Identification and quality assessment of High Nature Value (HNV) farmland in the North-West of Ireland

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Abstract

High Nature Value (HNV) farmland is farmland that is managed at low intensity and which supports a high diversity of flora and fauna. HNV farmland has been acknowledged as being essential to the conservation of biodiversity in Europe. In recent years, as agricultural support payments have progressively incorporated measures to support farmland biodiversity, the identification and enhancement of HNV farmland has become increasingly important. To date methods of identifying HNV farmland have been highly variable amongst E.U. Member States or even within countries. Additionally, methods of measuring the quality of HNV regions have been limited and have had variable successes. This provides the incentive for this study which examined the habitat composition of 60 farms in the Counties Mayo, Sligo and Leitrim in the north-west of Ireland. This data was used to aid the identification of HNV farmland in Ireland and development of HNV grassland quality assessment.

The first part of this study works towards developing a nature value index for pastoral farmland in a Northern Atlantic biogeographic region. Using data from 30 farms, a simple 10 point nature value index was developed following a five step statistical process. The benefit of this index is that it is based on three easily measured variables i.e. (i) proportion of improved agricultural grassland on a farm, (ii) stocking density and (iii) length of linear habitats per hectare on a farm. These values are combined to assign a nature value score to a farm. This score has the potential to be used as an identification tool for HNV farmland and could also be used to inform targeting of agri-environment supports and monitoring of the success (or failures) of measures within such schemes.

The second part of this study aims to increase the understanding of the farm types that are associated with HNV landscapes. Using farm biodiversity values and farm management values, four distinct farm types within a HNV landscape have been identified. These farm types represent the gradient of management intensities in a HNV landscape. This information can be used to inform the development of future agri-environment schemes and highlights those areas which may benefit from targeted supports to enhance and maintain biodiversity levels.

The final section of this study examines the vegetation groupings associated with HNV farmland and investigates the potential of assessing the floristic quality of fields in HNV landscapes. Four primary vegetation groups associated with HNV farmland were identified and described using cluster analysis and indicator species analysis. Additionally, a measure of the quality of fields within this landscape was developed based on HNV grassland indicator species. This measure of quality was found to relate to the nature value index developed in part one of this study. The use of the quality score in combination with the nature value index provides a holistic measure of the biodiversity value of HNV farmland in pastoral regions. These measures have the potential to be used as part of targeted agri-environmental schemes.

Table of Contents

Chapter 1. General Introduction

1.1 Agriculture in the EU

There are 12.2 million farms across the European Union (EU), which covers 174.1 million ha, the equivalent of two fifths of the total land area in the EU (Eurostat, 2015). Agriculture and land management in Europe is primarily influenced by the Common Agriculture Policy (CAP) (Reed et al., 2014; Sutherland, 2002). The CAP was developed as a response to the need to increase food production across Europe after World War II (Robinson & Sutherland 2002). This led to the intensification of agriculture and the loss of semi-natural habitat cover and farmland biodiversity (Tscharntke et al., 2005a). The CAP is composed of two funding streams known as Pillar 1 and Pillar 2. Pillar 1 provides market supports including direct payments to farmers. Pillar 2 provides supports for rural development and environmental public goods (Reed et al., 2014). Agri-environmental payments account for a significant proportion of expenditure from Pillar 2.

Since the original policy was developed, it has undergone a number of reforms to address consumer and farmer concerns relating to fair markets, monetary supports and environmental condition (Rickard, 2004). The MacSharry reforms (1992) aimed to reduce overproduction and direct subsidies and for the first time environmental issues were addressed within the CAP (Robinson & Sutherland 2002; Schomers & Matzdorf 2013). Agenda 2000 was the next major reform of the CAP. This agreement strengthened the environmental and rural development policies in Pillar 2 (Kearney, 2010). The ability to transfer Pillar 1 funds to Pillar 2, known as modulation, was also introduced in these reforms. This was a voluntary measure which allowed transfer of up to 20% of funds from Pillar 1 to Pillar 2 that had the potential to provide greater funds for agri-environment schemes (AESs) (Caballero, 2007). Reforms to the CAP in 2003 decoupled direct payments from production in favour of Single Farm Payments. (Hennessy and Kinsella, 2013). The Single Farm Payment (SFP) provided farmers a payment per hectare of their farm. This could be provided as a total direct payment or could be linked to production. However, in order to receive SFP, adherence to good environmental practices was required. This is known as cross-compliance (Hennessy and Kinsella, 2013). Under these reforms modulation became compulsory which increased the funds available to agri-environment measures (Boatman et al., 2007).

The most recent reforms, CAP 2014-2020, initially appeared to provide greater supports for environmental measures, which became known as 'greening' measures. However, from initial consultation to final implementation, the strength of greening measures decreased (Lovec and Erjavec, 2015; Matthews, 2013). Initial proposals from the European Commission aimed to incorporate greening measures into Pillar 1. This would have effectively made environmental supports compulsory and limit the interpretation of the policy by Member States, which could weaken environmental measures when implemented (Matthews, 2013). However, much to the disappointment of a number of environmental NGOs, the Commission limited the penalties associated with non-compliance of greening measures, which effectively made greening measures voluntary. Additionally, Pillar 2 budgets have been reduced and this may reduce the benefits of agri-environmental schemes (AESs) in Member States (Matthews, 2013). The CAP proposes the introduction of Ecological Focus Areas (EFA), areas of a farm dedicated to environmental concerns rather than production. It is hoped that these areas will contribute to farm biodiversity levels particularly on large, intensively managed farms. However, this measure is aimed at arable land and for livestock systems, which are associated with persistent environmental quality issues, and no substantial reforms are proposed (Westhoek et al., 2012).

Farming systems across the EU are highly variable. For example, agricultural land covers just over 50% of the land in Germany. There are approximately 350,000 farms with an average size of 57ha and crop production accounts for 70% of farmland. In comparison, agricultural area covers 28% of the Slovenian land area. Permanent pasture contributes to 57 % of the agricultural land area. The average holding size is 6.3ha. Such variability of farming systems across the EU makes developing agricultural supports more challenging.

A farm typology is a tool which simplifies the diversity of farming systems for further analysis or targeting of specific farm systems (Alvarez et al., 2014; Valbuena et al., 2008). Farm typologies can be based on economic, social or environmental factors. Typologies are important in supporting economic, environmental and social assessments, linking farming to environmental data, informing stratified random samples and are a way to link expert knowledge with statistical sources (Andersen et al., 2006). A number of farm typologies are used across the EU including the Farm Accountancy Data Network (FADN) (Reidsma et al., 2006). Data for FADN has been collected since 1989. It is based on approximately 1,000 variables relating to physical, structural, economic and financial data. The area reflected by FADN relates to roughly 90 % of the total Utilisable Agricultural Area (UAA) of Europe (European Commission, 2013a). From this information, a typology of farm production systems across Europe has been developed. Groups described within FADN typology are: specialist field crops, specialist permanent crops, specialist grazing livestock, mixed cropping and mixed crops/livestock based on economic size (Reidsma et al., 2006). FADN continues to be a significant record of farming in

Europe and is important in providing information for policy makers at an EU and at national level (European Commission, 2013a).

However, as the focus of EU agricultural policy becomes increasingly focused on sustainability it is necessary to incorporate environmental factors into farm typologies. The SEAMLESS project (Andersen et al., 2006) was established in order to address this issue within the EU-15 and to incorporate social and environmental variables into a typology alongside economic data. This typology is based on four aspects that link economic, environmental and social aspects of farming. The aspects used are: farm specialisation; land use; scale of production and intensity. The final typology resulted in 189 farm types across the EU-15. An overview of this farm typology is shown in Figure 1.1.

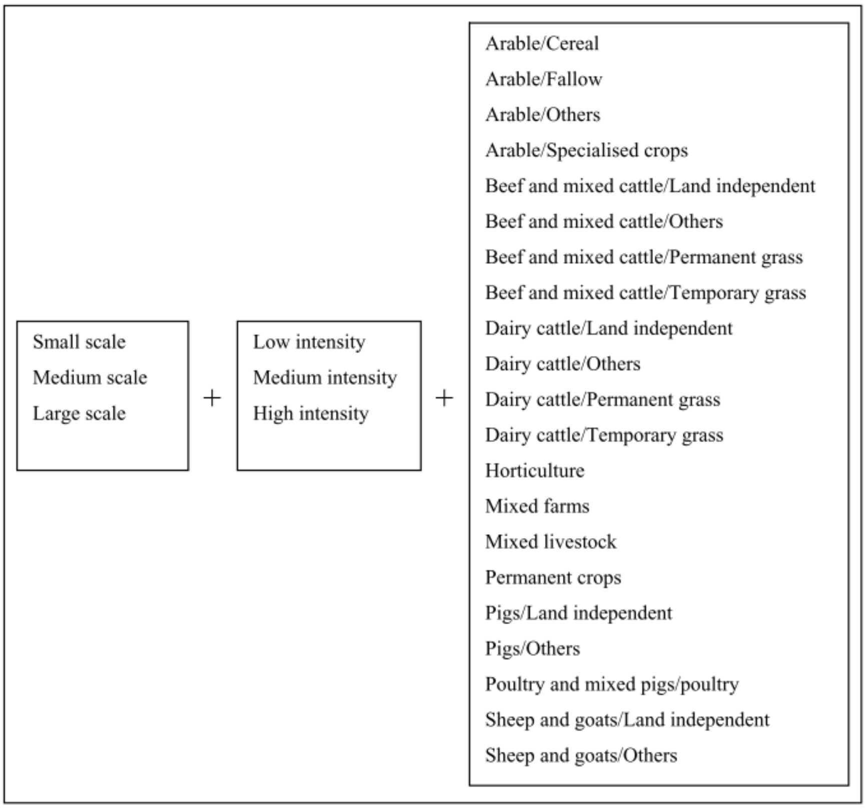

Figure 1.1 Overview of farm typology developed from SEAMLESS project (Andersen et al. 2006)

This typology was then expanded to EU-25 level (Andersen, 2010). The SEAMLESS project provides a base from which changes to environmental and agricultural policies can be informed.

Projects such as

SEAMLESS are useful in developing broad typologies which can be used to target payments on extensive farming areas at a broad scale, i.e. EU level. However, the development of typologies at a regional or landscape level identifies dominant farm types and mixes of farming styles in a region which aids the construction and implementation of policies and supports at a Member State level.

1.2 Agriculture in Ireland

Agriculture has always been important to Ireland, not alone for its impacts on the environment but also socially and economically. Traditionally, agriculture was dominated by pasture based systems with hay production being an important feature (O'Mara, 2008a). Extensive farming practices associated with low stocking densities and low intensity land management resulted in a high diversity of plant species and habitats with a high proportion of semi-natural habitats present on farms. With increasing modernisation of agriculture since the 1970s agricultural management practices have changed considerably in Ireland (Crowley and Meredith, 2015; O'Rourke et al., 2012). Management has become increasingly intensified to meet production goals. This has resulted in increased land improvement works such as draining, reseeding and increased nutrient input (McMahon et al., 2012).

Currently, the agri-food sector in Ireland contributes €24 billion to the national economy and is responsible for almost 10% of employment in the country (Teagasc, 2011). 4.2 million hectares of land (64% of the total land area) is dedicated to agriculture in Ireland of which the majority is committed to pasture based agricultural practices. There are approximately 139, 860 farms in the Republic of Ireland with an average farm size of 32.7 ha (Central Statistics Office, 2012). Farms in the West, Midlands and Border regions (Figure 1.2) tend to be smaller than those in the South or East. Beef production is the dominant farm type followed by dairy and mixed grazing and livestock systems. Sheep farming is more frequent in Western, Midland and Border counties (Central Statistics Office, 2012).

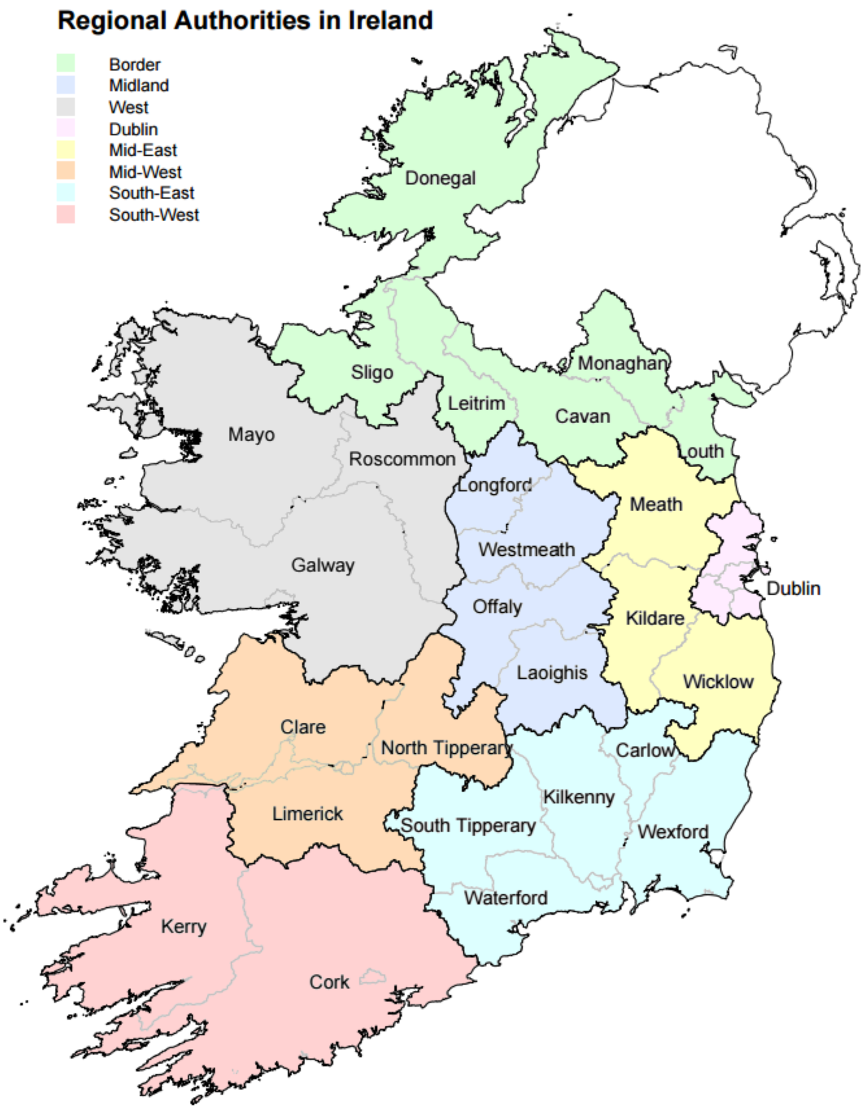

Figure 1.2 Regional Authorities in Ireland (from Central Statistics Office 2013)

Accession of Ireland to the European Economic Community (EEC), now known as the European Union (EU), in 1973 was the starting point for agricultural development in Ireland (Kearney, 2010). Irelands' membership provided the benefit of drawing from a more balanced market for beef and sheep products alongside income supports provided by the CAP and enabled Irelands agricultural sector to compete in European markets (An Chomhairle Oidhreachta/The Heritage Council, 1999; Kearney, 2010). However, the imposition of milk quotas as part of the CAP negatively impacted on Irish agriculture and led to disapproval amongst farmers and representatives in Ireland and other EU Member States (Hennessy and Kinsella, 2013). Although MacSharry reforms in 1992 phased out price supports and provided farmers with direct payments for area and stocking numbers. However, despite these supports the focus of policy was still production. The Agenda 2000 reforms finally made steps towards creating a sustainable agriculture culture.

Under the new CAP reforms, there has been some concern that greening measures may have minimal benefits to biodiversity in the Irish agricultural setting (Matthews, 2013). The continued focus on production subsidies and the possibility to move funds from Pillar 2 to Pillar 1 are seen as weaknesses in the CAP measures to support biodiversity levels associated with agricultural systems (Westhoek et al., 2012).

1.3 Biodiversity & Agriculture

Globally, human activity has created highly diverse landscapes. One of the primary influencing factors which have contributed to this has been agriculture (Howard, 2011). Agricultural practices from 5,000 to 4,000 BC cleared large tracts of woodland to create open spaces and semi-natural grasslands (Thomas, 1999). Agriculture does not only produce food but also has a significant effect on the environment. Presently, it is estimated that agricultural pasture and crop land covers up to 38% of the Earths land area (Swinton et al., 2007) making agriculture a significant influencer on global biodiversity levels. According to Dale & Polasky 2007, Palm et al. 2013 and Power 2010 agriculture provides a range of ecosystem services including pollination, carbon sequestration, soil retention and good water quality and helps to maintain and enhance biodiversity of flora and fauna (Figure 1.3). However, there can often be trade-offs between production services and other ecosystem services as a result of farm management practices (Power, 2010).

Agriculture can contribute to ecosystem services by stabilising soils, providing diversity of crops and regulating water storage in soil by maintaining plant cover, soil organic matter and soil biotic communities. However, it can also have negative impacts including loss of biodiversity, emission of pollutants and excessive nutrient inputs to waterways (Power, 2010). Trade-offs between production services and other ecosystem services, such as clean water provision and carbon sequestration, often occur as there is a market for production goods but no market for other ecosystem services. By creating a market for ecosystem services through agri-environment schemes (AESs) it may be possible to balance production and intensification with ecosystem services and biodiversity on farmland (McGurn and Moran, 2013; Power, 2010)

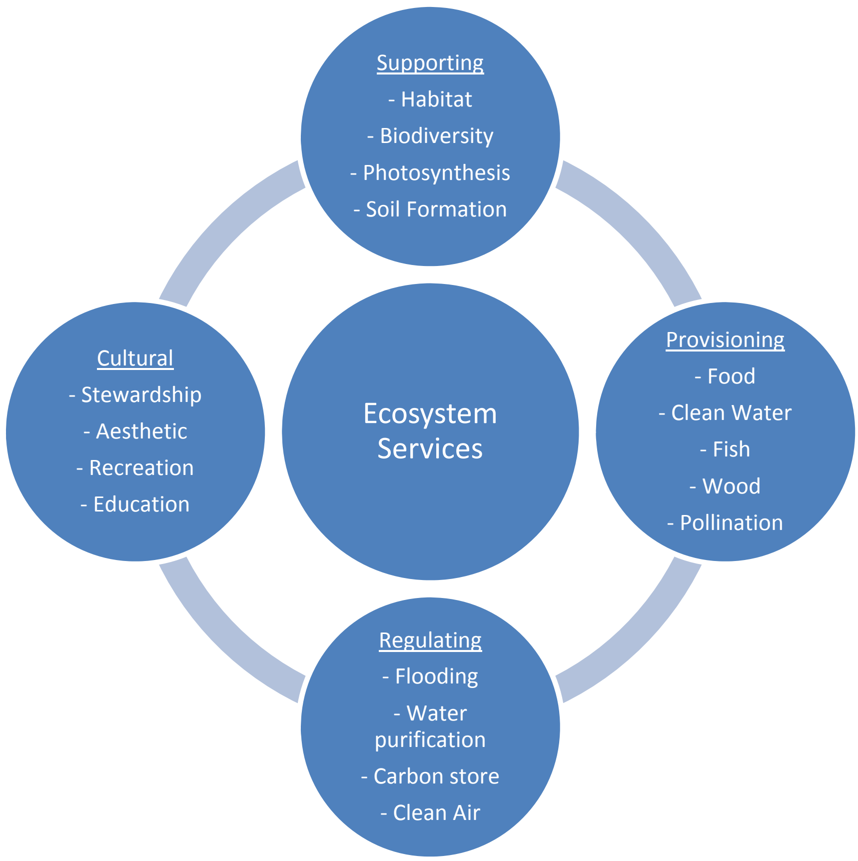

Figure 1.3. Ecosystem services which are supported by extensive farming practices

One way of conserving farmland biodiversity is through the maintenance of semi-natural habitats and features in the landscape. This is also important for maintaining ecosystem services associated with agriculture (Öckinger and Smith, 2007; Tscharntke et al., 2005a). Semi-natural habitats on farms contributes significantly to the diversity of flora and fauna in the landscape (Duelli and Obrist, 2003; Öckinger and Smith, 2007; Stoate et al., 2009; Walz, 2011; Weibull and Östman, 2003). Extensive agricultural systems, such as the dehasas in Spain (Plieninger and Wilbrand, 2001), contribute greatly to biodiversity at a landscape scale. These areas consist of mosaics of habitats which are capable of supporting a wide diversity of flora and fauna. At a smaller scale, the presence of semi-natural habitats has been shown to increase farm biodiversity (Firbank, 2005; Weibull and Östman, 2003). Semi-natural landscape features such as hedgerows and streams associated with farmland also contribute to biodiversity levels (Dover and Settele, 2009; García-Feced et al., 2014; Padoa-Schioppa et al., 2006; van der Zanden et al., 2013). Greater cover of semi-natural features, such as treelines and streams, increases landscape heterogeneity, and in turn is associated with increased plant and animal diversity. In more intensive agricultural landscapes, semi-natural landscape features often act as refuge for farmland biodiversity (Marshall and Moonen, 2002; Merckx et al., 2009; Weibull et al., 2000).

As agricultural practices have intensified over the last century, levels of farmland biodiversity have declined significantly (Donald et al., 2001; Robinson and Sutherland, 2002; Tscharntke et al., 2005a). Semi-natural habitat cover has declined in favour of more highly managed, improved grasslands that support few plant species and results in a decrease in associated invertebrate, animal and bird diversity (Hoogeveen et al., 2004; Krauss et al., 2003; Morelli, 2013; Tscharntke et al., 2005a). In Europe, highly diverse landscapes thrived up until the end of the Second World War (Tscharntke et al., 2005a). Post-war, there was an increased requirement for food to feed the population. This combined with technological developments and improvement led to a move towards intensification of agriculture (Aglionby et al., 2010; Boatman et al., 2007; Eurostat, 2013). As agricultural methods continued to intensify semi-natural habitats and traditional extensive farming practices came under pressure. This trend has carried on into the 21st century and has significantly reduced the cover of semi-natural habitats and their associated diversity across EU Member States (Hendrickx et al., 2007; Tscharntke et al., 2005a).

Alternately, abandonment of small, extensively managed farmland is of increasing concern across Europe (Keenleyside and Tucker, 2010; Renwick et al., 2013; Rey Benayas, 2007). Smaller, extensive farms are generally associated with high biodiversity (Kleijn et al., 2009). These farm types are typically located in remote areas or regions with challenging landscapes for agricultural improvement. Often, these farms are unable to compete with farms in areas with more productive land. Land owners find farming in these regions to be economically unsustainable and abandon part, if not all, of the farm (Caballero, 2007; MacDonald et al., 2000; Rey Benayas, 2007). The impacts of abandonment of agricultural land include a reduction in landscape heterogeneity, desertification, biodiversity loss and reduced water supply (Rey Benayas, 2007). A number of studies have highlighted the negative impact of abandonment on species diversity of, amongst others, birds, butterflies and plants (Dover and Settele, 2009; Doxa et al., 2010; Krauss et al., 2010; Marini et al., 2007; Woodhouse et al., 2005). In order to prevent this, suitable supports for extensive farming systems need to be introduced across the EU (Rey Benayas, 2007).

Afforestation is also a threat to farmland biodiversity (Keenleyside et al., 2014; Stoate et al., 2009; Swaay and Warren, 2006). This forestry industry is not necessarily damaging to biodiversity, in fact it may contribute to biodiversity levels if forests are planted within intensive landscapes (Buscardo et al., 2008). Afforestation can appear to be an attractive alternative for farmers to gain some income from grasslands or peatlands that are poor in terms of their economic production (Duesberg et al., 2014). However, the planting of large tracts of coniferous plantation on less productive but highly diverse habitats can lead to a significant reduction in landscape biodiversity (Buscardo et al., 2008). European policy currently provides greater monetary supports and incentives for afforestation than extensive farming practices (Beaufoy, 2008). A change in policy focus combined with more informed application of afforestation grants may prevent the loss of biodiversity due to afforestation.

1.3 High Nature Value farmland in Europe

In response to public demand and following a number of CAP reforms, recommendations have been made for the support of low-intensity agricultural systems alongside production focused supports. From this the concept of High Nature Value farmland was developed (Beaufoy, 2006). High Nature Value (HNV) farmland is defined by Andersen et al. (2003) as,

"*areas in Europe where agriculture is a major (usually the dominant) land use and where that agriculture supports or is associated with either a high species diversity or the presence of species of European conservation concern or both.*"

There are three types of HNV farmland identified at EU level (Figure 1.44). Type 1 is dominated by semi-natural habitats. This is the most frequent HNV type. It supports high levels of diversity of plants, invertebrates, birds and animals and is reliant on extensive management practices. Type 2 consists of a mosaic of habitats and landscape features e.g. hedgerows. This type contributes to landscape heterogeneity and the diversity associated with such landscapes. Type 3 HNV farmland is often composed of intensive grasslands but supports habitats or populations of species of conservation interest (Andersen et al., 2003a; Lomba et al., 2014).

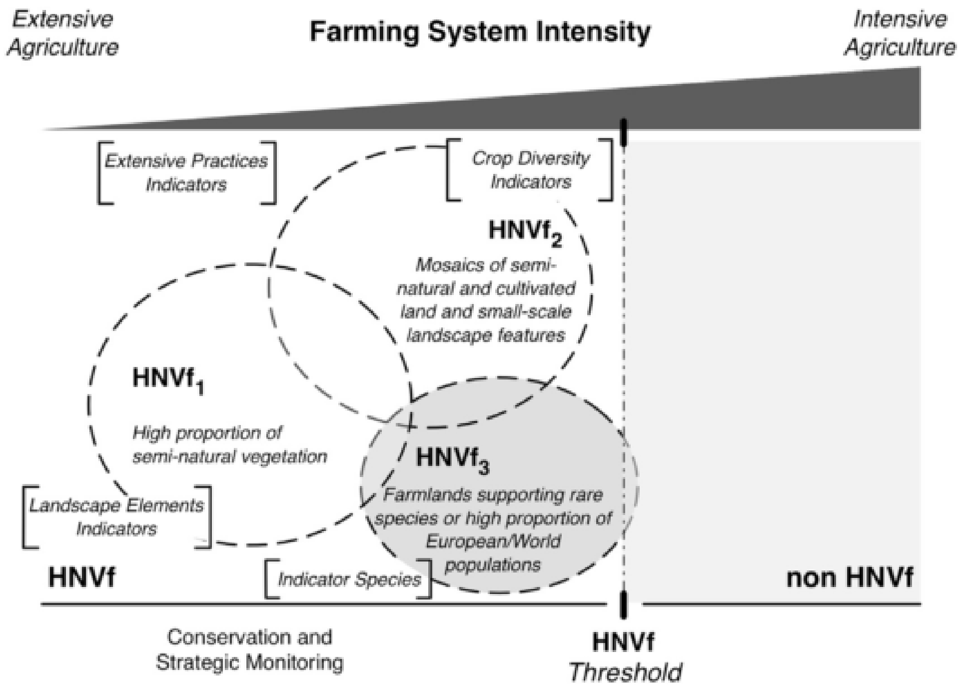

Figure 1.4 Spectrum of High Nature Value farmland (HNV) to non HNV (from Lomba et al. 2014).

In recent years the definition and description of HNV farmland has developed. To adequately encompass the relationships between HNV and other farmland types it is suggested that describing HNV as whole farm, partial and remnant systems is more informative (Keenleyside et al., 2014) (Figure 1.55).

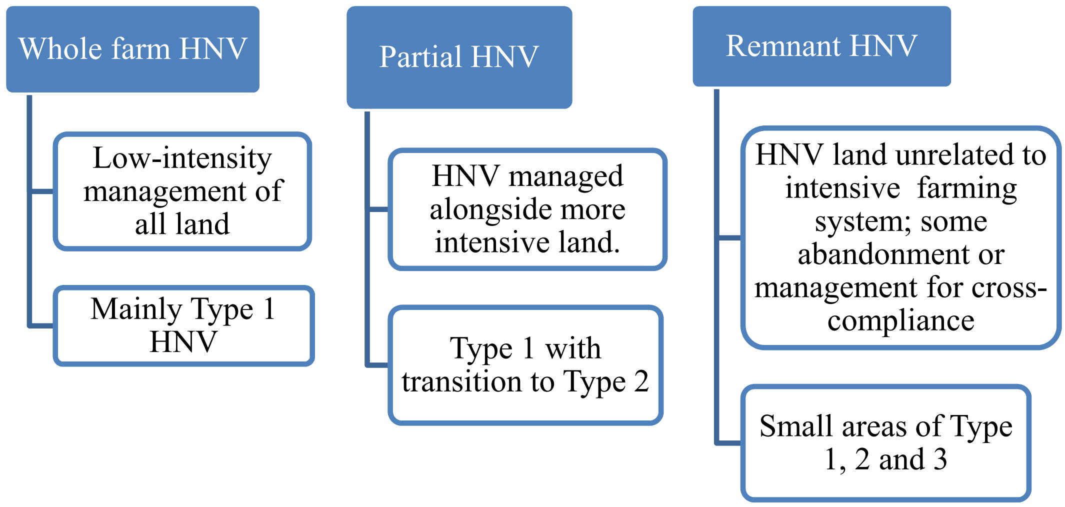

Figure 1.5 Whole farm, partial and remnant HNV systems (adapted from Keenleyside et al. 2014)

Whole farm HNV relates to entire farms that are managed as low intensity systems, often in a wider landscape of similar farms. Partial HNV systems rely on low intensity management of some land, alongside intensive practices. These are the farming systems that require the most support to prevent abandonment or intensification (Keenleyside et al., 2014). Finally, remnant HNV farmland relates to faming systems where the HNV is unrelated to the intensive farming system, with some abandonment or management for cross-compliance, nature conservation or agri-environment (AE) payments (Keenleyside et al., 2014).

High Nature Value farmland contributes to biodiversity levels across the EU. HNV regions are associated with high semi-natural habitat cover which supports plant, animal and bird species of conservation importance (Beaufoy, 2008; Lomba et al., 2015; Peppiette, 2011). The extensive grazing practices associated with these regions also prevent scrub encroachment and enhance grassland structure to benefit invertebrate, plant and bird species (Hoiss et al., 2012; Isselstein et al., 2005; Török et al., 2014; Verhulst et al., 2004).

The European Commission have highlighted that optimising measures under CAP to protect HNV areas is essential to the conservation of biodiversity in Europe (Beaufoy, 2006). Studies on CAP support for HNV farmland found it difficult to quantify the exact values required to ensure the protection of HNV regions due to the different approaches in assessing HNV farmland extent and quality across Member States (Keenleyside et al., 2014). It was estimated that, in general, increases in support were needed across EU Member States. In particular, regions such as Bulgaria and Croatia required substantial funding increases to prevent further abandonment of HNV farmland (Keenleyside et al., 2014). Biodiversity associated with farmland has commonly been protected through agri-environment schemes, such as the Agri-Environment Options Scheme (AEOS) in Ireland (Department of Agriculture Food and the Marine, 2012). However, a number of studies found these schemes to be more beneficial for biodiversity levels on intensive farms and that High Nature Value farming systems would benefit from more targeted, zonal or regional supports (Bignal and McCracken, 2000; Feehan et al., 2005; Hoogeveen et al., 2004; Sutherland, 2002; Whittingham et al., 2007).

The changes proposed in the CAP Reform (2014-2020) have moved towards incorporating enhanced protection of environment into Pillar 1, described as 'greening' (European Commission, 2013b). In Pillar 2, 30% of the budget for the Rural Development programme has been allocated for voluntary measures such as those incorporated into agri-environmental schemes (European Commission, 2013b). Although these are positive moves towards adequate support for HNV regions concerns have been voiced as to their benefits in implementation (Keenleyside et al. 2014). Member States are in control of implementing funding and the extent to which HNV farmland is accounted for in measures at country level remains to be seen (Keenleyside et al., 2014).

1.4 High Nature Value farmland in Ireland

It is estimated that HNV farmland covers 1,154,495 ha of the Republic of Ireland (Keenleyside et al., 2014; Paracchini et al., 2008). Although there have been a number of studies on the biodiversity associated with agriculture in Ireland the gap in research in relation to the description of agricultural systems that support HNV farmland in Ireland has been highlighted (Bleasdale and Dromey, 2011). In Ireland, a typology has been developed for a HNV region in the south-west. Farm management, socio-economic and attitudinal variables were used to construct a typology of hill farms on the Iveragh peninsula in Co. Kerry. Four main groups were identified within the typology; environmental stewards, support optimisers, traditionalists, and production maximisers (O'Rourke et al., 2012). This typology highlighted the high biodiversity associated with this area, which is considered a HNV region. It also highlights the variation within such a region that may, within a broader typology, be lost. This supports the need to develop regional typologies in order to be able to fully support farming in extensive landscapes.

The BurrenLIFE project established in 2004 has shown that targeted measures in cooperation with local communities and government departments can successfully protect and enhance HNV farmland (Williams et al., 2009). However, as in other regions of Ireland and the EU, this unique landscape came under pressure from both intensification and abandonment. Supports available through the CAP did not help to support biodiversity within the region and increased threats to the area such as nutrient influx centred on ring-feeders and overwintering of cattle in sheds.

The need for regionally targeted supports for the maintenance and enhancement of biodiversity in regions such as the Iveragh Peninsula has been highlighted. Studies such as this which develop typologies of farming styles within HNV regions are important drivers for policy change. They provide the baseline knowledge of regional management styles and provide a baseline for monitoring the successes of targeted agri-environmental schemes. A number of other case studies on farming styles within HNV regions have been completed including those for South West Ulster/North Connaught (McGurn, 2015) and for Connemara and the Aran Islands (Smith et al., 2010).

1.5 Identification of extent and quality of HNV farmland in Europe

The Common Monitoring and Evaluation Framework (CMEF) provide guidelines for monitoring Rural Development Programmes across the EU. They have described indicators for the assessment of policy objectives. Three of these indicators relate specifically to HNV farmland: Baseline Indicator 18, is defined as the Utilisable Agricultural Area of HNV farmland; Common Result Indicator 6, relates to the total hectares under successful land management; and Impact Indicator 5, involves monitoring the change in extent and condition of HNV farmland (Cooper et al., 2007). The method by which Member States measure the extent of HNV within their territories is left open for MS to decide (Peppiette, 2011).

A number of Member States have developed methods of estimating the extent of HNV. In Scotland, a baseline of the extent of HNV farmland was gathered using the proportion of rough grazing on farm and the related livestock densities (Scottish Government 2011). This model used rough grazing as a proxy for semi-natural habitat and livestock density as a measure of management intensity. From this it was estimated that 44% of agricultural land in Scotland could be considered HNV in

2007. Additionally, this method could be used to monitor the change in extent of HNV farmland and showed a decrease to 43% in 2008 and to 40% in 2009. The importance of common grazing systems for maintaining HNV in Scotland was also highlighted as 20% of HNV farmland identified was associated with areas where common grazing practices still occur (Scottish Government 2011).

Germany developed a method of identification using field studies, where a list of indicator species were counted across 30 x 2 m transects within individual land parcel over a four year period. This data is extrapolated out to provide Länder (regional) and national scores every second year. HNV farmland identified using this method was categorised along a nature value scale: HNV I – exceptionally high nature value, HNV II – very high nature value or HNV III – moderately high nature value. This has the added benefit of providing a quality measure in addition to measuring the extent of HNV farmland (Benzler, 2012). This method recorded 13.2% of agricultural land in Germany as HNV systems in 2009 but found this value to have reduced to 11.8% in 2013. This method provides accurate estimates of HNV cover and additionally can be used as a monitoring tool. To date, despite the benefits of this method, it has not been copied in other countries as yet, possibly as a result of the labour and time requirements required in the initial survey.

In Ireland, there have been no similar methodologies developed. In recent years a number of studies have described HNV farming systems in Ireland and identified threats to these areas and the need for adequate supports (McGurn and Moran, 2013; McGurn, 2015; O'Rourke and Kramm, 2012; O'Rourke et al., 2012; Sullivan et al., 2010).

To date, very few studies have attempted to assess the quality of HNV at a national, regional or parcel level (Peppiette, 2011) within Member States. The main reason for this appears to be the need for site sampling to assess individual site quality which is not seen as a feasible option in terms of time and resources (Peppiette, 2011). It is important to measure the quality of HNV sites alongside the extent so as to be able to monitor the effectiveness of AESs or other support measures (Sutcliffe and Larkham, 2010). As described above, a method for assessing the quantity and quality of HNV has been developed in Germany (Oppermann, 2008). This method is based on available datasets at a regional level alongside a structured sampling methodology. This is a very useful method within Germany where the regional data is already available but may not be suitable for application in other EU Member States. The use of plant indicator species has been suggested as a method for measuring quality of HNV sites (O'Neill et al., 2013; Sutcliffe and Larkham, 2010). The potential for use of indicator species for measuring HNV quality within an AES has been shown in a study completed in the Southern Transylvanian region of Romania (Sutcliffe and Larkham, 2010). This study found that the presence or absence of 28 vascular plant indicator species was sufficient to measure the quality of HNV sites. Although this was restricted to three grassland types potentially present in the country, the statistical method used could be applied to identify indicator species for other grassland habitats in other regions.

1.6 Scope and objectives of this study

This research took place on lowland and upland areas in west to north western Ireland with pasture-based farming systems being the dominant farming style (Figure 1.66). Farms were chosen in this region as it has been highlighted as having a high potential cover of HNV farmland (European Environment Agency, 2004). The farms included in the study represent a range of farming types and intensities ranging through coastal, lowland and upland regions. In year one, the farms surveyed were located within six electoral districts. Electoral districts (ED) are the smallest units for which agricultural statistics are available in Ireland. The six EDs represented three ecotypes; coastal, lowland and upland. The sample farms were stratified randomly sampled within this, i.e. ten farms from a coastal region, ten from lowland and ten from upland. This was done to ensure that the farms surveyed represented the variance in landscape challenges which are likely to be encountered in the wider region. Survey farms from Counties Sligo and Leitrim were randomly spread so as to sample the diversity of farming styles across the region.

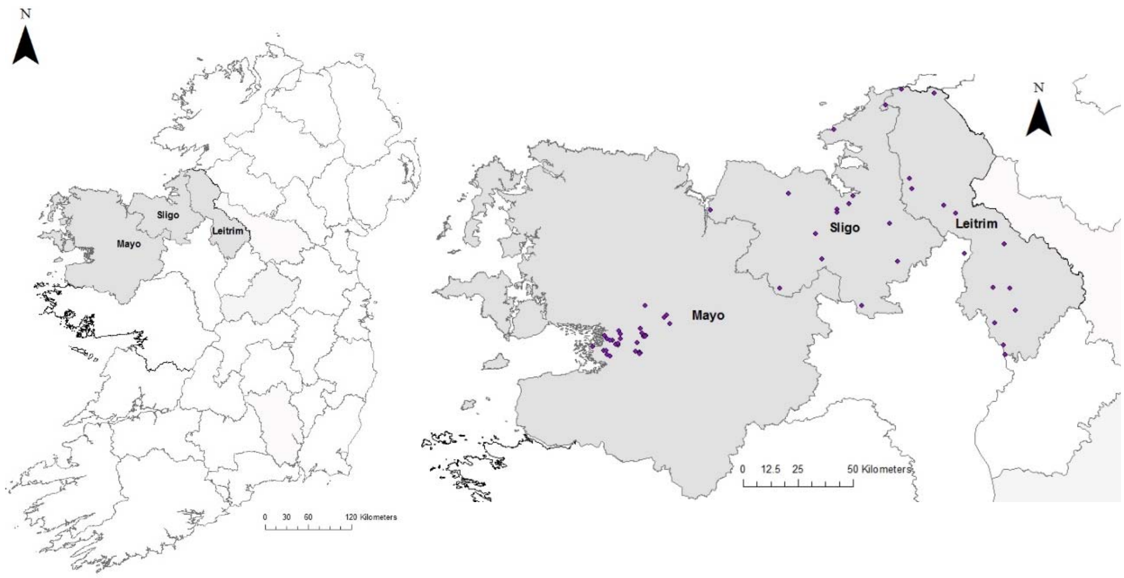

Figure 1.6. Study area in relation to Republic of Ireland and location of study sites in north-west of Ireland.

The objectives of this research were to:

- Develop a method of identification of High Nature Value farmland in a high biodiversity region
- Identify the farming types present within a High Nature Value landscape

- Investigate the plant groups associated with these farm types and which management and landscape factors affect these groups
- Investigate the use of vascular plants for assessing the quality of High Nature Value farmland

1.7 Structure of the thesis

This thesis follows a paper-based format and consists of three papers. Chapter 2 looks at the use of farmland management and habitat parameters for the development of a nature value index which may be useful in the identification of HNV farmland. Chapter 3 develops a typology of farmland in a HNV region using landscape and farm scale variables. This is important to the future development of regionally informed, targeted agri-environmental schemes. Chapter 4 identifies the plant groups associated with a HNV farming region and highlights groups which require specific measures to preserve on farm plant diversity. The potential use of vascular plant groups for assessing the quality of HNV farmland was also described. The same farms were studied throughout and as a result there is, of necessity, some repetition within the chapters. Chapter 5 provides a general discussion of the findings of the study as a whole and provides recommendations for future research. Supporting information is included as Appendices with cross-references in the paper-based chapters.

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Chapter 2. Methodology

2.1 Introduction

This chapter introduces the research methodology use for this study. Selection of sample farms and background information of the statistical programmes used is followed by sections describing the analysis utilised in the subsequent chapters.

2.2 Selection of survey farms

The wider study area of the project, i.e. Counties, Mayo, Sligo and Leitrim were selected as they have previously been identified as having a potentially high cover of HNV farmland (European Environment Agency, 2009). In year one, a baseline of farming intensities, management practices and landscape challenges was desired in order to reflect the variety of farming styles and pressures in a HNV landscape. The Clew Bay region of County Mayo was selected for surveying as a number of ecotypes, e.g. upland, lowland and coastal, are present in a compact region which could facilitate sampling. Six electoral divisions (ED) were selected to provide a sampling zone within which two EDs contained coastal regions, two were dominated by upland areas and two provided large areas of lowland pasture. Within each subset (i.e. ecotype) ten farms were sampled, totalling thirty farms in year one. In the following two year sampling periods, thirty farms were surveyed across Counties Sligo and Leitrim, fifteen in each county. Large proportions of both counties had previously been identified as having a high potential cover of HNV farmland.

Farms were sourced through cold calling, chain referral sampling (Heckathorn, 2002) and through collaboration with agricultural advisors. As farms can be considered a hidden population, sourcing willing participants was initially a complicated process. Using agricultural advisors as an initial contact point led to increased willingness of farmers to participate within the study. From a broad list of potential participating farmers who had initially been contacted by their advisors, final survey farms were selected through random selection using a random number generator.

2.3 Data analysis

Figure 2.1 visually represents the analysis flow completed for the following chapters. The steps are described, in general detail, in the sections below.

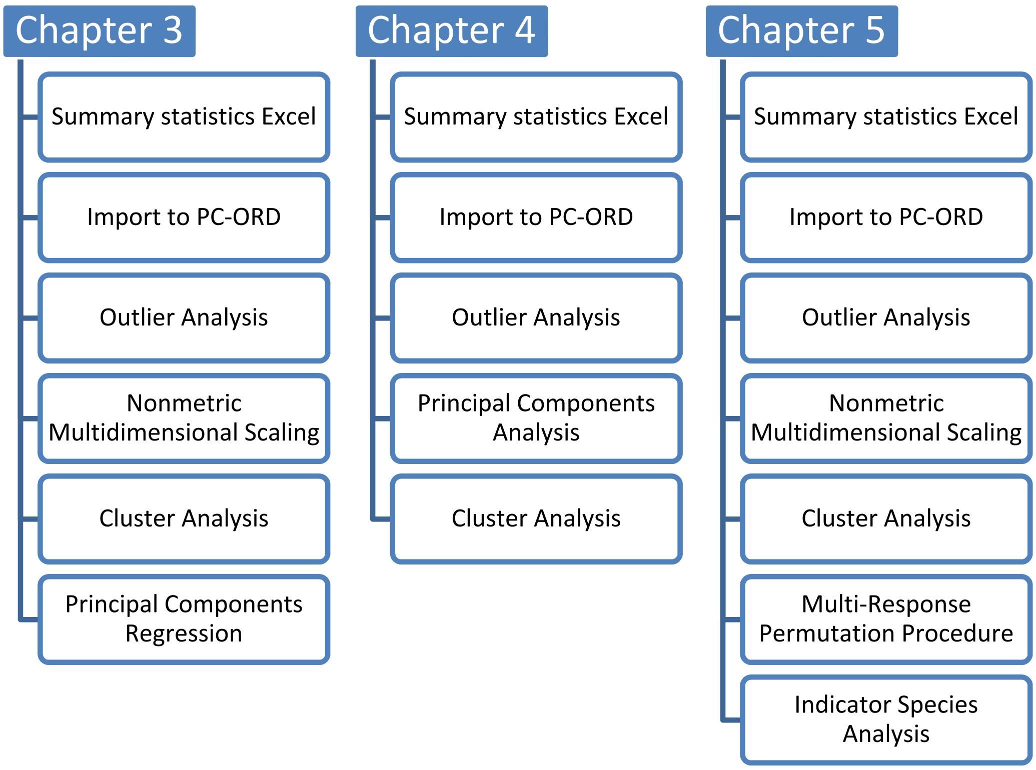

Figure 2.1 Analysis flow path which was used to answer specific research objectives in Chapter 3, 4 & 5

All habitat, species and farm management questionnaire data were assembled in separate tables using Microsoft Excel (Microsoft, 2010). Information relating to habitat area, farm size, boundary type and density were extracted from ArcMap 10.1

and was also collated in Microsoft Excel. Basic analysis of this data, such as percentage cover of habitat type per farm, proportion of farmers partaking in agri-environment schemes and stocking density per hectare of farm were calculated in Excel.

The statistical programmes used for further analysis were SPSS v. 20 (IBM Corp., 2011) and PC-ORD v. 6 (McCune and Mefford, 2011). SPSS was primarily used for descriptive statistics, correlations and nonparamtetric testing. PC-ORD was used for detailed analysis including Principal Components Analysis and Non-metric Multidimensional Scaling in addition to Cluster Analysis and Indicator Species Analysis. The following sections will describe the tests conducted to fulfil the objectives of each research question proposed in the subsequent chapters. The term ‘matrix’ is used for tables used in PC-ORD.

It is essential to select a suitable distance measure when completing multivariate analysis in PC-ORD. A distance measure translates patterns of dissimilarity in the raw dataset to a standard response that can be used by all multivariate tests within the programme. In this study, Sørensen distance measure is used in all instances where a distance measure is selected by the user e.g. NMS. Sørensen was selected as it has been repeatedly shown to be effective in measuring species or sample similarity. Sørensen is also more suitable for datasets that are zero-rich or where a zero record may not mean a zero in reality i.e. just because a species was not recorded during a survey does not mean the habitat does not support this species (McCune and Grace, 2002). PCA automatically assigns Euclidean distance measures.

2.3.1 Outlier Analysis

Outliers are data with extreme values or samples with an unusual combination of values for one variable. Outliers can skew results and can lead to misinformed conclusions. Outlier Analysis in PC-ORD automatically identifies outliers that are more than two standard deviations from the mean of the sample units in the matrix. The user can then decide to keep or remove the outlier(s). Outliers may be kept if they represent an unexpected group in the data or are considered important variables within the larger dataset.

Outlier analysis was used as a screening step within all stages of the analysis completed in PC-ORD for this study. The decision to retain or remove outliers was based on standard deviations from the mean and significance of the variable for further analysis steps. In Chapters 3 and 4, variables which were greater than two standard deviations from the mean related to commonage farms or heath/peatland habitats which are important habitat components of commonage farms. These variables were retained as commonage farms were considered an important group for consideration in the study. Alternatively, in Chapter 5, outliers, which related to fields with unusual species assemblages, were removed as they skewed the analysis steps which followed and this could potentially lead to incorrect interpretation of the final results.

2.3.2 Non-metric Multidimensional Scaling

Ordination involves arranging items around a scale, called an axis in PC-ORD. This has the benefit of graphically summarising complex datasets and identifying patterns and relationships within the data. Nonmetric Multidimensional Scaling is an ordination technique which deals well with non-normally distributed data which makes it suitable for ecological datasets. This method is considered to be the most suitable ordination technique for ecological community datasets (McCune and Grace, 2002). The main benefits of this technique are that it does not assume linear relationships among variables and it can be used with a range of distance measures. The main disadvantages associated with NMS were slow computation with large datasets and difficulty finding a best solution but these issues have been significantly decreased as computing power has increased.

A ‘stress test’ is run as an Autopilot NMS ordination on the sample data. This aids the selection of the final number of dimensions to interpret for further analysis. This involves running a ‘slow and thorough’ NMS on 1,2,3,4,5, and 6 axes alongside randomisation tests (PC-ORD runs this automatically with little input required from the user). This provides a stress value for each axis which can be visualised as a screeplot and a p value associated with the randomisation testing. This is repeated three times to ensure the results are consistent. The final number of dimensions to interpret should be based on a stress less than 25 and a p value less than 0.05.

When a satisfactory number of axis to interpret is selected, a final supervised run of real data is conducted. At this stage, autopilot is turned off and the user selects the desired settings, i.e. number of axes to interpret and the number of runs of the data. This provides the final ordination output. The final stress and p-value are reviewed to ensure they fit the requirements outlined above.

In this study, NMS is applied to a primary matrix containing habitat cover per farm (Chapter 3). A secondary matrix was also constructed and overlaid on the graphic of the ordination. This secondary matrix contains a number of environmental and management variables which are used to interpret the ordination. Some of these variables are correlated however, this does not affect the ordination and aid the visual interpretation of the data therefore they are retained. NMS was also utilised in Chapter 5 on a primary matrix containing abundance values for plant species per field. NMS was the most appropriate analytical tool for these datasets as the variables (habitats or species) were non-normally disturbed and were zero-rich.

2.3.3 Principal Components Analysis

Principal Components Analysis (PCA) is the most basic form of ordination. PCA aims to reduce a large number of variables to a smaller number of 'components' which can be used for further analysis or interpretation of relationships in a dataset. PCA can be used on data that deviates slightly from normality however it is most suited to variables with approximately linear relationships and does not handle zero-rich data effectively, this limits its use in ecological community analysis.

In order to conduct PCA, a main matrix is required. PCA automatically applies a Euclidean distance measure. The option to apply a randomisation test to evaluate the significance of the PCA results is advisable. The result file provides an eigenvalue for each axis, the proportion of variance which each axis represents and a broken-stick eigenvalue for each axis constructed by PCA. As a rule of thumb, it is advisable to interpret those axes whose eigenvalues are greater than the broken stick eigenvalue. If the randomization test has been applied, the user will be supplied with a table of stopping rules which can also be used to inform the number of axis to interpret.

In this study, PCA is applied to a matrix of farm level variables (Chapter 4) which were previously investigated for linearity and normality in SPSS. Outlier analysis identified one outlier which is removed as outliers can have a strong influence on the results of PCA.

2.3.4 Principal Components Regression

Principal Components Regression (PCR) is used for analysing multiple regression data that display multicollinearity. Multicollinearity refers to the case where two or more variables in multiple regression model are highly correlated which can negatively impact on interpretation of regression analysis.

PCR is a two-step analysis. The first step involves conducting a PCA, as described above. The components identified, which are not correlated, are used in the second step; stepwise multiple regression analysis. Stepwise multiple regression is useful in identifying the primary influencing variables on a single dependant variable. This model carries out multiple regression numerous time removing the weakest correlated variables each time. The results provide information on the variables which provide the greatest explanation for the distribution in the dataset. This step is completed in SPSS. A model summary table is provided in the output. The adjusted R^2 value provided in this summary gives the proportion of variability in the dataset explained by the variable of interest. A second output table provides an ANOVA F-value and p-value. This tests the fit of the model to the data. The F-value should have an associated significant p-value in order to consider the model a good fit. Finally, a co-efficient table provides the statistical significance of each of the variables. Where p is less than 0.05 the coefficients are considered statistically significant. In Chapter 3, PCR is used to identifying which variables are most influential on the distribution of farms within an NMS ordination. This is used to inform further analysis in developing a method of identifying farm level nature value.

2.3.5 Cluster Analysis

Cluster Analysis is one of the simplest statistical approaches to assembling homogenous groups. Hierarchical agglomerative cluster analysis calculates a distance matrix which can be written to a secondary matrix and overlaid on an ordination such as that produced in NMS or displayed as a dendogram. Cluster analysis groups data based on a distance criteria selected by the user and combines attributes of both groups. This can be repeated multiple times to produce a number of groups. The user can then decide on the most appropriate number of groups for interpretation and further analysis.

Cluster Analysis is used in Chapter 3, 4 and 5 to identify groupings in the ordinations. The groups described in the following chapters are selected following consideration of a number of grouping levels. The most appropriate cluster grouping is decided upon using the percentage of chaining. Chaining is the addition of single items to an existing group. If there is a high percentage of chaining very little splitting of data into groups has occurred, therefore a lower percent chaining is desirable. Indicator Species Analysis can also be used to interpret which level of clustering should be interpreted and is described below.

2.3.6 Indicator Species Analysis

In PC-ORD, Indicator Species Analysis (ISA) is based on Dufrêne and Legendre (1997) method of calculating species indicator values. A perfect indicator of a particular group is always present and should be exclusive to said group. ISA produces indicator values for each species based on the standard of a perfect indicator. The indicator value then undergoes a Monte Carlo randomisation test to for significance.

ISA is used in Chapter 5 of this thesis to identify indicator species of vegetation groupings. A threshold level of indicator value with 95% significance ($p \leq 0.05$) with an observed Indicator Value (IV) of 25 or greater is used to identify indicator species of groups (Dufrene and Legendre, 1997) selected using CA. ISA also provides a mean p-value and number of significant indicators for each cluster level. These values for each clustering level are presented on separate graphs, i.e. one graph contains all mean p-values for all cluster levels and a second graph contains the number of significant indicators per clustering level. The clustering level with the lowest mean p-value and highest number of significant indicators can be interpreted as the most appropriate clustering level to interpret.

2.3.7 Multi Response Permutation Procedure

Multi Response Permutation Procedure (MRPP) is used to test whether there is a difference between two or more groups. MRPP is a nonparametric test which only provides a measure of 'effect size' and a p-value. The differences amongst groups are described using alternative tests such as ISA (described above). MRPP assumes that a suitable distance measure has been selected and that sample units are independent.

MRPP is used in Chapter 5 of this thesis to assess that the groups identified in cluster analysis of vegetation data resulted in statistically separate groupings. The final result of MRPP is an A value, which is a measure of within-group agreement, and a T value, which describes the separation between groups. A p-value associated with the T value is used to evaluate how likely the observed difference is by chance. A lower p-value indicates the more likely the observed difference is due to chance.

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Chapter 3. Development of a nature value index for pastoral farmland – a rapid farm-level assessment

(Published in Ecological Indicators (56) p 31-20)

3.1 Abstract

Sustainable agriculture is important for the safeguarding of natural resources (e.g. semi-natural habitats, clean water and energy), food production and for the survival of rural communities. As part of the EU strategy towards sustainability Member States are committed to identifying and protecting areas of agrobiodiversity. Identification of the extent and support of High Nature Value (HNV) farmland across the EU was an important policy requirement of Member States Rural Development Programmes (RDP) (2007-2013) but problems defining the extent of HNV farmland have delayed progress to date. Following a five step statistical process, we developed a simple 10 point nature value index based on percentage improved agricultural grassland, stocking density (LU/ha UAA) and length of linear habitats per hectare on a farm. We propose a nature value index which has potential to be applied to a range of pastoral farming systems across Europe. This index is a simple to use, easily accessible identification tool based on farm-level data which can be utilised in sustainability indices and HNV farmland identification.

3.2 Introduction

Agricultural intensification in recent decades has led to a significant decrease in farmland biodiversity (Donald et al., 2001; Reidsma et al., 2006). In particular, it has resulted in the loss of semi-natural habitats and reduced resources for birds, mammals and butterflies in addition to disrupting pest control and crop pollination (Tscharntke et al., 2005a). Sustainable agricultural systems are now becoming increasingly important to meet the needs of growing world populations, both in terms of food production and wider ecosystem services including regulatory, support, cultural and aesthetic services (Tilman et al., 2002).While sustainability indices which measure the economic aspects of farms have been developed (Pannell and Glenn, 2000; Rigby et al., 2001), the social and environmental aspects have proven more difficult to quantify (Purvis et al., 2009).

A number of EU environment policies have been introduced in tandem with the Common Agricultural Policy (CAP) since the late 1970s to encourage the protection of farmland biodiversity (among other things). These include the Birds Directive (74/409/EEC), the Nitrates Directive (91/676/EEC) and the Habitats and Species Directive (92/43/EEC). Pillar II of the CAP includes provisions for agri-environment schemes and most recently one of the proposed priorities of the Rural Development Plan (2014-2020) has included specific reference to restoring, enhancing and maintaining biodiversity associated with High Nature Value farmland (Department of Agriculture Food and the Marine, 2014a). High Nature Value (HNV) farmland encompasses farming styles that are positively linked to biodiversity (Andersen et al., 2003b). There are three types of HNV farmland. Type 1 is described as farmland dominated by semi-natural vegetation under low intensity management. Type 2 is characterised by farms and landscapes with a lower proportion of semi-natural vegetation, existing in a mosaic of arable and/or permanent crops and semi-natural features and Type 3, farmland which supports species of conservation concern (Andersen et al., 2003b).

All farms in Europe fall somewhere in a continuum from intensive, highly productive, low biodiversity farms to extensive, low productivity, high biodiversity HNV farms. To date, measuring and monitoring agricultural biodiversity has involved the use of various surrogates as indicators of overall biodiversity (Dauber et al., 2003; Henle et al., 2008; Samoy et al., 2007). Land cover, species richness and land use intensity are some of the main components utilised in various agrobiodiversity indicators. While Overmars et al. (2012) have developed an indicator for biodiversity in agricultural areas using all three components. This indicator is based on maps of potential occurrence of 132 species (plants and vertebrates) combined with information on the influence of environmental pressures. The index is complex to construct and is an indicator of biodiversity at landscape rather than farm level. This method and a number of other methods for measuring farmland biodiversity have been developed at landscape scales (Aavik and Liira, 2009; Pointereau et al., 2007). However, given that monies to protect agrobiodiversity are generally paid to individual landowners, a farm level indicator of biodiversity would be more useful for developing and implementing policy incentives, e.g. agri-environment-climate actions under the CAP. The Nature Balance Scheme (Oppermann 2003) is an index which addresses agrobiodiversity at farm level but its use of 47 indicators under four sectors makes it complex to undertake and the author has suggested that aspects of it may be unreliable and difficult to reproduce.

This provides the incentive for our study, the primary aim of which is to develop a rapid, cost effective and simple index of nature value at farm level. The index which we present here (based on Irish farms) could be adapted for use across European pastoral systems as a stand-alone index or incorporated into wider measures of agricultural sustainability across Member States.

3.3 Materials and Methods

This study investigated the relationship among farmland habitat and plant species diversity, land cover and land use intensity to develop a composite nature value index. The index was compiled using a five step process involving analysis of data collected from 30 farms in County Mayo, western Ireland. The resulting index was tested on 60 farms in Counties Galway, Sligo and Leitrim (Figure 3.1A).

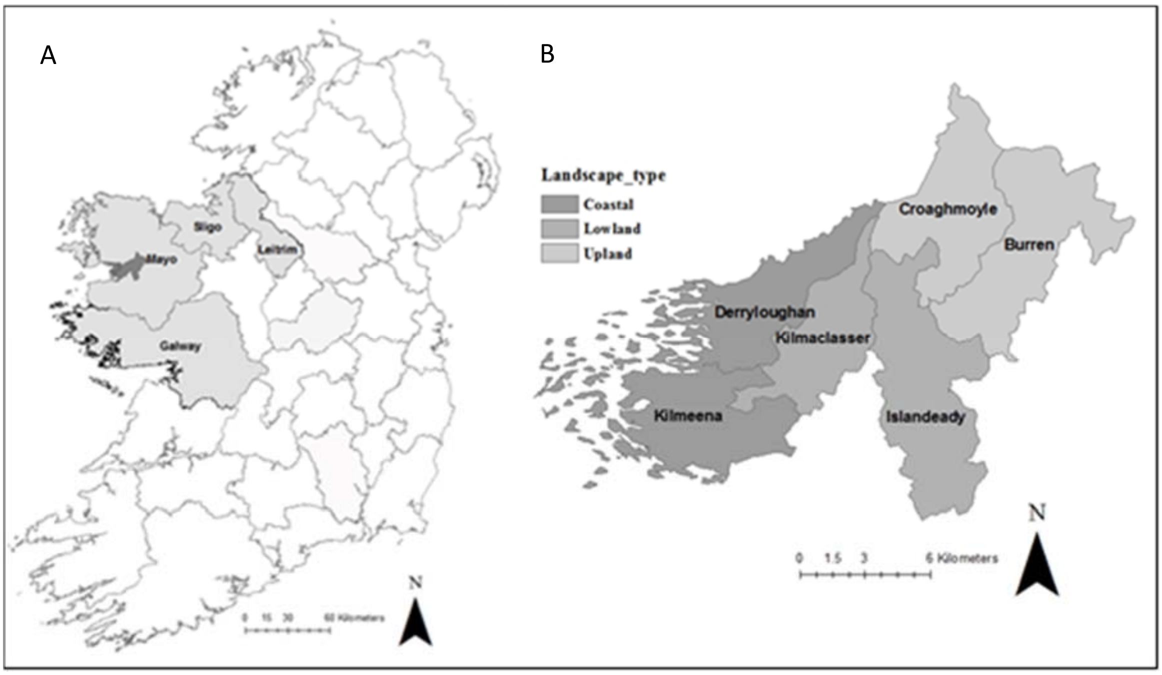

Figure 3.1. A: Location of counties Mayo, Sligo, Leitrim and Galway with Mayo study area indicated B: Location of study area in Co. Mayo, Ireland with landscape types of electoral divisions indicated

3.3.1 Study Area

The study area is situated in the west of Ireland. This region was chosen as it has been identified as an area with high potential cover of High Nature Value (HNV) farmland (European Environment Agency, 2009). Six electoral divisions (ED), the smallest legally defined areas in Ireland for which small area population statistics are published, were chosen in Co. Mayo. The study area was 19,337ha in size and covered a range of landscape types i.e. coastal (C), lowland (L) and upland (U) with a variety of topographies, soil types, geology and agricultural intensities. Upland was defined as being 150m above sea level after Fossitt (2000). Coastal EDs were defined as having at least one boundary along the Atlantic coastline (Figure 3.1B).

3.3.2 Farm selection

Farms were sourced through a combination of cold calling, chain referral sampling (Heckathorn, 2002) and consultation with local agricultural advisors. Sixty farmers which equated to 12% of farms within the study area were willing to participate in the study. From this, 30 farms were selected for surveying. The farms were surveyed using stratified random sampling. The stratification was based on three ecotypes; coastal, lowland and upland. Ten farms within each ecotype were surveyed to ensure that farming styles which may be influenced by landscape structure were represented. Requirements for inclusion in the study were that the farm contained less than 20% coniferous plantations and that the land was actively farmed. A site was considered actively farmed if it was under continuous management such as grazing, mowing, tillage or similar activity which modifies the natural environment in some form with the result being the production of goods for the common market (adapted from Colreavy, 2012a, 2012b; Eurinco, 2011). All participants were interviewed to gather baseline farm management data related to stocking density and type, fertiliser use, reseeding, land rental and participation in agri-environmental schemes.

3.3.3 Field Survey

Farm surveys were carried out over a three month period from July to September 2011. Farm boundaries, provided by the farmer or their advisor, were digitised using ArcGIS® software v. 10.1 (ESRI, 2011).

A structured 'W' walk was carried out across each field within a farm unit recording all habitats and plant species encountered (following Sullivan *et al.* 2010). Rented land was surveyed if it was rented for more than five years. During the walk all vascular plants were recorded and abundance assigned using the DAFOR scale (Kent, 2011). Plant species data were used to identify habitats on each farm and to calculate plant diversity indices. Habitats in each field were categorised after Fossitt (2000). Linear habitats (e.g. hedgerows, drainage ditches, stone walls) were recorded if they exceeded 20m in length (Smith et al., 2011). Data for commonages (such as habitat type and area) were provided by the National Parks and Wildlife Service

(NPWS). Commonage is land that is in common ownership on which grazing, turbary or estover rights are held by two or more farmers (Aglionby et al., 2010; Van Rensburg et al., 2009). Commonage in Ireland is typically composed of various mosaics of wet and dry heathland, upland blanket bog and upland grasslands. Total area of the farm included the area of commonage available to the participating farmer based on farm shares within the commonage.

3.3.4 Data Analysis

ArcGIS (ESRI, 2011) was used to map all habitat data gathered in the field and was used to calculate area of habitats and length of linear habitats for further analysis. Statistical analyses followed a five step process and were carried out in PC-ORD v 6 and SPSS v.20 (IBM Corp., 2011). Further details on the statistical analysis used is presented in Chapter 2.

In the first step, Non-metric Multidimensional Scaling (NMS) of farmland habitats was carried out to identify patterns in habitat composition across farms. NMS was used as it avoids the assumption of linear relationships among variables and allows the use of distance measures suited to non-normally distributed data (McCune and Grace, 2002). The Sørensen (Bray-Curtis) distance measure was used because the data are zero rich and heterogeneous. A second matrix containing a number of explanatory variables was compiled (Table 3.1).

Table 3.1 Explanation of environmental and management variables used in exploration of NMS ordinations of surveyed farms

Code	Explanation of environmental and management variables
Ecoregion	Landscape unit
Fields no	Number of fields on farm
To area	Total farm area in hectares
To UAA	Total area of utilisable agricultural area in hectares
Hab no	Number of recorded habitats
Hab ex linear	Number of habitats excluding linear habitats
%imp	Percentage improved agricultural grassland on farm
%SN	Percentage semi-natural habitat on farm
Spp rich	Species richness of the farm excluding linear habitats
WL(m)	Length of hedgerows and treelines in meters
WL(m/ha)	Length of hedgerows and treelines in meters per hectare
FW (m)	Length of freshwater linear habitats in meters
FW (m/ha)	Length of freshwater linear habitats in meters per hectare
BL	Length of stone walls and earthbanks in meters
BL (m/ha)	Length of stone walls and earthbanks in meters per hectare
Linear To (m)	Total length of linear habitats in meters
Lin To (m/ha)	Total length of linear habitats in meters per hectare
LU/ha	Livestock Units per hectare
LU/ha UAA	Livestock Units per hectare of Utilisible Agriculture Area

These variables were overlain on the ordination. For each of the variables a correlation co-efficient with the axis scores was calculated to determine the relationship between farmland habitat composition and associated variables (McCune and Grace, 2002).

The second step used cluster analysis (CA), a hierarchical, polythetic method, to identify groups of farms with similar habitat composition. It was carried out using PC-ORD v.6. A Sørensen distance measure with flexible beta linkage at $\beta = -0.25$ was applied. Flexible beta linkage was used as it is compatible with Sørensen distance measure and is space-conserving (McCune and Grace, 2002).

Thirdly, Principal Components Regression (Graham, 2003) was carried out, to investigate the relationship between the measured environmental variables which were correlated with the NMS ordination axes ($r > 0.5$) and both farm habitat diversity and plant diversity. This was done to identify the most suitable proxy for nature value within an index from the measured variables. Due to multicollinearity among the environmental variables, Principle Components Analysis (PCA) was used to produce ordination axes which are uncorrelated. PCA was carried out in PC-ORD v 6. PCA is relatively robust against deviations from multivariate normality, provided the data are relatively unskewed (McCune and Grace, 2002). PCA sample scores were used as predictor variables in stepwise multiple regression with habitat diversity, habitat number, plant species richness and plant diversity using SPSS v. 20. A plot of residuals against predictor values showed a random constantly spread scatter of the points which indicated linear distribution of the data.

The fourth step used the results of the above analyses to develop a ten point index for the identification of the nature value of farms using three variables. The variables used were assigned a maximum score of 5, 3 and 2, respectively, based on interpretation of above analysis. The scores of 5, 3 and 2 were each subdivided into 10 categories. The sum of the three scores provides an indication of the nature value of farms ranging from 1, suggesting low nature value, to 10, indicating high nature value

In the fifth step, to verify that the index score relates to habitat and plant diversity, the sample farms were scored and Pearson correlations between habitat diversity, plant diversity and the index scores achieved for individual farms were undertaken using SPSS. The index was validated with data available from 13 farms from Co. Sligo, 15 farms from Co. Leitrim and an independent study on 32 lowland grassland farms carried out in east Co. Galway (Sullivan et al., 2010). These 60 farms were scored using the nature value index and Pearsons correlations of the index score with habitat diversity, habitat number, plant species richness and plant diversity were carried out using SPSS.

3.4 Results

3.4.1 Farm structure and habitat composition

A total of 30 farms covering an area of 836.5 hectares were used to develop the index. Mean farm size (including commonage) was 27.89ha ± 22.62 (SD) and ranged from 9.3ha to 121.4ha. Thirty farm habitats (commonage was counted as one habitat, as it was not mapped in detail) were identified, with the number of habitats per farm ranging from four to 12. The variation in management intensity, farm characteristics and habitat composition across the sample farms are shown in Table 3.2.

Table 3.2 Summary of baseline farm statistics

Farm Characteristics	% of farms (N=30)
Farms with fields reseeded in last 5 years	53.3
Farms with rented land (5 years or more)	36.66
Farms participating in agri-environment schemes	70
Farms cutting hay	30
	Mean ± SD
Total area (ha)	27.89 ± 22.62
Total utilizable agricultural area (ha)	25.17 ± 21.67
Number of non-linear habitats	7.40 ± 2.26
Percentage improved agriculture grassland (%)	29.76 ± 21.09
Percentage semi-natural habitat (%)	63.99 ± 23.04
Plant species richness excluding linear habitats	82.26 ± 18.24
Total length of linear habitats (m)	5549.82 ± 2414.16
Length of linear habitats in of the farm (m/ha)	241.39 ± 83.50
Livestock Units per hectare	1.10 ± 0.70
Livestock Units per hectare of UAA	1.22 ± 0.75

Commonage was present on five (17%) surveyed farms. Buildings and artificial surfaces were present on all farms. Five grassland habitats were identified. The dominant grassland type was wet grassland (GS4) which was identified on 29 (96.7%) farms and improved agricultural grassland (GA1) which was identified on 28 (93.3%) farms. Dry calcareous and neutral grassland (GS1) occurred on 9 farms, dry meadows and grassy verges (GS2) occurred on 2 farms and acid grassland (GS3) occurred on 15 farms. Scrub (WS1) occurred on 22 (73.3%) farms and woodland (WD1, WD2, WD3, WD4 & WD5 combined) occurred on 17 (56.7%) farms. A list of habitats encountered and explanation of codes are included in Appendix A.

3.4.2 Index development

Step 1: NMS

NMS ordination of farms in habitat space was undertaken and a 3-dimensional ordination was recommended. The final ordination resulted in a final stress of 10.06 and final instability of <0.0001. From the ordination it is possible to identify groupings situated from the positive to negative ends of both axes. Axis 1and 2 explained 35% and 32% of the variation respectively (Figure 3.2) while axis 3 accounted for 23% of variance in the ordination.

An overlay of data contained in a second matrix shows the relationship between the ordination of the farms and the potential explanatory environmental and management variables (Figure 3.2).

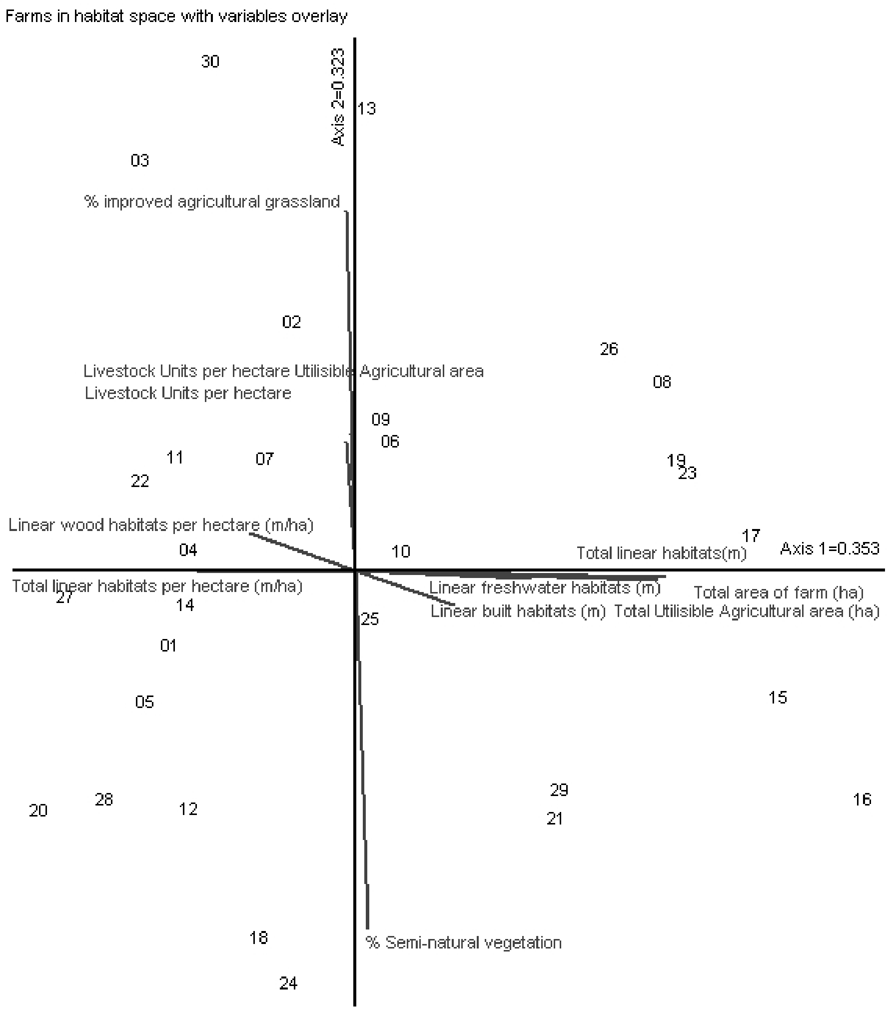

Figure 3.2 NMS ordination of farms in habitat space with environmental and management overlays.

Total utilisable agricultural area (ha) and total area (ha) of the farm have the greatest influence on axis 1 whilst axis 2 is strongly correlated with the percentage improved agricultural grassland and the percentage semi-natural habitat cover on the farm. Livestock units (per ha and per haUAA) are also influential on axis 2 (Table 3.3).

Table 3.3 Pearsons correlation (r) between measured environmental and management variables and the NMS ordination axes based on decreasing strength of correlations on axis 1

	Axis 1	Axis 2	Axis 3
Variable	r	r	r
Total utilizable agricultural area (ha)	**0.822**	-0.061	-0.299
Total area of the farm (ha)	**0.813**	-0.081	-0.261
Total length of linear habitats in meters (m)	**0.746**	-0.059	0.343
Total length of linear habitats in meters per hectare of the farm (m/ha)	**-0.574**	-0.107	0.187
Percentage semi-natural habitat (%)	0.224	**-0.867**	0.233
Percentage improved agriculture grassland (%)	-0.204	**0.869**	-0.235
Livestock Units per hectare UAA	-0.176	**0.517**	-0.252
Livestock Units per hectare	-0.139	**0.535**	-0.262
Number of fields	0.08	-0.06	0.058
Number of habitats excluding linear habitats	-0.038	-0.253	0.068
Plant species richness	-0.016	-0.289	0.330
Number of all recorded habitats	-0.014	-0.299	0.120

Step 2: Cluster Analysis

Cluster analysis (CA) was used to group farms by exploring the similarities/dissimilarities in habitat composition. CA resulted in 4.75% chaining of the data, a natural break which resulted in three discreet groups (A, B and C) being chosen as the most appropriate number (Figure 3.3).

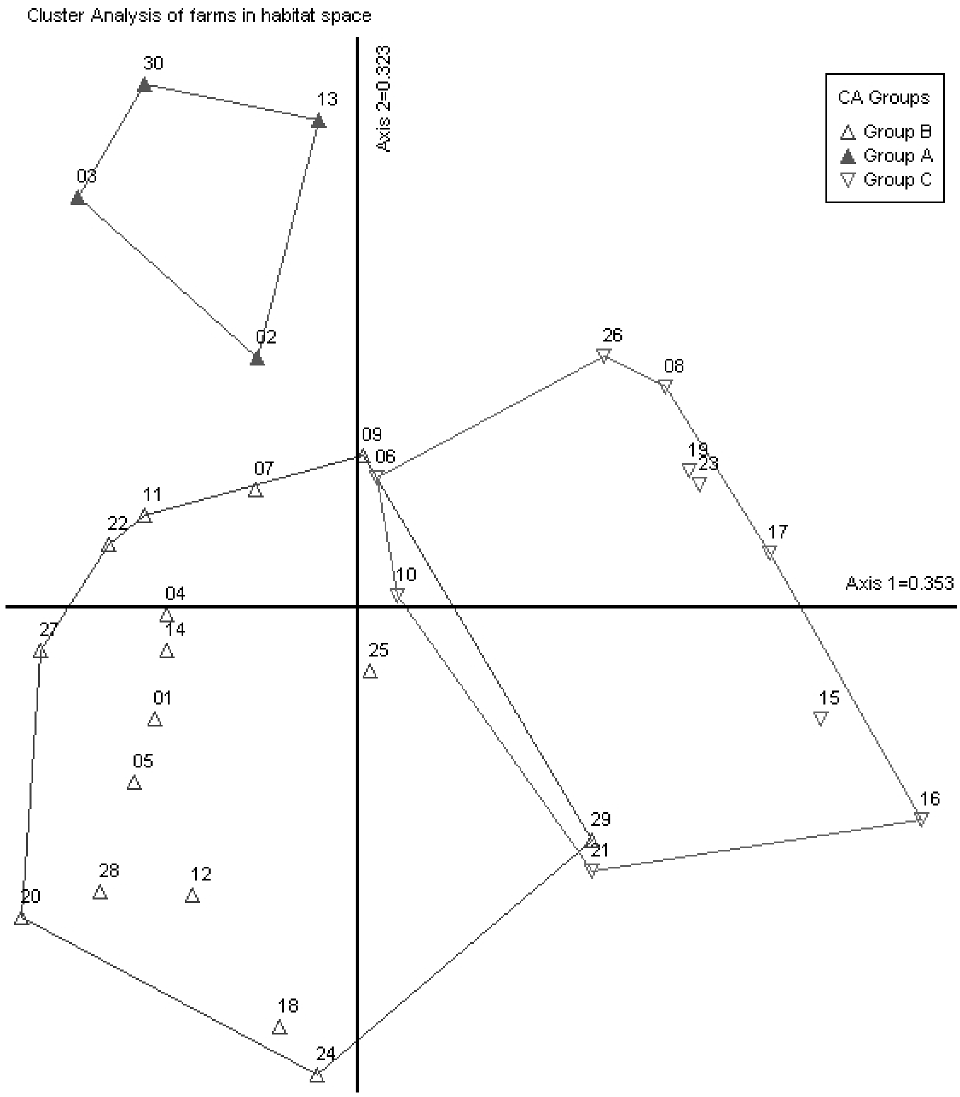

Figure 3.3 NMS ordination of farms showing the separation of cluster analysis groups

Averages of the variable data relating to these groupings were compiled (Table 3.3). Group A farms had an average of 65.9% improved agricultural grassland and average livestock units per hectare UAA of 1.9. This suggests that the farms within this group have a medium to low potential nature value (Reidsma et al., 2006). Characteristics of the farms within groups B and C, such as greater proportion of semi-natural habitat cover and lower livestock units per hectare, suggest higher potential nature value. Values in Table 3.4 were used to inform change points in the index to distinguish between low and high nature value farmland.

Table 3.4 Farm characteristics of groups identified in cluster analysis grouping level 3

Cluster Group	A	B	C
Number of farms in the group	4	16	10
Number of fields	11.25±3.26	14±3.96	13.3±5.14
Total farm area in hectares	12.7±3.7	17.5±6.43	50.5±26.8
Total area of utilisable agricultural area in hectares	11.8±3.02	15.0±6.2	46.8±25.8
Number of recorded habitats	9.75±2.75	11.87±2.5	11.8±2.82
Number of habitats excluding linear habitats	6.5±2.64	7.75±2.20	7.2±2.34
Percentage improved agricultural grassland	65.9±5.41	24.2±14.4	24.1±20.2
Percentage semi-natural habitat on farm	29.7±6.90	71.1±15.6	72.0±20.8
Species richness of the farm excl. linear habitats	70.5±17.1	86.12±17.1	80.8±18.7
Total length of linear habitats in meters	3026±1178	4656±1374	7988±2076
Total length of linear habitats (m/ha)	241.8 ±102	276.6±61.1	184.8±72.3
Livestock Units per hectare	1.8 ± 0.8	1.0±0.5	1.1±0.8
Livestock Units per hectare of UAA	1.9 ± 0.81	1±0.6	1.2±0.9

Step 3: Principle Components Regression

Principle Components Regression (PCR) was used to further investigate the effects of a range of variables identified from NMS ($r > 0.5$) on habitat and plant diversity of the farms. The PCA of the measured environmental variables showed two principal components with total explained variance of 78.8% (Table 3.5). The eigenvalues for the first two principal components are 4.236 and 2.424, respectively. These two components were considered significant because their eigenvalues were greater than the broken-stick eigenvalues of 2.929 and 1.929, calculated in PC-ORD. This highlights that these axes contain more information than expected by chance (McCune and Grace, 2002).

Table 3.5 Principle component loadings for the first two principle components in decreasing strength of correlations on axis 1

	PC1	PC2
Variable	r	r
Percentage improved agricultural grassland on farm	-0.8487	0.3781
Percentage semi-natural habitat on farm	0.8486	-0.3766
Livestock Units per hectare	-0.8037	0.4642
Livestock Units per hectare of utilisable agricultural area (ha)	-0.8132	0.4399
Total area (ha)	0.6689	0.7172
Total area of utilisable agricultural area (ha)	0.6455	0.7326
Total length of linear habitats per hectare (m/ha)	-0.3939	-0.6165
Variance explained	*50.9*	*27.962*

Table 3.5 shows the principal component loadings for the first two components. The loadings express the degree to which each extracted component correlates with the environmental variables (McCune and Grace, 2002). Component 1 (PC1) explains

50.92% of the variation and is positively correlated with percentage semi-natural habitat cover and negatively correlated with stocking density (LU/ha and LU/ha UAA) and percentage improved agricultural grassland. PC1 can be described as a landcover and landuse intensity component with axes scores increasing with increasing dominance of semi-natural vegetation and decreasing land use intensity. The second component (PC2) explains 27.96% of the variation and is positively correlated with total area, total UAA and negatively correlated with linear habitats (m/ha) of the farm. This can be described as a landscape heterogeneity component with axis scores increasing as landscape heterogeneity decreases.

Table 3.6 shows the results of the stepwise multiple regressions of habitat and species richness and diversity variables using the first two principle components as predictors. PC2 (landscape heterogeneity component) explains 30.1 % of the variation in the diversity of habitats, suggesting increased habitat diversity as landscape complexity increases (smaller farm size, increasing density of hedgerow). PC1 (landcover and land use component) explains 13.4% and 15.9% of the variation in habitat number and plant diversity per farm, respectively. This suggests that habitat diversity increases as percentage semi-natural vegetation increases and land use intensity decreases.

Table 3.6 Stepwise multiple regression of habitat and plant variables versus principle component of PCA of environmental variables. SC = Standardized coefficient, which is a measure of the relative importance of each significant predictor in a model

	Variable	R^2	F-value	p-value	SC
Habitat diversity					
Step 1	PC2	0.301	12.075	0.002	0.549
Habitat number					
Step 1	PC1	0.134	4.319	0.047	0.366
Plant diversity					
Step 1	PC1	0.159	5.277	0.029	0.398

Step 4: Index development

A nature value index was developed which can be applied at a farm level to identify the nature value status of a farm (Table 3.7). From the results of the analyses three variables; percentage improved agricultural grassland, livestock units per hectare UAA and linear habitats (m/ha), were selected for use in the index. Percentage improved agricultural grassland is used as a surrogate for semi-natural habitat, which is considered one of the main contributors to overall biodiversity of a farm. It scores a maximum of 5 and is divided into 10 categories in increments of 10%. Livestock units per hectare UAA is a well understood measure of management intensity of a farm and has been used previously in allocating agricultural payments. It scores a maximum of 3 and is divided into 10 categories in increments of 0.25 LU/ha UAA. Linear habitats (m/ha) provides an assessment of the complexity of landscape features within farm boundaries. It receives a maximum score of 2 and is divided into 10 categories in increments of 25 metres per hectare starting at 100 m/ha (Table 3.7).

Table 3.7 Ten point nature value scoring system

% improved Grassland	Score	Livestock Units per ha UAA	Score	Total length of linear habitat (m/ha)	Score	Final Score
91 - 100	0.5	> 2.26	0.3	< 100	0.2	1
81-90	1	2.01 - 2.25	0.6	101 - 125	0.4	2
71 - 80	1.5	1.76 - 2.00	0.9	126 - 150	0.6	3
61 - 70	2	1.51 - 1.75	1.2	151 - 175	0.8	4
51 - 60	2.5	1.26 - 1.50	1.5	176 - 200	1	5
41 - 50	3	1.01 - 1.25	1.8	201 - 225	1.2	6
31 - 40	3.5	0.76-1.00	2.1	226 - 250	1.4	7
21 - 30	4	0.51 - 0.75	2.4	251 - 275	1.6	8
11 - 20	4.5	0.26 - 0.5	2.7	276 - 300	1.8	9
0 - 10	5	0.15- 0.25	3	> 300	2	10

Step 5: Index validation

Correlations between the index scores of individual farms (index scores for farms are available in Appendix B) and Shannon's diversity scores for plant species richness, habitat diversity, total number of habitats per farm and plant diversity were used to verify the accuracy of the index score assigned to a farm (Table 3.8). All four were correlated with the index scores.

Table 3.8 Pearson (r) correlations of Index score of Mayo farms versus diversity indices

	Index score	Plant species richness	Habitat diversity	Habitat number	Plant diversity
Index Score	1				
Plant species richness	0.424*	1			
Habitat diversity	0.542**	0.693**	1		
Habitat number	0.464*	0.592**	0.715**	1	
Plant diversity	0.360*	-0.072	0.025	-0.114	1

**Correlations significant at 1% level (2-tailed)

*Correlations significant at 5% level (2-tailed)

Correlations between plant species richness, habitat diversity, habitat number and plant diversity were carried out against the index scores for 60 farms from counties Galway, Sligo and Leitrim Table 3.9) (index scores for validation farms are available in Appendix C). It was found that the index scores were strongly correlated with habitat diversity, plant diversity and plant species richness. Habitat number was not correlated with the index score.

Table 3.9 Pearson (r) correlations of Index score of Galway, Sligo and Leitrim farms versus diversity indices

	Index score	Plant species richness	Habitat diversity	Habitat number	Plant diversity
Index Score	1				
Plant species richness	0.465**	1			
Habitat diversity	0.392**	0.512**	1		
Habitat number	0.154	0.556**	0.762**	1	
Plant diversity	0.591**	0.417**	0.192	0.002	1

**Correlations significant at 1% level (2-tailed)

3.5 Discussion

This research identifies three easily quantified components which, when combined in a single index, provides a novel and meaningful assessment of the nature value status of a farm. Although the index has been developed using data from the north-west of Ireland, all three components i.e., percentage of improved agricultural grassland, livestock unit per hectare of UAA and linear habitat in (m/ha) have been described as being important in the assessment of farmland biodiversity across Europe (Baudry et al., 2000; Cooper et al., 2007; Sullivan et al., 2011).

Habitats are important indicators of biodiversity (Bunce et al., 2013). The proportion of semi-natural habitats in an agricultural landscape has been found to be an effective predictor of farmland diversity (Billeter et al., 2008; Hendrickx et al., 2007). Indeed, semi-natural habitat patches within the agricultural landscape have been found to be essential for enhancing biodiversity (Duelli and Obrist, 2003). For the purposes of the index, percentage of improved agricultural grassland was used as a proxy for the percentage of semi-natural habitats on a farm. The advantage of this is that improved agricultural grassland is more easily quantified and recognised by non-ecological specialists than semi-natural habitats. From the results given in the preceding section, the proportion of improved agricultural grassland was found to be highly influential on the distribution of farms within the ordination. Additionally, the proportion of semi-natural habitat was found to be an important variable in first principal component used for PCR. The strength of these relationships were used to inform the weightings applied in the nature value index.

Livestock units are described as an important feature of land management in numerous studies (Ausden, 2007; Bignal and McCracken, 1996; Gibson, 2009; Olff and Ritchie, 1998). Extensive farming systems associated with high biodiversity typically have a stocking density of <1LU/ha (Cooper et al., 2007). Nickel & Hildebrandt (2003) found that low intensity grazing may result in increased diversity of plants and higher numbers of Auchenorrhyncha species (invertebrate order including leafhoppers and cicads) when compared to other management regimes. The polluting effects of increasing livestock units on the environment have also been described (Firbank et al., 2013) highlighting the importance of managing livestock numbers at an appropriate level to support sustainable farming. Livestock units were found to have a strong correlation to the second axis of the NMS as described above. This suggests that livestock units were influential in the habitat diversity of farms. Furthermore, livestock units were found to be an important variable in first principal component used for PCR, alongside the proportion of semi-natural habitat. This reflects the relationship between stocking density and habitat diversity of farms by highlighting that higher stocking rates are typically related to higher proportion of improved agricultural grassland as previously shown in other studies (Cooper et al., 2007; Nickel and Hildebrandt, 2003).

Linear habitats are significant contributors to biodiversity on farmlands by acting as connectivity networks between habitats for plants and animals, food sources and shelter (Baudry et al., 2000; Le Cœur et al., 2002). Distribution of hedgerows has been found to be of importance for the protection of some species such as forest carnivores in agricultural landscapes (Pereira and Rodríguez, 2010). Field boundaries may also be significant contributors to the semi-natural habitat area of farms, particularly farms with lower proportions of non-linear semi-natural habitats (Sullivan et al., 2013). In the results described above, linear habitats on a farm measured in metres per hectare were found to be influential on the ordination of farms within the NMS ordination, though this variable had a weaker correlation than the previous two variables described. Additionally, this variable was found to be a significant variable within the second principal component used within PCR. This is reflected in the lower weighting of this variable within the nature value index than the other two variables.

Highly diverse landscapes are indicative of sustainable agricultural systems that conserve ecosystem services including biodiversity (Tilman et al., 2002). The goal of measuring and valuing ecosystem services is to use policies to better manage natural resources (Power, 2010). A combination of the three variables above within a single index, which is easy to use and measure, will allow for the development of more targeted agri-environmental schemes in the future. The proposed index could be incorporated into the environmental aspect of sustainable agriculture policies. Additionally, metrics such as this could be incorporated into 'green' farming initiatives such as OriginGreen in Ireland (Bord Bia, 2012).

Another potential use for this nature value index is the identification of HNV farmland. Identification of the extent of and support of High Nature Value (HNV) farmland across the EU has been an important policy requirement of Rural Development Programmes (RDP) (2007-2013) of member states but problems around defining the extent of HNV farmland has limited progress (Keenleyside et al., 2014). A number of different systems have been proposed by EU member states for the identification of HNV farmland (Oppermann et al., 2012). In Scotland (Rural Analytical Unit. Scottish Government, 2011), HNV farmland has been characterised using rough grazing and livestock units per available forage hectare. However, this method, based on upland areas, could underestimate the potential HNV cover in Ireland and other regions where HNV extends across lowland areas. The German system for identification and quantification of HNV is complex (Oppermann, 2008) in that it is based on a number of German landscape and plant indicator taxa databases. However, similar databases containing quality measures for the assessment of landscape elements and their contribution to biodiversity are not currently available throughout all EU member states. For these states other HNV identification indices which are easier to calculate and apply are urgently required.

Cluster analysis (CA) results presented in this study, existing European typology of HNV farmland (Andersen et al., 2007) and farm statistics were considered to inform change points in the index to distinguish between HNV and non-HNV farms. Group A farms have a high proportion of improved agricultural grassland cover and high LU/UAA which suggests a non-HNV group (in Ireland). Combined, groups B and C appear to represent HNV farmland and reflect the variation in HNV types. Percentage improved agricultural grassland and livestock units per hectare UAA have similar values in Groups B and C. Group B has a higher average length of linear habitats (m/ha), a key feature of Type 2 HNV farmland. Type 2 HNV farmland is described as a mosaic of low intensity agriculture with natural and structural elements such as hedgerows, stone walls and patches of scrub (Rural Analytical Unit. Scottish Government, 2011). Linear habitats measured solely in metres results in a high variation of the mean. By providing length of linear habitats in metres per hectare provides a measure of density of linear habitats in the landscape. This measure provides a better assessment of diversity as increasing density of linear habitats has been shown to increase farmland diversity (Baudry et al., 2000; Thenail and Baudry, 2004).

The need to distinguish HNV from non-HNV farmland at a land parcel level has recently been highlighted (Keenleyside et al., 2014). Based on the research presented in this paper, farms scoring greater than 4.5 using our index could be classed as HNV farms. This change point is based on the range of values within the variables utilised in the index as gathered from survey farms and was further informed by European typologies for each variable, where available. Type 1 and Type 2 HNV farmland, by definition, is dominated by semi-natural vegetation. For the purposes this study 'dominant' was defined as equal to or greater than 50% semi-natural vegetation cover. Additionally, a number of studies have shown that stocking density of greater than 1 typically reflects intensive management practices which do not support HNV farming systems. There are no similar measures for linear habitats. However, it has been shown that lower densities of linear habitats on pastoral farmland typically relates to more intensively managed land where field boundaries have been removed to increase production area. Typically farms with greater than 50% improved agricultural grassland, high stocking densities and low densities of linear habitats were found to score less than 4.5 in this study. This informed the suggested change point from non-HNV to HNV farmland. This change point should be tested in similar regional landscapes to investigate its accuracy and amended if needed.

It is difficult to further distinguish between HNV Type 1 and 2 farms. HNV type 1 and 2 farms are both associated with high semi-natural cover and high density of landscape features such as hedgerows and streams. Type 1 farms are dominated by semi-natural habitat so are expected to score highly on the nature value index based on the proportion of improved agricultural grassland. However, the density of linear habitats are typically higher on HNV type 2 farms. Therefore, it is possible for HNV type 1 and 2 farms to receive similar final scores using the nature value index. Due to the potential overlapping of scores between typologies and as both types are equally important for biodiversity further research needs to be carried out before a recommendation is made for applying change points moving from Type 2 to Type 1. As the identification of Type 3 farmland is based on unique cases, it cannot be included in this index.

When scored, the Mayo sample farms resulted in 4 non-HNV and 26 HNV farms. In comparison, the farms used for validation resulted in 16 non-HNV and 44 HNV farms. Galway farms scored 14 non-HNV and 18 HNV, Sligo resulted in 1 non-HNV and 12 HNV and Leitrim farm scores resulted in 1 non-HNV and 14 HNV. The scores reflect the increased management intensity in the Galway region in comparison to Sligo/Leitrim. Although the Sligo and Leitrim farms scored similarly, there is a difference in the ranges of farm scores between the counties. The lowest farm score in Sligo is 2.6 and the highest is 8.4. In comparison the lowest Leitrim farm score is 3.3 and the highest is 9.7. The range of scores reflects the lower intensity of farms in Leitrim in comparison to Sligo (Central Statistics Office, 2012).

This index could easily be applied throughout Ireland to identify potential HNV hotspots that would benefit from targeted supports through the RDP.

While the change points suggested appear to be useful for the identification of HNV farmland typologies, they are not intended to be definitive but to allow for discussion and examination of other scenarios in the identification of HNV farmland in other regions of Europe. It is important to recognise that all farmland has some nature value even those farms falling into the non-HNV category.

3.6 Conclusions

Demand for sustainable agriculture and its associated ecosystem services continue and the ability to quantify it is of increasing importance. Any measure of sustainable agriculture will have to incorporate a number of economic, social and environmental indicators. The index proposed in this paper could be incorporated into an environmental indicator of sustainable agriculture. The proposed index is simple to use, can be easily implemented and with further testing could be modified for use in other pastoral regions across Europe. Additionally, it can empower farmers to make informed decisions in relation to management of biodiversity of their farm. The development of this index of the nature value status of a farm is a step towards developing a holistic environmental indicator of sustainable agriculture in Europe.

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Chapter 4. Typology of a High Nature Value farmland region in an Atlantic pastoral area

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4.1 Abstract

High Nature Value (HNV) farmland supports high levels of biodiversity and is associated with farming practices that provide a range of ecosystem services such as clean air and water. Despite EU Member States commitment to supporting farmland biodiversity, HNV areas are still under supported by agri-environmental schemes. This is partly due to the lack of understanding of farm types that are associated with HNV landscapes. This paper develops a typology of HNV farmland based on fifty-eight farms within a pastoral landscape in the north-west of Europe. Using farm biodiversity values, such as habitat number, field size and length of linear features, and farm management variables, four distinct farming types are identified. The main factors differentiating farms using Cluster Analysis were (1) farm size, (2) stocking density, (3) percentage of the farm covered by semi-natural habitat and (4) the length of linear features on a farm. The four groups separate along an intensity gradient of farming system and relate to whole, partial and remnant HNV systems. Our results show that the development of farmland typologies is important for highlighting regional diversity of agriculture. Understanding this diversity is important for the development of targeted supports to ensure suitable measures are implemented to enhance and maintain agrobiodiversity levels.

4.2 Introduction

Given the loss of farmland biodiversity across Europe over the last forty years, European agricultural policy has, more recently, focused on “green” measures with a move towards supporting production of public goods including biodiversity protection and enhancement, within a multifunctional model of agriculture (European Council, 2005). This shift in policy focus necessitates the identification of farm types that are capable of producing a wide range of environmental services (O’Rourke and Kramm, 2012). As a result, it has become increasingly important to develop farm typologies that reflect environmental factors such as management intensity and the presence of extensive farmland habitats (Andersen et al., 2007). This facilitates the recognition of gaps in economic and environmental supports; it emphasises the links between farm management and environmental condition; and simplifies complex systems for communicating the factual condition of agriculture to non-specialist policy makers (Andersen *et al.* 2006).

Farm typologies have frequently been used for economic and social assessments (Daskalopoulou and Petrou, 2002; Gaspar et al., 2008). For example, the United States Department of Agriculture developed a typology of farmland based on Gross Cash From Income (GCFI), a farmer’s primary occupation and whether a farm is run by a family (Hoppe and Macdonald, 2013). Within the EU-25, the SEAMLESS project constructed a typology of farming designed to inform changes in agricultural and environmental policies. The typology is based on the economic size of farms, the total output in Euro per hectare and the standard gross margins from different land use. The resulting typology is suitable for assessing needs for change in agricultural and environmental policies (Andersen, 2010). However, top-down approaches to developing farm typologies do not always reflect the complexity and diversity of farming systems accurately. A bottom-up, regional approach for typology construction should be used in conjunction with the top-down approach (Cabello et al., 2014; Lomba et al., 2014).

Across the EU, Member States have accounted for regional differences in agricultural systems in a number of studies (Andersen, 2010; Andersen et al., 2003b; European Environment Agency, 2005), some of which have been focused on extensively managed farmland (Gaspar et al., 2011, 2008; López-i-Gelats et al., 2011; O'Rourke et al., 2012; Sutkowska et al., 2013). Many of these typologies, based on farmer questionnaires and in some cases farm habitat surveys, were developed using multivariate analysis, Principal Components Analysis and Cluster Analysis. These studies work to highlight the diversity of farming at a regional level and demonstrate that there is a range of farming intensity from low intensity management to intensively managed, often specialised farms.

Low intensity farms in Europe have been described as High Nature Value (HNV) farmland areas which support high species and/or habitat diversity (Andersen et al., 2003b). There are three types of High Nature Value farmland. Type 1 HNV farmland is associated with extensive areas of semi-natural habitat and low intensity management practices. Type 2 HNV farmland contains mosaics of semi-natural and cultivated land. Finally, Type 3 HNV farmland is intensively managed but supports European or global populations of species of conservation concern (Andersen et al., 2003b; Lomba et al., 2014). The description of HNV areas, as completed by a number of studies (Andersen et al., 2006; Cooper et al., 2007; Pointereau et al., 2007), is important as they: a) highlight the range of ecosystem services which are supported by HNV farming systems, important to the wider population; and b) focus attention on the threats of modern intensification practices or abandonment to biodiversity (Paracchini et al., 2008; The Heritage Council, 2010). However, most of these studies have contributed to the mapping of the extent of HNV systems rather than characterise the different farming types that contribute to HNV landscapes.

It has been suggested that focusing on the definition of HNV types above limits the ability of Member States to fully understand the complex needs of HNV regions (Keenleyside et al., 2014). A complementary view to characterising HNV at a farm and parcel level has been described; whole farm, partial and remnant HNV (Keenleyside et al., 2014). Whole farm HNV relates to entire farms that are managed as low intensity systems, often in a wider landscape of similar farms. Partial HNV systems rely on low intensity management of some land, alongside intensive practices. These are the farming systems that require the most support to prevent abandonment or intensification (Keenleyside et al., 2014). Finally, remnant HNV farmland relates to farming systems where the HNV is unrelated to the intensive farming system with some abandonment or management for cross-compliance, nature conservation or agri-environment (AE) payments (Keenleyside et al., 2014). By using these descriptors of HNV farmland it may make it easier to characterise agricultural regions for targeted policy measures and supports.

Characterising HNV farmland facilitates the development of policies targeted at less productive, less economically viable farms which contribute significantly to the protection of farmland biodiversity. The potentially negative impacts of blanket agricultural policies have been highlighted in Spain, Scotland and Ireland respectively (Caballero, 2001; Kleijn et al., 2006; Morgan-Davies et al., 2012; O'Rourke et al., 2012). These include failing to protect vulnerable habitats (Caballero, 2001) or rare species (Kleijn et al., 2006) in these regions. Such studies emphasise the importance of developing farm typologies to better inform and implement policy.

Agricultural land covers 61 percent of the Republic of Ireland (O'Mara, 2008b) of which 20% is estimated to be HNV farmland (Paracchini et al., 2008). Farming in Ireland is varied in terms of type, intensity and productivity resulting from differences in climate, geology, topography and soil type. This has an impact on the economic viability of farms across Ireland. Based on average family farm income, farms in the west and north–west are less economically productive, where the landscape is more challenging in terms of topography and productivity, compared to farms in the south or east (Hennessy et al., 2011). However, these extensively managed farms with restricted food production capabilities are often found to be the greatest contributors to biodiversity and ecosystem services including clean water, clean air, soil conservation and carbon sequestration (Caraveli, 2000; Tscharntke et al., 2005b).

To date, in Ireland, there have been few typologies of extensive farmland constructed. A national typology of Irish farming has been developed using the Farm Accounts Data Network (FADN) (Green and O'Donoghue, 2013). This top-down typology describes farms solely on farming systems and standard gross margins of income and is limited in its use for informing sustainable agricultural policies. The National Farm Survey data that are gathered and consequently used for such research show a geographic trend toward the south-east of the country (Green and O'Donoghue, 2013). There is one farmland typology which has considered HNV farmland specifically and includes environmental aspects of farming, such as semi-natural habitat cover or landscape features. This typology of farmland of the Iveragh peninsula, Co. Kerry, a HNV region in south west Ireland, identified four distinct groups: environmental stewards, support optimisers, traditionalists and production maximisers, and was based on farming intensity, farm continuity and semi-natural vegetation cover (O'Rourke et al., 2012). However, this study focused only on upland hill farming systems and is more focused on socio-economic than environmental impacts in the region.

The objective of this paper is to develop a farm typology using a combination of land cover, farm management and landscape structure variables in a High Nature Value pastoral landscape in a northern Atlantic biogeographic region. This typology is based on the environmental setting of farms rather than economic production values, which has been the main focus of most farm typologies to date. The overall aim is to inform future policy and agri-environmental scheme developments by describing the types of HNV farms present on farmland in an Atlantic biogeographic region of Europe and quantify the degree of variability between farm types to determine where more targeted supports are required to maintain their nature value and biodiversity levels into the future.

4.3 Materials and Methods

4.3.1 Study area

The research was conducted in counties Mayo, Sligo and Leitrim, in the north-west of Ireland (Figure 4.1). This region of Ireland experiences high levels of rainfall for the country (mean 1142 ml per year) and slightly lower than national average temperatures (average daily temp. 9.6 °C) (Walsh, 2012). The dominant soil type in the region is poorly drained non-calcareous mineral soils and the bedrock is predominantly limestone and calcareous shale. The most frequent landcover types are pasture and heterogeneous agricultural areas (Environmental Protection Agency, 2015).

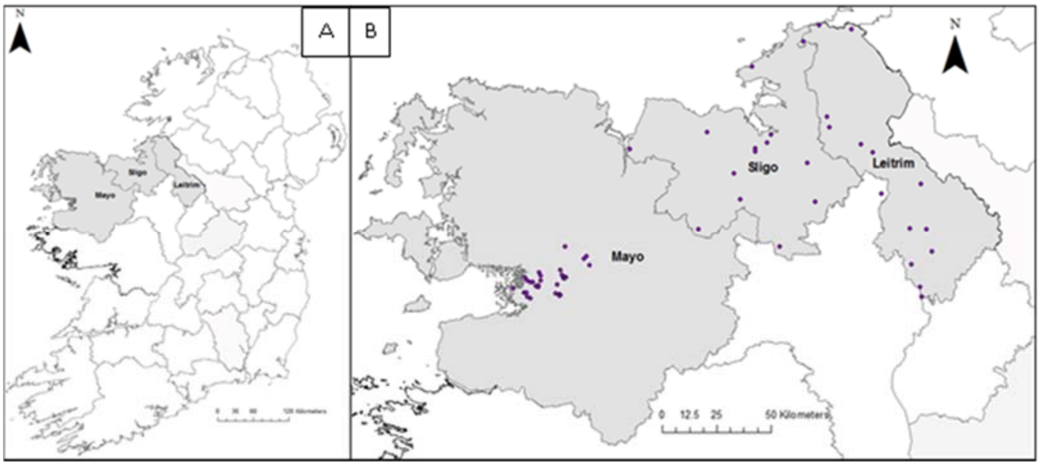

Figure 4.1. (A) Location of study area within Ireland (B) Location of study farms within areas indicated

There are approximately 20,500 farms in this region (grey area Fig. 4.1A), of an estimated 139,860 in the Republic of Ireland (Central Statistics Office, 2012). Average farm size in the region is 24.6 ha UAA compared to a national average of 32.7 ha UAA. The region has a high proportion (130,284 ha) of commonage (where two or more farmers have grazing or turbary rights (Van Rensburg et al., 2009)) and rough grazing (65,654 ha). These represent 31.8% and 15% of the national cover, respectively (Central Statistics Office, 2012). These areas are often composed of mosaics of heath and peatland habitats and contribute greatly to landscape biodiversity. Specialist beef, specialist sheep and mixed livestock grazing are the most frequent farm types in the region (Central Statistics Office, 2012) with 31% of farmers over 65 years compared with 26% nationally (Central Statistics Office, 2012).

4.3.2 Farm management and biodiversity surveys

Fifty-eight farms were surveyed in Co. Mayo in 2011, Co. Sligo in 2012 and Co. Leitrim in 2013. Farm selection was limited to six Electoral Divisions (EDs), the smallest areas for which economic data are available in Ireland. Farms in 2012 and 2013 were spread randomly across counties with the aim of capturing regional variation in farming intensity and habitat cover. Farms were selected through contacts provided by agricultural advisors, cold calling and chain referral sampling (Heckathorn, 2002). Requirements for inclusion in the study were that the farm was actively farmed and contained less than 20% cover of coniferous plantations. 'Actively farmed' can be described as land used for agricultural activity including rearing or growing of agricultural products, where land is kept in a state suitable for grazing or cultivation and is maintained in good agricultural and environmental condition (Department of Agriculture Food and the Marine, 2014b). Farm questionnaires gathered data relating to farm management such as fertiliser use, grassland reseeding, land rental, stocking density and participation in agri-environment schemes.

4.3.3 Farm management and biodiversity surveys

All land within the farm boundary was walked and all habitats were identified. All vascular plants encountered during a structured 'W' walk across each field were recorded (following Sullivan et al, 2010) and abundance was assigned using the DAFOR scale (D = Dominant, A = Abundant, F = Frequent, O = Occasional, R = Rare) (Kent, 2011). Nomenclature of plants followed Hubbard (1992), Parnell and Curtis (2012) and Rose and O'Reilly (2006). Habitats were identified using Fossitt (2000). Rented land was surveyed if it was rented for a minimum of five consecutive years. All farm habitats were then digitised following Heritage Council habitat mapping guidelines (Smith et al., 2011) and these data were analysed using ArcGIS® software v. 10.1 (ESRI, 2011).

4.3.4 Data analysis

Variables relating to farmland habitats such as habitat number, field size, habitat patch size, length of linear habitats and farm fragmentation were calculated. These variables have been shown to affect farm and landscape level diversity (Fahrig, 2003; Krauss et al., 2010; Morelli, 2013; Sullivan et al., 2013). Soil and geology variables were obtained from the EPA and GSI, respectively. Preliminary analysis relating to distribution of habitats and responses to the questionnaire was carried out using SPSS v. 20 (IBM Corp., 2011). Following this, multivariate statistical analysis was undertaken using PC-ORD v. 6 (B McCune and Mefford, 2011). Further details of the statistical analysis applied is provided in Chapter 2.

Outlier analysis identified one outlier farm which had a large farm size and extensive area of commonage. This was removed from further analysis. Principal Components Analysis (PCA) was carried out on the fifty-seven farms and eighteen variables which were measured at farm level and were suitable for analysis (Table 4.1) using a correlation cross-product matrix and displayed as a distance-based biplot. Cluster analysis, a hierarchical analytic method, was performed using the principle components scores for the first four axes identified from PCA to identify groups used to create a typology of the sample farms. Cluster analysis (CA) creates groups of farms based on their homogeneity. Euclidean distance measure and Wards linkage method was used. Shannons Diversity of habitats was extracted from PC-ORD summary tables. A nature value index score was calculated using the index developed by Boyle, Hayes et al. (2015). Fragmentation of the farm was calculated as the number of non-contiguous land parcels managed as one farm.

Table 4.1 Code and explanation of variables used for Principal Components Analysis

Variable	Full explanation of variable
Size (ha)	Farm size (ha)
No fields	Number of fields
LU/haUAA	Livestock units per hectare UAA
Lin tot (m/ha)	Total cover of linear habitats (m/ha)
% imp	Percent improved agricultural grassland cover
Plant spp rich	Plant species richness of farm
Av plant spp rich	Average plant species richness of fields per farm
HNVscore	Nature value index score
Desper	Proportion of farm under designation (ha)
Comaper	Proportion of commonage on farm (ha)
%Wood	Percent woodland cover on farm
Av_field	Average field size
Av_patch	Average patch size
Frag	Number of non-contiguous land parcels of farm
H	Shannon Diversity (H)
S	Number of habitats on farm
Range_el	Elevation range across farm (m)
Max_el	Maximum elevation of farm (m)

4.4 Results

4.3.1 General features of farming in the North West region

The mean size of farms in the study area was 35.29 hectares (ha) (± 26.2 ha) with an average farm size of 32.13 ha corrected for Utilisable Agricultural Area (UAA) (± 25.4). The average number of fields per farm was 13 (± 5.4) with an average field size of 2.5 ha (± 2.0). Nineteen percent of the farms surveyed had shares in commonage, and of these farms commonage made up 27.4% of the total farm area on average. 34.5% of farms had some part of their farm designated as Special Area of Conservation (SAC) or Special Protection Area (SPA). 75.9% of farmers participated in an agri-environmental scheme with 96.5% of farmers producing silage and 46.5% saving hay, 31 farmers made silage only whilst just 2 farmers made hay only. Almost half (44.8%) of farmers undertook grassland reseeding in the five years prior to the commencement of the study with 87.9% of farmers applying artificial fertilisers and 41.4% of farmers considering it necessary to rent additional land to boost farm productivity.

4.3.2 Results of farm typology

Principal Component Analysis

PCA yielded four principal components (PCs) explaining 68.2% of the original variance (Table 4.2). Axis 1 to 4 explained 27.8%, 19.1%, 11.6% and 9.7% of the variation, respectively. The results of the ordination with variables overlaid are shown in Figure 4.2.

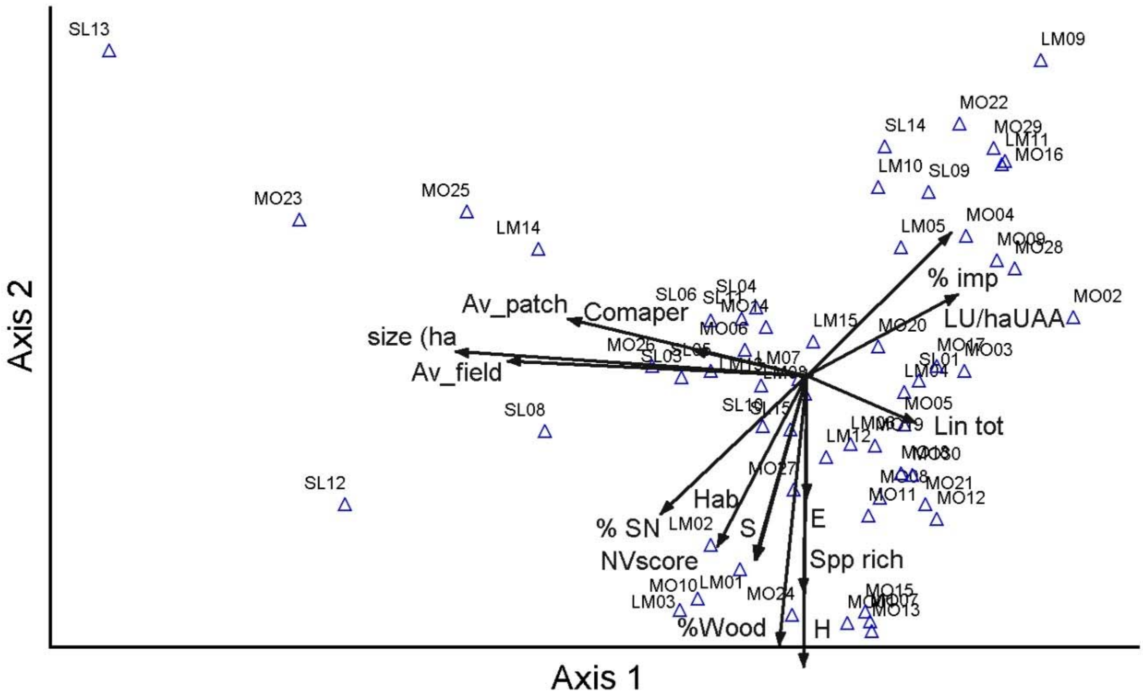

Figure 4.2 Principal Components Analysis ordination with variables overlay (MO –Mayo, SL – Sligo, LM – Leitrim. % imp – proportion improved grassland, LU/haUAA – Livestock Units/ha Utilisable Agricultural Area, Lin tot – Total cover of linear habitats on farm (m/ha), spp rich – Total species richness of farm, H – Shannons Diversity of habitats, % wood – proportion woodland on farm, Hab – number of habitats on farm, NVscore – nature value score, % SN – proportion semi-natural habitat on farm, Av_field – Average field size, Size(ha) – farm size, Av_patch – Average habitat patch size)

Table 4.2 The principal components identified by Principal Components Analysis with significant values for investigative variables highlighted in bold

	1	2	3	4
Farm size (ha)	**-0.38**	0.12	0.23	0.06
Number of fields	0.07	-0.16	**0.33**	-0.05
Livestock units per hectare UAA	0.25	0.22	**0.36**	-0.11
Total cover of linear habitats (m/ha)	0.21	-0.17	-0.27	0.02
Proportion improved agricultural grassland cover	0.25	0.29	**0.33**	-0.01
Plant species richness of farm	-0.04	**-0.42**	0.26	0.01
Average plant species richness of fields per farm	-0.15	0.02	-0.07	**0.49**
Nature value index score	-0.19	**-0.32**	**-0.42**	0.01
Proportion of designated area on farm	-0.12	-0.08	-0.06	0.02
Proportion of commonage on farm	-0.22	0.13	-0.15	**-0.53**
Proportion of woodland on farm	-0.04	**-0.36**	0.03	0.15
Average field size (ha)	**-0.35**	0.10	0.14	**0.34**
Average patch size (ha)	**-0.31**	0.18	0.12	**0.30**
Number of habitats on farm	-0.15	**-0.33**	**0.33**	-0.26
Shannon Diversity of habitats (H)	-0.11	**-0.40**	0.27	-0.11
Number of non-contiguous land parcels of farm	-0.09	-0.06	0.18	0.14
Range of elevation of farm	**-0.39**	0.13	0.02	-0.27
Maximum elevation of farm	**-0.38**	0.15	-0.05	-0.26
Variance	27.78	19.07	11.59	9.75
Eigenvalue	5.00	3.43	2.09	1.75

PC1 appears to relate to farm structure and shows a direct negative relationship with size of a farm, average field size, average patch size, range of elevation and maximum elevation.

PC2 appears to relate to farm biodiversity**.** This factor shows negative relationships with plant species richness per farm, nature value score, proportion of woodland on farm and number of habitats on farm and Shannons diversity of habitats (H').

PC3 appears to relate to farm management intensity and shows positive relationships with number of fields, livestock units per hectare UAA, proportion of improved agricultural grassland on farm and habitat number on farm area of the farm and negative relationships with nature value score.

PC4 appears to relate to farm fragmentation positively related to average field size, average patch size and average species richness of fields, and is negatively correlated with the area of commonage on a farm.

4.3.3 Farm typology

The four factors with Eigenvalues greater than 1.0 (Kaiser, 1960) and accounting for 68.2% of original variance were subjected to Cluster Analysis and yielded four distinct farm types. Table 4.3 summarises the quantitative variables defining each farm type and the frequencies for each response of the qualitative variables, respectively.

Table 4.3 Mean and standard deviation of quantitative and qualitative variables for groups identified in cluster analysis

Group	1 (N=21)	2 (N=16)	3 (N=18)	4 (N=3)
Typology	Extensive farmland	Extensive farmland - threatened	Intensive farmland	Commonage farms
Farm type	Suckler	Suckler	Sheep	Sheep
Geographical setting	Lowland	Lowland	Lowland	Upland
Dominant habitat	Wet grassland	Wet grassland	Improved agricultural grassland	Wet grassland
Dominant soil type	AminPD	AminPD	AminPD	Blanket Peat
Farm size (ha)	40.12 (± 16.65)	28.07 (± 16.18)	21.64 (± 15.76)	96.41 (± 47.02)
Livestock Units/haUAA	0.71 (± 0.4)	1.03 (± 0.5)	1.98 (± 0.7)	0.58 (± 0.3)
Proportion improved agricultural grassland	13.41 (± 9)	27.55 (± 14.6)	58.87 (± 15.5)	10.7 (± 9.2)
Proportion of seminatural habitat	82.89 (± 9.9)	67.83 (± 15.4)	35.91 (± 16.7)	87.03 (± 9.2)
Linear habitat cover (m/ha)	244.96 (± 83.2)	265.78 (± 83.7)	223.88 (± 73)	83.84 (± 29.9)
Number of fields	10.47 (± 2.4)	17.27 (± 5.8)	11.23 (± 4.6)	10.5 (± 1)
Proportion designated area	13.99 (± 30.8)	2.48 (± 7.9)	4.72 (± 11.5)	0.94 (± 1.5)
Proportion commonage	3.23 (± 8.9)	0.72 (± 2.3)	1.35 (± 4.9)	44.8 (± 32.1)
Proportion woodland	8.97 (± 8)	7.72 (± 8)	1.36 (± 2.8)	0.63 (± 0.4)
Average field size	3.72 (± 1.5)	1.55 (± 0.7)	1.68 (± 1.1)	5.23 (± 4.8)
Average habitat patch size	1.58 (± 0.7)	0.89 (± 0.4)	0.99 (± 0.5)	3.24 (± 3.4)
Number of habitats	6.74 (± 2.3)	7.77 (± 1.9)	5 (± 2.1)	7.5 (± 2.4)
Number of non-contiguous land parcels	4.79 (± 2.6)	4.36 (± 3.4)	2.77 (± 1.1)	3.5 (± 1.3)
Nature Value index score	8.06 (± 0.8)	7.27 (± 1.3)	4.45 (± 1.1)	7.68 (± 0.4)
Plant species richness of farm	79.26 (± 18.1)	90.27 (± 13.3)	63.69 (± 12.9)	69 (± 6.5)
Average plant species richness per field	23.64 (± 9.14)	11 (± 7.8)	11.99 (± 8.6)	14.77 (± 8.9)
Shannons diversity (H')	1.22 (± 0.5)	1.43 (± 0.3)	0.93 (± 0.2)	1.07 (± 0.1)

Results show a differentiation largely based on semi-natural habitat cover, livestock units, species richness and cover of linear habitats. Most of the groups were lowland farms dominated by wet grassland while suckler farming was the most common enterprise. Deep poorly drained mineral soils from acidic parent material (AminPD) were the most frequent soil type across the groups.

Group 1 represents extensively managed farms (N=21). These farms have a low mean stocking rate (0.71 LU/ haUAA) and high cover of semi-natural habitat (82.89% of farm area). This group had the highest mean proportion of woodland on farm (8.97%), highest mean proportion of designated area per farm (13.99%) and the highest mean plant species richness per field (23.64). This group had the highest nature value score (8.06) and the highest number of non-contiguous land parcels (4.79).

Group 2 (N=16) has a high cover of semi-natural habitat (67.83%) but has a higher mean stocking density (1.03 Lu/ ha UAA). This group has a lower nature value index score than Group 1 (7.27) and a lower mean plant species richness per field (11) but displays a higher total plant species richness per farm (90.27). The habitat maps produced for members of this group reflected a polarisation effect on these farms.

Group 3 relates to relatively intensively managed farmland (N=18). Livestock density is high and semi-natural habitat cover is low (1.98 LU/ ha UAA and 35.9% semi-natural habitat cover, respectively). This group has the lowest number of habitats (5) and lowest number of non-contiguous land parcels (2.77). Plants species richness of farms is lowest in this group (63.69) and has the lowest nature value index score of groups (4.45).

Group 4 relates to farms which use extensive areas of commonage (N=3). Livestock units (0.58 LU/ ha UAA) and improved agricultural grassland cover (10.7%) is low in these farms due the extensive areas of commonage which is generally dominated by semi-natural habitat. The mean proportion of commonage associated with this group is 44.8% and linear habitat cover is low as a result of the large commonage cover (83.84 m/ha). The mean nature value score of this group is 7.68 and mean plant species richness of farms is 69. Examples of farms habitat distribution from each group are given (Figure 4.3) highlighting the major differences in land cover between different farm types.

The example farm for Group 1 is dominated by wet grassland. Other habitats present on this farm are wet heath, lowland blanket bog and scrub. The example of Group 2 farms has a number of improved agricultural grasslands surrounding the homestead (coloured grey, identified as built/artificial surfaces). This farm still has a number of semi-natural habitats, most of which are located towards the outer edge of the farm boundary. This is an example of the effects of farm polarisation. Group 3 farm example is dominated by improved agricultural grassland with small pockets of semi-natural habitat. Finally, the example of Group 4 farms has a large proportion of upland blanket bog which is still actively used for sheep grazing.

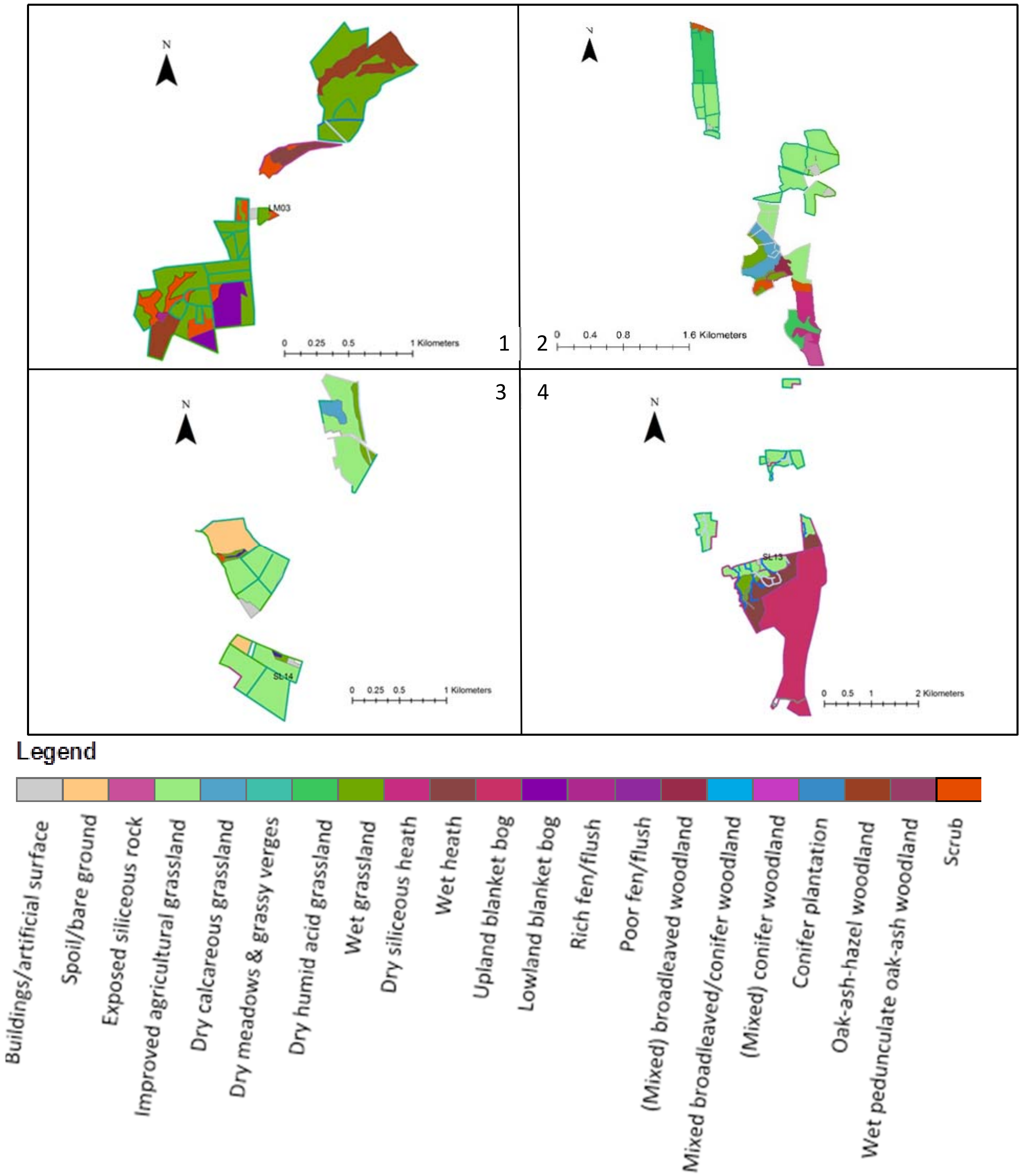

Figure 4.3 Examples of farms from groups 1, 2, 3 and 4.

4.5 Discussion

The results from this study have identified four farming types present in a HNV region based on habitat and management factors. Differentiations between land use intensity which impacted on farmland diversity were identified. The results show a range in stocking density from those associated with low intensity management (< 1 LU/ ha UAA) (Andersen et al., 2003) through to those which do not support high levels of farmland biodiversity (>1.5 LU/ ha UAA). Threats to farmland biodiversity including abandonment and polarisation of farm management are shown in the typology and are particularly evident in habitat maps produced for Group 2. This group may currently be considered extensive HNV farmland based on its semi-natural habitat cover. However, the semi-natural habitats on these farms exist on the periphery of the farm. As a result the semi-natural habitats are threatened by abandonment whilst land closer to the homestead is used more intensively. If this polarisation continues, the quality and benefits to biodiversity of the semi-natural habitats is at risk of being lost.

Polarisation of farms, where intensively managed land is further improved and intensified alongside abandonment of less productive, extensively managed land, is becoming increasingly common (Lomba et al., 2014). Polarisation results in the loss of semi-natural habitat quality to improved grassland where possible and partial or complete abandonment in economically unproductive parts of farms. This is particularly important to monitor in HNV regions as these are areas most susceptible to and most affected by polarisation (IEEP and Alterra, 2010). Polarisation of farmland not only impacts on the biodiversity levels of farmland but can also contribute to the loss of soil carbon and a decrease in water quality. The main measures needed to mitigate this problem includes regionally targeting policy measures and giving greater supports to extensive farming systems (IEEP and Alterra, 2010). Developing typologies such as the one described in this paper highlights those farms which require specific targets to reverse the effects of polarisation.

Within the EU, a number of studies have identified different HNV farmland typologies. A report on the development of a HNV indicator (Andersen et al., 2003b) describe three main types of HNV farmland. Type 1 HNV is described as being dominated by semi-natural vegetation. The typology developed in this study reflects a number of subtypes within HNV Type 1 farms dominated by semi-natural habitat. The low intensity farm groups identified within the typology, Groups 1, 2 and 4 are dominated by semi-natural habitat (i.e. greater than 50 % semi-natural habitat cover). It is interesting to note that there does not appear to be a Type 2 group present within the north-west of Ireland. Type 2 HNV farmland represents farmland that is composed of a mosaic of habitats, including cropped areas, and small landscape features (Andersen et al., 2003b). Crop production is not common within this region but may be more important in Eastern regions of the country where crop production is more frequent.

Focusing on the formal definitions of HNV farmland into types 1-3 may be restrictive in characterising farming systems, it is more appropriate to consider the groups within this typology using the Keenleyside et al (2014) description of HNV farmland. Groups such as 1 and 3 represent whole farm HNV, dominated by semi-natural habitats with high cover of linear habitats and in the case of Group 3, having a high proportion of land owned as commonage. Group 2 may be more similar to partial HNV where semi-natural habitat is still dominant but management intensity has increased (as evidenced from the stocking rates). These farms are ultimately at risk of losing their biodiversity value through intensification or abandonment if appropriate supports for the biodiversity and ecosystem services of farms are not provided (NPBR, 2012). In this study there does not appear to be a representative of remnant HNV groups where semi-natural habitat cover is reduced and farm management practices are intensive.

The typology presented in this paper also describes a relatively more intensive managed group. Farming systems such as those within Group 3 are important to characterise within a HNV region as it reflects the spectrum of farming intensities which contribute to a heterogeneous, highly bio-diverse landscape. It is important to note that these, farms, while more intensively farmed in the context of the survey region are not likely to be considered high intensity on a national or EU scale. It is also important to note that these “intensive” farms may continue to support species of conservation concern and could be categorised as Type 3 or remnant HNV farmland. However, this study was habitat focused and no species of conservation concern, i.e. species listed in Annex II of the Habitats Directive 92/43 EEC, were recorded on the more intensively managed farms.

The typology described in this study reflects a diverse landscape which supports a diversity of farming types. A number of studies have recommended that greater understanding of the biodiversity of agricultural landscapes alongside measures and policies designed and implemented at regional level is desirable for the protection and enhancement of farmland diversity (Bartolini and Brunori, 2014; Luick et al., 2013; Signorotti et al., 2013). In particular, reference to whole and partial HNV systems, a combination of direct payments, environmentally coupled payments and capacity building support has been recommended to prevent abandonment or intensification in these types of areas (Keenleyside et al., 2014). Additionally they recommend that, at a regional level, continued research and monitoring of HNV landscapes is essential for targeting supports and evaluating their impacts on HNV farmland (Andersen et al., 2003b; Keenleyside et al., 2014).

Agri-environmental schemes (AESs) implemented under the Common Agricultural Policy (CAP) have not always benefited biodiversity due to their broad nature and lack of understanding of various farming types (Feehan et al., 2005; MacDonald et al., 2000; Ribeiro et al., 2014). AESs have often aimed at mitigating the impacts of more intensive farming practices or designed for farms with small proportions of semi-natural vegetation (i.e. remnant HNV) by implementing measures such as installing bird and bat boxes, providing piped water sources for animals and establishing arable margins (Department of Agriculture Fisheries and Food, 2013; Department of Agriculture Food and the Marine, 2012; Feehan et al., 2005). Targeting AES to specific measures for supporting on farm species and habitat diversity (Feehan et al., 2005; Sutherland, 2002; Whittingham et al., 2007) would benefit HNV farms.

Landscape heterogeneity is variation in habitat types across the landscape. This is desirable as it increases species diversity and composition by providing habitat connectivity networks and refuges (Weibull and Östman, 2003). The need to adjust agri-environmental schemes regionally to maximise biodiversity benefits was highlighted in a study on the effects of CAP reform in southern Portugal (Ribeiro et al., 2014). For example in Ireland, support payments under the Agri-Environment Options Scheme (AEOS) (Department of Agriculture Food and the Marine, 2012) limits the area of plant species-rich grassland for which an applicant can receive support (Department of Agriculture Food and the Marine, 2012). Measures such as this favour farms where intensive habitats are dominant. Improved measures supporting marginal or low productivity farms, such as those in Group 1, 2 and 4 in this study, are needed to protect HNV farmland. By developing a typology of farming in a HNV region the baseline information on farming types within a landscape are provided. This information can be used in the development of future AESs by highlighting what supports are needed to maintain and enhance HNV farming systems.

Recently, there has been an increasing interest in the potential of results based agri-environment schemes (McGurn and Moran, 2013; Reed et al., 2014). Such schemes are based specifically on the environmental service deliverables which ensures that targets for biodiversity protection and management are met. Further to this, spatial targeting of such payments is being increasingly supported. Though spatial targeting may be more complex in application, it is considered to be more efficient economically than blanket AESs (Reed et al., 2014). By targeting extensive farming systems, identified within a typology, and by implementing measures that are regionally and scientifically appropriate for the maintenance and enhancement of biodiversity at farm level, a year-on-year biodiversity or sustainability score for farms could be calculated on which support payments could be based (Underwood, 2014).

Within the context of informing new AESs, the categories outlined in this study could be used for the targeting of specific measures to maintain and enhance farmland biodiversity. Group 4 relates to commonage farms. Maintenance of biodiversity on farms with extensive commonage requires cooperation amongst farmers. Targeting supports for the development of co-operative management regimes or local forums for farms within this category could promote and encourage agriculturally and environmentally positive management of commonage farms (Van Rensburg et al., 2009). Such co-operative measures could be encompassed within locally-led schemes which are included within the most recent Rural Development Programme (2014-2020). Cooperative based schemes have been shown to be successful by letting farmers take the lead in conservation effort. This is largely driven by empowering the farming community to feel confident in the fact that they know how best to manage their resources rather than being controlled by national level policies. Additionally, it has been shown that farmers involved in agri-environmental schemes were more likely to participate in co-operative management schemes (Di Falco and van Rensburg, 2008). This may be a side-effect of increased environmental education and awareness and could be beneficial by developing locally-led schemes within the structure of an agri-environment scheme. Cooperative management schemes require core members who can lead and enthuse other participants in order to successfully implement such schemes and achieve the aims and targets of such schemes. Additionally, it is recommended that these schemes should be results based to increase incentives for cooperation between all interested parties in order to receive full support payments. Group 1 farms are extensively managed at present. These farms are associated with part-time or retired famers and a high cover of heath/peatland habitats. This category relates to whole farm HNV systems and would benefit from direct targeting of agricultural supports.

Group 2 farms relate to partial farm HNV systems. The farms have been intensified where possible with the remaining semi-natural habitat existing as a result of constraints within the natural environment. Farms in this category are being under or over managed and are at risk of losing their HNV status. Targeting of supports which incentivise sustainable management of the semi-natural habitat areas would prevent abandonment and potentially increase the productivity of the seemingly unproductive, marginal areas on farms. For example, incentives to graze under wooded areas rather than excluding animals from grazing in these areas would prevent abandonment and scrub encroachment in these areas whilst maintaining species and habitat diversity. A dual support system of direct payments for maintaining low intensity farming practices and payment for results from measures for habitat or species management or restoration would make whole and partial HNV systems viable into the future.

Category 3 farms may continue to benefit from current AES prescriptions as discussed previously. Farms within this category should not be excluded from application to future AES or from targeted results based schemes based on their inclusion in this category. Even intensive farms may contribute to HNV landscapes by contributing to landscape heterogeneity and providing niches for particular species of conservation concern associated with more intensive farmland e.g. Type 3 HNV farms.

Studies describing regional farming typologies, as described in this paper, alongside a measure of quality would be particularly useful in implementing spatially targeted results based scheme by providing baseline data and highlighting areas which are vulnerable and require specific supports. By taking account of typologies as described in this paper and others across the EU (O'Rourke et al., 2012; Ribeiro et al., 2014; Sutkowska et al., 2013), more environmentally and economically sustainable policies can be developed.

4.6 Conclusion

This study has described a typology of a High Nature Value region of the northern Atlantic. Knowledge of the farming systems present in this region and their associated biodiversity values can inform future agri-environmental policies and supports. There is a need for targeted supports of low intensity, high biodiversity farms. Currently these farms are not supported by agri-environment schemes which are often designed with remnant HNV areas or more intensive farm types in mind. This is of increasing importance as the focus of agri-supports such as CAP turn towards maintaining ecosystem services and biodiversity levels associated with HNV areas. The typology described reflects the continuum of farmland known to relate to HNV landscapes across pastoral farming systems in North Western Ireland. The application of Keenlyeside et al (2014) description of whole, partial and remnant HNV groups has shown that concerns for extensive farmland at an EU level (i.e. intensification, abandonment and afforestation) are very real at an Irish regional scale. Increased knowledge and understanding of these areas in Ireland and other regions of the EU will allow for the development of more targeted measures, which will be more beneficial environmentally and economically in the future.

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Chapter 5. What are the vegetation groupings on High Nature Value farmland in an Atlantic region of Europe and can we relate grassland habitat quality to the overall farm nature value?

(Prepared for submission to Journal of Vegetation Science)

5.1 Abstract

Questions: What vegetation groupings occur in a High Nature Value farmland landscape? Can we describe the floristic quality of fields within these groups for use in monitoring HNV farmland habitat quality? Does the floristic quality link to the nature value of the farm?

Location: A High Nature Value farmland region in Counties Mayo, Sligo and Leitrim in north-west Ireland.

Methods: The occurrence and abundance of vascular plant species were recorded across fields on 60 farms within the study region. Classification and ordination techniques were used to identify distinct plant groups. Habitat quality of the grassland dominated vegetation groups in particular was assessed based on indicator species for High Nature Value grassland.

Results: Non-metric multidimensional scaling revealed a vegetation continuum across sites. Cluster analysis, indicator species analysis and multi response permutation procedure suggest four groups: wet semi-natural grassland, semi-improved grassland, other semi-natural grassland and peat/heathland semi-natural habitats. Ellenberg moisture levels and plant diversity of fields were influential variables in the ordination of species data. Farm scale variables indicate a continuum from intensive management practices to extensive across the groups. The field level quality score reflects the continuum across habitat management intensities; with the highest scores in the semi-natural habitat groups. This field score within farm is correlated with the overall nature value score of farms.

Conclusions: These groups can be used to identify the fields which require targeted supports for the maintenance of high plant diversity. Additionally, the relationship between field quality score and the farm nature value score means that while nature value scores can be used to indicate the HNV potential of a farm the grassland quality scores could be used to monitor these farms to ascertain whether objectives under agri-environment schemes are met as required by the Common Agriculture Policy.

5.2 Introduction

Intensification of agricultural land through nutrient application, drainage, increased stocking density and expansion of field sizes has led to a decline in semi-natural habitats and farmland diversity across Europe since the end of the Second World War (Benton et al., 2003; Boatman et al., 2007; Henle et al., 2008; Stoate et al., 2001). In response to this, increasing significance in recent years has been placed on sustainable agriculture across Europe (Buckwell et al., 2014; European Commission, 2013b). Since the 1990's, changes in the Common Agricultural Policy (CAP) (through the MacSharry reforms, Agenda 2000 and most recently 'Greening of the CAP'(Ackrill, 2000)) have attempted to address the decline in farmland biodiversity. This has been done mainly by incorporating concepts relating to sustainable agriculture into policy, particularly through rural development programmes and agri-environmental schemes (European Commission, 2013b).

Under both Pillars I and II of the CAP, the presence and extent of High Nature Value farmland has been considered an indicator of biodiversity and environmental quality (Bartolini and Brunori, 2014). High Nature Value (HNV) farmland can be described as low intensity agricultural systems associated with high species and/or habitat diversity (Andersen et al., 2003b). HNV farmland can be described in terms of whole farm, partial and remnant HNV (Keenleyside et al., 2014). Whole farm HNV is where the majority of farm is under low-intensity management; partial HNV systems occur where the farm, as a business, carries out low intensity management of some land alongside more intensively managed areas. Finally, remnant HNV occurs where high nature value features (e.g. woodland or species-rich grassland) occur on a farm which is focused on intensive production. These HNV features often only persist due to AE scheme requirements or conservation designations and are not integral to the farm system (Keenleyside et al., 2014). HNV farms contribute to the sustainable agriculture objectives across Europe by providing environmental goods such as species-rich habitats, clean water, carbon sequestration and flood mitigation (Oppermann et al., 2012). In addition, a primary feature of HNV farmland is the significant cover of semi-natural habitats. While there have been many several attempts to map HNV farmland across Europe (Pointereau et al., 2007; Samoy et al., 2007) there has been less emphasis on how to measure the quality of the habitats on these HNV farms.

The presence of semi-natural habitats contributes greatly to the biodiversity of farmland (Petit and Firbank, 2006; Stoate et al., 2009). To fully appreciate the contribution of a farm to biodiversity, an understanding of the composition and diversity of plant groups present on the farm is key. Studies of plant community composition and how it is affected by agricultural management have been undertaken on semi-natural habitats, most commonly grassland studies, across

Europe (Austrheim et al., 1999; Feehan et al., 2005; Stoate et al., 2009). These studies highlight the importance of preserving extensive management practices to maintain semi-natural habitats on farms and the diversity this supports, for example in Norway extensive farming has maintained sub-alpine semi-natural grasslands that would have otherwise undergone succession to forest (Austrheim et al., 1999).

In Ireland, semi-natural habitats associated with farmland are being lost as management practices change (Sheridan et al., 2011). Approximately 60% of Ireland is covered by grassland, most of which is associated with agriculture (Department of the Environment Heritage and Local Government, 2007). From 1990 to 2000, arable and permanent grassland cover increased by 30% whilst pastures and mixed farmland, natural grasslands and heathland and wetlands decreased (Environmental Protection Agency, 2006). As agricultural practices intensify, the proportion of semi-natural grasslands contributing to this cover is being steadily reduced. The Irish Semi-natural Grasslands survey (ISGS) (O'Neill et al., 2013) was carried out between 2007 and 2012 across the Republic of Ireland. This survey has provided baseline information on the current status of semi-natural grasslands in Ireland and also identified a number of species which are considered indicators of HNV grassland. It has highlighted plant communities which are at risk and require greater consideration in developing agri-environmental policy (O'Neill et al., 2013). In particular grassland habitats described under Annex I of the Habitats Directive (Council of the European Communities 1992) including *Nardus* grassland (*Nardus stricta – Festuca ovina* grassland), *Molinia* meadows (*Molinia caerulea – Succisa pratensis* grassland) and Lowland hay meadows (*Festuca rubra – Rhinanthus minor* grassland) are at risk and 38% of lowland semi-natural grassland sites recorded in the 1970s no longer existed in 1996 (O'Neill et al., 2013).

Soil nutrient inputs, in particular, have been found to have a negative impact on plant species richness and composition whilst increasing slope has been found to have a positive relationship with species numbers and composition (Marini et al., 2007). In semi-natural alpine agricultural meadows slope, soil moisture, soil nutrient level and soil pH have been found to affect the composition of plant communities (Gusmeroli et al., 2013). Identifying management and environmental factors associated with plant composition of farmland habitats can aid in the identification of negative and positive influencers on biodiversity and can inform development of agricultural policies which support biodiversity conservation (McMahon et al., 2012).

Unlike the ISGS, which targeted semi-natural grasslands only, this research investigates all vegetation types occurring on farmland in a HNV region. To date, there have been very few studies on the plant species composition of farmland in HNV regions in Ireland and those which have been carried out have focused specifically on semi-natural grasslands (O Donovan, 2007; O'Neill et al., 2013). Additionally, across Ireland most vegetation studies have been carried out at a fine scale using quadrat studies. A whole farm approach, which has been lacking in previous studies, allows greater scope for assessment of the relative importance of different vegetation groups to overall farm biodiversity, thus facilitating improved targeting of biodiversity enhancement measures. We studied vascular plant diversity and composition on all farmland habitats at field-scale to address the following questions in the context of HNV farmland: (i) what are the vegetation groups associated with farmland in this region?; (ii) can we assess the floristic quality of the vegetation in the fields?; and (iii) does the floristic quality of vegetation relate to the nature value of the whole farm?

We present the vegetation groupings of HNV farmland and analyse potential factors influencing them. We then identify groups of conservation concern in this region. We also investigate the development of a quality score for fields and its potential use for monitoring HNV farmland. The methodology used in this paper can be used in other EU Member States to develop a similar field quality score for farmland within a HNV region. We also discuss policy mechanisms that could support these grasslands such as results-based agri-environmental schemes.

5.3 Materials & Method

5.3.1 Study area

Study farms were situated in a region identified as an area with high potential cover of HNV farmland (European Environment Agency, 2009); 30 farms were surveyed in Co. Mayo, 15 in Co. Sligo and 15 in Co. Leitrim (Figure 5.1). This region of Ireland has mean temperatures lower than the national average (average daily temp. 9.6 °C) and high levels of rainfall (mean 1142 mm per year) (Walsh, 2012). The dominant bedrock is limestone and calcareous shale and the dominant soil type in the region is poorly drained non-calcareous mineral soils. The most frequent landcover types are pasture and heterogeneous agricultural areas (Environmental Protection Agency, 2015). To investigate vegetation types associated with a High Nature Value (HNV) farmland region, vascular plant presence and abundance were recorded across 778 fields from 60 farms in north-west Ireland between the months of June-September, 2011-2013

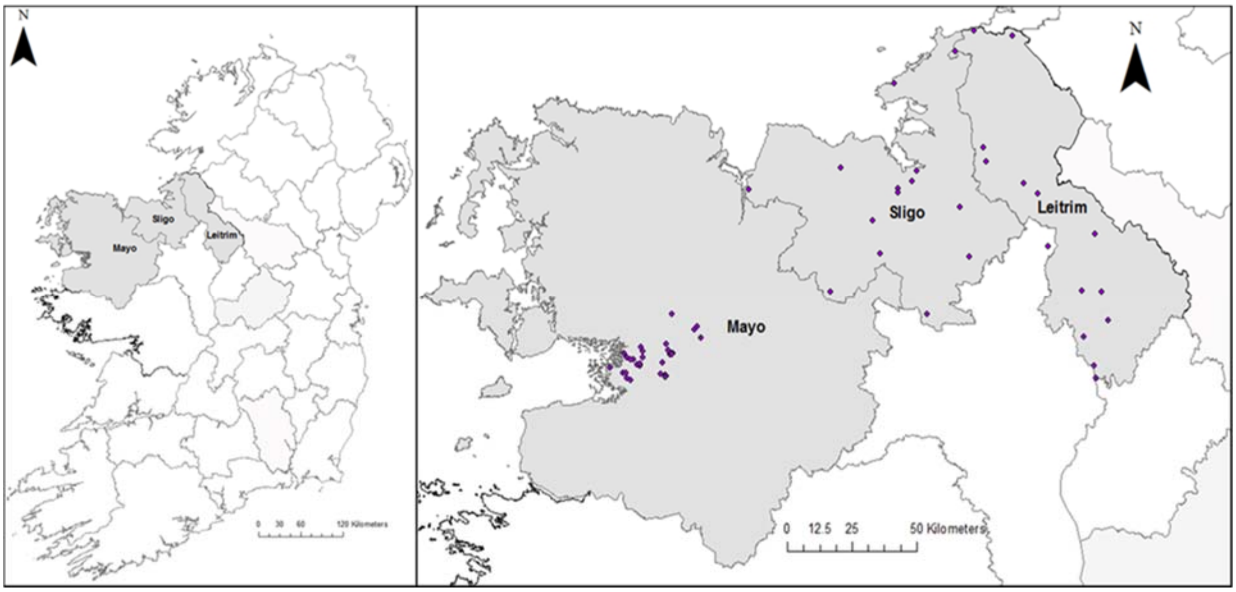

Figure 5.1 Location of study area in the north-west of Ireland and location of study sites in Counties Mayo, Sligo, Leitrim in North-West Ireland

5.3.2 Field work

Farms were surveyed in Mayo in year one, Sligo in year two and Leitrim in year three. Farms selection was limited to six Electoral Divisions (EDs), the smallest areas for which economic data is available in Ireland, in year one. This was done to develop an information baseline for more detailed studies on the relationship between HNV status of farms and plants and invertebrate biodiversity within a larger study (Boyle, Hayes et al. 2015; Hayes et al. 2015). Farms in years two and three were spread across counties with the aim of capturing the regional variation in soils, farm management and habitats. Farms were sourced through cold calling, chain referral sampling (Heckathorn, 2002) and support from agricultural advisors. Only active farms with less than 20% coniferous plantation cover were considered for study. An active farm was defined as land used for agricultural activity including rearing or growing of agricultural products, where land is kept in a state suitable for grazing or cultivation and is maintained in good agricultural and environmental condition (Department of Agriculture Food and the Marine, 2014a).

Farm boundaries were digitised using ArcGIS® software v. 10.1 (ESRI, 2011) as indicated on Single Farm Payment Scheme maps provided by farmers. A structured 'W' walk was carried out across each field within a farm unit recording all vascular plants encountered (following Sullivan et al. 2010). Rented land was surveyed if it was rented for a minimum of five continuous years. All vascular plants recorded were assigned abundance scores following the DAFOR scale (D = Dominant, A = Abundant, F = Frequent, O = Occasional, R = Rare) (Kent, 2011). Commonage was not surveyed in this study. As a result it should be noted that heath and peatland habitats, the main contributors to commonage habitat in this region, and their associated plant species are underestimated. Information regarding commonage in the study area is available from the National Parks and Wildlife Service (NPWS) on request.

5.3.3 Data analysis

Data were collected from 778 fields and 225 plant species were recorded. Following preliminary analysis of the data, fields where more than one habitat was recorded within the field boundaries were removed. These fields were most frequently semi-natural grassland habitats with areas of scrub or woodland or fields dominated by improved agricultural grassland but which had semi-natural grassland or peatland areas within the field boundary. This reduced the dataset to 525 fields and increased the homogeneity if the data which has the benefit of increasing the accuracy and reliability of the statistical analysis. Outlier analysis was carried out on field and plant data using PC-ORD version 6 (B McCune and Mefford, 2011). Twenty-nine fields were identified as outliers and removed. This resulted in a final dataset of 496 fields with 213 plant species for analysis. Six plant species were identified as outliers. These were frequently occurring species which are likely to be representative of the population and so were retained in the dataset (Osborne and Overbay, 2004).

The relationship between fields in terms of their species composition was examined using non-metric multidimensional scaling (NMS). This analysis avoids assumptions of linearity among variables and can be used with distance measures suited to non-normally distributed data (McCune and Grace, 2002). Sørensen (Bray-Curtis) distance measure was used because the data are zero rich and heterogeneous. Initial autopilot run of the data was used to identify the number of axes which should be interpreted. Randomisation of the data with a Monte Carlo test was used to assess whether the NMS ordination axes had lower stress than expected by chance. A final stress below 20% is considered suitable for interpretation of ecological data. A final instability of 10^{-4} or less is considered acceptable (McCune & Grace 2002). A second matrix of explanatory variables i.e. species diversity indices, Ellenberg values for light, pH, moisture and nitrogen was used to help interpret the ordination results.

Cluster analysis (CA) was carried out to identify vegetation groupings within this HNV landscape. Flexible beta sorting (β = -0.25) was used providing a space conserving method (McCune & Grace 2002). This prevents significant distortion of the space between fields when forming new groups. Selecting the number of groups to interpret requires compromise between homogeneity of groups and using minimal number of groups. In order to verify groups two methods were used in this study: (1) indicator species analysis was used to identify the grouping with the lowest average p value and highest number of significant indicators (Dufrene and Legendre, 1997); (2) a multi-response permutation procedure (MRPP) was used to assess within-group homogeneity.

MRPP can be used to validate the number of groups identified in the cluster analysis as it provides a measure of chance-corrected within-group agreement (*A* value), which is independent of sample size, and a T-value (McCune & Grace 2002). An *A* value of greater than 0.1 is considered high for community ecology data (McCune and Grace, 2002).The latter is the difference between the observed and expected within-group distances divided by the square root of the variance in the expected within-group distance. The change in A- and T- values for each cluster is used as a measure of the effect on within-group homogeneity and between-group separation from adding an additional group (Robbins and Matthews, 2009). Indicator species analysis (ISA) was also used to identify indicator species within groups. ISA constructs indicator values for each species in each group and tests for statistical significance using the Monte Carlo test. A threshold level of indicator value with 95% significance (p value ≤ 0.05) with an observed Indicator Value (IV) of 25 or greater was chosen as a cut-off for identifying indicator species within groups (Dufrene & Legendre 1997).

The Irish Semi-natural Grasslands Survey (ISGS) compiled a list of indicator plant species for High Nature Value grasslands (Table 5.1). This list was used to assess the habitat quality of the grasslands in this study. A subset of the whole dataset contained these species. This subset was extracted from the main dataset and Shannon’s diversity index was calculated for each field. We selected Shannon’s diversity index as it takes into account species abundance and evenness but also downweighs the presence of rare species (Magurran, 2004). As this score was based on the presence as well as abundance of the HNV grassland indicator species, some fields received a score of 0. The quality scores within groups identified from the cluster analysis were examined to see whether the clusters related to increasing quality and diversity. The quality score was also compared to a farms nature value score (Boyle, Hayes et al. 2015) to assess the suitability of the field quality score as a measure of total on farm biodiversity levels. Further details on the statistical tests applied to the data is provided in Chapter 2.

Table 5.1 High Nature Value plant species identified by the Irish Semi-natural Grasslands Survey 2007-2012 (O'Neill et al 2013). Species identified in this study given in bold

Vascular plant species	Vascular plant species	Vascular plant species	Vascular plant species
Achillea ptarmica	***Cirsium dissectum***	***Juncus articulatus***	*Pimpinella major*
Agrostis capillaris	*Coeloglossum viride*	***Juncus conglomeratus***	***Plantago lanceolata***
Alchemilla glabra	***Conopodium majus***	*Knautia arvensis*	***Platanthera bifolia***
Alopecurus pratensis	***Crepis capillaris***	*Koeleria macrantha*	*Platanthera cholrantha*
Anacamptis pyramidalis	***Crepis paludosa***	*Lathyrus linifolius*	***Polygala serpyllifolia***
Antennaria dioica	***Dactylorhiza fuchsii***	*Lathyrus palustris*	*Potentilla anglica*
Anthoxanthum odoratum	***Dactylorhiza maculata***	***Lathyrus pratensis***	***Potentilla erecta***
Anthyllis vulneraria	***Danthonia decumbens***	***Leontodon autumnalis***	***Potentilla palustris***
Arabis hirsuta	***Daucus carota***	*Leontodon hispidus*	*Primula veris*
Asperula cyanchica	*Epipactis palustris*	*Leontodon saxatilis*	***Primula vulgaris***
Blackstonia perfoliata	***Equisetum palustre***	***Leucanthemum vulgare***	***Prunella vulgaris***
Brachypodium pinnatum	***Euphrasia*** **spp.**	***Linum catharticum***	*Pseudorchis albida*
Briza media	***Festuca ovina***	***Listera ovata***	***Ranunculus acris***
Bromopsis erecta	***Filipendula ulmaria***	***Lotus corniculatus***	***Ranunculus bulbosus***
Bromus racemosus	*Filipendula vulgaris*	***Lotus pedunculatus***	***Ranunculus flammula***
Caltha palustris	***Galium palustre***	***Luzula campestris***	***Rhinanthus minor***
Campanula rotundifolia	***Galium saxatile***	***Luzula multiflora***	*Sanguisorba minor*
Carex binervis	*Galium uliginosum*	***Lychnis flos-cuculi***	*Sanguisorba officinalis*
Carex caryophyllea	***Galium verum***	***Lysimachia nemorum***	*Sesleria caerulea*
Carex echinata	*Gentiana verna*	***Mentha aquatica***	***Succisa pratensis***
Carex flacca	*Gentianella amarella*	***Molinia caerulea***	***Thymus polytrichus***
Carex nigra	*Gentianella campestris*	***Nardus stricta***	*Tragopogon pratensis*
Carex panicea	*Geranium sanguineum*	*Neotinea maculata*	***Trifolium pratense***
Carex pilulifera	*Gymnadenia conopsea*	*Ophioglossum vulgatum*	*Trisetum flavescens*
Carex pulicaris	*Helictotrichon pubescens*	*Ophrys apifera*	***Veronica officinalis***
Carex viridula	***Heracleum sphondylium***	*Ophrys insectifera*	***Vicia cracca***
Carlina vulgaris	*Hordeum secalinum*	***Orchis mascula***	***Viola canina***
Carum verticillatum	***Hydrocotyle vulgaris***	*Orchis morio*	*Viola palustris*
Centaurea nigra	***Hypochaeris radicata***	*Origanum vuulgare*	*Viola persicifolia*
Centaurea scabiosa	***Juncus acutiflorus***	***Pilosella officinarum***	*Viola riviniana*

5.4Results

A total of 225 plant species were recorded across 778 fields covering a total of 1853.3 ha. *Holcus lanatus* has the highest frequency, occurring on 95% of sites. Three other species occur with a frequency >80%: *Juncus effusus* (87%), *Trifolium repens* (86%) and *Ranunculus repens* (83%). These are species frequently found in wet grassland. A full list of species recorded and their percentage frequency (the percentage of sites containing that species) is provided in Appendix D. *Lolium perenne* was occurred often (78%), followed by *Trifolium pratense* (77%), *Cynosurus cristatus* (75%), *Agrostis capillaris* (75%), *Anthoxanthum odoratum* (72%) and *Bellis perrenis* (71%). 164 species occurred in < 5% of fields. These species related to habitats such as salt marsh and woodland that occurred infrequently on farmland and included species such as *Glaux maritima* (0.1%) and *Lonicera periclymenum* (1.3%), non-native species including *Gunnera tinctoria* (0.1%) or uncommon species including *Daboecia cantabrica* (0.4%) and *Saxifraga hypnoides* (0.3%).

A total of 253 fields were removed as they contained more than one habitat, to reduce instability and noise in the data. Of these fields 97 (38%) had a mixture of wet semi-natural grassland and other grassland (improved agricultural grassland or other semi-natural grassland e.g. acid grassland) within the field boundary, 93 (37%) contained a mixture of scrub and grassland, 35 (14%) had a mixture of grassland and heath/peatland and 28 (11%) contained a mixture of grassland and woodland. Outlier analysis identified twenty-nine fields which were removed from further analysis. NMS ordination of 496 fields and 213 plant species resulted in a final stress of 17.84% and final instability of 0.04 for three dimensions ($p = 0.0196$) and a 3-dimensional ordination was recommended (Figure 5.2).

A second matrix of field level explanatory variables was overlaid on the NMS to help explain the distribution of field points in the main matrix. Ellenberg moisture (F), plant species richness (S), evenness (E) and Shannon's diversity (H) were positively correlated with axis 1 whilst Ellenberg reaction (R), which reflects soil pH, and Ellenberg nitrogen (N) were negatively correlated (Table 5.2). Ellenberg moisture (F) was positively correlated with axis 2 and Ellenberg light was negatively correlated with axis 3.

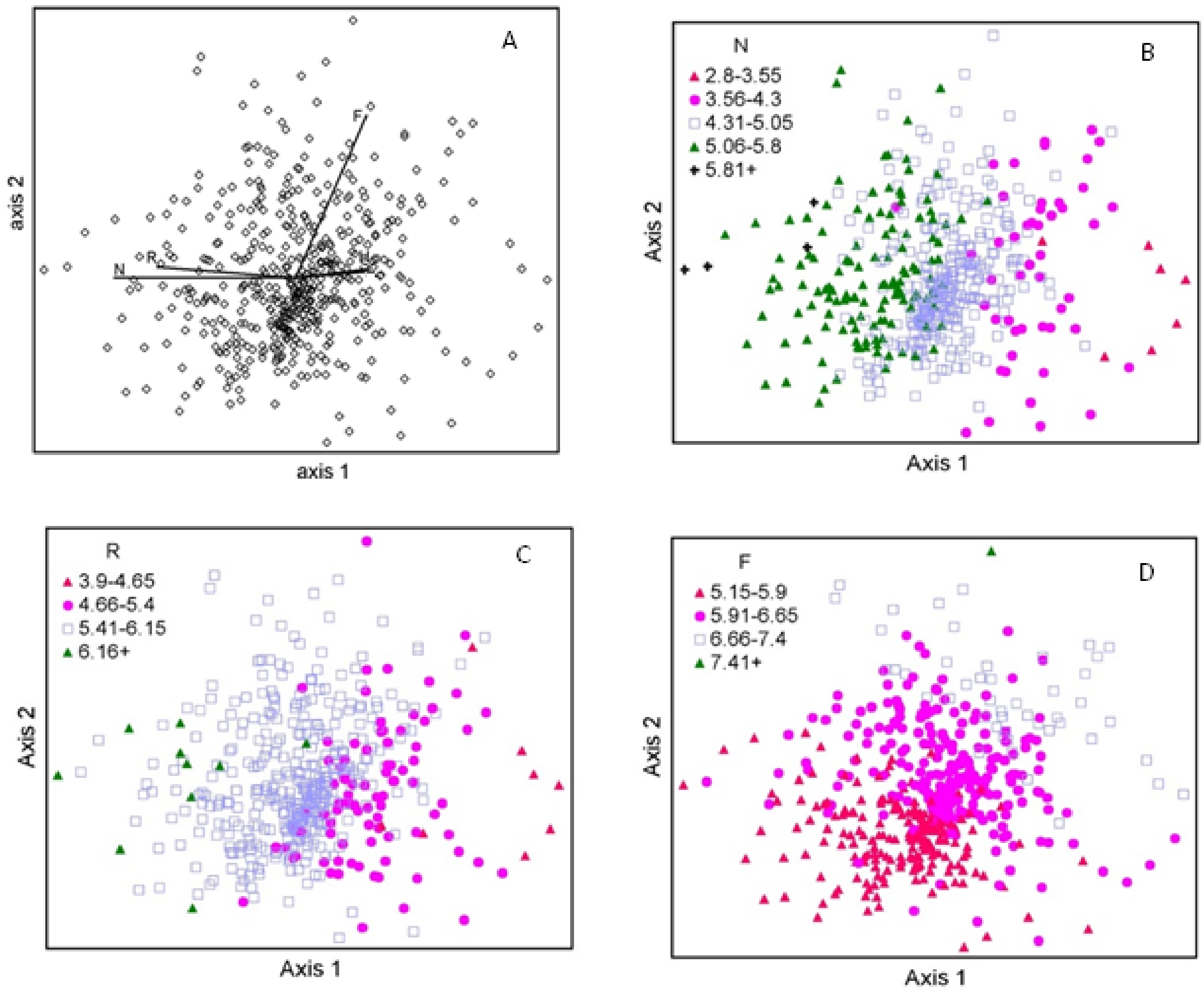

Figure 5.2 Non-metric multidimensional scaling ordination of fields showing overlays of (A) all environmental variable vectors, N - Ellenberg Nitrogen, R - Ellenberg Reaction, F – Ellenberg Moisture H – Shannon's Diversity of plant species, (B) Ellenberg Nitrogen, (C) Ellenberg Reaction and (D) Ellenberg Moisture.

Table 5.2 Field size, Ellenberg scores and diversity scores for fields used in second matrix and correlations with axis from NMS

Axis:	1	2	3
Variable	r	r	R
Area (ha)	0.06	0.04	0.07
Ellenberg Light (L)	-0.26	-0.10	**-0.37**
Ellenberg Moisture (F)	**0.53**	**0.79**	0.19
Ellenberg Reaction (R)	**-0.74**	0.21	-0.18
Ellenberg Nitrogen (N)	**-0.85**	-0.01	-0.24
Plant Species Richness (S)	**0.53**	0.15	-0.23
Evenness (E)	**0.42**	0.14	-0.10
Shannons Diversity (H')	**0.54**	0.18	-0.22

The ordination did not display any obvious clusters or divisions between groups so cluster analysis was carried out to identify groupings within the data. Using indicator species analysis the most suitable clustering level for interpretation was selected. Following Dufrene & Legendre (1997) four clusters were selected for interpretation (Figure 5.3).

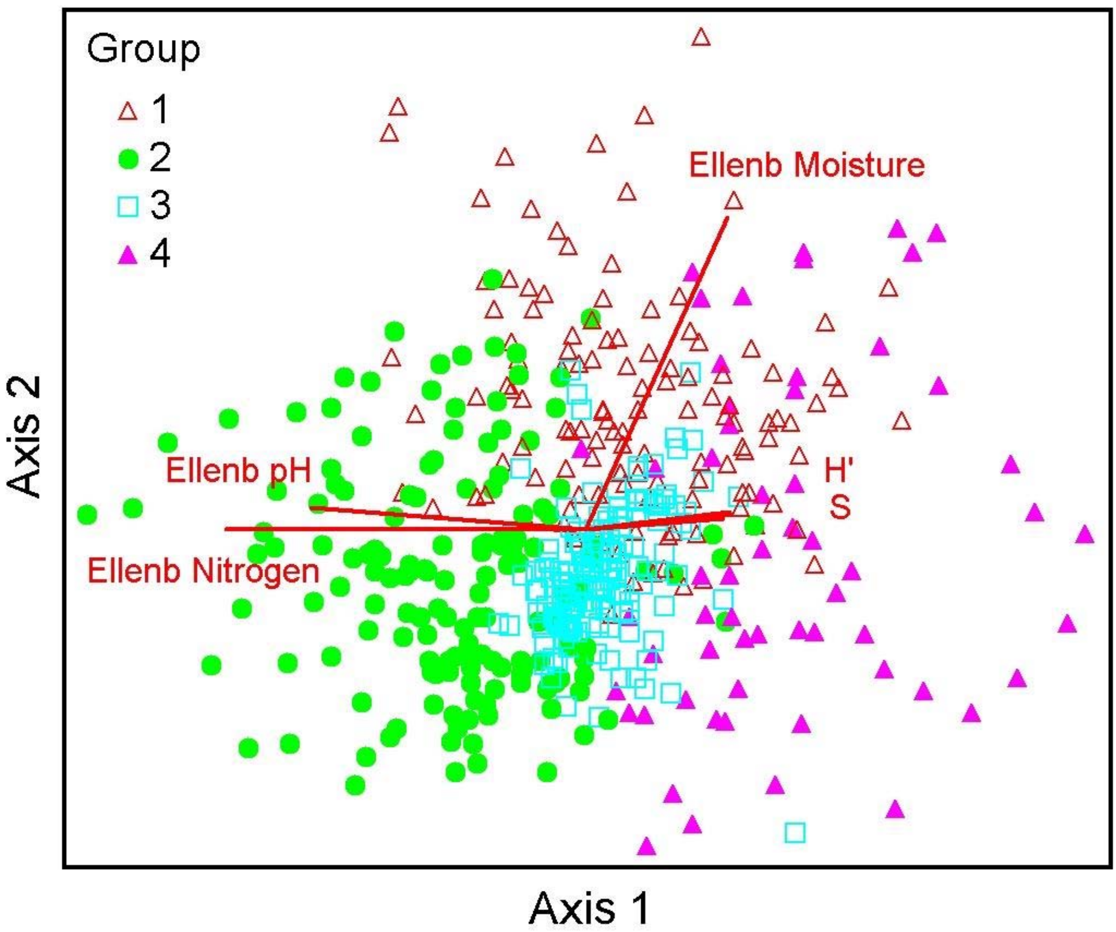

Figure 5.3 Non-metric multidimensional scaling ordination of fields with the four groups identified from cluster analysis identified.

5.4.1 Vegetation groupings in a HNV landscape

Group 1 (N=123) had the highest mean Ellenberg moisture value (6.42±0.3). Group 2 (N=153) had the highest mean Ellenberg reaction (5.76±0.2) and nitrogen values (5.16±0.3). This group also had the lowest species richness (19.49±4.8) and covered the greatest area (270.5ha). Group 3 (N=162) had the highest mean species richness (29.03±6.1) and mean Shannon's diversity (3.23±0.2). Group 4 (N=58) had the lowest mean Ellenberg nitrogen (4.10±0.5) and covers the smallest area (113.54ha). Plant species evenness, Ellenberg moisture and Ellenberg reaction did not vary greatly between groups

.

Mean and standard deviations of variables per group used for interpretation of the ordination and indicator species (p <0.01) are given in Table 5.3.

Table 5.3 Number of fields and total area within each group, mean and standard deviation (±) of exploratory variables for groups identified from cluster analysis level 4. Indicator species (p <0.01) and observed indicator value from Indicator Species Analysis listed for each group.

Group / Variable	1 Wet semi-natural grassland	2 Semi-improved grassland	3 Semi-natural grassland	4 Peat/heathland semi-natural habitat
N (fields)	123	153	162	58
Total area (ha)	195.47 (25%)	270.05 (35%)	202.27 (26%)	113.54(154%)
Ellenberg moisture	6.42 (± 0.33)	5.74 (± 0.31)	5.92 (± 0.31)	6.29 (± 0.45)
Ellenberg reaction	5.58 (± 0.26)	5.76 (± 0.23)	5.57 (± 0.13)	5.14 (± 0.43)

Ellenberg nitrogen	4.68 (± 0.33)	5.16 (± 0.35)	4.86 (± 0.18)	4.10 (± 0.46)
Species richness	25.90 (± 7.64)	19.49 (± 4.83)	29.03 (± 6.13)	28.76 (± 9.33)
Evenness	0.97 (± 0.01)	0.96 (± 0.01)	0.97 (± 0.01)	0.97 (± 0.01)
Shannons diversity (H')	3.11 (± 0.29)	2.83 (± 0.25)	3.23 (± 0.20)	3.21 (± 0.34)
Indicator species (Observed indicator value given)	*Ranunculus flammula* (32.2) *Juncus effusus* (30.7) *Ranunculus repens* (30) *Agrostis stolonifera* (29.5) *Glyceria fluitans* (29.4) *Juncus acutiflorus* (26.4)	*Lolium perenne* (37.2) *Trifolium repens* (28.3) *Rumex obtusifolius* (26.7)	*Cirsium arvense* (47.4) *Rumex crispus* (42.8) *Taraxacum officinale* (38.4) *Holcus mollis* (38.2) *Agrostis canina* (36) *Bellis perennis* (35.6) *Anthoxanthum odoratum* (34.4)	*Potentilla erecta* (49.8) *Succisa pratensis* (41) *Molinia caerulea* (33.8) *Lotus corniculatus* (26.3)

Filipendula ulmaria (25)	*Cynosurus cristatus* (31.3) *Poa pratensis* (30.2) *Ranunculus acris* (29.8) *Alopecurus pratensis* (29.1) *Agrostis capillaris* (27.9) *Poa trivialis* (27.5) *Holcus lanatus* (27.4) *Plantago lanceolata* (26) *Cerastium fontanum* (25.1)

Multi Response Permutation Procedure (MRPP) was used to validate the groups. The groupings of fields identified in cluster analysis were highly significant ($p < 0.001$). The within-group agreement A value was 0.212 indicating the groups are more homogeneous than expected by chance.

Grassland habitat quality was assessed using High Nature Value grassland indicators listed in the Irish Semi-natural Grasslands Survey (ISGS) (O'Neill et al., 2013). Scores were calculated for 438 fields (Groups 1, 2 and 3 (Group 4 was excluded as it was not a grassland group)) and ranged from 0 to 2.99 (See Appendix E). A total of 121 fields (28%) scored 2 or greater and 8 fields (2%) scored 0.

5.4.2 Group-level grassland quality

The wet semi-natural grassland group had the highest mean quality score (1.99 ±0.45). The other semi-natural grassland group had a mean quality score of 1.82 (±0.35). The semi-improved grassland group (Group 2) had the lowest mean quality score (1.32 ±0.53). A one-way ANOVA was used to test for differences between the quality scores of the three groups. Quality scores between groups differed significantly F (3, 438) = 88.026, P = <0.001. A post hoc Tukey test indicated that each group was significantly different from the other ($P<0.01$). The quality scores were divided into 0.75 increments and overlain on the NMS ordination (Figure 5.4). All fields from Group 4 were assigned to category 5 to highlight that these are non-grassland habitats.

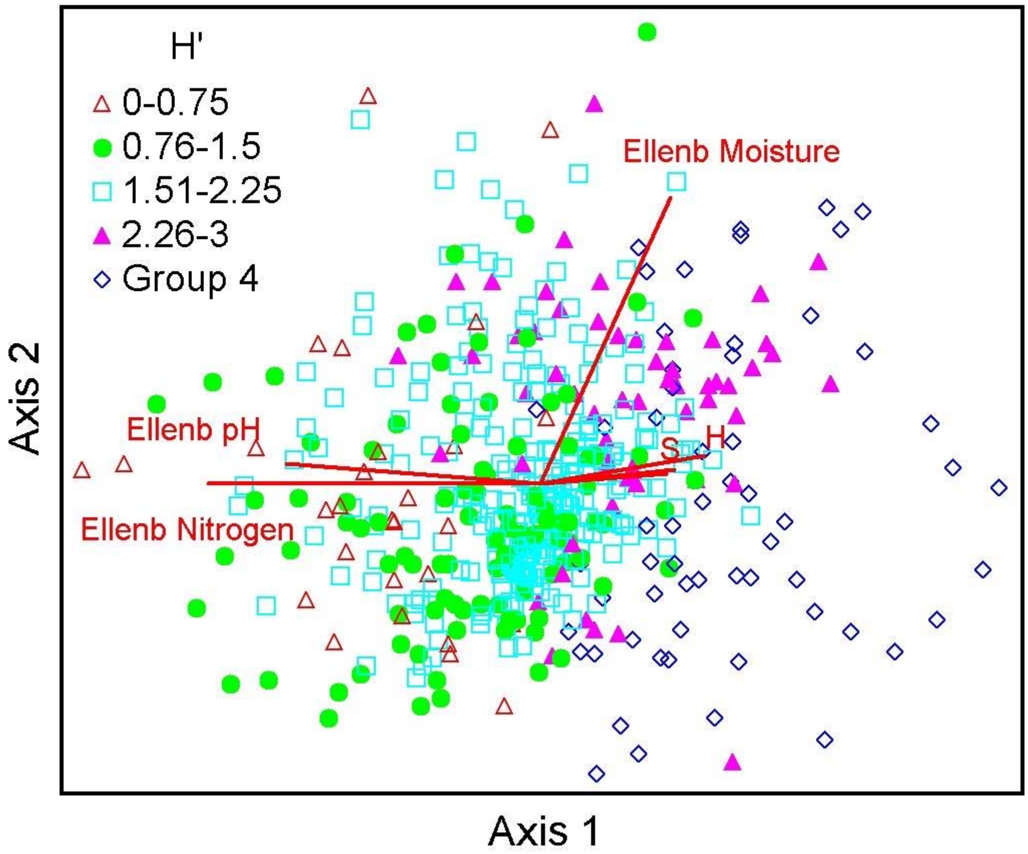

Figure 5.4 Non-metric Multidimensional Scaling ordination of fields with grassland field quality score categories overlaid. Categories are in increments of 0.75. Group 4 which is not a grassland group is assigned to category 5 as the quality score does not apply to this group.

5.4.3 Farm-level grassland quality

The mean, minimum and maximum quality score per farm are given in Table 5.5. The mean farm score ranged from 1.00 to 2.47. Eleven farms (19%) scored a mean field quality score of greater than 2. The lowest maximum field quality score was 1.55 (SL08) and the highest minimum field quality score was 2.35 (LM08). The field quality score ranges on a farm could vary dramatically, for example LM01 had a maximum score of 2.84 and a minimum score of 0. On the other hand some farms had high quality fields throughout, for example LM08 had a minimum field quality score of 2.35 and a maximum of 2.93.

5.4.4 Grassland quality and relationship to farm nature values

The relationship between mean grassland quality score per farm and overall farm nature value score was investigated using a Pearson's correlation. The farm nature value score was found to be significantly correlated ($p = 0.528$) to field quality score (Table 5.5). Farms with high mean grassland quality scores have correspondingly high nature value scores, for example the eleven farms with high mean grassland quality scores (> 2.0) had nature value scores greater than 6.5. Some farms with moderate nature value scores contained very high quality grasslands alongside a high proportion of more intensively managed grassland (e.g. LM15 and LM10). Farms with low mean grassland quality scores tend to have a higher proportion of the semi-improved grassland grouping (Group 3). Farms LM03 and MO10 had no fields in Groups 1, 2 or 3 and so could not be assigned grassland quality scores.

Table 5.5 Mean, minimum and maximum grassland quality score and nature value score per farm given with mean Ellenberg light, moisture, pH and light values per farm. Pearsons correlation between mean fields score and nature value score is included. Table organised based on decreasing quality score.

Farm ID	Mean field grassland quality score (H')	NVscore	Mean Ellenberg Nitrogen	Mean Ellenberg Moisture	Mean Ellenberg pH	Mean Ellenberg Light	Mean Ellenberg Salt	Mean species richness per field	Proportion Group 1 (%)	Proportion Group 2 (%)	Proportion Group 3 (%)	Proportion Group 4 (%)
LM08	2.47 (±0.2)	7.4	2.29	2.29	2.57	2.71	1.43	33.14	31.9	0	0	68.1
MO06	2.34 (±0.3)	7.9	3.00	1.40	2.60	2.80	1.60	34.80	0	32.1	67.9	0
MO07	2.30 (±0.4)	8.4	2.88	1.88	3.00	2.88	2.00	32.63	49	0	51	0
LM15	2.11 (±0.5)	5.6	3.27	1.55	3.00	3.00	2.27	25.64	55.2	44.8	0	0
MO19	2.11 (±0.3)	9.4	3.00	1.73	3.00	3.00	2.09	34.64	0	0	100	0
LM07	2.11 (±0.3)	8.9	3.00	2.30	2.50	2.20	1.30	23.40	100	0	0	0
LM13	2.07 (±0.4)	9.7	2.56	2.44	2.44	2.44	1.67	24.11	57.5	0	0	42.5
LM05	2.03 (±0.3)	8.6	2.56	2.44	2.67	2.89	1.67	26.22	30.8	4.2	0	65
MO24	2.03 (±0.3)	9.4	3.00	1.75	3.00	2.63	2.00	31.13	33	0	67	0
MO12	2.01 (±0.8)	6.5	3.33	2.00	3.00	2.83	2.83	37.50	8.3	0	91.7	0
MO27	2.00 (±0.4)	7.9	2.64	2.21	2.43	2.79	2.14	32.71	68.7	0	31.3	0
LM06	1.99 (±0.3)	7.3	3.26	1.87	2.96	2.87	1.52	22.74	61.3	41.2	0	13.5
LM14	1.98 (±0.4)	7.8	3.00	2.43	2.57	2.71	2.00	23.29	54.8	0	0	45.2
MO08	1.89 (±1.16)	6.3	2.25	2.25	2.50	3.13	1.88	25.50	33.3	22.8	0	43.9
LM12	1.86 (±0)	6.7	2.50	2.00	2.00	3.00	2.00	25.50	34.7	0	0	65.3
MO30	1.85 (±0.4)	8.9	3.14	1.36	2.86	2.86	2.00	28.86	0	0	100	0
MO26	1.81 (±0.3)	7.7	3.00	1.50	3.00	2.83	2.00	30.17	16.2	0	83.8	0
MO05	1.8 (±0.4)	7.5	3.33	1.83	2.83	2.83	2.17	32.83	0	15.8	44.2	40
MO04	1.78 (±0.2)	4.1	3.13	1.67	3.00	3.07	2.13	28.73	0	0	100	0
MO15	1.77 (±0.4)	7	3.07	1.79	2.79	2.86	2.21	27.93	5	12.8	63.4	18.8
SL09	1.77 (±0.5)	6.3	3.17	1.67	3.00	2.67	1.83	21.17	41.7	50.6	0	7.7
MO14	1.76 (±0.3)	7.6	2.80	1.60	2.40	2.80	1.80	29.80	0	0	88.8	11.2
SL10	1.76 (±0.2)	8.4	2.83	1.83	2.83	2.17	1.33	20.83	68.6	9.9	0	21.5
SL12	1.76 (±0.2)	7.9	3.40	1.20	2.60	2.40	1.40	32.60	0	35.2	0	64.8
MO20	1.75 (±0.3)	6.3	3.20	1.40	3.00	2.90	2.00	29.10	0	0	94.5	5.5
MO21	1.72 (±0.2)	7.3	3.25	1.67	2.92	2.75	2.08	23.58	0	17	83	0
MO11	1.72 (±0.4)	8.3	3.20	1.80	2.80	2.60	2.40	26.00	58.5	23	18.5	0
LM02	1.72 (±0.5)	9	3.29	2.29	2.71	2.86	1.14	21.71	16.1	2.9	61	20
LM10	1.72 (±0.6)	5.4	3.75	2.00	3.00	2.75	2.75	23.88	78.7	21.3	0	0
MO13	1.72 (±0.2)	8.6	3.00	1.31	2.85	3.00	2.31	28.15	15	0	85	0
MO29	1.70 (±0.3)	4.1	3.14	1.14	3.00	3.00	2.00	27.57	0	25.9	74.1	0
SL06	1.69 (±0.7)	8.3	3.00	2.00	2.67	2.50	2.00	24.17	53.9	46.1	0	0
LM04	1.63 (±0.4)	5.9	3.50	1.77	2.88	2.42	1.69	22.58	38.2	61.8	0	0
MO23	1.63 (±0.2)	7.6	2.57	1.57	2.29	2.86	1.57	28.43	0	28.9	53	18.1
SL15	1.63 (±0.4)	4.9	3.83	1.83	3.00	2.75	2.17	21.50	12.2	87.8	0	0
LM01	1.61 (±0.9)	6.8	3.43	1.43	3.00	2.71	1.00	23.86	21.3	69.6	9.1	0
MO17	1.61 (±0.8)	6.6	3.30	2.00	2.70	2.90	2.20	24.80	48.1	27.4	24.5	0
MO25	1.61 (±0.4)	8.1	3.00	1.43	2.86	2.86	2.29	23.00	69.8	15.2	15	0
MO03	1.57 (±0.2)	4.9	2.29	1.29	2.57	3.00	1.43	24.00	0	70.6	7.1	22.3
MO18	1.57 (±0.4)	7.4	3.00	1.29	2.71	2.57	2.00	25.14	21.9	20	58.1	0
SL04	1.55 (±0.2)	7.8	3.50	2.00	3.00	2.00	3.00	18.50	100	0	0	0
MO22	1.54 (±0.3)	4.7	3.80	1.20	3.00	3.20	2.60	26.00	0	27.3	72.7	0
SL05	1.49 (±0.5)	8.3	3.40	2.00	3.00	2.60	2.20	21.40	54.9	45.1	0	0
MO28	1.48 (±0.3)	5.9	3.25	1.50	2.88	2.88	2.00	27.13	0	5.8	94.2	0
MO09	1.43 (±0.6)	4.9	3.00	1.00	2.50	3.00	2.00	25.50	0	0	100	0
SL03	1.39 (±0.5)	4.9	3.46	1.08	3.00	2.77	1.62	18.00	0	100	0	0
SL13	1.35 (±0.4)	7.2	3.57	1.00	2.86	2.71	2.29	19.00	0	100	0	0
MO01	1.34 (±0.8)	8.4	2.92	1.38	2.46	2.31	1.46	20.92	29.2	8	15.9	46.9
SL11	1.32 (±0.5)	7.1	3.17	1.50	3.17	2.50	1.83	19.30	6.8	93.2	0	0
SL14	1.22 (±0.3)	2.6	3.25	1.25	3.00	3.00	2.50	27.00	0	72	0	28
LM09	1.18 (±0.7)	3.3	4.29	1.29	3.43	3.14	3.00	19.43	0	100	0	0
SL01	1.16 (±0.5)	7.1	3.33	1.33	2.80	2.53	1.67	20.60	0	48.9	0	51.1
MO02	1.15 (±0.4)	4.3	3.67	1.00	2.89	3.00	2.00	17.33	0	100	0	0
MO16	1.15 (±0.6)	3.3	3.47	1.13	2.93	2.80	2.13	20.13	10.8	56.6	32.6	0
SL08	1.11 (±0.6)	7.8	3.67	1.33	3.00	3.00	2.00	23.00	0	73.8	0	26.2
LM11	1.00 (±0.4)	4.1	4.20	1.60	3.20	2.80	2.20	20.00	5.4	94.6	0	0
LM03	0.00	9	2.00	2.33	2.33	3.00	1.33	34.33	0	0	0	100
MO10	0.00	8.2	3.00	2.00	3.00	3.00	2.00	41.00	0	0	0	100
Pearson Correlation between mean quality score and nature v: 0.528**												

** Correlation is significant at the 0.01 level

5.5 Discussion

The main pressures on farmland biodiversity in EU Member states are production focused agricultural policies, biomass and energy production and international trade negotiations (Henle et al., 2008) together with individual goals of member states for the agriculture sector such as Horizon 2020 (Perrings et al., 2010). Increasingly, agricultural policy is focusing on maintaining and enhancing farmland biodiversity. In order to manage plant diversity (which contributes to overall farm diversity) effectively information on what plant communities remain in agricultural settings is essential (Parkes et al., 2003)

5.5.1 Vegetation groupings

The study area was identified as having high potential cover of HNV farmland (European Environment Agency, 2009) and is dominated by lower intensity agriculture than the south-west or east of Ireland (Lafferty et al., 1999). This is reflected in the vegetation groupings identified in this research. The results of this research show quite different plant vegetation groupings than were identified on lowland farmland grassland in east Co. Galway, Ireland (Sullivan et al., 2011). A semi-improved grassland category was identified in the east Co. Galway region along with an improved agricultural grassland grouping (Sullivan et al., 2010). In the north-west region there is evidence of the semi-improved grassland group (Group 2) though the species-richness was higher. However, there was no equivalent improved agricultural grassland group identified on the farms in the north-west which reflects the lower farming intensity of this region than the east Co. Galway region.

Lower nitrogen levels have been shown to have significant effects on plant species richness at a field level (Klimek et al., 2007). This is reflected in the north-west region where vegetation groupings with lower Ellenberg N (Groups 1, 3 and 4) had higher plant species richness (greater than 25). Increased application of artificial nitrogen and increased drainage of fields are typical management practices associated with more intensively managed farmland (Henle et al., 2008; Overmars et al., 2014) but given the absence of an improved agricultural grassland group in the north-west these practices appear to be less prevalent or less successful, possibly due to soil types and typography. The semi-improved group identified in the north-west of Ireland in this study had higher Ellenberg nitrogen, higher reaction (pH) values and lower Ellenberg moisture values than the semi-natural vegetation groups. It is important to note the high cover of non-grassland habitats on farms in this area. For example, LM03 and MO10 were dominated by fields primarily composed of peat/heathland habitat. These areas are important contributors to landscape biodiversity levels (Jongman and Bunce, 2008; Sheridan et al., 2011) and in Ireland may contribute to the majority of the Utilisable Agricultural Area (UAA) of individual farms. In many regions across Ireland and Europe today the only remaining semi-natural habitats on farms are linear features such as drainage ditches and field boundaries (Herzon and Helenius, 2008; Hietala-Koivu et al., 2004; Manhoudt and de Snoo, 2003; Sullivan et al., 2013) however in this region of Ireland many of the farms have high proportions of non-linear semi-natural habitats as reflected in the fact that of the groups identified, three represent semi-natural vegetation and 65% of the farm area. Similarly, remote sensing studies have found up that up to 63.3% of E.U. agricultural areas can be classified as permanent pasture, which is associated with semi-natural grassland habitat (García-Feced et al., 2014). This study focused on enclosed farm habitats. As a result the contribution of vegetation associated with commonages is likely underestimated. Further study including commonage data would likely increase the total area covered by the plant community reflecting heath/peatland habitats.

5.5.2 Grassland quality scores

Vegetation quality scores have been shown to be effective measures of the conservation value of natural areas in a number of countries including Australia and the United States (Matthews et al., 2015; Parkes et al., 2003). The richness and composition of plants have been used to identify ecological indicators of habitat quality in the US (Matthews et al., 2015). Using expert opinion, species are assigned a 'C' value based on their likelihood to occur in natural habitat along a scale of 0 to 10. The mean C value alongside a Floristic Quality Index (FQI) is used to select areas which require targeted conservation measures. In this study we used presence and absence data of plant species to assess plant species composition and abundance. The FQI uses expert opinion to assign C values to plant species; this is a subjective method of assigning importance to species. In this study, indicator species of HNV grassland used have been identified from a national semi-natural grasslands survey, which reduces subjectivity or bias which may be placed on certain species. This list can be used to assess the quality of farmland in an Atlantic pastoral region and indeed across Ireland (as the list was developed from a national dataset). These values have been developed into a measure of quality which also has the potential to target conservation measures for vulnerable farmland habitats. This is also the first time an assessment of quality has been carried out on HNV farms in Ireland and one of few attempts in Europe (Benzler, 2012; Oppermann, 2008).

By monitoring the changes in the quality score, which is applied at field level, the success of targeted AES measures can be monitored on a year-on-year basis or across the lifespan of an AES. This is particularly useful as there is increasing demand for targeted policy measures which are scientifically based and produce results that can be monitored (Piorr, 2003). Monitoring could be completed by agricultural advisors who are required to complete farm inspections already under existing agri-environment schemes. This would involve initial training for advisors but could be a viable option when incorporated into existing farm inspections. Using regionally specific indicators of high quality grasslands, other EU Member States can develop a similar quality score which could be applied as an evaluation or monitoring tool for HNV grasslands. Additionally, the development of a quality score for peatland/heathland habitats may be possible by using indicators from a study similar to the ISGS which was completed for uplands (Perrin et al., 2014). This could be used alongside the grassland quality score to get an overall quality score for a farm with commonage.

The presence of high species quality fields within the semi-improved grassland group shows the lower intensity of farm management in this region compared with other parts of Ireland. These fields may be suitable targets for grassland restoration within AE schemes. The restoration of semi-improved grasslands is preferential to that of intensively managed fields as the likelihood of success is increased (Crofts and Jefferson, 1999; Worcestershire Wildlife Trust, 2011). An added benefit of the quality score is that it can be used on non-HNV farms to identify areas which still support high levels of biodiversity. On farms which are considered non-HNV, the quality score can be used to identify isolated fields which would benefit from targeted supports within an AES. Measures similar to current AES supports such as those to maintain species-rich grasslands (Department of Agriculture Food and the Marine, 2015) could be assessed and monitored using the quality score.

5.5.3 Grassland quality scores and overall nature value of farms

The quality score is correlated with the nature value score (Boyle, Hayes et al. 2015) and they can be used in partnership to assess farms for targeted AESs. On farms that qualify as HNV using the nature value score, the quality score can be used to monitor field quality. HNV farms threatened by abandonment often have low quality semi-natural grassland cover. Using the quality score in conjunction with the nature value score could help to identify at risk areas and allow for the implementation of targeted measures which would improve the grassland quality and maintain the HNV status of a farm.

It is particularly important to note that not all farms with high field quality scores have a high nature value score at farm level and vice versa (Table 5.5). There is significant variation in field quality on individual farms e.g. LM15 (quality score – 2.11, minimum – 1.1, maximum – 2.7, NV score – 5.6) and MO01 (quality score – 1.34, minimum – 0, maximum – 2.1, NV score – 8.4). Although a farm as a whole can be considered HNV based on semi-natural habitat cover, the quality of grassland on farm may vary (shown in Table 5.5). This has implications in the development and implementation of AESs. Farms, such as MO01, which have high nature value scores but low mean field quality scores, may need targeted measures to implement suitable management practices on farm to increase the quality scores of its grasslands.

Farms with low nature value scores and high mean field scores (LM15) reflect the fact that more intensively managed agricultural systems may have high nature value features which contribute to landscape heterogeneity and biodiversity value. These farms contribute to biodiversity levels at a landscape scale by creating mosaics of habitats both extensively and more intensively farmed. This has been shown to benefit biodiversity levels not just for plants but also for birds, butterflies and small invertebrates amongst others (Benton et al., 2003; Verhulst et al., 2004; Weibull et al., 2000). These farms, which may be considered remnant HNV systems, also require targeted measures within AESs, such as measures for support of species-rich grassland (Department of Agriculture Food and the Marine, 2012), to maintain such diversity on the farm.

5.6 Conclusions

The extensive, regional-scale sampling used in this project has led to results that highlight groups which require special consideration in developing AESs. The division of fields into four groups describes the variation in species composition of fields within a HNV landscape. The groups reflect the influence of environmental and management variables on the vegetation of HNV farmland. The management variables associated with these groups can be used to inform the development of AESs which support high biodiversity levels on farm.

The inclusion of a quality score to assess fields is a step towards addressing the question of how to measure the overall quality of HNV farmland. The score also has the potential to be used as a monitoring tool to assess the success (or failure) of measures implemented as part of an AES. By relating the field quality score to a farm level measure of diversity makes the score more suitable for inclusion in an AES. The nature value score has been shown to describe the HNV status of farms in the west of Ireland, an Atlantic pastoral region, accurately and can be used in the quantification of HNV farmland (Boyle, Hayes et al. 2015). This study has shown that the nature value score also relates to the field level quality of HNV farmland. By using both measures in conjunction, these scores can be used to substantially enhance efforts to measure the extent and quality of HNV farm and non-HNV farms alike within Ireland and other pastoral regions in Europe.

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6. Discussion

6.1 General Discussion

The three primary aims of this research were

1. Investigate the development of an index or scoring system for the identification of HNV farmland
2. Identify the farming styles associated with HNV regions in Ireland to better inform agri-policy development
3. Identify the plant groups associated with HNV farming in the North-West of Ireland which could be incorporated into agri-environmental schemes for targeting payments or monitoring success of schemes.

The outcomes of each are discussed below.

6.1.1 Development of a nature value index for pastoral farmland – a rapid farm level assessment

High Nature Value farmland is becoming increasingly central to environmental agricultural policy within the EU (Bartolini and Brunori, 2014). However, the information available on the extent and quality of HNV farmland with Member States is variable (Lomba et al., 2014; Peppiette, 2011). This limits the extent to which measures supporting HNV farmland and extensive farming practices can be implemented at a national level. Identification of HNV farmland using various indicators has been an aim of agricultural policy since 2001 (Samoy et al., 2007). Member States are required, as part of the Implementing Regulation for the European Agricultural Fund for Rural Development (EAFRD), to measure the extent of HNV farmland and monitor changes in extent or quality of such areas (Cooper et al., 2007; European Commission, 2006). To date, few countries have succeeded in mapping the extent of HNV accurately (Lomba et al., 2014). Countries such as Slovakia and Bulgaria have mapped extensive areas of HNV by incorporating semi-natural vegetation inventories with Land Parcel Identification Systems (LPIS) (Beaufoy, 2008; Peppiette, 2011). Germany used a system of ground truthing randomly selected plots stratified based on landcover categories and ecoregions previously identified for the country. This method allowed for the mapping of extent and quality of HNV farmland of sample farms which was then extrapolated out to a national level (Benzler, 2012). This fulfilled EFRAD requirements for measurement and monitoring. A method developed in Scotland utilised existing databases which could be used and accessed easily for monitoring of HNV regions. Rough grazing areas, contributing to at least 70 % of farms Utilisable Agricultural Area (UAA), combined with livestock units less than 0.5 per available forage hectare, was used as an indicator of HNV farming. This resulted in an estimate that 44 % of Scottish agricultural land could be classified as HNV in 2007 (McCracken, 2012). These methods show the potential for all Member States to comply with EFRAD requirements for identification and monitoring of HNV farmland.

It has been suggested that identification of HNV farmland should begin at farm level to inform regional and national policy measures (Beaufoy, 2008; Lomba et al., 2014). This study develops a nature value score for farms based on farm level data. Similarly to the Scottish study, values representing the proportion of semi-natural habitat cover per farm – percent of improved agricultural grassland - and stocking density – livestock units per hectare UAA are used. Additionally a variable representing landscape complexity is also incorporated – length of linear habitat per hectare. These three variables have been shown in numerous studies to be useful indicators of land use intensity and biodiversity levels (Duelli and Obrist, 2003; Marshall and Moonen, 2002; McMahon et al., 2012; Sullivan et al., 2011; van der Zanden et al., 2013; Weibull et al., 2003).

Scaling these three variables based on analysis and expert opinion it was possible to develop a scoring system for the nature value of farmland, ranging from 1 to 10, within an Atlantic influenced pastoral setting. HNV farmland can be influenced by field, farm or landscape level practices. In order to support and maintain the biodiversity associated with HNV it is necessary to provide supports and target measures at various scales to maximise a farm or landscapes HNV potential (Keenleyside et al., 2014) The index can be used as an indicator of HNV farmland which can be used to identify areas which require targeted measures to maintain or enhance HNV farmland at a farm or parcel scale as suggested by Keenleyside et al. (2014). A cut-off point of 4.5 on the nature value scoring system was shown in this study to adequately separate HNV Type 1 and Type 2 farms from non-HNV farms. This cut off point was based on Cluster Analysis and comparisons to the EU typology of HNV farmland (Andersen et al., 2003a) for all sixty farms. As Type 3 farms are dominated by intensive grassland, they fall into a non-HNV category using this cut-off. However, in Ireland, Type 3 HNV farmland is readily identifiable using existing datasets such as feeding grounds of rare or legally protected bird species. Therefore, despite falling outside of a HNV category using the nature value index, these areas can easily be identified and maintained as appropriate.

The benefit of the nature value index proposed is that it allows for rapid assessment of a farm. It has the potential to be used for both identification and monitoring purposes by comparing a farms score across years. It also requires very little specialist knowledge to identify each variable. Improved agricultural area can often be identified as silage producing or heavily grazed fields; farmers and farm advisors are familiar with livestock units and their calculation; and length of linear habitats can be easily calculated from basic, up-to-date aerial maps. This makes the index easily understandable and utilisable by all interested stakeholders; farmers, advisors or policy makers alike.

6.1.2 Typology of High Nature Value farmland in a Northern Atlantic pastoral landscape

The ability to quantify and monitor the extent of HNV farmland is a first step in supporting high biodiversity, extensive farming. The next step involves identifying the farming styles that contribute to creating HNV landscapes. Pasture based farming systems, which are commonly the dominant farming systems in HNV regions, are often highly complex and contribute greatly to landscape heterogeneity, which consequently supports high levels of biodiversity (Mądry et al., 2013). Constructing a typology of farming simplifies the diversity of farming styles (Valbuena et al., 2008). This allows for the development of well-informed agri-environmental schemes, highlighting at risk farming groups and targeting payments where they are most needed (Ribeiro et al., 2014).

Depending on the aim of the typology e.g. production strategy of farms (economic), farmer decision process (social) or as in this study habitat structure and pressures (environmental), the variables utilised may differ (Valbuena et al., 2008). The study presented in this thesis is focused on the development of a typology of farms based on habitat composition on farms. Variables known to impact on or be affected by habitat composition were used to generate a typology of farming within a pastoral region associated with HNV farmland. Stocking density and cover of semi-natural habitat were important influential variables on the typology development.

Importantly, the typology developed in this study has highlighted the threat of abandonment and intensification to HNV farms. Abandonment of agricultural land in high biodiversity areas, such as HNV regions, is a serious concern which can lead to biodiversity loss, soil erosion and the loss of cultural traditions (Rey Benayas, 2007). HNV regions are particularly at risk as a result of already challenging landscapes, ageing farmer populations and insufficient policy supports (Keenleyside and Tucker, 2010; O'Rourke et al., 2012; Oppermann et al., 2012). Intensification of farmland was also highlighted in the typology constructed in this study. There are groups which have been intensified and are no longer classed as HNV farms as expected. However, the main concern are those farms which still support semi-natural habitats but whose management practices, measured as stocking density in this study, are not compatible with extensive farm practices. These farms are further intensifying their farming practices in a response to policy measures which are not constructed for the support of extensive farmland (Poláková et al., 2011). With the development of farm typologies such as that outlined in this thesis, more appropriate measures can be developed with agri-environmental schemes to support extensive farming practices and reduce the risk of further intensification of farms in HNV regions.

In addition to the threat of whole farm abandonment and intensification, the issue of polarisation of farms was also highlighted from this study. Recently, it has appeared that within farms intensively managed land is being further improved, whilst more extensive areas which are less productive are being abandoned and succumbing to scrub encroachment (Bogdan et al., 2012; Lomba et al., 2014). This leads to an overall loss of on farm biodiversity in HNV regions in particular (Bogdan et al., 2012; IEEP and Alterra, 2010).

The typology constructed highlights that HNV regions contain a continuum of farming styles based on semi-natural features, intensity of land-use and farm structure (Andrieu et al., 2007). It is important to be able to characterise farming styles within this continuum to develop AESs that account for the differences in farm types and that adequately protect biodiversity and maintain high quality ecosystem services (Andersen et al., 2007). With increasing interest in developing regionally targeted, outcome based AESs (McGurn and Moran, 2013; Reed et al., 2014; Renwick et al., 2013), typologies such as these provide a good baseline for the development of measures which take account of unique differences and challenges to farming within regions.

6.1.3 Identification of plant groups associated with High Nature Value farmland

Typologies allow HNV farmland types to be identified and described. Following this, specific measures within AESs can be developed to maintain and enhance on farm biodiversity levels. Often measures, particularly for the protection of semi-natural habitats, rely on indicator plant species or plant groups for the identification of suitable sites for implementing measures or for monitoring of the success of an AES (Department of Agriculture Food and the Marine, 2012; Natural England, 2013; Rural Development Service, 2005). The study presented for this thesis identifies plant groups associated with farms in a HNV region.

Similarly to the study on the typology of HNV farms, the vegetation study showed the diversity of HNV farms is a continuum from high species diversity to low. The diversity of fields based on vegetation could be grouped into four clusters which extended across a continuum of species diversity, management intensity and soil moisture levels. The groups identified in this study are described as wet semi-natural grassland, other semi-natural grassland, semi-improved grassland and peat/heathland semi-natural habitats.

The semi-improved grassland grouping relates to fields within the study sites which are managed more intensively. However, the presence of high quality scoring fields within this grouping indicates that even the more intensively managed fields in this region may not be considered intensive on a national scale. These sites are important sites for targeting within intensive landscapes as they contribute to landscape heterogeneity. Landscape heterogeneity is associated with higher biodiversity levels by helping to maintain and enhance species richness in an agricultural setting (Aavik and Liira, 2009; Benton et al., 2003).

Using the Irish Semi-natural Grassland Survey HNV grassland indicator species (O'Neill et al., 2013) as a measure of the quality of grassland fields is the first step towards measuring the quality of HNV farmland in Ireland. This study has shown the applicability of the ISGS species in measuring and monitoring the quality of grassland sites in HNV regions. Use of the field quality score and farm nature value would have the benefit of identifying areas which require targeted AES measures whilst allowing the success of such measures at field level to be monitored. Using the quality score in conjunction with the nature value score could help to identify at risk areas and allow for the implementation of targeted measures which would improve the environmental quality of grasslands and maintain the HNV status of a farm.

6.1.4 Limitations of the study

The research presented in this thesis has some limitations. The main constraint to this study is the limited study area. The study was completed on sixty farms in the north west of Ireland. This limitation is imposed as a result of the scale and time of the project. However, the study farms cover a wide range of ecotypes and intensities of farming within the region and which are considered to be represented of farming in a pastoral landscape. Additionally, a total of 778 fields were surveyed which contained a variety of habitats including grassland, woodland, heath/peatland and coastal habitats. The variety of habitats and variety of management intensities of the fields sampled are considered to have accounted for regional variation in farming.

The nature value index development is limited by the small number of farms (N =30) used for its initial development. However, the index was further tested on 30 farms surveyed within the project and a further 30 farms sampled as part of a separate study which are located within a region associated with more intensively managed farmland. Additionally, the index has been applied at a national scale within the Ideal-HNV project which has found the index scores to accurately reflect the nature value of farms in extensive regions across the Republic of Ireland. This validates the applicability of the nature value index at a larger scale.

Similarly, the typology of agricultural systems produced within this study is based on sixty farms. This typology focuses on the habitat composition, management intensity and landscape features of farms. This provides an environmental typology of farms which is useful for highlighting the environmental threats and pressures of farming in a HNV region. Incorporating socio-economic factors such as farmer age, family size and the requirement to work off-farm, would result in an holistic typology of farmland which would highlight social pressures in addition to environmental factors. This would provide greater detail in relation to threats and pressures to agricultural systems for policy makers when developing measures to support and enhance existing farming systems.

The vegetation study is limited by reducing the dataset from 778 to 496 fields. Initial testing of the entire dataset did not yield results from cluster analysis which were interpretable or useful for further analysis. As a result the data set was reduced to increase the homogeneity of the data. This decreases the noise in the data and increases the accuracy of the final results. The final results provide a useful measure of quality for homogenous grassland fields. This limits the applicability of the quality score in application but is an initial step towards developing an holistic quality measure of HNV farmland within a pastoral setting.

6.1.5 Conclusions

The identification and monitoring of HNV farmland within Ireland and other EU Member States is now becoming imperative as the CAP 2014-2020 cycle commences. Commitment has been made by all Member States to identify the extent of HNV but this has yet to be completed by a number of countries. This is often as a result of the fact that no clear guidelines or criteria on the identification of HNV systems have been outlined at an EU level. The study presented in this thesis has developed a stepwise method of identifying the extent of HNV farmland based on current semi-natural habitat cover, stocking densities and linear features. Further to this, the farming systems associated with HNV systems have been characterised and the plant groups associated with these systems have been described. In combination all three contribute to the goals of identifying and monitoring of HNV systems. The limitation of this study is the extreme westerly location of the study area in terms of the EU as a whole. However, by incorporating regionally specific variables, as advised by a number of previous studies (Keenleyside et al., 2014; Reed et al., 2014), the same methods can be used for developing a similar suite of indicators for HNV in other Atlantic pastoral systems in Europe.

At present, there is a move towards the development of spatially targeted outcome based agri-environmentally schemes (McGurn and Moran, 2013; Reed et al., 2014). The results of this thesis have the potential to inform the development of such a scheme for the north-west of Ireland. In combination with similar studies in Ireland

(O'Rourke et al., 2012; Sheridan et al., 2011; Williams et al., 2009) and the outcome of the IDEAL-HNV project in late 2015, it would be possible to develop a regionally targeted, outcome based agri-environmental scheme which could be applied in agricultural regions of varying intensities across Ireland. Such a scheme would benefit extensive farmers in HNV regions better than past and current agri-environment schemes in Ireland by addressing regionally specific issues and enhancing regional individualities such as the Burren in County Clare.

6.2 Further Research

- The development of a nature value score for farms across different biogeographic regions of Europe following the methodology outlined in Chapter 2 would aid the identification and monitoring of the extent and quality of HNV farmland across Europe. This would require assembling a dataset of habitat composition of a sample selection of farms for analysis using NMS. A second dataset of collating a range of farm and landscape level variables into an explanatory matrix would be required for interpretation of the ordination. Following this, the analysis pathway described in Chapter 2 could be implemented. This would likely identify different variables to those detailed in this study but which could be assembled in a similar manner. This would result in a nature value index appropriate for use in the region in question.
- Further research is needed to identify a suitable change point for the identification of HNV Type 1 and Type 2 using the nature value index. This could be done by applying the cut-off points in other HNV regions in Ireland or other areas of Europe and assessing its accuracy through field assessments and socio-economic surveys. Type 1 and Type 2 farmland identification is

complex as both types are associated with a high cover of semi-natural habitat, which is associated with the variable with the highest weighting within the index presented in Chapter 2. Type 2 HNV farmland also supports a high cover of liner habitat. Further application of the nature value index in regions across Ireland and other similar pastoral landscapes may provide a dataset which can be used to statistically provide a cut-off point between the two Types.

- Development of typologies of HNV regions across Ireland, such as the Iveragh peninsula in Co. Kerry, the Burren in Co. Clare or the Ininshowen Penninsula in Co. Donegal, which have all been highlighted as potential HNV regions in Ireland (European Environment Agency, 2009), would contribute to the development of regionally targeted agri-environment schemes. Such schemes which take into account regional difficulties such as landscape restrictions or threats to farm biodiversity such as farm polarisation can direct the most approporiate measures to address such issues. Blanket agri-environmental schemes may not address some of the threats and pressures which are identified at a regional scale but may not be obvious when developing national scale typologies.
- Incorporating socio-economic factors, including age, gender, family size, off-farm work and farmer awareness and attitudes to biodiversity associated with agricultural management, into farm typologies would enhance the development and implementation of such agri-environmental schemes further and identify the supports needed by farms in HNV regions. This allows for the development of holistic schemes which address both social and

environmental issues. This could potentially result in schemes which would be more successful protecting the longevity of agricultural systems in future.

- Development of a quality score for peatland/heathland habitats may be possible using indicators from a study similar to the ISGS which was completed for uplands (Perrin et al 2014) and woodlands (Perrin et al 2008). This could be used alongside the grassland quality score to get an overall quality score for a farm with commonage or those which utilise woodland for grazing. The upland and woodland studies do not provide HNV indicators. However, utilising the indicators for Annex I type habitat it may be possible to compile a list of indicators associated with heath/peatland and woodland which may occur in HNV regions.

6.3 General Conclusions

- The nature value index presented in this thesis is a step towards identifying HNV farmland in Ireland and potentially in pastoral farmland regions within the EU.
- The index can be used to indicate the difference between non-HNV and HNV farms; however the distinction between HNV Type 1 and Type 2 is more difficult to define.
- The development of farming typology for the study area characterises farm styles associated with HNV farming in an Atlantic influenced pastoral system.
- The main threats to HNV farming systems were identified as intensification, abandonment and polarisation.
- Plant groups associated with farming in a HNV region have been identified and highlight the importance of wet grasslands in this region

- The need to include a semi-improved grassland category for national habitat assessments is highlighted.
- The combination of all three primary findings; an index of the nature value of a farm, the typology of HNV farming and an assessment of the quality of HNV grassland, has the potential to contribute to the development and monitoring of regionally targeted outcome based agri-environment schemes in Ireland which are more beneficial to extensive farming systems associated with HNV landscapes.

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Appendix A

Habitats recorded on sixty farms surveyed in Counties Mayo, Sligo and Leitrim in the north-west of Ireland. Habitat code with explanation of habitat is given as per Fossitt (2000)

Habitat Code	Habitat Type	Habitat Code	Habitat Type
FS1	Reed and large sedge swamp	WN1	Oak-birch-holly woodland
GA1	Improved agricultural grassland	WD1	(Mixed) broadleaved wood
GA2	Amenity grassland	WD2	Broadleaved/conifer wood
GS1	Dry calcareous & neutral grassland	WD3	(Mixed) conifer wood
GS2	Dry meadows & grassy verges	WD4	Conifer plantation
GS3	Dry-humid acid grassland	WD5	Scattered trees/parkland
GS4	Wet grassland	WS1	Scrub
GM1	Marsh	ER1	Exposed siliceous rock
HH1	Dry siliceous heath	ED2	Spoil & bare ground
HH2	Dry calcareous heath	ED3	Recolonising bare ground
HH3	Wet heath	ED4	Active quarries & mines
HD1	Dense bracken	BC3	Tilled land
PB2	Upland blanket bog	BL3	Buildings & artificial surfaces
PB3	Lowland blanket bog	CM1	Lower salt marsh
PF1	Rich fen & flush	LS1	Shingle & gravel shores

Appendix B

The following Tables in Appendix B and C provide the nature value index score attained by each sample farm in Counties Mayo (Appendix B) and Counties Sligo, Leitrim and Galway (Appendix C). An indication is also given as to a farms HNV potential. A suggested change point of 4.5, less than 4.5 being non-HNV and greater as likely to be HNV, is based on the range of values of the variables utilised within the index and on European typologies of the variables used, where available. This change point is only provided as a suggestion and further analysis and testing of such a value is required before using this value as a definitive cut-off point in any agri-environmental or support measure.

Nature value score and HNV status calculated for farms surveyed in Co. Mayo, Ireland

Farm number	Score	Status	Farm number	Score	Status
Farm 1	8.4	HNV	Farm 16	8.1	HNV
Farm 2	4.9	HNV	Farm 17	7.7	HNV
Farm 3	4.3	Non-HNV	Farm 18	9.4	HNV
Farm 4	8.4	HNV	Farm 19	4.1	Non-HNV
Farm 5	6.3	HNV	Farm 20	7.5	HNV
Farm 6	7.9	HNV	Farm 21	8.2	HNV
Farm 7	7.4	HNV	Farm 22	4.9	HNV
Farm 8	3.3	Non-HNV	Farm 23	6.3	HNV
Farm 9	6.6	HNV	Farm 24	9.4	HNV
Farm 10	8.6	HNV	Farm 25	7.0	HNV
Farm 11	6.5	HNV	Farm 26	7.6	HNV
Farm 12	8.3	HNV	Farm 27	5.9	HNV
Farm 13	4.7	HNV	Farm 28	8.9	HNV
Farm 14	7.3	HNV	Farm 29	7.9	HNV
Farm 15	7.6	HNV	Farm 30	4.1	Non-HNV

Appendix C

Nature Value index scores and HNV status calculated for validation farms from Counties Galway (G), Sligo (S) and Leitrim (L)

Farm number	Index Score	HNV Status	Farm number	Index Score	HNV Status
Farm G1	3.9	Non-HNV	Farm L1	7.1	HNV
Farm G2	5.4	HNV	Farm L2	8.7	HNV
Farm G3	4.1	Non-HNV	Farm L3	9	HNV
Farm G4	6.8	HNV	Farm L4	6.8	HNV
Farm G5	8.8	HNV	Farm L5	9.2	HNV
Farm G6	6	HNV	Farm L6	7.9	HNV
Farm G7	4.6	HNV	Farm L7	9.2	HNV
Farm G8	4.6	HNV	Farm L8	7.1	HNV
Farm G9	6.5	HNV	Farm L9	4.2	Non-HNV
Farm G10	6	HNV	Farm L10	6.6	HNV
Farm G11	4.7	HNV	Farm L11	5.2	HNV
Farm G12	3.2	Non-HNV	Farm L12	7	HNV
Farm G13	7.5	HNV	Farm L13	9.7	HNV
Farm G14	5	HNV	Farm L14	7.5	HNV
Farm G15	4.6	HNV	Farm L15	5.3	HNV
Farm G16	4.7	HNV	Farm S1	7.4	HNV
Farm G17	7.1	HNV	Farm S2	5.5	HNV
Farm G18	2.2	Non-HNV	Farm S3	7.8	HNV
Farm G19	3.9	Non-HNV	Farm S4	8	HNV
Farm G20	3.2	Non-HNV	Farm S5	8	HNV
Farm G21	6.4	HNV	Farm S6	8.1	HNV
Farm G22	3	Non-HNV	Farm S7	6.3	HNV
Farm G23	5	HNV	Farm S8	8.4	HNV
Farm G24	5.8	HNV	Farm S9	7.1	HNV
Farm G25	3.9	Non-HNV	Farm S10	7.9	HNV
Farm G26	1.8	Non-HNV	Farm S11	6.9	HNV

Farm G27	4.3	Non-HNV	Farm S12	2.6	Non-HNV
Farm G28	7	HNV	Farm S13	4.6	HNV
Farm G29	4.5	Non-HNV			
Farm G30	3.4	Non-HNV			
Farm G31	4	Non-HNV			
Farm G32	1.6	Non-HNV			

Appendix D

Species recorded on 778 fields in Counties Mayo, Sligo and Leitrim in the north-west of Ireland and percentage frequency of each species in fields

Species	Frequency occurrence (%)	Species	Frequency occurrence (%)
Acer pseudoplatanus	1.03	*Juncus bulbosus*	5.27
Achillea millefolium	5.27	*Juncus conglomeratus*	7.71
Achillea ptarmica	0.90	*Juncus effusus*	86.50
Agrostis canina	59.00	*Juncus foliosus*	4.63
Agrostis stolonifera	69.28	*Juncus inflexus*	2.44
Agrostis tenuis	75.06	*Juncus squarrosus*	4.11
Ajuga reptans	0.77	*Lathyrus pratensis*	10.93
Alchemilla xanthochlora	1.16	*Leontodon autumnalis*	7.07
Allium ursinum	0.13	*Leucanthemum vulgare*	3.60
Alnus glutinosa	0.90	*Limonium humile*	0.13
Alopecurus geniculatus	44.22	*Linum catharticum*	1.16
Alopecurus pratensis	35.73	*Listera ovata*	0.13
Anagallis tenella	3.21	*Lolium multiflorum*	4.37
Andromeda polifolia	0.13	*Lolium perenne*	78.41
Angelica sylvestris	0.13	*Lonicera periclymenum*	1.29
Anthoxanthum odoratum	71.98	*Lotus corniculatus*	11.70
Anthriscus sylvestris	0.26	*Lotus pendunculatus*	0.26
Arctium minus	0.13	*Luzula campestris*	5.14
Arctostaphylos uva-ursi	0.26	*Luzula multiflora*	2.31
Arrhenatherum elatius	3.98	*Lychis flos-cuculi*	11.95
Aster tripolium	0.13	*Lysimachia nemorum*	1.67
Atriplex prostrata	0.13	*Lythrum salicaria*	7.20
Avena sativa	0.51	*Matricaria discoidea*	1.16
Baldellia ranunculoides	0.13	*Mentha aquatica*	10.15
Bellis perennis	70.57	*Menyanthes trifoliata*	0.51
Betula pendula	3.98	*Molinia caerulea*	15.42
Brachypodium sylvaticum	0.64	*Myosotis laxa*	4.63
Briza media	3.08	*Myosotis secunda*	0.77
Bromus commutatus	0.13	*Myrica gale*	2.44
Bromus hordeaceus	1.16	*Mysotis arvensis*	1.80
Callitriche stagnalis	1.41	*Mysotis scorpoides*	1.03
Calluna vulgaris	10.93	*Nardus stricta*	8.35
Caltha palustris	2.06	*Narthecium ossifragum*	5.40
Calystegia sepium	0.13	*Nasturtium microphyllum*	0.26
Campanula rotundifolia	0.39	*Neottia cordata*	0.26
Capsella bursa-pastoris	0.77	*Orchis mascula*	0.39
Cardamine flexuosa	15.17	*Oxalis acetosella*	0.51
Cardamine pratensis	27.89	*Parnassia palustris*	1.16

Carex binervis	2.19	*Pedicularis palustris*	1.54
Carex echinata	16.20	*Pedicularis sylvatica*	6.17
Carex flacca	9.64	*Persicaria maculosa*	3.34
Carex hirta	0.13	*Phleum bertolonii*	0.26
Carex hostiana	0.39	*Phleum pratense*	11.44
Carex laevigata	0.13	*Phragmites australis*	2.19
Carex leporina	24.81	*Pilosella officinarum*	0.51
Carex limosa	0.77	*Pinguicula lusitanica*	0.39
Carex nigra	16.97	*Pinguicula vulgaris*	1.29
Carex panicea	8.74	*Plantago lanceolata*	50.00
Carex pulicaris	0.51	*Plantago major*	6.56
Carex rostrata	2.70	*Plantago maritima*	0.13
Centaurea nigra	4.63	*Platanthera bifolia*	0.39
Centaurium erythraea	0.26	*Poa angustifolia*	0.13
Cerastium fontanum	57.33	*Poa annua*	34.45
Cerastium glomeratum	2.19	*Poa compressa*	4.50
Chrysosplenium oppositifolium	0.51	*Poa nemoralis*	0.26
Circaea lutetiana	0.26	*Poa pratensis*	32.90
Cirsium arvense	25.45	*Poa trivalis*	50.64
Cirsium dissectum	17.99	*Polygala serphyllifolia*	4.11
Cirsium palustre	51.67	*Polygala vulgaris*	1.29
Cirsium vulgare	2.57	*Polygonum arenastrum*	2.57
Conopodium majus	1.03	*Potentilla anserina*	21.98
Convolvulus arvensis	0.13	*Potentilla erecta*	28.92
Corylus avellana	2.44	*Potentilla palustris*	2.44
Crataegus monogyna	4.76	*Potentilla sterilis*	0.13
Crepis capillaris	5.01	*Primula vulgaris*	1.29
Crepis paludosa	1.16	*Prunella vulgaris*	26.35
Crocosmia x crocosmiflora	0.39	*Prunus spinosa*	1.03
Cynosurus cristatus	75.19	*Pteridium aquilinum*	7.97
Daboecia cantabrica	0.39	*Quercus petraea*	0.51
Dactylis glomerata	15.04	*Quercus robur*	0.26
Dactylorhiza fuchsii	5.66	*Ranunculus acris*	42.80
Dactylorhiza maculata	2.70	*Ranunculus bulbosus*	2.57
Dactylorhiza purpurella	0.39	*Ranunculus ficaria*	0.26
Danthonia decumbens	1.03	*Ranunculus flammula*	33.55
Daucus carota	0.13	*Ranunculus lingua*	0.13
Deschampsia cespitosa	9.90	*Ranunculus repens*	82.65
Deschampsia flexuosa	0.90	*Rhinanthus minor*	0.39
Digitalis purpurea	1.03	*Rhododendron ponticum*	0.13
Drosera rotundifolia	1.16	*Rhynchospora alba*	0.64
Eleocharis palustris	2.19	*Rosa spinosissima*	0.13
Elytrigia juncea	0.13	*Rubus fruticosus*	19.02
Empetrum nigrum	0.39	*Rumex acetosa*	29.43
Epilobium angustifolium	0.13	*Rumex acetosella*	29.43
Epilobium montanum	17.87	*Rumex crispus*	36.38

Epilobium palustre	5.01	*Rumex obtusifolius*	19.02
Equisetum arvense	0.51	*Sagina procumbens*	13.37
Equisetum fluviatile	1.29	*Salix cinerea*	10.80
Equisetum palustre	5.91	*Saxifraga hypnoides*	0.26
Erica cinerea	3.21	*Schoenus nigricans*	1.03
Erica tetralix	5.40	*Senecio aquaticus*	17.22
Eriophorum angustifolium	7.46	*Senecio jacobea*	39.72
Eriophorum vaginatum	1.80	*Silene uniflora*	0.13
Euphrasia nemorosa	4.24	*Sisymbrium officinale*	0.13
Fallopia japonica	0.13	*Solidago virgaurea*	0.26
Festuca arundinacea	2.70	*Sorbus aucuparia*	1.93
Festuca ovina	10.80	*Sparganium erectum*	0.51
Festuca pratensis	16.20	*Stachys palustris*	0.90
Festuca rubra	8.48	*Stachys sylvatica*	0.26
Festuca vivipara	9.13	*Stellaria graminea*	0.51
Filago vulgaris	1.54	*Stellaria media*	25.71
Filipendula ulmaria	26.35	*Stellaria pallida*	0.13
Fraxinus excelsior	1.80	*Suaeda maritima*	0.13
Galium album	0.13	*Succisa pratensis*	16.58
Galium aparine	0.77	*Taraxacum officinalis*	60.80
Galium palustre	20.18	*Thymus polytrichus*	0.13
Galium saxatile	0.90	*Trichophorum caespitosum*	3.60
Galium verum	1.16	*Trifolium campestre*	2.19
Geranium robertianum	1.67	*Trifolium medium*	2.44
Geum rivale	0.26	*Trifolium pratense*	77.12
Glaux maritima	0.13	*Trifolium repens*	85.73
Glyceria fluitans	38.30	*Triglochin palustris*	1.93
Gnaphalium uliginosum	0.51	*Tripleurospernum maritima*	0.13
Gunnera tinctoria	0.13	*Typha latifolia*	0.39
Hedera helix	0.90	*Ulex europaeus*	16.97
Heracleum sphondylium	7.20	*Urtica dioica*	20.69
Holcus lanatus	94.86	*Vaccinium myrtillus*	2.57
Holcus mollis	45.24	*Valeriana officinalis*	0.39
Hyacinthoides non-scripta	0.64	*Veronica anagallis-aquatica*	0.13
Hydrocotyle vulgaris	2.96	*Veronica beccabunga*	2.44
Hypericum elodes	0.26	*Veronica chamaedrys*	0.13
Hypericum perforatum	0.26	*Veronica filiformis*	0.26
Hypericum tetrapterum	4.24	*Veronica montana*	0.13
Hypochoeris radicata	20.18	*Veronica officinalis*	0.64
Ilex aquifolium	1.80	*Veronica persica*	1.67
Iris pseudacorus	24.04	*Veronica serphyllifolia*	5.27
Juncus acutiflorus	20.44	*Vicia cracca*	6.43
Juncus articulatus	19.15	*Viola canina*	0.90
Juncus bufonius	10.67		

Appendix E

Field quality scores based on High Nature Value grassland indicator species and membership to group assigned using cluster analysis for each field

Field	Quality Score	Cluster group	Field	Quality Score	Cluster group	Field	Quality Score	Cluster group
LM014	2.85	1	SL037	1.55	2	MO1311	1.64	3
LM015	1.52	2	SL0312	1.28	2	MO1312	1.47	3
LM017	1.28	2	SL0314	2.25	2	MO1314	1.51	3
LM018	1.08	2	SL0316	1.06	2	MO1317	1.72	3
LM019	0.00	2	SL0317	1.49	2	MO1319	1.82	1
LM0110	2.03	2	SL0318	1.56	2	MO1320	1.89	3
LM0112	2.55	3	SL0320	1.52	2	MO141	1.85	3
LM022	1.06	2	SL041	1.72	1	MO143	1.86	3
LM023	2.55	3	SL042	1.39	1	MO144	1.51	3
LM024	1.75	3	SL051	1.99	2	MO147	--	4
LM027	--	4	SL052	1.28	2	MO1411	1.83	3
LM028	1.32	1	SL053	0.67	1	MO151	1.74	2
LM029	1.59	1	SL055	1.83	1	MO152	1.86	3
LM0210	2.07	3	SL057	1.67	1	MO153	1.33	2
LM032	--	4	SL062	0.56	2	MO154	2.07	3
LM033	--	4	SL065	0.95	2	MO156	1.89	3
LM036	--	4	SL066	2.31	2	MO157	1.49	3
LM041	1.04	2	SL067	2.07	2	MO158	1.32	3
LM042	0.69	2	SL068	2.14	1	MO159	1.32	3
LM043	1.75	2	SL069	2.12	1	MO1511	1.85	3
LM044	1.06	2	SL072	1.04	2	MO1512	2.30	3
LM045	1.75	2	SL073	0.56	2	MO1513	--	4
LM046	2.08	1	SL074	--	4	MO1514	1.73	3
LM047	1.70	1	SL075	0.56	2	MO1515	1.82	3
LM048	1.71	1	SL082	0.67	2	MO1518	2.31	1
LM049	1.72	1	SL083	1.55	2	MO161	0.00	2
LM0410	2.01	1	SL085	--	4	MO163	1.26	2
LM0414	1.89	1	SL091	1.28	2	MO164	0.67	2
LM0415	2.12	1	SL092	2.34	1	MO165	1.38	2
LM0417	1.32	2	SL093	2.33	1	MO167	1.47	1
LM0418	1.67	1	SL094	--	4	MO168	0.00	2
LM0419	2.41	1	SL095	1.35	1	MO169	1.01	1
LM0420	1.56	1	SL096	1.55	2	MO1610	1.26	2
LM0422	2.25	1	SL104	--	4	MO1611	1.01	2
LM0423	0.69	2	SL106	1.79	1	MO1612	1.64	3
LM0424	1.08	2	SL109	1.48	1	MO1613	1.28	3
LM0425	1.32	1	SL1010	1.48	2	MO1615	2.11	3
LM0426	1.75	2	SL1011	2.21	1	MO1616	0.69	2
LM0427	1.86	2	SL1012	1.86	1	MO1618	1.71	3
LM0428	1.49	2	SL1102	1.56	2	MO1619	1.71	3

LM0429	1.89	2	SL1103	1.01	1	MO171	1.08	3
LM0431	1.74	2	SL1104	1.01	2	MO172	1.47	2
LM0432	1.85	2	SL1105	0.69	2	MO173	2.50	1
LM051	--	4	SL1108	1.83	2	MO174	2.59	1
LM052	--	4	SL1109	1.85	2	MO175	2.40	1
LM053	--	4	SL123	--	4	MO176	1.86	1
LM054	--	4	SL124	--	4	MO178	1.86	1
LM055	--	4	SL1210	1.83	2	MO179	0.00	2
LM056	2.15	2	SL1211	1.89	2	MO1711	1.68	1
LM057	2.14	1	SL1212	1.55	2	MO1712	0.67	2
LM058	1.56	1	SL131	1.32	2	MO186	1.56	3
LM059	2.26	1	SL136	1.28	2	MO187	1.31	2
LM061	2.20	1	SL137	2.08	2	MO188	1.31	2
LM062	1.86	2	SL138	1.47	2	MO189	1.10	3
LM063	2.44	1	SL1310	1.10	2	MO1810	2.38	1
LM064	2.22	1	SL1311	1.10	2	MO1811	1.59	3
LM065	2.12	1	SL1312	1.10	2	MO1812	1.71	3
LM066	2.21	1	SL142	1.56	2	MO193	1.78	3
LM067	1.73	2	SL143	1.00	2	MO194	1.85	3
LM068	2.34	2	SL148	1.08	2	MO195	2.49	3
LM069	1.87	1	SL149	--	4	MO196	2.22	3
LM0610	1.59	2	SL152	1.04	2	MO197	2.19	3
LM0611	1.72	1	SL154	1.55	2	MO198	1.64	3
LM0612	1.56	1	SL156	1.73	2	MO199	2.06	3
LM0613	1.77	1	SL157	1.06	2	MO1910	2.53	3
LM0614	1.72	1	SL158	1.47	2	MO1911	2.27	3
LM0615	--	4	SL159	1.28	1	MO1912	2.27	3
LM0616	2.52	1	SL1511	1.89	1	MO1913	1.95	3
LM0617	2.12	1	SL1512	1.68	2	MO201	1.83	3
LM0620	2.14	1	SL1516	2.03	2	MO202	1.52	3
LM0621	2.01	1	SL1517	1.68	2	MO203	1.85	3
LM0622	2.01	1	SL1518	2.03	2	MO205	2.21	3
LM0623	1.75	2	SL1519	2.11	2	MO206	1.28	3
LM0624	1.91	2	MO011	--	4	MO207	1.89	3
LM0627	2.01	2	MO012	--	4	MO2010	1.71	3
LM071	2.11	1	MO013	--	4	MO2011	--	4
LM072	1.87	1	MO014	--	4	MO2013	--	4
LM073	1.82	1	MO016	--	4	MO2014	1.74	3
LM075	1.87	1	MO018	--	4	MO211	1.61	3
LM076	2.45	1	MO019	1.85	3	MO212	1.10	3
LM077	2.31	1	MO0110	2.10	3	MO213	1.08	3
LM079	2.50	1	MO0111	--	4	MO214	1.87	2
LM0710	2.44	1	MO0113	0.00	2	MO215	1.67	3
LM0711	1.56	1	MO0118	1.39	1	MO218	2.18	3
LM0712	2.13	1	MO0119	1.39	1	MO219	1.47	3
LM081	2.35	1	MO0120	--	4	MO2110	1.97	3
LM082	--	4	MO021	0.67	2	MO2111	2.17	3

LM083	--	4	MO025	1.04	2	MO2112	1.83	3
LM084	--	4	MO027	0.64	2	MO2114	1.67	3
LM085	--	4	MO028	1.33	2	MO2116	2.07	3
LM086	--	4	MO0211	1.81	2	MO223	1.08	2
LM088	2.60	1	MO0212	0.64	2	MO224	1.37	2
LM091	1.73	2	MO0213	1.35	2	MO225	1.70	3
LM092	1.75	2	MO0214	1.56	2	MO226	1.70	3
LM093	1.48	2	MO0215	1.33	2	MO227	1.83	3
LM094	0.00	2	MO031	1.77	2	MO231	1.59	2
LM095	0.64	2	MO032	1.59	2	MO232	1.37	3
LM096	1.58	2	MO034	1.32	2	MO233	--	4
LM097	1.06	2	MO036	1.58	3	MO237	--	4
LM101	2.34	1	MO038	--	4	MO238	1.68	3
LM102	1.91	1	MO039	--	4	MO239	1.82	3
LM103	1.56	1	MO0312	--	4	MO2310	1.67	3
LM104	1.89	1	MO043	1.68	3	MO244	1.74	3
LM106	2.14	1	MO044	1.98	3	MO245	1.86	3
LM107	2.25	1	MO045	1.56	3	MO246	2.07	1
LM108	0.64	2	MO046	1.49	3	MO247	2.34	1
LM1011	1.00	2	MO047	1.68	3	MO248	2.02	3
LM111	1.67	2	MO048	1.71	3	MO249	1.71	3
LM112	1.01	2	MO049	1.68	3	MO2410	2.06	3
LM113	1.00	2	MO0410	2.34	3	MO2411	2.47	3
LM114	0.64	1	MO0411	1.64	3	MO252	1.73	1
LM115	0.69	2	MO0412	1.70	3	MO253	1.52	2
LM121	1.86	1	MO0413	1.67	3	MO254	1.00	2
LM123	--	4	MO0414	1.82	3	MO255	1.89	3
LM131	1.57	1	MO0415	2.07	3	MO258	1.31	3
LM134	1.91	1	MO0417	1.83	3	MO259	1.82	3
LM135	1.75	1	MO0419	1.83	3	MO2510	1.99	1
LM136	--	4	MO051	1.33	2	MO261	1.97	3
LM139	2.53	1	MO053	2.21	3	MO262	2.10	1
LM1310	2.42	1	MO054	1.86	3	MO267	1.56	3
LM1311	--	4	MO055	1.74	3	MO268	1.95	3
LM1312	--	4	MO056	--	4	MO269	1.80	3
LM1315	2.21	1	MO058	--	4	MO2610	1.47	3
LM142	--	4	MO061	2.03	2	MO271	1.85	3
LM143	--	4	MO062	2.22	3	MO272	1.86	3
LM144	1.52	1	MO063	2.47	3	MO273	2.10	3
LM145	1.71	1	MO064	2.87	3	MO275	1.82	1
LM146	1.86	1	MO067	2.14	3	MO276	1.39	1
LM149	2.38	1	MO071	2.61	1	MO277	2.76	1
LM1410	2.44	1	MO072	2.74	3	MO278	2.43	1
LM152	2.35	1	MO074	2.63	3	MO279	2.08	1
LM153	1.10	2	MO075	2.25	3	MO2710	1.95	1
LM154	1.77	2	MO077	1.56	3	MO2711	2.18	1
LM155	2.52	1	MO079	2.43	1	MO2716	1.51	3

LM157	2.46	1	MO0710	1.73	3	MO2717	1.64	3
LM159	1.89	2	MO0714	2.45	3	MO2719	2.43	1
LM1512	2.14	2	MO081	2.76	1	MO2720	2.07	3
LM1513	1.75	2	MO082	2.74	1	MO281	1.08	2
LM1514	2.17	1	MO083	0.67	2	MO282	1.26	3
LM1516	2.73	1	MO084	--	4	MO285	1.32	3
LM1517	2.37	1	MO085	0.56	2	MO287	1.47	3
SL011	--	4	MO086	--	4	MO288	1.70	3
SL013	--	4	MO087	2.69	1	MO289	1.51	3
SL014	--	4	MO088	--	4	MO2812	1.56	3
SL015	--	4	MO093	1.01	3	MO2813	1.98	3
SL016	1.68	2	MO094	1.85	3	MO293	1.28	2
SL017	1.86	2	MO106	--	4	MO294	2.12	3
SL018	1.28	2	MO111	1.75	2	MO295	1.28	3
SL019	1.26	2	MO114	1.55	3	MO296	1.85	3
SL0112	1.33	2	MO115	1.85	3	MO297	1.85	3
SL0113	1.01	2	MO117	1.52	1	MO298	1.85	3
SL0114	1.01	2	MO1110	1.95	1	MO299	1.67	3
SL0115	1.06	2	MO124	2.51	1	MO301	1.52	3
SL0116	1.04	2	MO125	2.18	3	MO302	2.20	3
SL0117	1.28	2	MO126	1.94	3	MO303	2.10	3
SL0119	0.00	2	MO128	1.97	3	MO304	2.34	3
SL021	--	4	MO129	0.56	1	MO305	2.53	3
SL022	--	4	MO1212	2.90	3	MO308	2.11	3
SL023	--	4	MO131	1.99	3	MO309	1.85	3
SL031	1.06	2	MO132	1.72	3	MO3010	1.83	3
SL032	1.70	2	MO133	1.67	3	MO3011	2.19	3
SL033	1.83	2	MO134	2.10	1	MO3012	1.70	3
SL034	1.32	2	MO135	1.64	3	MO3013	1.26	3
SL035	1.48	2	MO139	1.82	3	MO3014	1.51	3
SL036	0.00	2	MO1310	1.32	3	MO3015	1.52	3
						MO3017	1.31	3