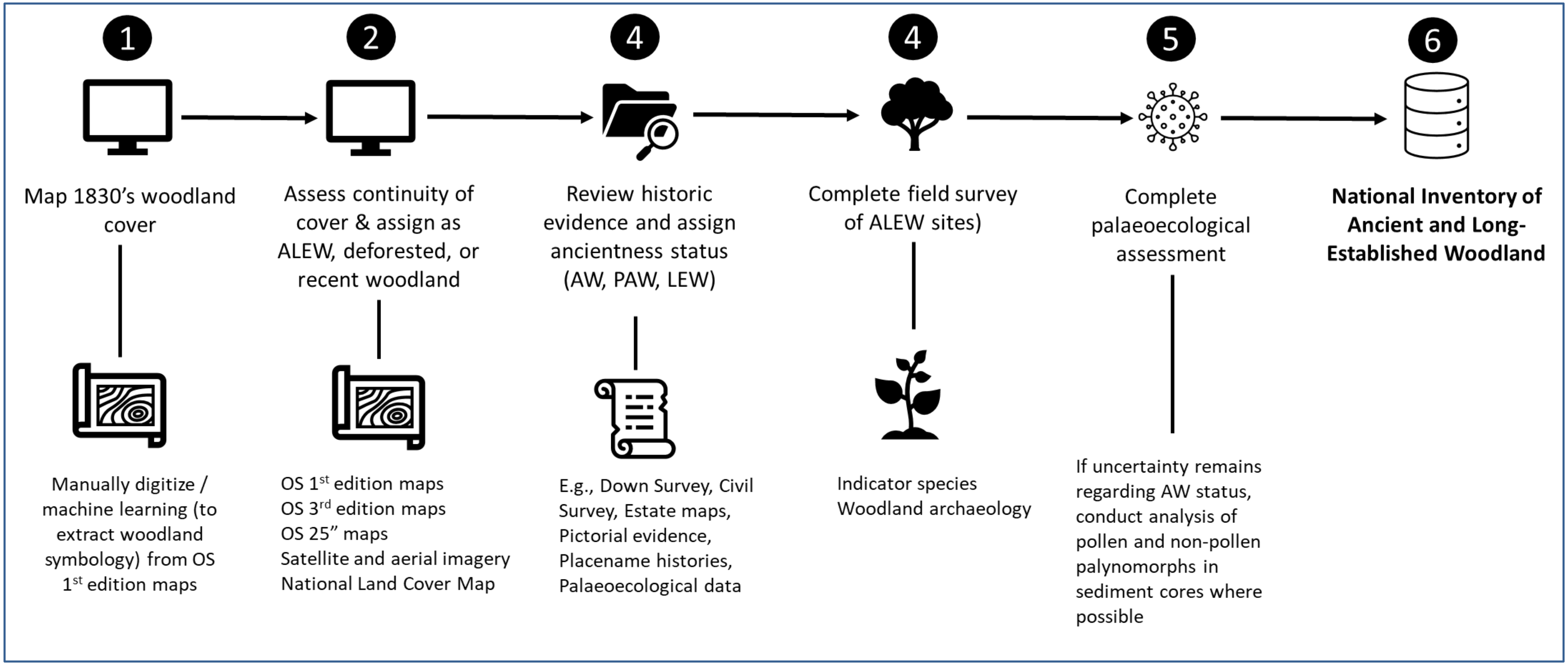

Figure 33 Schematic of the process and inputs required for the National Inventory of Ancient and Long-established woodlands in Ireland.

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Appendix 1

Post-2010 studies on woodland and vegetation history in Ireland

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Appendix 2

Conservation assessment, including conservation status and current pressures[5] for Annex I woodland monitoring sites that occur in ALEWs (after Perrin & Daly, 2010).

Site Code	Site Name	ALEW Status	Annex I	Area Assessment	Structure and Function	Future Prospects	Overall Condition	Trend	Negative Impacts[5]
346	Deerpark	LEW (I)	91E0	Green	Red	Red	Red	No change	D01.01, I01
534	Fidwog	LEW (I)	91E0	Green	Red	Red	Red	Declining	I01
1084	Gaybrook Demense	LEW (II)	91E0	Green	Amber	Red	Red	No change	B02.01.02, I01
1820	Killeeshal	LEW (I)	91E0	Green	Red	Red	Red	No change	I01
15	Borris	LEW (I)	91E0	Green	Amber	Amber	Amber	Declining	I01, B02.02
1288	Game Wood	LEW (I)	91E0	Green	Amber	Amber	Amber	Declining	H05.01, B06, I01
1409	Hazelwood Demesne	LEW (I)	91E0	Green	Amber	Amber	Amber	Improving	I01
1711	Ballyseedy Wood	LEW (I)	91E0	Green	Amber	Amber	Amber	Declining	I01
1932	Marl Bog	PAW	91E0	Green	Amber	Amber	Amber	Declining	K04.03, J02.04, I01
1315	Coolyduff	LEW (I)	91E0	Green	Green	Green	Green	No change	H05.01, D01.01, I01
1317	The Gearagh	PAW	91E0	Green	Green	Green	Green	No change	I01
1488	Scartbarry	LEW (II)	91E0	Green	Green	Green	Green	No change	K02.03, I02, H05.01
151	Bricketstown House	LEW (II)	91A0	Green	Red	Red	Red	No change	B06, I01
338	Vale of Clara	LEW (I)	91A0	Green	Red	Red	Red	Declining	B06, I01
414	Derrygorry Wood	LEW (I)	91A0	Green	Red	Red	Red	New site	B06, I01

498	Erne Head	LEW (I)	91A0	Green	Red	Red	Red	No change	B02.03, I01, I02
746	Baltynanima	LEW (I)	91A0	Green	Red	Red	Red	Declining	B06, G01.03.02, I01, I02, D01.01
749	Tomnafinnoge	AW	91A0	Green	Red	Red	Red	No change	B06, I01
779	Shelton North	PAW	91A0	Green	Red	Red	Red	Declining	H05.01, B06, I01
781	The Devil's Glen	PAW	91A0	Green	Red	Red	Red	Declining	B06, I01
1290	Derrycunihy	AW	91A0	Green	Red	Red	Red	Declining	J01.01, B06, I01
1305	Manch East	PAW	91A0	Green	Red	Red	Red	No change	I01, I02
1355	Philip's Wood	LEW (I)	91A0	Green	Red	Red	Red	No change	H05.01
1401	Union Wood	PAW	91A0	Green	Red	Red	Red	Declining	B02.03, B06, D01.02, I02, I02
1423	Mullangore Wood	PAW	91A0	Green	Red	Red	Red	No change	B06, I01
1441	Carndonagh	LEW (I)	91A0	Green	Red	Red	Red	Declining	B06
1481	Ummera Wood	LEW (I)	91A0	Green	Red	Red	Red	No change	I01
1491	French Wood	LEW (I)	91A0	Green	Red	Red	Red	No change	B02.04, I01, H05.01
1497	Bealkelly Wood	PAW	91A0	Green	Red	Red	Red	Declining	B06, I01
1515	Garrannon Woods	AW	91A0	Green	Red	Red	Red	No change	I01, I02
1543	Glenmore Wood	LEW (I)	91A0	Green	Red	Red	Red	No change	I01
1670	Stradbally (Mine Avenue Wood)	PAW	91A0	Green	Red	Red	Red	No change	I01, H05.01
1710	Ballintlea	LEW (I)	91A0	Green	Red	Red	Red	No change	I01
1792	Glanballyma	LEW (I)	91A0	Green	Red	Red	Red	No change	I01
1821	Knocknaree Wood	PAW	91A0	Green	Red	Red	Red	Declining	I01, H05.01

2027	Eamonns Wood/ Cahnicaun	AW	91A0	Green	Red	Red	Red	New site	B06, I01
179	Clonogan Wood	LEW (II)	91A0	Green	Amber	Amber	Amber	Improving	B06, I01, H05.01
180	Glandoran Upper/ Carthy's Wood	PAW	91A0	Green	Amber	Amber	Amber	Improving	H05.01, I01
334	Garadice Lough Peninsula	PAW	91A0	Green	Amber	Amber	Amber	Improving	I01
777	Glen of the Downs	LEW (I)	91A0	Green	Amber	Amber	Amber	Improving	I01, G01.02, G01.03.02
784	Oldboleys	LEW (I)	91A0	Green	Amber	Amber	Amber	Declining	B06, I01
785	Castlekevin	PAW	91A0	Green	Amber	Amber	Amber	Declining	J02.07, B06, I01
786	Giants Cut & Lugduff	LEW (I)	91A0	Green	Amber	Amber	Amber	Improving	L07, B06, I01
1273	Uragh Wood	AW	91A0	Green	Amber	Amber	Amber	Declining	B06, I01
1411	Slishwood	PAW	91A0	Green	Amber	Amber	Amber	New site	I01
1460	Kilmeen Wood	LEW (I)	91A0	Green	Amber	Amber	Amber	No change	I01
1495	Camillan Wood	AW	91A0	Green	Amber	Amber	Amber	New site	B06, I01
1552	Cahermurphy	LEW (I)	91A0	Green	Amber	Amber	Amber	Improving	B02.02, D01.01, B06, I01
1602	Ballynahinch	PAW	91A0	Green	Amber	Amber	Amber	Improving	I01, D01.01
1737	Graigues	LEW (I)	91A0	Green	Amber	Amber	Amber	Declining	B06, D01.01
1763	Pontoon Woods	PAW	91A0	Green	Amber	Amber	Amber	No change	I01, D01.01, H05.01
1777	Brackloon Woods	PAW	91A0	Green	Amber	Amber	Amber	Improving	I01
1859	Grove Wood	LEW (I)	91A0	Green	Amber	Amber	Amber	Improving	I01,L07, I02,B06,
515	Kylecorragh	LEW (I)	91A0	Green	Green	Green	Green	Improving	H05.01, I01
783	Deputy's Pass	LEW (II)	91A0	Green	Green	Green	Green	New site	I01

791	Kilmacrea Wood	LEW (I)	91A0	Green	Green	Green	Green	No change	B06, I01
1277	Lyranes Lower Wood	LEW (I)	91A0	Green	Green	Green	Green	No change	I01
1302	Prohus Wood	PAW	91A0	Green	Green	Green	Green	No change	H05.01
1316	Glengarriff	AW	91A0	Green	Green	Green	Green	Improving	I01
1323	Kilcatherine	LEW (II)	91A0	Green	Green	Green	Green	No change	H05.01,I01
1422	Ballyarr Wood	PAW	91A0	Green	Green	Green	Green	No change	I01
1427	Ardnamona Wood	PAW	91A0	Green	Green	Green	Green	No change	B06, I01
1459	Island Wood	LEW (I)	91A0	Green	Green	Green	Green	No change	L07, B06, I01, I02
1498	Drummin	LEW (I)	91A0	Green	Green	Green	Green	Improving	I01
1580	Ballykelly Woods	LEW (I)	91A0	Green	Green	Green	Green	No change	I01
1587	Derrymore Wood	LEW (I)	91A0	Green	Green	Green	Green	Improving	B06, H05.01
1749	Dooneen Wood	LEW (I)	91A0	Green	Green	Green	Green	No change	A10.01
1760	Brennan's Glen	LEW (I)	91A0	Green	Green	Green	Green	No change	A10.01, I01, H05.01
1827	Bohadoon South	LEW (I)	91A0	Green	Green	Green	Green	No change	B02.02
1878	Drum Wood	PAW	91A0	Green	Green	Green	Green	No change	I01, L07
2026	Shanacloon Wood	PAW	91A0	Green	Green	Green	Green	New site	L07, I01
1291	Reenadinna Wood	AW	91J0	Green	Red	Amber	Red	No change	B06, I01
1594	Garryland Wood	LEW (I)	91J0	Green	Red	Amber	Red	No change	K04.03, I01
1986	Curraghchase	LEW (I)	91J0	Green	Red	Amber	Red	No change	I01
2021	Kylagowan	PAW	91J0	Green	Red	Amber	Red	General survey only	B06, I01

[5] Descriptions of Negative Impacts codes: B02.01.02 forest replanting (non-native trees), B02.02 forestry clearance, B02.03 removal of forest undergrowth, B02.04 removal of dead and dying trees, B06 grazing in forests/ woodland, D01.01 paths, tracks, cycling tracks, G01.02 walking, horse riding and non-motorised vehicles, G01.03.02 off-road motorized driving, H05.01 garbage and solid waste, I01 invasive non-native species, I02 problematic native species, J01.01 burning down, J02.07 water abstractions from groundwater, K02.03 eutrophication (natural), L07 storm, cyclone.

Appendix 3

Criteria for choosing LEAF project case-study counties (Chapters 2 and 3).

1. Over 1000 km^2
2. Less than 2500 km^2 due to time constraints
3. Availability of OS 1"st edition maps and high resolution contemporary aerial imagery
4. Range of land cover types and land cover histories, including broadleaf and conifer woodlands (current forest cover >8%)
5. Availability of Down Survey County, barony, and parish maps
6. Availability of other historical sources of information

Appendix 4

Historic sources of information on 16th, 17th and 18th century woodland cover in Ireland (non-exhaustive). MPF denotes Maps and Plans from the Public Record Office, National Archives, UK.

Name	Scale	Year	Map/Text
Down Survey	General	1658	Map & Text
Civil Survey	General	1656	Text
Books of Survey and Distribution	General	1680	Text
Grand Jury Records	General	18th/19th C.	Map & Text
Irlande (Boazio)	General	1599	Map
Hibernia Pars Australis (Hondius)	General	c.1630	Map
Ireland (Ortelius)	General	1601	Map
The Kingdom of Ireland (Jaillot, Sanson)	General	1693	Map
The Plott of Irelande with the Confines (Norden)	General	1599	Map
Hibernia insula non procul ab Anglia vulgare Hirlandia vocata (Goghe)	General	1567	Map
Maps C.4.c.I. Leinster, Mouster, Ulster and Connaughir (Bleau)	Provincial	1662	Map
Brown's map of Connaught	Provincial	1591	Map
John Speed’s map of Connacht	Provincial	1616	Map
John Speed’s map of Leinster	Provincial	1616	Map
John Speed’s map of Munster	Provincial	1616	Map
Jobsons maps of Munster	Provincial	1589	Map
Provincial maps of Robert Lythe	Provincial	1567 - 1572	Map
Provincial maps of Richard Bartlett	Provincial	c.1602	Map
Maps of the Escheated Counties of Ireland (Bodley)	Provincial	1609	Map
The provinces of Leinster, Mounster, Ulster & Connaught	Provincial	1647	Map
Munster (except County Clare)	Provincial	1580	Map
Strafford Survey transcripts	Provincial	1630s	Text
Donegal (Wenceslaus)	County	1661	Map
County maps of Ireland (Moll)	County	1654-1734	Map
MPF 1/69. 'the newly made counties of Wicklow & Ferns (Burghley)	County	1579	Map
MPF 1/71 1587. Map of Mayo and Sligo counties, Ireland (Browne)	County	1587	Map
MPF 1/76 1590. County Monaghan (Browne and Baptiste)	County	1590	Map
MPF 1/79 1591. County Monaghan (Browne and Baptiste)	County	1591	Map
MPF 1/91 1589. Map of County Sligo and County Leitrim (Browne)	County	1589	Map
MPF1/92. Mayo (Baptiste)	County	1585	Map
MPF 1/97 1587. County Limerick (Jobson)	County	1587	Map
MPF 1/277 1560. Ireland: Queen's County (Tomkin)	County	1560	Map
Co. Wicklow (Nevill)	County	1760	Map
A New and Correct Map of County of Waterford (Smith)	County	1746	Map
MPF 1/70. County Carlow: Idrone Barony	Local	1580	Map
MPF 1/52 1609. County Cavan: Loughtee (Bodley)	Local	1609	Map
MPF 1/53 1609. County Cavan: Tullygarvey (Bodley)	Local	1609	Map
MPF 1/54 1609, County Cavan: Clankee (Bodley)	Local	1609	Map
MPF 1/55 1609. County Cavan: Castlerahan (Bodley)	Local	1609	Map
MPF 1/56 1609. County Cavan: Clanmahon (Bodley)	Local	1609	Map
MPF 1/57 1609. County Cavan: Tullyhunco (Bodley)	Local	1609	Map
MPF 1/58 1609. County Cavan: Tullyhaw (Bodley)	Local	1609	Map
MPF 1/94 1558. Cork and Kerry, around Bantry Bay	Local	1558	Map
MPF 1/100 1587. Coast of Munster from Kinsale & Dingle	Local	1587	Map
MPF 1/299 1585. Map of part of Munster, Ireland	Local	1585	Map

MPF 1/308 1587. O'Sullivan's country, Bantry Bay, Cork	Local	1587	Map
MPF 1/130 1583. County Galway: Athenry (Browne)	Local	1583	Map
MPF 1/78 1572. County Kerry: Castlemaine	Local	1572	Map
MPF 1/226 1580. County Kerry	Local	1580	Map
MPF 1/309 1587. 1 item extracted from SP 63/131	Local	1587	Map
MPF 1/92 1585. Map of Mayo, Killala Bay to Inishbofin (Browne)	Local	1585	Map
MPF 1/102. 1533-1603. County Offaly: Banagher	Local	1533	Map
MPF 1/310 1590. 1 item extracted from SP 63/156	Local	1590	Map
MPF. 87. Map of the coast from Knockfergus to Dundrum (Lythe)	Local	1580	Map
Map of Old Head Bay and Kinsale Harbour (Greenville Collins)	Local	1694	Map
Near Cahir Castle	Local	1599	Map
Moyry Pass, Dundalk (Bartlett)	Local	1602	Map
Lough Muckruske, Leitrim (Bartlett)	Local	1602	Map
Bellew of Mount Bellew Papers	Estate papers	pre-1750	Text
Clonbrock Estate Papers	Estate papers	pre-1750	Text
Conyngham Papers	Estate papers	pre-1750	Text
D'Arcy of Hyde Park Papers	Estate papers	pre-1750	Text
De Vesci papers	Estate papers	pre-1750	Text
Doyne Papers	Estate papers	pre-1750	Text
Gardiner Papers	Estate papers	pre-1750	Text
Headfort Estate Papers (Additional)	Estate papers	pre-1750	Text
Inchiquin Papers	Estate papers	pre-1750	Text
Lismore Castle Papers	Estate papers	pre-1750	Text
Longfield Map Collection	Estate papers	pre-1750	Text
Leitrim Papers	Estate papers	pre-1750	Text
Longfield Map Collection	Estate papers	pre-1750	Text
Mahon Papers	Estate papers	pre-1750	Text
Mahon Papers (Additional)	Estate papers	pre-1750	Text
Mansfield Papers	Estate papers	pre-1750	Text
Ormond Family Papers	Estate papers	pre-1750	Text
Ormonde Papers (Additional)	Estate papers	pre-1750	Text
O'Hara Papers	Estate papers	pre-1750	Text
Phillips Maps	Estate papers	pre-1750	Text
Powerscourt Papers	Estate papers	pre-1750	Text
Prior-Wandesforde Collection	Estate papers	pre-1750	Text
Smythe of Barbavilla	Estate papers	pre-1750	Text
Westport Estate Papers	Estate papers	pre-1750	Text
Wicklow Papers	Estate papers	pre-1750	Text

Appendix 5

Site reviews for relevant palaeoecological studies

Palaeoecological site summaries for the reviewed sites. Sites with a strict local-scale resolution are listed in Appendix 6.

The following summaries provide the IPOL site code and ALEW type where relevant: AW - Ancient Woodland; LEW(I) - Long Established Woodland stands where no evidence of antiquity could be found in older documentation; LEW(II) - Long Established Woodland stands where there is evidence that they are not ancient; PAW - Possible ancient woodland; ND - ALEW status not determined.

Reenadinna Wood (IPOL site 4, ALEW 765-AW) is a yew woodland considered ancient by Perrin & Daly. The woodland is examined by Mitchell (1987; 1990) from a small basin 30 x 40 metres in diameter with *Taxus* (Yew) surrounding the basin. Although the sediments of the basin were 241cm deep, only the top 97 cm yielded pollen, below this are likely to be late glacial sediments. The last 600 years are estimated from two lower radiocarbon dates to be represented by just 8 cm of accumulation. The temporal resolution is coarse and there may be a hiatus in peat formation. Despite these limitations the pollen diagram shows yew woodland persistent through some 2700 years. This is supported by another pollen diagram (undated) from blanket bog at Ladies View (Vokes, 1966) which also shows a clear domination of yew woodland following the Elm decline. There is some indication of open areas with some *Plantago lanceolata* (Ribwort Plantain) in the pollen record and notes of field boundary features in the landscape indicating that parts of the yew wood regenerated after a phase of human land use and grazing. This may be further supported by observations of Lockhart (2022) who refers to metallophyte plants linked to an old copper mine similar to that on Ross Island. A dendrological study in the area (Galvin et al., 2014) revealed tree rings going back c. 200 years however, it is not clear if this was limited by practical extraction limits or by tree age, as the project was focused on obtaining a climate record.

Ross Island (IPOL site 5, ALEW 2718-AW) is a study from a small hollow with a single basal radiocarbon date of 4130+-50 (4828-4532 cal BP (95.4%)). The main feature of the pollen diagram is a marked shift from *Quercus* (Oak), *Pinus* (Pine) and *Corylus* (Hazel) dominated to an *Alnus* (Alder) then *Salix* (Willow) dominated pollen spectra, which the authors (Mitchell & Cooney, 2004) attribute to the cessation of mining of copper ore after the Bronze age. However, a more recent diagram from Derrycarhoon (Kearney & O'Brien, 2021) located to investigate the impact of copper mining did not find a similar shift in arboreal species, perhaps because cessation of mining was followed by increased agricultural activity rather than land abandonment. Woodlands may have been much altered by differing series of land uses causing differing dynamics. Ross Island is described in the SAC synopsis as having “one of the richest herb layers in the Killarney woods” (Department of Heritage Arts and the Gaeltacht, 2013). Pollen data show that the former closed canopy woodland present until the mid-Holocene contained a depauperate herb flora (Mitchell & Cooney, 2004). The current biodiversity value seems to be linked to woodland continuity, canopy openness and species turnover with disturbance.

Rough Island (IPOL site 6, ND) was the site of two mor humus profiles (FR1 and FR2) by Mitchell (1990). The stratigraphic profiles are short (c. 20 cm) covering an estimated 250 years, but nevertheless show some interesting dynamics and also highlight the benefit of multiple local cores, demonstrating the quite different woodland and grazing histories of two ends of the small island. FR1 shows evidence of *Arbutus unedo* (Strawberry tree) growing in a more open woodland as a successional stage after burning and pastoral land use, later overtaken by *Corylus* (Hazel) and *Ilex* (Holly) forming a canopy, before becoming overshadowed by oak woodland. Again, this sequence shows successional and facilitative processes following on from landscape openness rather than continuous forest cover. FR2 shows a closed canopy woodland followed by disturbance when Ilex became dominant and then a return to *Quercus* dominated, but with some non-native *Fagus* (Beech). It is not possible to determine longevity of woodland as the short core is not dated.

Derrycunihy (IPOL sites 16 and 19, ALEW 758-AW) has been the subject of two small-hollow pollen analyses, one undated (O'Sullivan, 1991) and one with four radiocarbon dates (IPOL16) (Mitchell, 1988), later supplemented by a tephra analysis in the same site (Reilly & Mitchell, 2015). The tephra analysis confirms the assumptions of Mitchell that the youngest radiocarbon date of 950±60 is too old to be accurate. The Hekla 1104 tephra at 20-22cm and 1510 tephra at 14-16cm instead show a slowing of peat accumulation between these dates. Much earlier woodland was mixed *Pinus* (Pine) and *Quercus* (Oak) and the loss of this woodland from 200 years BP seemed to be linked to increased diversity. From 20cm Mitchell notes indications of increasing wetness under reduced canopy. Derrycunihy is described in the SAC synopsis as "perhaps the most natural Sessile Oak (Quercus petraea) wood in the country" (Department of Heritage Arts and the Gaeltacht, 2013). However, Mitchell and Cooney note that herb pollen is very low in the lower half of the pollen diagram indicating that this herb flora is a product of the current disturbed and more open woodland. Despite its ancient status Derrycunihy wood seems to have gone through a phase of high disturbance and change just prior to the written records and Mitchell considers that the current woodland is secondary growth.

Glaisín na Marbh (IPOL site 18, ALEW 751-AW) O'Sullivan (1991) examines two sites in this woodland. GNMII is unusual for a small hollow in containing what seems to be a continuous Holocene record constrained by 5 radiocarbon dates. The most recent date at 88-93cm in the pollen core is 3540±35 BP (3699-3957 cal BP). The pollen diagram has 10 samples above this date and is therefore only capable of providing an interpretation at coarse temporal resolution through the period of increasingly intensive human intervention; potentially much change can occur in a 200-300-year period. In these 10 samples *Betula* (Birch) and *Alnus* (Alder) fluctuate notably. In the last c. 2000 years the pollen implies a shift from a *Pinus* (Scots Pine) dominated profile to one of increasing openness represented by increasing abundance of grass, but also increasing *Alnus* (Alder) and *Betula* (Birch), with *Fraxinus* (Ash), *Taxus* (Yew), *Ilex* (Holly), and later *Sorbus* taxa, starting to contribute small amounts of pollen. This phase of woodland indicates some species turnover in the last 3700 years with a major break illustrated by the complete disappearance of Pine pollen in the last c. 2000 years as grasses increase, indicating disturbance-driven changes.

O'Sullivan rejected a full count of the GMNI core in order to focus on the longer GNMII core. GMNII comprises more than 3m of sediment. A Bayesian model of the chronology shows a remarkably steady sediment accumulation, with 83 cm covering the last c.3700 years. Given this, a continuous 1cm sampling resolution could deliver a sub-50-year temporal resolution. Investigations at this temporal scale could elucidate detailed dynamics and small interruptions in woodland cover which might be missed at the coarser resolution of O'Sullivan's 1991 study.

Camillan 2 (IPOL site 22, ALEW 766-AW) shows strong evidence of successional processes linked to, and driving, shifts in soil properties which facilitate woodland development on former heath after burning, through a soil neutralising phase of dense *Ilex* (Holly), to *Betula* (Birch) and on to a developing *Quercus* (Oak) wood c. 170 years ago. However, the study here is from a short and undated stratigraphy, so it is difficult to determine the date of woodland incursion. The site is also notable for the high level of *Arbutus unedo* (Strawberry tree) pollen in the former phase as a heathland (Mitchell, 1990; O'Sullivan & Kelly, 2006).

A second site **Camillan 1 (IPOL site 138, ALEW 766-AW)** (Mitchell, 1988) has a chronology constrained by three radiocarbon dates, a recalibrated model implies accumulation over c. 8700 years showing a relatively smooth chronology. A second site was later tested for tephra (Reilly & Mitchell, 2015), the tephra depths/dates fit well in the existing radiocarbon chronology and agree remarkably well with a recalibrated curve using IntCal20 implemented during this study. This provides insight into the chronology at the top of the core. Mitchell divides the pollen into four zones and notes a large peak in charcoal at the base of the uppermost zone (zone 4) with a reduction in *Betula* (Birch) and *Alnus* (Alder). The disturbance is dated by the radiocarbon date to 1095±50 years BP. However, the remodelled chronology shows the base of this zone at 34 cm to be older, dated to AD 718 c. 1270 cal BP. Midway through the zone at 20 cm *Ilex* (Holly), then *Taxus* (Yew) start to dominate, demonstrating reduction of grazing pressure at a date newly modelled at AD 1130 c. 860 cal BP, followed by a dominance of *Quercus* (Oak) in the most recent sample.

Mullangore Wood (IPOL site 45, Adjacent to ALEW 1373-PAW) this is a small hollow study with one radiocarbon date spanning a timescale of the last 650 years (IPOL data). Telford (1978) was consulted and there appear to be two sites, Derrybeg bog and a small mor humus “Charcoal site”. The details of both are limited but show some disturbance and regeneration of the woodland after a burn phase indicated by presence of charcoal.

Uragh wood N3 (IPOL site 54, ALEW 674-AW) and Uragh Wood (IPOL site 150, ALEW 674-AW) are sites in the Cloonee and Inchiquin Loughs, Uragh Wood SAC. (ALEW 673-674). Perrin & Daly note that the Irish for Uragh wood is An Iúrach / Iúbhrach Inse an Iocha or ‘Yew-land’ (2010, Appendix 2A) and *Taxus* (Yew), is mentioned in the current vegetation as an occasional tree. *Taxus* has a limited but continuous presence in the pollen record from Uragh Wood (Little et al., 1996 – IPOL 150) until c. 800 years ago, however, a pollen diagram from a mor humus deposit c. 100m from the woodland (Cunningham *et al*., 1999 – IPOL 54) does not provide any evidence of *Taxus* in the past, although this is perhaps due to lack of identification of the pollen. The N3 pollen diagram extends to c. 1000 years ago (930 cal BP), whilst the site studied by Little *et al*., extends to c. 3000 years. The most recent samples show *Corylus* (Hazel) pollen as dominant (c. 20-30%) together with low percentages of *Betula* (Birch) (c. 10%), *Salix* (Willow), *Fraxinus* (Ash) and *Ilex* (Holly) (under 5%). Interestingly *Quercus* (Oak) pollen presence is very limited in the last 400 years in the pollen diagram at this site, despite being the dominant tree species in the current adjacent woodland. Cunningham attributes the rise in the *Corylus* pollen type to the pollen of the dwarf shrub *Myrica gale* (Bog Myrtle), which is listed as present in the SAC site synopsis (Department of Arts, Heritage and the Gaeltacht, 2016) and has a similar pollen morphology to *Corylus. Myrica* is included as *Corylus*-type pollen in many studies. The main interpretation from this site is that the woodland was very probably more widespread and extended further to the north-west, covering the now-open site of the N3 core until c. 400 years ago (c. 380 cal BP). The former woodland contained *Quercus* (Oak) as a dominant with *Salix* (Willow), *Fraxinus* (Ash), *Ilex* (Holly) and *Alnus* (Alder). Furthermore, the list of tree species in the present woodland is broader than recorded by pollen studies, including *Populus tremula* (Aspen), *Arbutus unedo* (Strawberry tree), *Juniperus communis* (Common Juniper) and *Sorbus aucuparia* (Rowan).

Cappanawalla (IPOL site 72-ND), Gortaclare (IPOL site 73-ND), and Sliabh Rua (IPOL site 75-ND) are sites in the currently open landscape of the Burren, Co. Clare. The core from Cappanawalla is from a minerogenic small basin in an open upland environment. Pollen indicates former *Pinus sylvestris* (Scots Pine) and *Corylus* (Hazel) woodland of an open nature that is now largely missing from the local environment (although there is a patch of WN2 woodland nearby). The particular challenge for this study is the assertion that the Burren should be an open landscape of transhumance agriculture, of some antiquity, and that this activity is awarded a role in the maintenance of biodiversity. Although these sites are now open, the pollen data generally offers a contrasting argument. The authors (Feeser & O'Connell, 2009) argue strongly that pollen indicates a relict herbaceous community once associated with open Pine and Hazel woodlands, persisting despite the recent demise of the arboreal component so that the concept of shadow woods may apply (Rotherham, 2017a&b).

Oak Island, Lough Anessaundoo (IPOL site 135-ND), and Birch Island, Lough Derrycunlaghmore (IPOL site 136-ND) are two Connemara Lake islands examined by Hannon and Bradshaw (1989) which are currently wooded. The mor humus profile from Oak Island has date estimates derived from the inception of modern pine regeneration (presumed to be c. 250 years ago) and extrapolation down core presuming constant pollen influx. The paper provides ages as BP; however, since the age of the 0-1cm sample is given as 6 years, this is assumed here to be BP in 1988 – the year before the publication date. The pollen data show a remarkable shift, c. 1700, to woodland from an area dominated by *Calluna vulgaris* (Heather) and *Pteridium aquilinum* (Bracken). A low-point in woodland cover appears c. 1500 when *Corylus* (Hazel), *Alnus* (Alder) and *Betula* (Birch) pollen disappears. This is concurrent with a peak in charcoal. When the woodland regenerates it is dominated by *Taxus* (Yew) and *Betula*. *Quercus* (Oak) and *Ilex* (Holly) start to increase and dominate after c. 1800. *Sorbus* sp. (Whitebeam, Rowan, etc.) pollen also appears regularly from c.1700-1900. Similarly, Birch Island, Lough Derrycunlaghmore (IPOL site 136) shows a regeneration of woodland from a low point c. 300 years ago (estimated from the timing of *Pinus* arrival). Pre-clearance woodland was dominated by *Salix* (Willow). Post 300 years ago the regeneration is dominated by *Taxus* (Yew) which seems, to the authors, to act as a pioneer species. The smaller island does not show the spread of *Quercus* (Oak) or *Ilex,* in contrast to oak island.

Charleville (IPOL site 175, ALEW 176-AW) (Stefanini, 2003) it was not possible to access this study, but the pollen diagram was consulted. The stratigraphy is undated and spans 55cm of sediment. Of note is a large turnover of species in the topmost 8cm with a rise in *Quercus* (Oak) and a fall in other tree species. The woodland depicted before this was mixed broadleaf and more continuous, with a continuous *Pinus* (Scots Pine) presence. From the pollen data only, a hiatus near the surface cannot be ruled out given the rapid change in the pollen spectra.

Brackloon Hollows A and B and Brackloon Lough (IPOL sites 263, 264 and 265, ALEW 815-830-PAW) were studied by von Engelbrechten *et al*. (2000). The site is also reviewed in detail in Cunningham (2006) with a wealth of information about its palaeoecology and written history. The main record is 15m deep, spanning the full Holocene, but with a regional pollen signal. Two hollows were also analysed but only Hollow A produced suitably preserved pollen. Two radiocarbon dates are available. The site has been dated further using tephra (Reilly & Mitchell, 2015). The site shows evidence of the onset of wetter climate of the Atlantic period with reductions in *Ulmus* (Elm) and *Corylus* (Hazel) alongside increases in *Alnus* (Alder) about 6000 years ago and a mid-Holocene Elm decline c. 5000 years ago. Further species turnover with a shift from *Quercus* (Oak) to *Fraxinus* (Ash) seems to show typical signs of Neolithic land use and abandonment, increasing into the Bronze age, but with some continuity of woodland cover. The sites are located within a suite of NSNW and ALEW-PAW sites, including ALEW 815: Brackloon Hollows A, and ALEW 830: Brackloon Hollows B. It seems likely that the woodlands are ancient as the arboreal pollen component remains over 60% into the last 2000 years, however subsamples spanning this period are limited so the resolution of ecological change is coarse in scale. This site would be worth revisiting sampling at a greater resolution over the last 2000 years, and including NPP analysis to determine grazing history over the last 1000 years where woodland starts to increase.

St. John's Wood (IPOL site 283, ALEW 337-AW) is reported on in Budd and von Engelbrechten (1999) and Budd (1998), a PhD thesis. At the time of the publication of the PhD thesis no radiocarbon dates were available, but the later core reanalysis provides four radiocarbon dates over the short c. 45 cm of useable sediment below which there was a base layer of inwashed mineral component. The assumption for the post glacial base of the core is made by reference to a strong presence of *Juniperus* (Juniper) and seems to be supported by the basal radiocarbon date. Remarkably this short core demonstrates a reasonably smooth and continuous chronology through the four dates, with a basal date of 7270±70 BP (6335-5991 cal BP) indicating perhaps, a very slowly accumulating sediment. However, Budd (1998) notes shifts in the pollen taxa that could indicate a significant hiatus in the accumulation between Zone SJW1 the basal zone, and zone SJW2, similarly there is a sharp boundary in abundance of several taxa at the transition to zone SJW3 with a fall in tree pollen and appearance of some herbaceous types including *Succisa* (Devil's-bit scabious), *Melampyrum* (Cow wheat) and Lilliaeae (Lily family) pollen. This phase with *Melampyrum* and Lilliaceae among others precedes the rise in *Plantago lanceolata* (Ribwort Plantain) and Asteraceae (Daisy family). Innes *et al*. (2010) find *Melampyrum* as an indicator of disturbance in woods in

Bluewath Beck in the North York Moors, UK, associated with *Pteridium* (Bracken) and HDV-18, a fungal spore indicator of grazing. The reduction in *Ulmus* (Elm) pollen just below the 1240±60 BP radiocarbon date (1291-1001 cal BP) also appears late compared to expected dates for this event. Throughout the stratigraphy, woodland seems to be continuous (Budd, 1998); however, it is also noted that tree pollen falls to 45% of total land pollen in the uppermost sections, and there is tentative evidence of clearance phase or perhaps woodland exploitation.

Garrannon Wood (IPOL site 389, ALEW site 24-AW), the core used in this study is short at 23 cm and is a mor humus woodland floor deposit. The core is dated at base as 530±40 BP (633-503 cal BP). Bohan (1997) notes that over this short period the wood undergoes significant change from a woodland with *Quercus* (Oak), *Betula* (Birch) and *Corylus* (Hazel) and a flourishing understorey of herbaceous plants and Rosaceae (Rose Family) shrubs, that was probably coppiced, to a wood containing planted *Fagus* (Beech) and *Pinus* (Scots Pine) and most recently *Castanea sativa* (Sweet Chestnut). Some parts of Garrannon Wood are listed as PAW (ALEW 15-20) and it is unclear if the mapping was accurate enough to determine if the study site was definitely in ALEW 24, as shown in IPOL, or if it may have been further to the northwest in one of the PAW sites.

Redbog (Kildare) (IPOL site 401-ND) is an early study with no associated radiocarbon dates. The kettle hole is rather large at c. 500m long and limited pollen is presented in the paper which focused mainly on major tree pollen types (Mitchell, 1951). There is also a comment that the more recent peat was too sparse in pollen grains to gain a meaningful count.

Lough Inchiquin1 (IPOL site 423, Near ALEW 673-AW) The sediment is a mor humus, dating is via reference to a similar pollen curve in a dated study by Lynch (1981), on a nearby island in Lough Inchiquin. The assumption is that the top of the core is modern and the base is c. 3000 years BP. The diagram reflects a heathland in the earlier half of the stratigraphy, with *Arbutus unedo* (Strawberry tree) present and increasing which the author puts down to disturbance, the heath later being replaced with a grass dominated landscape with an influx of *Quercus* (Oak) and *Ilex* (Holly) with some *Betula* (Birch) throughout. The core is taken from the northeast shore of the lough with Uragh Wood (ALEW 673) on the southwest shore.

Kilcurley (IPOL site 447-ND) is a small uncategorised area of wet woodland selected by O Carroll (2012) due to the presence of patches of woodland on the first, second and third edition OS maps. The core is constrained by 6 radiocarbon dates, however these show some overlap between older and younger dates demonstrating the difficulties of finding small woodland hollows with secure, steady accumulation of sediment. An inwash event is evident at 42-49 cm. *Fraxinus* (Ash) pollen appears just below this zone indicating perhaps some land disturbance and then abandonment surrounding the site followed by an event producing eroded material. More recent woodland is *Alnus* (Alder) dominated and indicates that in Ireland wet woodland might be an important and overlooked community with millennial longevity.

Old Head Wood (IPOL site 167, ALEW 832-LEW(I)) is an undated, unpublished BA thesis (Ni Ghrainne, 1988) with a time span of 0-200 years. It was not possible to access this study.

Glena (IPOL site 422, ALEW 751-AW) is an unpublished BA thesis (Jacob, 1990). It was not possible to access this study.

Bog of the Frogs (IPOL site 435, ALEW 2075-LEW(I)) is a peat basin site with one radiocarbon date. It was not possible to access this unpublished BA thesis (Cooney, 1994) but the pollen diagram was examined. It focuses on heathland changes, but shows a reduction in woodland pollen types prior to 1850. Given the location adjacent to LEW(I) a reanalysis of this site with increased chronological controls could be considered.

Glen of the Downs (IPOL site 436, ALEW 1065-LEW(I)) is a study from a forest hollow within ALEW 1065 (Brett, 1998). It was not possible to access this thesis but the pollen diagram was examined. The stratigraphy spans c. 75cm of sediment and the presence of *Quercus* (Oak) pollen is relatively steady throughout the sequence at around 20% of total land pollen. *Pinus* (Scots Pine) pollen increases in the topmost 25cm perhaps indicating recent planting and c.

150 years of history to that point. Given the likelihood of a sample spanning perhaps 400-600 years as an extrapolated estimate from this, it would be worth resampling this area with the addition of chronological controls.

Sites listed due to having multiple cores, or likely to have some local relevance to stand-scale woodland history

Doo Lough 1 and Doo Lough 2 (IPOL 9 and 421, adjacent to ALEW 766-AW) (Healy, 1987) were selected as these are listed as multiple cores. However, coming from a lake site, they are likely to give a regional pollen signal. The sites are adjacent to ALEW 766 and the Camillan wood sites.

Ladies View (IPOL site 15) (Vokes, 1966) is a regional scale diagram from blanket bog but is close to ALEW and LEW sites of Derrycunihy (ALEW 757 to 762-AW and LEW(I)) and Looscaunagh Wood (ALEW 778 and 770, 771 LEW(I)). It is undated but is presumed to be a full Holocene sequence and shows the conversion from *Pinus* (Scots Pine) woodland to mixed broadleaf with *Quercus* (Oak) and *Betula* (Birch) dominant through to the present.

Ballinloghig Lake (IPOL site 32-ND) is a small corrie lake likely to have an extra-local pollen signal. No ALEW woodland is mapped according to Perrin and Daly, however Barnosky (1988) describes an extant “small wind-shorn woodland of *Corylus avellana*, *Quercus petraea*, *Ilex aquifolium*, *Betula pubescens* and *Salix aurita*”. The pollen diagram is dated by 11 radiocarbon dates, but the topmost parts of the core are not dated, and the authors show the diagram through to 1200 BP. The top of the pollen sequence indicates that woodland similar to the present was in existence at this time and may indicate some continuity of the small patches, but it is not possible to interpret single stand dynamics in the landscape.

Lough Namackanbeg (IPOL site 34-ND) and Connemara National Park FRKII (IPOL 35) (O’Connell *et al*., 1988). It has not been possible to access this publication.

Clonsast Bog (IPOL site 66-ND) is a poorly dated site studied by Mitchell (1951) and is of limited use for the study of local woodland.

The Barrees monoliths (IPOL site 84-ND) comprise sediments extracted from various sites in the Barrees townland on the Beara peninsula by Overland and O’Connell (2008) together with a core from **Lough Beag (IPOL site 77-ND).** The mainly open cultural landscape is interspersed with small patches of oak woodland which the authors state is of interest as it does not appear on the 1842 6-inch OS mapping for the area. The cores in this study demonstrate a carefully compared set of sites with good radiocarbon dating, depicting a loss of woodland c. 1500-1000 years ago, prior to mapped evidence, again demonstrating that shadow woodlands in Ireland may be important. The presence of various ferns, including *Hymenophyllum* (Filmy Ferns), also provides some indication that woodland biodiversity may have persisted through periods of management via small woodland fragments.

Lios Lairthín Mór (IPOL site 91-ND) is an area of open vegetation in the north-west Burren (Jeličić & O'Connell, 1992). The site is a large bog. However, the authors carefully sampled from the bog edge, closest to terrestrial vegetation surrounding the bog, and so assume some local element to the pollen spectra. The authors find evidence for woodland in the Burren over the last c. 3200 years, with “canopy trees such as ash, oak and elm, as well as hazel scrub and some alder and birch”, but in a predominantly open landscape. A recursion of woodland from AD 200-580 with *Corylus* (Hazel), *Fraxinus* (Ash), some *Quercus* (Oak), and *Taxus* (Yew), is followed by a decrease in woodland over recent centuries, the widespread removal linked with dramatic human population expansion. Shadow woods again are likely and, as with other Burren sites and conclusions from O’Connell and colleagues, we may be missing opportunities to develop wooded areas from shadow woods in pastoral landscapes.

Cashelkeelty (IPOL site 96-ND) This publication (Lynch, 1981) was not accessed. However, a review by Barber (1982) notes a regional pollen source so the work is not explored further.

Mount Gabriel (IPOL site 102-ND) is a study area with multiple cores. Mighall *et al*. (1999) state that the main study in this area is regional in nature, however, Cadogan Bog, listed as Blanket Bog in the IPOL database, is described as depicting local vegetation change. Cadogan is constrained by two radiocarbon dates, the lower at 35-38cm (3280±70 BP, 3689-3368 cal BP), and the uppermost c. 10 cm shows evidence of modern conifer planting. The authors note that *Pinus* (Scots Pine) loss between 5000-3800 years BP is likely driven by human population expansion, but that woodland including *Corylus* and *Betula* likely persisted, increasing during the Iron Age lull, and then declining by c. 1000 years ago. Mighall *et al*. (2008) explores several sites using both macrofossils and NPPs to elucidate changes. A notable discussion is that of the loss of wet woodland in the Mesolithic creating fen and wetland areas devoid of trees. Although this loss was much earlier in the Holocene the wet woodland ecotype is one that could be considered more widely in damaged wetland areas.

Derryinver Hill (IPOL site 116-ND) (Molloy & O'Connell, 1993). These four cores depict Bronze age landscape change in an area of archaeological importance, and mainly depict open vegetation degrading into bog and heath following land abandonment. The early periods show some importance of woodland with *Corylus* (Hazel), but this is lost early in prehistory.

Hags Glen (IPOL site 126-ND). This study is not focused on woodland and uses multiple cores and survey to map alluvial fan deposits. Although not near woodland in the present day the message from the paper (Anderson *et al*., 2000) is one of increasing slope instability due to climate forcing and anthropogenic land clearance. Woodland was clearly present in the pollen record until AD 550-680 although preceded by millennia of clearance episodes.

Maum Townland (IPOL site 134-ND) (Coxon, 1987) is an undated diagram, mainly of early Holocene interest.

Mooghaun (IPOL site 143-ND) is a site from a small lake (Molloy, 2005). This paper was not accessed, however, a discussion of this site in O'Connell *et al*. (2001) highlights that there is little evidence of human land use connected to the expansion of *Taxus* (Yew) in the later Neolithic at this site and this may infer a greater role for climatic factors in the species turnover of woodland. The authors also highlight the role of community structure and facilitation of regeneration, in areas where clearances removed dominant canopy trees species. Turnover to new woodland types emerged where the loss of *Ulmus* (Elm) removed competition for light.

Carrownaglogh (IPOL site 151-ND) is a suite of soil monoliths and one longer monolith focused on interpreting cultural land use (O'Connell, 1986). The long monolith, which is dated with four radiocarbon dates, is regional in pollen signal and spans c.3200 years, with evidence of woodland and phases of woodland clearance.

Lough Ine (IPOL site 186) and Ballyally Lough (IPOL site 187) is a study of multiple lake cores (Buzer, 1980) and therefore regional in signal. The Lough Ine site is adjacent to Knockomagh Wood (ALEW 432-434- LEW(I) & LEW(II)) to the northwest. Lough Ine preserves a remarkably constant arboreal pollen proportion through time.

Claggan Mountain (IPOL site 216-ND) This study using multiple cores (Foss & Doyle, 1990) was focused on history of *Erica erigena* and is not considered further here.

Slish Lake (IPOL site 221 near ALEW-PAW) Dodson and Bradshaw (1987) state that they took cores from the north shore but this is unclear from IPOL mapping which shows the site between ALEW 162 and 166. This is a multiple core site and, despite its name, actually comprises a study of a lake core and a mor humus profile. The latter is undated except for reference to a *Pinus* (Pine) curve calibrated to the dated lake core at 1850 BP, after which *Myrica-Calluna* heath dominated until a *Fagus* (Beech) pollen increase from modern planting. The authors attribute the high *Betula* (Birch) pollen curve to a more regional signal within a heathland, despite a basal area of 46% *Betula* in their survey of the area. Both woodland and heathland currently surround the lake. Although the area is now considered PAW it is likely that it went through a period of openness after loss of the original woodland and before development of the modern woodland. However, the extra-local nature of the dated profile means that it cannot be ruled out that pockets of woodland survived in the now planted areas.

Union Wood Lake (IPOL site 222, near ALEW 144-149 and 414-418-PAW) Two cores were taken near the edge of the lake so are likely to be dominated by the local woodland to the south of the lake. It is difficult to assess the amount of native woodland loss in the most recent sediments as the authors (Dodson & Bradshaw, 1987) note that the pollen signal is swamped by the regional pine signal from planted forestry. A continuity of native woodland in the locality seems likely prior to planting. A particularly severe fire occurred c. 1200 BP which seems to have arrested woodland regeneration. Fig. 7 in Dodson and Bradshaw summarises woodland change around Union Wood Lake and Slish Lake. The direct replacement of degenerating ancient woodland with planted woodland is evident at Union Lake, in contrast to nearby Slish Wood where an earlier breakdown of woodland led to a period of heathland which seems to precede the plantation woodland.

Dromteewakeen2 (IPOL site 234-ND) this unpublished MSc thesis (McDonnell, 1991) was not accessed.

Ardlow Inn (IPOL site 239-ND) is an undated bog site in a currently open landscape (Jessen, 1949).

Lough Gealáin (IPOL site 248-ND) this unpublished PhD thesis (Feeser, 2009) was not accessed.

Croaghaun East (IPOL site 285-ND) Dwyer and Mitchell (1997) investigate blanket bog development correlated with tephra layers. The publication shows short sequences from the mid Holocene, which are not considered relevant here.

Ballydoo Lough (IPOL site 285-ND) is a series of short cores with a limited temporal span. Huang and O'Connell (2000) use the site to correlate with known vegetation history in the recent past and the depiction of small patches of carr woodland in the diagram may be useful for interpretations elsewhere but is not of relevance otherwise to this study.

Derryclure bog (IPOL site 453) is a study of a bog pine woodland (O'Connell, 1990) and is not reviewed further.

Lough Dargan (IPOL site 453-ND) is a small lough which Ghilardi and O'Connell (2013) presume from general pollen source modelling to have a pollen catchment of 1-2km. There is a well-dated chronology, and top samples are estimated to come from c. 1660 but could reach the 19th Century. The reasonably secure chronology allows for pollen concentration and accumulation rates to be determined and these data show the strong decrease in the arboreal pollen component after the Iron Age lull. Of note is a continued low presence of *Pinus* (Scots Pine) indicating a continued role for this tree species, plus the continued presence of scrub woodland in the landscape. Several ALEWs surround this lough including Slish Wood to the north-east and Union Wood to the west both within 3km radius of the lough. This extralocal pollen diagram has a fine temporal rather than spatial scale.

Woodfield bog (IPOL site 462-ND) (van der Molen, 1988) is included from the filter methods as the name includes wood. The author investigates the OS maps for the area and finds woodland cover limited and increasingly cover of plantation woodland. The short pollen diagram over c. 300 years shows a reduction in *Corylus* with plantation forestry increases.

Mullaghcleevaun (IPOL site 466-ND) (Bowler & Bradshaw, 1985) is a study of multiple cores from blanket bog and is focused on bog erosion and not examined further.

Kilkenny Courthouse (IPOL site 469-ND) (Stefanini, 2009) is an archaeological context study and not reviewed further.

The Gearagh (IPOL site 476, ALEW 524, 523 and 522-PAW) Brown (1999) studied modern pollen from surface samples. The study site is within or adjacent to the Gearagh complex of

WN4 wet woodland. There is some alignment with a core depicting medieval woodland but the main conclusion is that the sediment core depicts local pollen. Further study of suitable stratigraphic sequences may be beneficial in this possible ancient alluvial floodplain woodland.

Clonad bog (IPOL site 484-ND) is listed as a peat monolith (O Carroll, 2018) and is likely to contain a regional pollen signal.

Comeragh Mountains (IPOL site 487-ND) (Stefanini, 2013) is a multiple core study from blanket peat and is likely to have a more regional signal.

Lisheen bog (IPOL site 496-ND and Derryville IPOL site 336) (O Carroll, 2015) is listed as multiple cores but is not near ALEW and is unlikely to have a local scale pollen signal.

Sites published since 2019

Lough Inchiquin 2 (IPOL site 506) is a more rigorously dated palaeoenvironmental investigation at regional scale (Spencer *et al*., 2019) and is useful for comparison with other sites in the Burren, particularly for woodland change context for Capannawalla, Gortaclare and RUA.

Ward River Brackenstown, Co. Dublin (Flynn & Mitchell, 2019). In this study of c. 160 years of sediment from a millpond, Flynn and Mitchell make reference to the woodland surrounding the millpond, evidenced in the 1837 and 1897 OS maps, with the woodland in an otherwise agricultural landscape. Species turnover is linked to the abandonment of the mill and the 1940 and 1970 *Ulmus* (Elm) decline is evident from the pollen record. Elm is replaced by slight increases in *Fraxinus* (Ash), *Quercus* (Oak), *Betula* (Birch) and *Fagus* (Beech). The turnover is remarkable for its rapidity, thus demonstrating the value of fine temporal resolution palaeoecological studies where sediment profiles make this possible.

Cuckoo Lough, Co. Kerry (Hawthorne, 2015; Hawthorne *et al*., 2021). Although the study site is a lake core the small size of the lake indicated likelihood of a local pollen signal. The record presents a full Holocene picture of woodland change in an upland landscape. The pollen diagram shows sparser woodland cover and a higher proportion of *Betula* (Birch) during the period since the Iron Age. The main focus of the study is on the shifts in species aligned with landscape scale fire events which were more frequent in the early to mid-Holocene and have reduced with anthropogenic land use change. The implications for woodland management of the shift to open grassy areas more prone to fire, are discussed, this may be especially important if climate change leads to drier spring or summer seasons.

Lough Cullin, Co. Kilkenny (Kearney *et al*., 2022) This study is from a small lake. Arboreal pollen at the top of the core c. 780-1035 AD "suggests sizable areas of woodland remained locally". Prior to that there had been periods of clearance for pastoral land followed by the resurgence of woodland from the Neolithic with the last resurgence c. 2400-1500 years ago. Although this pollen diagram does not extend to the time period covered by mapping the findings may tentatively indicate that Kilkenny has always contained a sizeable area of woodland, as found in Chapter 3, thus providing woodland continuity over a long time period.

Appendix 6

Review of local-scale palaeoecological sites under current categorisation of ALEW status

The confirmation of AW status using palaeoecology is given as “Yes” if there is clear evidence of woodland over recent centuries in alignment with definitions by Perrin & Daly (2010). Where sites show former disturbance over millennial timescales this is indicated in the separate column labelled “clear former disturbance”. Several sites can only be very tentatively assigned due to lack of chronology or few samples across a long time period.

ALEW – AW palaeoecological sites review									
Site name, County	**IPOL no.**	**IPOL Time span estimate**	**NSNW no.**	**Fossitt code/ EU Code**	**ALEW no. and type**	**Confirmed AW via palaeoecology**	**Clear former disturbance**	**Notes (see Appendix 5 for more detail)**	**Citation**
Garrannon Wood, Clare	389	0-650	1515	WN1/91A0	24 - AW plus suite of AW and PAW	Yes	Yes	Short core; c. 600 years with species turnover and more recent non-native component.	Bohan (1997)
St. John's Wood, Roscommon	283	0-7500	467	WN2/WN6/ 91A0	337 - AW	Yes - Tentative	Yes	Lacks temporal detail. Woodland cover seems continuous but with some more open phases.	Budd & von Engelbrechten (1999)
Uragh Wood N3, Kerry	54	0-1000	1273	WN1 / WN7 91A0 / - / 91D0	673 - AW	Yes	No	Core is in the open woodland edge and demonstrates recent woodland loss.	Cunningham et al. (1999)
Uragh Wood, Kerry	150	0-3400	1273	WN1 / WN7 91A0 / - / 91D0	673 - AW	Yes	Yes	Loss of native pine from the area is probably due to humans and fire regimes.	Little et al. (1996)

Glaisín na Marbh, Kerry	18	0-11000	-	-	751 - AW	Yes - Tentative	Insufficient data	Possible earlier break in woodland with the loss of pine. There are few samples over large periods of time.	O'Sullivan (1991)
Glena, Kerry	422	0-250	-	-	751 - AW	Insufficient data	Insufficient data	Short timescale	Jacob (1990)
Derrycunihy1, Kerry	16	0-7800	1290	WN1/91A0	758 - AW	Yes	Yes	High disturbance and change just prior to first mapping	Mitchell (1988)
Derrycunihy2, Kerry	19	0-6000	1290	WN1/91A0	758 - AW	Yes	Yes	Woodland is continuous but with more herb species and likely more open in the present	O'Sullivan (1991)
Reenadinna Wood, Kerry	4	0-8000	1291	WN3/91J0	765 - AW	Yes - Tentative	Yes	Yew woodland persistent over millennia, but some archaeological evidence for clearance phase and limited samples	Mitchell (1990)
Camillan2, Kerry	22	0-250	1495	WN1/91A0	766 - AW	Insufficient data	Insufficient data	Short timescale	Mitchell (1990)
Camillan1, Kerry	138	0-9500	1495	WN1/91A0	766 - AW	Yes	No	Secondary woodland developing through successional processes on former heathland c.1000 years ago	Mitchell (1988)
Charleville, Offaly	175	Unknown	574	WN2 / WN6 / WN7	1676 - AW	Insufficient data	Insufficient data	Possible continuity but not possible to be	Stefanini (2003)

				- / 91E0 / -				definitive as there is no chronology	
Ross Island, Kerry	5	0-4500	-	-	2718 - AW	Yes - Tentative	Yes	Results are tentative due to lack of detailed chronology. Woods likely to have become more open and culturally manipulated.	Mitchell & Cooney (2004)
ALEW – PAW palaeoecological sites review									
Site name-County	**IPOL no.**	**IPOL Time span estimate**	**NSNW no.**	**Fosscode/ EU Code**	**ALEW no. and type**	**Confirmed AW via palaeoecology**	**Clear former disturbance**	**Notes**	**Citation**
Union Wood Lake – Sligo (Extra-Local site)	222	0-7500	A-1401	WN1/91A0	A-144-149 & 414-418 PAW	Yes - AW	Yes	Direct replacement of planted woodland onto degenerating ancient woodland	Dodson & Bradshaw (1987)
Slish Lake (wood) - Sligo	221	0-1900	1411	WN1 / WN2 / WN6/ 91A0	162 - PAW	No – LEW	Yes	Pockets of woodland may have survived before the planting, but there seems to be planting onto heathland	Dodson & Bradshaw (1987)
Brackloon Hollow A - Mayo	264	0-5000	A-1777	WN1/91A0	815-PAW	Insufficient data	Insufficient data	Some evidence of continuity but needs more detailed analysis	von Engelbrechten *et al.* (2000)
Brackloon Hollow B - Mayo	265	Unknown	A-1777	WN1/91A0	830-PAW	Insufficient data	Insufficient data	Lacks pollen preservation and not fully analysed	von Engelbrechten *et al.* (2000)

Mullangore Wood - Donegal	45	0-650	1423	WN1/91A0	1373 - PAW	Yes - Tentative AW	Yes	Burn phase may have cleared some woodland. Lacks chronology, limited data.	Telford (1978)
ALEW – LEW palaeoecological sites review									
Old Head Wood – Mayo	167	0-200	1778	WN1/91A0	832-LEW(I)	Insufficient data	Insufficient data	Short timescale	Ni Ghrainne (1988)
Glen of the Downs – Wicklow	436	0-400	777	WN1/91A0	1065-LEW(I)	Yes - Tentative AW		Lacks chronology	Brett (1998)
Non ALEW sites under current woodland									
Rough Island - Kerry	6	0-250	-	-	-	Insufficient data	Insufficient data	Short timescale	Mitchell & Cooney (2004)
Oak Island, Lough Anessaundoo - Galway	135	0-1000	-	-	-	Suggest categorisation as LEW	Yes	Secondary woodland	Hannon & Bradshaw (1989)
Birch Island, Lough Derrycunlaghmore - Galway	136	0-1000	-	-	-	Suggest categorisation as LEW	Yes	Secondary woodland	Hannon & Bradshaw (1989)
Kilcurley - Offaly	447	0-2000	-	-	-	Suggest categorisation as AW	No	Small site with some evidence for continuity and turnover of local woodland	O Carroll (2012)

Appendix 7

Review of local-scale palaeoecological sites in currently open landscapes where the data indicate potential shadow woodlands

Results of review of local-scale palaeoecological sites in currently open landscapes where the palaeoecology shows evidence of recent woodland loss, indicating potential shadow woodlands. Where a NSNW site number is given the prefix A- this indicates that there is a woodland in the vicinity, but the site is not within the woodland, perhaps indicating shrinkage of area of former woodland.

Site name-County	IPOL no.	IPOL Time span estimate	NSNW no.	Fosscode/ EU Code	Potential shadow wood	Notes (See Appendix 5 for more detail)	Citation
Cappanawalla - Clare	72	0-3500	A-1514	WN2 / non-Annex	Yes	Loss of *Pinus* and *Corylus* in open woodlands with affinity to those in Scandinavia	Feeser & O'Connell (2009)
Gortaclare - Clare	73	0-1900	-	-	Yes	Loss of *Pinus* and *Corylus* in open woodlands with affinity to those in Scandinavia	Feeser & O'Connell (2009)
RUA - Clare	75	0-1000	-	-	Yes	Loss of *Pinus* and *Corylus* in open woodlands with affinity to those in Scandinavia	Feeser & O'Connell (2009)
Lough Beag – Cork	77	500-11500	-	-	Yes	Loss of woodland c. 1500-1000 years ago	Overland & O'Connell (2008)
Barrees Basin (BAR-L1) – Cork	79	0-4500	A-6028	WN1	Yes	Loss of woodland c. 1500-1000 years ago	Overland & O'Connell (2008)
Barrees Monoliths – Cork	84	0-2200	A-6028	WN1	Yes	Loss of woodland c. 1500-1000 years ago	Overland & O'Connell (2008)
Lios Lairthín Mór - Clare	91	0-3000	-	-	Yes	A decrease in woodland over recent centuries	Jeličić & O'Connell (1992)
Mount Gabriel – Cork	102	0-8000	-	-	Yes	Long-term loss of wet woodland	Mighall *et al*. (1999)
Hag's Glen - Kerry	126	0-4500	-	-	Yes	Woodland depicted was lost c. 1500 years ago	Anderson *et al*. (2000)

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