# SPATIAL TYPOLOGY OF AGRICULTURAL AND SOCIO-ECONOMIC ACTIVITY IN RURAL IRELAND

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## Abstract

This report presents a spatial typology of agricultural and socio-economic activity in rural Ireland to inform regionally tailored bioeconomy strategies. Using georeferenced data from the Census of Agriculture (2020), CORINE Land Cover (2018), and Census of Population (2022), factor and cluster analyses were applied to identify patterns in land use, farming structures, and rural labour force profiles. Nine key factors and five spatial clusters were identified, revealing a diverse rural landscape ranging from traditional farming areas and commercialised agricultural zones to fragmented cropland, afforested regions, and environmentally sensitive peatlands. The typology illustrates strong regional variation, with the Northern and Western region defined by traditional and marginal farming, the Southern region by commercial agriculture and ecological constraints, and the Eastern and Midlands region by a blend of large-scale farming and peri-urban diversification. This data-driven approach offers a strategic foundation for spatially targeted bioeconomy planning that aligns with local capacities, environmental priorities, and rural development needs.


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# Introduction

This report presents a spatial typology of agricultural and socio-economic activity in rural Ireland based on the latest publicly available and pertinent georeferenced statistic data. This data includes the Census of Agriculture Ireland 2020 (CSO Ireland, 2020), the CORINE Land Cover Geodatabase for Ireland 2018 (EPA Ireland, 2018), and the Census of Population Ireland 2022 (CSO Ireland, 2022).

A spatial typology of agricultural and socio-economic activity is critical for developing a regional bioeconomy strategy in Ireland because it provides a structured, data-driven way to understand the distribution of land use, agricultural productivity, and workforce composition across the three Regional Assemblies of the Northern and Western (NW) region, the Southern region, and Eastern & Midlands (EM) region. The identification of patterns and clusters of activity has the potential to allow policymakers and stakeholders to tailor region-specific bioeconomic initiatives in order to leverage regional strengths and address challenges.

# Methodology

## Statistic Approach

Factor analysis was considered to be the most appropriate statistical technique for generating a spatial typology since it helps to identify latent structures within datasets by reducing a large number of interrelated variables into a smaller set of factors. By applying factor analysis modelling to the spatial analysis of agricultural and socio-economic activity the aim of this investigation was to provide a data-driven approach to uncover regional patterns, classify areas based on shared characteristics, and support targeted policy development.

A cluster analysis was employed alongside the factor analysis to further refine the spatial typology of agricultural and socio-economic activity in Ireland. While factor analysis identifies underlying patterns and dimensions within the dataset, cluster analysis groups geographic regions based on their shared characteristics, enabling the classification of spatial units. By applying cluster analysis, the study aims to create distinct regional classifications that capture variations in land use, farming structure, and socio-economic conditions. The overall approach is designed to enhance spatial interpretability and ensure that regions with common characteristics are grouped together, facilitating more targeted policy interventions and resource allocation. The approach aims to produce a multi-dimensional understanding of regional agricultural and socio-economic activity. Factor analysis provides insights into key driving forces, while cluster analysis transforms these insights into spatially meaningful groupings intended to support regional bioeconomic planning, rural development strategies, and policy implementation.

### Key Variables for Inclusion

Table 1 outlines the 29 key variables used to generate the spatial typology of agricultural and socio-economic activity in Ireland. Variables were georeferenced to the Electoral District (ED) Level and

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primarily consisted of agricultural activity, land use, and socio-economic distributions. Rural areas were distinguished from urban areas using the OECD classification of 150 persons per $Km^2$ (OECD, 1994).

Table 1: Key Variables for the Spatial Typology

| Spatial Typology of Agricultural and Socio-Economic Activity |
|---|
| Census of Agriculture Ireland 2020 |
| Area Farmed as a percentage of Total Landcover (%) |
| Average Farm Size (Ha) |
| Farm Number (N) |
| Grassland (Ha) as a percentage of Total Landcover (%) |
| Cereals and Crops (Ha) as a percentage of Total Landcover (%) |
| Number of Beef Livestock (N) |
| Number of Dairy Livestock (N) |
| Number of Sheep Livestock (N) |
| CORINE Geodatabase 2018 |
| Wetlands and Peatlands (Ha) |
| Forestry and Seminatural Areas (Ha) |
| Heterogeneous Agriculture (Ha) |
| CSO Census of Population Ireland 2022 |
| Population Density |
| No Formal Education as a percentage of Total Population (%) |
| Primary School and Lower Secondary Education as a percentage of Total Population (%) |
| Secondary School Education as a percentage of Total Population (%) |
| Technical College, Apprenticeship, Cert Level Education as a percentage of Total Population (%) |
| University Level Education as a percentage of Total Population (%) |
| Postgraduate Education as a percentage of Total Population (%) |
| A Employers and Managers as a percentage of Total Population (%) |
| B Higher Professionals as a percentage of Total Population (%) |
| C Lower Professionals as a percentage of Total Population (%) |
| D Non-Manual Workers as a percentage of Total Population (%) |
| E Manual Skilled Workers as a percentage of Total Population (%) |
| F Semi-Skilled Workers as a percentage of Total Population (%) |
| G Unskilled Workers as a percentage of Total Population (%) |
| H Own Account Workers as a percentage of Total Population (%) |
| I Farmers as a percentage of Total Population (%) |
| J Agricultural Workers as a percentage of Total Population (%) |
| K All Others gainfully Employed and Unknown as a percentage of Total Population (%) |

## Data Standardisation

Initial attempts to perform factor and cluster analysis was found to be invalid due to the distribution of zero-inflated data. Variables found in the Census of Agriculture Ireland 2020 and CORINE 2018 datasets were found to contain zero-inflation, which occurs when a dataset has a disproportionately high number of zero values, distorting statistical analyses. To mitigate the impact of zero-inflation and ensure statistical

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robustness, the dataset was standardised by adjusting all zero values to 1 before performing factor and cluster analyses. The approach was necessary in order to: 1) preserve variance in the dataset whereby extreme skewness and artificial clustering of zero values leads to unstable factor solutions, limiting the ability to identify meaningful latent structures in the data; 2) ensure factor analysis is statistically robust whereby excessive zero values result in low communalities and undermine the reliability of factor extraction; and 3) facilitate cluster differentiation whereby large numbers of zero values lead to clusters being overly determined by the presence or absence of an attribute, rather than the relative distribution of values across different regions. As such, it was deemed that by replacing zero values with 1, the relative differences between regions could be preserved, allowing for more stable factor structures without artificially inflating variances.

Following this, all values were standardised using z-scores in order to ensure that no group of variables were more influential than another due to differences in scale or unit.

## Exploratory Factor Analysis: Principle Axis Factoring

The principle axis factoring technique was deemed appropriate as an exploratory factor analysis (FA) method over and above the more commonly used principal components analysis (PCA). According to Costello and Osborne (2005), Principal Components Analysis (PCA) is limited to being a data reduction technique, generating output that sits irrespective of any potential underlying dimension that may be derived from latent indicators. Since factor components are generated using the entire variance in the dataset, differences between the shared and unique variance of indicators are not distinguished (Ford et al., 1986). Therefore, if components are uncorrelated and communalities are moderate, inflated values of variances can be generated by components (Gorsuch, 1997; McArdle, 1990).

On the other hand, factor analysis has the ability to expose any latent indicators that could be causing other indicators to co-vary and, as such, only shared variance appears in the solution (Costello and Osborne, 2005). Since during the factor extraction procedure, shared variance is separated from the factor's unique variance and error variance, this allows for the calculation of the underlying factor structure (Floyd and Widaman, 1995).

According to Fabrigar et al. (1999), where the data is relatively normally distributed, maximum likelihood factoring should be used since it facilitates an extensive index of goodness-of-fit models and the calculation of confidence intervals. However, in the case of the current dataset, assumptions associated with normal distribution were violated and thus principal axis factoring was considered the most appropriate approach (Fabrigar et al., 1999).

### Factor Extraction

Regarding the number of factors to extract, most statistical packages use a default extraction method that retains all factors with eigenvalues greater than 1. However, according to Velicer and Jackson (1990), there is growing consensus in the literature that this is a fundamentally

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inaccurate method for deciding on the number of factors to retain. Using a Monte Carlo analysis, Costello and Osborne (2005) found that 36% of samples retained too many factors using this default extraction method. Although alternative tests are available (i.e. Velicer's criteria and parallel analysis) (Velicer and Jackson, 1990), they are not currently included in commercially available statistical packages, with close observation of the scree test being the only viable alternative available for most social scientists (Costello and Osborne, 2005).

Scrutiny of the scree test involves observation of the graph of eigenvalues and an inspection of the breaking point in the data where the graph begins to straighten. Points above this breaking point tend to indicate the number of factors which should be retained. However, this observation can be obstructed if there are clusters of data near the breaking point, and so executing a number of analyses by manually setting the number of factors to retain is necessary. Hence, first the default analysis is performed, second, if the scree test suggests an alternative number, that number is retained and tested, and finally numbers above and below those two numbers are tested.

### Rotation

When several factors are extracted, their interpretation is naturally based on the items that load on them (Field, 2009). However, in the case that several items load on several factors, it may become difficult to interpret what they represent, and so, the objective of rotation is simply to clarify the data structure.

There are two types of rotation, orthogonal and oblique. Orthogonal rotations generate factors that are uncorrelated, while oblique rotations allow factors to correlate. Orthogonal rotation is the most common choice amongst researchers (i.e. varimax rotation) since it is considered to produce more interpretable results, however, theoretically and statistically speaking, oblique rotation seems like the more logical choice since it cannot be assumed in the social sciences that factors are uncorrelated (Field, 2009; Tabachnik and Fidell, 2001). If factors are correlated, the use of orthogonal rotation results in a loss of information and is therefore less accurate (Costello and Osborne, 2005). On the other hand, if factors are uncorrelated, orthogonal and oblique rotation produce very similar results (Tabachnik and Fidell, 2001). Since it seems reasonable to assume that factors would correlate to some extent, and since uncorrelated factors produce similar results in any case, it was decided to use oblique rotation facilitated by the direct oblimin technique.

### Hierarchical Cluster Analysis for Regional Classification

In order to generate a spatial typology of agricultural and socio-economic activity in rural Ireland a Hierarchical Cluster Analysis (HCA) was applied and electoral districts were classified into clusters based on their factor scores. The Ward's Method was selected as the clustering algorithm because it minimises intra-cluster variance, ensuring compact and well-separated clusters. Squared Euclidean Distance was used as the similarity measure, amplifying differences between districts with distinct factor score patterns.

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To determine the optimal number of clusters, the Dendrogram and Agglomeration Schedule were examined. The dendrogram showed a natural break at five clusters.

# Results and Discussion

## Kaiser-Meyer-Olkin (KMO) Measure

A typology of the variables shown in Table 1 as part of the Census of Agriculture 2020, CORINE Geodatabase 2018, and CSO Ireland 2022 suite was applied to FA modelling. With all variables included, the KMO statistic generated a value of .557, which is considered on the lower end of acceptability. Thus, the anti-image correlation matrix was scrutinised in order to check the anti-image measures of sampling adequacy (MSA). The socio-economic variable 'all others gainfully employed and unknown' was found to have the lowest MSA of any variable at .257 and so the variable was removed. Examination of the correlation matrix revealed that the variable 'area farmed as a percentage of total landcover' was too highly correlated with other variables and was thus removed. Similarly, the variables 'number of beef livestock' and 'number of diary livestock' were too highly correlated and thus the latter was removed from modelling. This reduced the dataset from 29 to 26 variables. The analysis was run again. The second analysis generated a KMO of .703 which is considered appropriate for factor analysis (see Table 2).

Table 2: KMO and Bartlett's Test

| KMO and Bartlett's Test | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy | | .703 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 67304.061 |
| | df | 210 |
| | Sig. | <.001 |

## Factor Analysis

The factor extraction process resulted in a solution where eight factors were retained, collectively explaining 65.03% of the variance in the dataset. The number of retained factors was determined using a combination of Kaiser's criterion (eigenvalues greater than 1) and the visual interpretation of the scree plot. The first factor accounted for the largest proportion of variance, with subsequent factors capturing progressively smaller amounts. Factor loadings were examined to assign meaningful interpretations to the extracted factors (see Table 3).

### Factor 1: Traditional Medium-Large Scale Farming Areas

Factor 1, explaining 18.97% of total variance, had strong positive loadings on Primary/Lower Secondary School Education (.678), Upper Secondary School Education (.456), Technical Education (.455), No Formal Education (.437), Farm Number (.466), Farm Size (.339), Grassland (.474), Skilled Workers (.482), Agricultural Workers (.421), Farmers (.417), Semi-Skilled Workers (.402), Unskilled Workers (.361), and Own Account Workers (.236). It also had negative loadings on Population Density (-.352), University Education (-.692), Postgraduate

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Education (-.814), Employers/Managers (-.494), Higher Professionals (-.51), Lower Professionals (-.664), and Non-Manual Workers (-.376).

Factor 1 represents sparsely populated traditional farming landscapes characterised by medium to large-scale agricultural enterprise, a predominantly skilled and semi-skilled workforce, and lower educational attainment. These sparsely populated areas are deeply embedded in conventional agricultural practices, with limited engagement in professionalised or knowledge-based industries.

### Factor 2: Large-Scale Commercial Farming Areas

Factor 2, explaining 8.61% of variance in the model, was strongly associated with Grassland (.639), Cropland (.358), Average Farm Size (.654), Farm Number (.506), University Education (.389), Postgraduate Education (.185), Technical Education (.307), Employers/Managers (.343), Higher Professionals (.286), Lower Professionals (.176), Agricultural Workers (.279), Farmers (.39), and Own Account Workers (.317). It was negatively associated with Population Density (-.322), No Formal Education (-.317), Primary/Lower Secondary School Education (-.32), Unskilled Workers (-.318), and Semi-Skilled Workers (-.246).

Factor 2 represents sparsely populated large-scale, commercially oriented agricultural regions that are characterised by expansive farm sizes, a structured farming workforce, and a highly educated population. Although these areas exhibit low population density, they also exhibit strong engagement in professional, managerial, and higher-skilled occupations, distinguishing them from more traditional, subsistence-based farming regions.

### Factor 3: Medium-Small Scale Arable Farming Areas

This factor, explaining 7.33% of total variance, exhibited strong positive loadings on Cropland (.168), Average Farm Size (.143), No Formal Education (.29), Primary/Lower Secondary School Education (.406), Upper Secondary School Education (.353), Employers/Managers (.464), Higher Professionals (.319), Lower Professionals (0.356), and Non-Manual Workers (0.467). Factor 3 also exhibited negative loadings on University Education (-.41), Postgraduate Education (-.38), Farmers (-.398), Agricultural Workers (-.403), Semi-Skilled Workers (-.126) and Unskilled Workers (-.264).

Factor 3 is characterised by medium-small scale capital-intensive arable farming alongside a professionalised and non-manual workforce. Unlike large-scale commercial farming areas (factor 2) or traditional livestock-dominated landscapes (factor 1), these regions exhibit cropland cultivation, a structured labour market, and an evolving employment profile that is transitioning towards professional and managerial occupations.

### Factor 4: Medium-Large Scale Mixed Farming Areas

Factor 4, explaining 7.28% total variance, was strongly associated with Grassland (.127), Cropland (.134), Average Farm Size (.205), Beef/Dairy Livestock (.696), Sheep Livestock (.677), Population Density (.169),

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Table 3: Correlation Matrix

| Variable Name | Factors | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Grassland | 0.474 | 0.639 | 0.095 | 0.127 | -0.12 | 0.46 | 0.094 | -0.043 | -0.064 |
| Cropland | 0.059 | 0.358 | 0.168 | 0.134 | -0.188 | -0.483 | 0.093 | -0.551 | 0.096 |
| Peatland | 0.014 | -0.009 | 0.024 | -0.03 | -0.049 | 0.107 | 0.111 | 0.114 | 0.889 |
| Forestry | 0 | 0.022 | -0.034 | 0.13 | 0.113 | 0.097 | -0.718 | -0.191 | -0.229 |
| Heter Agriculture | 0.03 | -0.017 | 0.009 | 0.062 | -0.034 | -0.22 | 0.67 | 0.172 | -0.386 |
| Average Farm Size | 0.339 | 0.654 | 0.143 | 0.205 | -0.089 | -0.237 | 0.004 | -0.294 | 0.061 |
| Farm Number | 0.466 | 0.506 | 0.075 | 0.031 | -0.152 | 0.574 | 0.118 | 0.042 | -0.091 |
| Beef/Dairy Livestock | 0.057 | 0.066 | 0.084 | 0.696 | 0.509 | -0.008 | 0.013 | 0.032 | 0.049 |
| Sheep Livestock | 0.048 | 0.056 | 0.083 | 0.677 | 0.504 | 0.026 | 0.11 | 0.094 | 0.051 |
| Population Density | -0.352 | -0.332 | -0.016 | 0.169 | 0.109 | 0.01 | -0.019 | 0.161 | -0.027 |
| No Formal Ed | 0.437 | -0.317 | 0.29 | -0.175 | 0.173 | 0.241 | 0.126 | -0.298 | 0.022 |
| Primary/Second Ed | 0.678 | -0.32 | 0.406 | -0.161 | 0.119 | 0.067 | 0.055 | -0.087 | -0.048 |
| Upp Secondary Ed | 0.456 | -0.015 | 0.353 | -0.007 | -0.021 | -0.187 | -0.168 | 0.271 | 0.058 |
| Technical Education | 0.455 | 0.307 | 0.067 | 0.039 | -0.055 | -0.36 | -0.18 | 0.27 | 0.018 |
| University Ed | -0.692 | 0.389 | -0.41 | 0.136 | -0.143 | 0.032 | 0.001 | 0.032 | 0.033 |
| Postgraduate Ed | -0.814 | 0.185 | -0.38 | 0.101 | -0.08 | 0.104 | 0.061 | -0.052 | -0.004 |
| Employers/Managers | -0.494 | 0.343 | 0.464 | -0.063 | -0.063 | -0.067 | -0.04 | 0.12 | -0.012 |
| Higher Professionals | -0.51 | 0.286 | 0.319 | -0.159 | 0.147 | 0.107 | 0.007 | -0.005 | 0.006 |
| Lower Professionals | -0.664 | 0.176 | 0.356 | -0.06 | 0.083 | 0.141 | -0.015 | 0.021 | -0.066 |
| Non-Manual Workers | -0.376 | 0.011 | 0.467 | 0.193 | -0.35 | 0.091 | -0.073 | 0.175 | -0.013 |
| Skilled Workers | 0.482 | 0.068 | -0.131 | 0.169 | -0.311 | -0.142 | -0.032 | 0.234 | -0.022 |
| Semi-Skilled Workers | 0.402 | -0.246 | -0.126 | 0.387 | -0.431 | 0.087 | -0.077 | 0.057 | -0.033 |
| Unskilled Workers | 0.361 | -0.318 | -0.264 | 0.349 | -0.292 | 0.141 | 0.008 | -0.1 | 0.029 |
| Own Account | 0.236 | 0.317 | 0.042 | -0.14 | 0.037 | -0.077 | -0.116 | 0.438 | -0.033 |
| Farmers | 0.417 | 0.39 | -0.398 | -0.296 | 0.346 | -0.089 | 0.005 | 0.056 | 0.005 |
| Agricultural Workers | 0.421 | 0.279 | -0.403 | -0.247 | 0.266 | 0.057 | -0.022 | 0.023 | 0.015 |

University Education (.136), Postgraduate Education (.101), Semi-Skilled Workers (.387), Unskilled Workers (.349), Skilled Workers (.169) and Non-Manual Workers (.193). Factor 4 was also negatively correlated with No Formal Education (-.175), Primary/Lower Secondary School Education (-.161), Farmers (-.296), Agricultural Workers (-.247), Own Account Workers (-.14), and Higher Professionals (-.159).

Factor 4 represents more densely populated regions characterised by a balance between livestock and arable farming, moderate educational attainment, and a diverse workforce comprising both manual and non-manual occupations. Unlike the traditional farming communities identified in factor 1 or the large-scale commercial farms of factor 2, factor 4 regions exhibit a structured agricultural landscape with a mix of livestock and crop farming alongside a more varied workforce composition. The presence of both cropland and pastureland suggests a diversified farming system, where farmers engage in both livestock rearing and limited crop cultivation, possibly to support feed supply or rotational farming practices. The more moderate farm size suggests that these areas do not exhibit the extensive, large-scale farming practices seen in factor 2, but neither are they smallholder farms, distinguishing them as medium-large sized agricultural regions with a balanced production system.

### Factor 5: Small-Scale Livestock Farming and Afforested Areas

Factor 5, explaining 5.59% total variance, was highly correlated with Forestry (.113), Beef/Diary Livestock (.509), Sheep Livestock (.504), Population Density (.109), No Formal Education (.173), Primary/Lower Secondary School Education (.119), Farmers (.346), Agricultural Workers (.266), and Higher Professionals (.147). It was also negatively correlated with Farmer Number (-.152), University Education (-.143), Non-Manual Workers (-.35), Skilled Workers (-.311), Semi-Skilled Workers (-.431), and Unskilled Workers (-.292).

Factor 5 represents more densely populated regions characterised by labour-intensive, small-scale livestock farming, a strong presence of forestry, and a labour force that is more reliant on traditional agricultural employment rather than non-manual or skilled occupations. These areas exhibit a more localised, smallholder-based agricultural structure, with lower formal education levels, fewer professional occupations, and a greater reliance on manual labour in farming and forestry. The presence of forestry in these areas is particularly notable, suggesting a landscape where agricultural land is interspersed with afforested areas. This could indicate a transition from traditional farming to forestry-related land uses, either due to land abandonment, afforestation incentives, or environmental conservation programs. The co-existence of livestock farming and forestry aligns with landscapes where marginal land use is common, and agricultural productivity may be constrained by soil quality, topography, or climatic conditions.

### Factor 6: Fragmented Cropland and Small Farm Structures

Factor 6, explaining 4.54% total variance, exhibited positive correlations with Farm Number (.574), No Formal Education (.241), Postgraduate Education (.104), Higher Professionals (.107), Lower Professionals (.141), and Unskilled Workers (.141). The factor also

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exhibited negative correlations with Cropland (-.483), Average Farm Size (-.237), Upper Secondary School Education (-.187), Technical Education (-.36), and Skilled Workers (-.142).

Factor 6 represents regions with a high number of farms, smaller agricultural landholdings, and a mixed socio-economic workforce with lower-skilled employment and limited technical education. These areas exhibit a high farm density but are characterised by small farm sizes, suggesting a fragmented land-use structure. The combination of lower educational attainment, mixed professional representation, and the absence of specialised agricultural training indicates an economically constrained, semi-rural environment where traditional farming persists but is not dominant. Farms are relatively small and are not oriented toward large-scale arable agriculture. Unlike the extensive grassland systems of factor 1 and factor 2, or the more commercialised operations of factor 4, factor 6 regions reflect a more localised, small-scale agricultural economy with limited intensification.

### Factor 7: Marginal Farming Landscapes

Factor 7, explaining 4.21% total variance, had high positive loadings on Heterogeneous Agriculture (.67), Farm Number (.118), Peatland (.111), and No Formal Education (.126). It had negative loadings on Forestry (-.718), Upper Secondary School Education (-.168), Technical Education (-.18), and Own Account Workers (-.116).

The strong positive correlation with heterogeneous agriculture suggests that factor 7 regions are characterised by diverse, small-scale farming systems where annual and permanent crops are grown alongside natural vegetation, pastures, and meadows. This indicates an agricultural landscape that is not dominated by monoculture but rather by mixed land use. The presence of peatlands supports the suggestion that these areas are likely marginal agricultural landscapes, where soil and drainage conditions may not support intensive cropping or large-scale commercial farming. Peatland areas are often low-yielding for agriculture and prone to environmental restrictions, which may explain why these regions retain more traditional or subsistence-oriented farming models rather than intensive agricultural operations. The positive association with farm number suggests a high density of small farms, likely fragmented and dispersed across marginal rural landscapes. These farms are unlikely to be highly mechanised or capital-intensive, further emphasising the persistence of low-input, traditional farming practices rather than large-scale agricultural modernisation.

### Factor 8: Semi-Rural Landscapes with Diversified Agricultural Structures

Factor 8, explaining 4.01% total variance, was positively associated with Peatland (.114), Heterogeneous Agriculture (.172), Population Density (.161), Upper Secondary School Education (.271), Technical Education (.27), Employers and Managers (.12), Non-Manual Workers (.175), Skilled Workers (.234), and Own Account Workers (.438). It was negatively associated with Cropland (-.551), Forestry (-.191), Average Farm Size (-.294), and No Formal Education (.298).

Factor 8 represents more densely populated semi-rural landscapes with a diversified agricultural structure, growing professional

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employment, and a shift towards more skilled and managerial occupations. These regions are characterised by heterogeneous agriculture and peatland, indicating a land-use pattern that includes a mix of crops, pastures, and natural vegetation, alongside wetland ecosystems. Unlike the intensive commercial farming identified in factor 2 or the small-scale livestock and forestry landscapes in factor 5, these areas support a mix of traditional and emerging agricultural practices, often within ecologically sensitive or constrained environments.

### Factor 9: Environmentally Sensitive Peatland Areas

Factor 9, explaining 3.86% total variance, was most strongly correlated with Peatland (.889), with negative correlations associated with Forestry (-.229) and Heterogeneous Agriculture (-.386).

Factor 9 regions are sparsely populated and dominated by extensive peatland ecosystems, with little afforestation or agricultural diversity. Unlike other factors, which capture varying intensities of farming and professional workforce structures, factor 9 reflects landscapes where agricultural productivity is severely constrained, forestry is underdeveloped, and economic activity is minimal. The defining feature of factor 9 is its extremely high correlation with peatlands. Peatlands are unique ecosystems characterised by water-saturated soils, acidic vegetation, and poor drainage, making them largely unsuitable for intensive farming or large-scale settlement. These regions are often ecologically significant, serving as important carbon sinks, biodiversity reserves, and natural flood regulators. Unlike factor 5, which integrates forestry with small-scale livestock farming, factor 9 regions exhibit little to no agricultural productive land use, and instead should remain largely untouched, or under conservation-based management.

## Cluster Analysis

As previously described, factor scores were entered into a Hierarchical Cluster Analysis in order to develop a spatial typology that demonstrates distinct regional classifications that geographically illustrate variations in land use, farming structure, and socio-economic activities. Results of this analysis are presented in Table 4.

Table 4: Cluster Analysis

| Factors | Clusters | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| 1 | -1.64735 | -1.36792 | 1.07099 | -0.64079 | 2.38877 |
| 2 | -6.32959 | 0.22589 | 1.3695 | -1.16815 | 0.80989 |
| 3 | 0.71852 | 0.41707 | 0.78644 | 0.10049 | -1.80284 |
| 4 | 0.93783 | -1.10359 | 0.6814 | 0.53011 | -0.23423 |
| 5 | -0.78888 | -1.8194 | 0.46407 | 1.70877 | 0.26029 |
| 6 | 0.47834 | -0.21098 | 0.39226 | 0.41065 | 0.07112 |
| 7 | 0.88407 | 8.11452 | -0.56762 | -0.06211 | -0.70529 |
| 8 | 1.549 | 0.04783 | -7.02861 | 0.06316 | 5.06802 |
| 9 | -0.52843 | 0.11512 | -2.90624 | 10.5734 | -2.59959 |

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### Cluster 1: Semi-Rural Landscapes with Arable and Diversified Agricultural Structures

Cluster 1 was negatively associated with Large-Scale Commercial Farming (-6.33) and Traditional Medium-Large Scale Farming (-1.65), and positively associated with Semi-Rural Landscapes with Diversified Agricultural Structures (1.55), Medium-Large Scale Mixed Farming Areas (.938), Marginal Farming Landscapes (.884) and Medium-Small Scale Arable Farming Areas (.719).

Unlike areas dominated by large-scale farming, Cluster 1 represents a transitional rural economy that is neither fully traditional nor entirely commercialised. Instead, these areas contain a mixture of agricultural structures, including medium-sized mixed farms, marginal agricultural lands, and smaller arable farming units. The absence of strong commercial farming structures suggests that large-scale mechanisation and capital-intensive farming do not define these areas. Instead, land use in Cluster 1 likely consists of smaller, more independent farm enterprises, combined with semi-rural settlements that have diversified their economic base beyond agriculture.

### Cluster 2: Marginal Agricultural and Rural Transition Zones

Cluster 2 was positively associated with Marginal Farming Landscapes (8.11) and negatively associated with Small-Scale Livestock Farming and Afforested Areas (-1.82), Traditional Medium-Large Scale Farming (-1.37) and Medium-Large Scale Mixed Farming Areas (-.1.10).

Cluster 2 regions are characterised by low intensity, fragmented agricultural activity, limited farm productivity, and challenging environmental conditions. Cluster 2 is distinct from structured, livestock-intensive, and afforested farming regions and does not align with conventional, medium-to-large-scale agricultural enterprise. Instead, these areas are typified by heterogeneous, small-scale, and low yield farming systems that are not commercially competitive.

### Cluster 3: Highly Commercialised Large-Scale Farming Areas

Cluster 3 was negatively associated with Semi-Rural Landscapes (-7.03) and Environmentally Sensitive Peatland Areas (-2.91), and positively associated with Large-Scale Commercial Farming Areas (1.37) and Traditional Medium-Large Scale Farming Areas (1.07).

Cluster 3 represents a category of rural landscapes characterised by expansive agricultural operations, high productivity, and structured farming economies. Unlike clusters associated with fragmented, marginal, or diversified agricultural economies, Cluster 3 aligns with traditional and large-scale commercial farming systems. This classification suggests a landscape where farming remains a dominant economic activity, relying on structured agricultural enterprises with well-defined production systems.

### Cluster 4: Environmentally Sensitive Areas with Small-Scale Livestock Farming

Cluster 4 was positively associated with Environmentally Sensitive Peatland Areas (10.57) and Small-Scale Livestock Farming and Afforested Areas (1.71) and was negatively associated with Large-Scale Commercial Farming (-1.17).

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Cluster 4 represents a unique rural landscape shaped by a combination of environmentally sensitive peatlands, small-scale livestock farming, and a growing presence of afforestation and forestry-related activities. Unlike the highly productive commercial farming regions, these areas are characterised by natural constraints that limit intensive agricultural expansion but encourage a multi-functional rural economy, where traditional farming coexists with forestry and conservation-driven land use. Cluster 4 areas are dominated by extensive wetland ecosystems. Peatlands are typically unsuitable for large-scale farming due to their poor drainage, acidic soils, and conservation restrictions, which limits their capacity for high-yield agriculture. Unlike Cluster 3, which represents highly productive commercial farming regions, Cluster 4 aligns more closely with low-intensity, environmentally constrained landscapes.

### Cluster 5: Medium-Large Scale Traditional Farming in Semi-Rural Landscapes

Cluster 5 was positively associated with Semi-Rural Landscapes with Diversified Agricultural Structures (5.07) and Traditional Medium-Large Scale Farming (2.39) and negatively associated with Environmentally Sensitive Peatland Areas (-2.59) and Medium-Small Scale Arable Farming (-1.80).

Cluster 5 represents a landscape where large-scale but traditional farming remains dominant, set within a semi-rural environment that is slowly evolving but still deeply rooted in agricultural heritage. Unlike the more fragmented or commercially intensive farming regions, Cluster 5 exhibits a structured yet traditional agricultural economy, where farming continues to define both land use and socio-economic activity. While modernisation is evident, these regions have largely maintained their conventional farming practices, relying on extensive pastoral systems, particularly grassland-based agriculture.

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## Application of Factor Analysis to a GIS Environment

### *Factor 1: Traditional Medium-Large Scale Farming Areas*

Table 5 and Figure 1 shows the spatial distribution of factor 1 scores in Ireland, interpreted as 'Traditional Medium-Large Scale Farming Areas'. The Northern and Western (NW) region showed the highest distribution of factor scores (based on 'high' to 'very high' scores whereby data is classified in accordance with non-uniform distribution, with the remaining divisions being 'moderate', 'low' and 'very low'). At county level, Cavan, Roscommon and Sligo showed the highest distributions, followed by counties Galway, Leitrim and Mayo.

As previously described, factor 1 is associated with medium-to-large scale agricultural regions where farming dominates the economy, educational attainment is lower, and employment is primarily characterised in terms of skilled and semi-skilled manual labour. These regions are sparsely populated, with limited engagement in professional or non-agricultural occupations, reinforcing their deeply rural and traditional character.

Factor 1 exhibits strong positive correlations with key agricultural indicators, including farm number, farm size, and grassland, indicating a dominant reliance on pasture-based farming. The positive association with agricultural workers and farmers supports the argument that farming is the central occupation in these regions, with a workforce directly engaged in primary agricultural activities. The presence of 'own account workers' also suggests a high level of self-employment in such areas. The educational profile of factor 1 regions is skewed towards lower formal and technical education. In some instance, this may suggest that many individuals transition into

Table 5: Traditional Medium-Large Scale Farming Areas per Region/County

| Scores | Low (%) | Moderate (%) | High (%) |
|---|---|---|---|
| REGION | | | |
| NW | 36.29 | 12.74 | 50.96 |
| Southern | 60.86 | 21.12 | 18.02 |
| EM | 64.72 | 20.23 | 15.05 |
| COUNTY | | | |
| Donegal | 48.99 | 13.42 | 37.58 |
| Sligo | 25.32 | 13.92 | 60.76 |
| Leitrim | 34.25 | 15.07 | 50.68 |
| Cavan | 28.09 | 7.87 | 64.04 |
| Monaghan | 58.57 | 8.57 | 32.86 |
| Galway | 28.50 | 14.95 | 56.54 |
| Mayo | 49.34 | 7.24 | 43.42 |
| Roscommon | 17.27 | 20.91 | 61.82 |
| Clare | 27.81 | 25.83 | 46.36 |
| Tipperary | 70.49 | 22.70 | 6.81 |
| Limerick | 45.19 | 25.93 | 28.89 |
| Waterford | 82.61 | 11.96 | 5.43 |
| Kilkenny | 87.61 | 10.62 | 1.77 |
| Carlow | 66.67 | 24.07 | 9.26 |
| Wexford | 69.35 | 24.19 | 6.45 |
| Cork | 60.19 | 22.22 | 17.59 |
| Kerry | 37.80 | 22.56 | 39.63 |
| Dublin | 95.24 | 4.76 | 0.00 |
| Wicklow | 69.51 | 19.51 | 10.98 |
| Kildare | 75.28 | 17.98 | 6.74 |
| Meath | 71.74 | 14.13 | 14.13 |
| Louth | 74.42 | 11.63 | 13.95 |
| Longford | 27.78 | 37.04 | 35.19 |
| Westmeath | 58.10 | 21.90 | 20.00 |
| Offaly | 55.81 | 22.09 | 22.09 |
| Laois | 54.64 | 32.99 | 12.37 |

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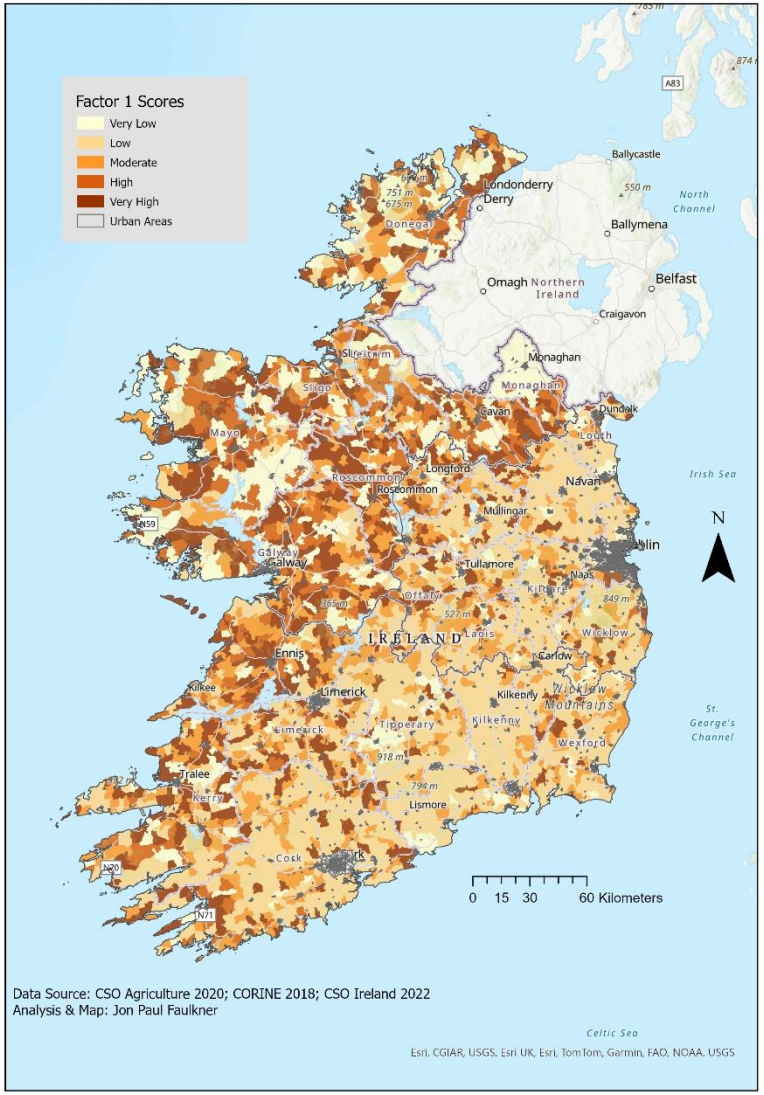
agricultural employment at an early stage. In contrast, there are strong negative correlations with university education and postgraduate education, indicating that higher education is not a significant feature of these regions. This lack of university-level education aligns with the manual labour-intensive nature of the workforce, where technical skills and hands-on agricultural experience are more prevalent than formal academic qualifications. The workforce composition in factor 1 regions, with its heavy concentration towards manual labour and negative correlation with professional employment, suggests that such regions lack significant representation in business, administrative, or professional services. Instead, economic activity is primarily centred around traditional, hands-on occupations, indicative of a more agricultural and rural workforce.

Unlike factor 8, which is associated with more diversified semi-rural economies, factor 1 represents isolated farming communities where agriculture remains the dominant livelihood. The lack of urban influence is illustrated by the absence of strong professional or knowledge-based industries in such areas. Unlike factor 2, which represents large-scale commercial farming with a highly educated workforce, factor 1 remains rooted in traditional, family-based farming with lower educational attainment.

Figure 1: Traditional Medium-Large Scale Farming Areas (Factor 1)

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### *Factor 2: Large-Scale Commercial Farming Areas*

Table 6 and Figure 2 show the spatial distribution of Factor 2 scores, interpreted as 'Large-Scale Commercial Farming Areas'. The Southern region showed the highest factor 2 scores, followed by the Eastern and Midlands (EM) region. At county level, Kilkenny showed the highest factor 2 scores, followed by Wexford, Kildare, Meath, Tipperary and Waterford. Counties Carlow, Cork, Laois, Offaly, and Westmeath also exhibited relatively high scores.

Factor 2 represents Ireland's large-scale commercial farming areas, where expansive farm enterprises operate with a highly educated workforce and professionalised management. These regions are characterised by low population density, large land holdings, and a structured economy, setting them apart from more traditional, small-scale, or labour-intensive farming communities.

Strongly associated with grassland, cropland, average farm size, and farm number, factor 2 is dominated by expansive commercial farms specialising in both livestock and arable agriculture. The large farm sizes suggest a high degree of land consolidation, where farming is structured around commercial viability rather than smallholder or subsistence-based models. The positive correlation with farmers and agricultural workers highlights that farming remains a core economic activity, but with a more organised and professionalised structure compared to smaller, family-run operations seen in factor 1. This suggests that these areas are home to large-scale farm enterprises that require a stable agricultural workforce, but at the same time supplemented by modern business and technical expertise.

Table 6: Large-Scale Commercial Farming Areas per Region/County

| Scores | Low (%) | Moderate (%) | High (%) |
|---|---|---|---|
| REGION | | | |
| NW | 66.82 | 22.90 | 10.29 |
| Southern | 15.78 | 22.61 | 61.61 |
| EM | 27.94 | 19.34 | 52.72 |
| COUNTY | | | |
| Donegal | 65.77 | 14.09 | 20.13 |
| Sligo | 60.76 | 26.58 | 12.66 |
| Leitrim | 71.23 | 20.55 | 8.22 |
| Cavan | 67.42 | 23.60 | 8.99 |
| Monaghan | 82.86 | 14.29 | 2.86 |
| Galway | 62.15 | 28.04 | 9.81 |
| Mayo | 74.34 | 15.13 | 10.53 |
| Roscommon | 50.00 | 40.91 | 9.09 |
| Clare | 32.45 | 38.41 | 29.14 |
| Tipperary | 12.70 | 16.74 | 70.56 |
| Limerick | 17.04 | 28.15 | 54.81 |
| Waterford | 17.39 | 13.04 | 69.57 |
| Kilkenny | 2.65 | 7.08 | 90.27 |
| Carlow | 12.96 | 18.52 | 68.52 |
| Wexford | 6.45 | 19.35 | 74.19 |
| Cork | 9.88 | 23.77 | 66.36 |
| Kerry | 30.49 | 38.41 | 31.10 |
| Dublin | 97.10 | 2.90 | 0.00 |
| Wicklow | 17.07 | 10.98 | 71.95 |
| Kildare | 11.24 | 12.36 | 76.40 |
| Meath | 8.70 | 16.30 | 75.00 |
| Louth | 37.21 | 16.28 | 46.51 |
| Longford | 38.89 | 40.74 | 20.37 |
| Westmeath | 17.14 | 20.95 | 61.90 |
| Offaly | 12.79 | 26.74 | 60.47 |
| Laois | 11.34 | 26.80 | 61.86 |

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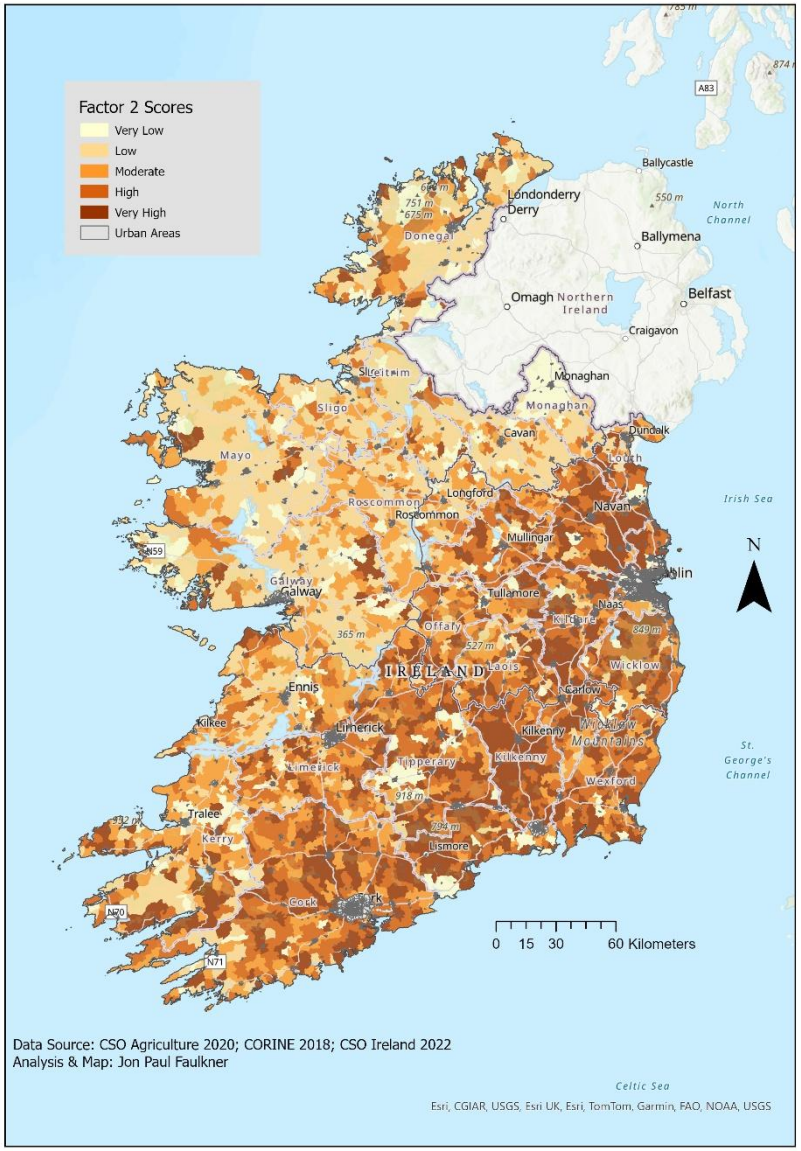
Unlike factor 1, which is characterised by lower levels of formal education, factor 2 regions exhibit higher levels of educational attainment, indicating a workforce with strong academic and vocational backgrounds. The strong presence of professional occupations suggests that these regions are not only agricultural hubs but also centres of business, management and technical expertise. This distinguishes them from more traditional farming areas, where employment is heavily weighted toward manual labour rather than professional or managerial roles.

The negative correlation with 'no formal education' and 'primary/lower secondary education' further supports these findings, indicating that such areas have moved away from traditional, low-education farming models and have embraced a more knowledge-driven agricultural economy. The sparse population of factor 2 suggests that such areas consist of large agricultural estates and commercial farms spread across vast landscapes. These regions do not rely heavily on low-skilled agricultural labour, but rather on a workforce with specialised skills and education. This distinguishes factor 2 regions from factor 5 (small-scale, labour-intensive livestock farming areas) and factor 6 (fragmented small-farm structures), both of which have a higher presence of unskilled and semi-skilled labour. Instead, factor 2 reflects a more modernised, large-scale farming system where efficiency, mechanisation, and specialised knowledge are more likely to drive agricultural productivity (de Roest et al., 2018).

Figure 2: Large-Scale Commercial Farming Areas (Factor 2)

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### *Factor 3: Medium-Small Scale Arable Farming Areas*

Table 7 and Figure 3 show the spatial distribution of factor 3 scores in rural Ireland, interpreted as 'Medium-Small Scale Arable Farming Areas'. The EM region exhibited the highest factor 3 scores, followed by the Southern region. At the county level, Wexford stands out with the highest proportion of factor 3 scores, closely followed by Kildare, Carlow, Meath, and Louth. Other counties with relatively high proportions of factor 3 scores included Kilkenny, Laois, Offaly and Tipperary.

Factor 3 regions represent a transitional phase in Ireland's rural economy, where traditional small-scale arable farming is integrated with professional employment and non-manual industries. While farming remains an important part of the economic structure, these regions may be experiencing a shift towards knowledge-based and service-oriented employment.

These regions maintain a strong presence of arable-based agriculture, but on a smaller scale compared to large-scale commercial farming regions (factor 2). The smaller farm sizes suggest a more fragmented agricultural landscape, likely comprising a mix of independently operated farms rather than highly consolidated agricultural estates. Despite the presence of active farming, factor 3 is negatively correlated with both farmers and agricultural workers, indicating that farming is capital-intensive and not the dominant form of employment in these regions. Instead, the economic structure is more diverse, with an emphasis on professional and non-manual occupations. Unlike traditional farming regions where manual labour dominates,

Table 7: Medium-Small Scale Arable Farming Areas per Region/County

| Scores | Low (%) | Moderate (%) | High (%) |
|---|---|---|---|
| REGION | | | |
| NW | 68.04 | 24.57 | 7.39 |
| Southern | 39.04 | 13.25 | 47.71 |
| EM | 24.05 | 15.48 | 60.46 |
| COUNTY | | | |
| Donegal | 53.69 | 26.85 | 19.46 |
| Sligo | 81.01 | 16.46 | 2.53 |
| Leitrim | 86.30 | 13.70 | 0.00 |
| Cavan | 87.64 | 12.36 | 0.00 |
| Monaghan | 72.86 | 24.29 | 2.86 |
| Galway | 44.39 | 34.11 | 21.50 |
| Mayo | 56.58 | 38.82 | 4.61 |
| Roscommon | 61.82 | 30.00 | 8.18 |
| Clare | 86.09 | 11.26 | 2.65 |
| Tipperary | 32.89 | 14.97 | 52.14 |
| Limerick | 73.33 | 15.56 | 11.11 |
| Waterford | 31.52 | 20.65 | 47.83 |
| Kilkenny | 7.08 | 17.70 | 75.22 |
| Carlow | 7.41 | 7.41 | 85.19 |
| Wexford | 5.65 | 1.61 | 92.74 |
| Cork | 31.17 | 16.67 | 52.16 |
| Kerry | 76.22 | 13.41 | 10.37 |
| Dublin | 66.67 | 0.00 | 33.33 |
| Wicklow | 30.49 | 9.76 | 59.76 |
| Kildare | 5.62 | 3.37 | 91.01 |
| Meath | 9.78 | 14.13 | 76.09 |
| Louth | 23.26 | 4.65 | 72.09 |
| Longford | 31.48 | 50.00 | 18.52 |
| Westmeath | 24.76 | 25.71 | 49.52 |
| Offaly | 15.12 | 16.28 | 68.60 |
| Laois | 9.28 | 15.46 | 75.26 |

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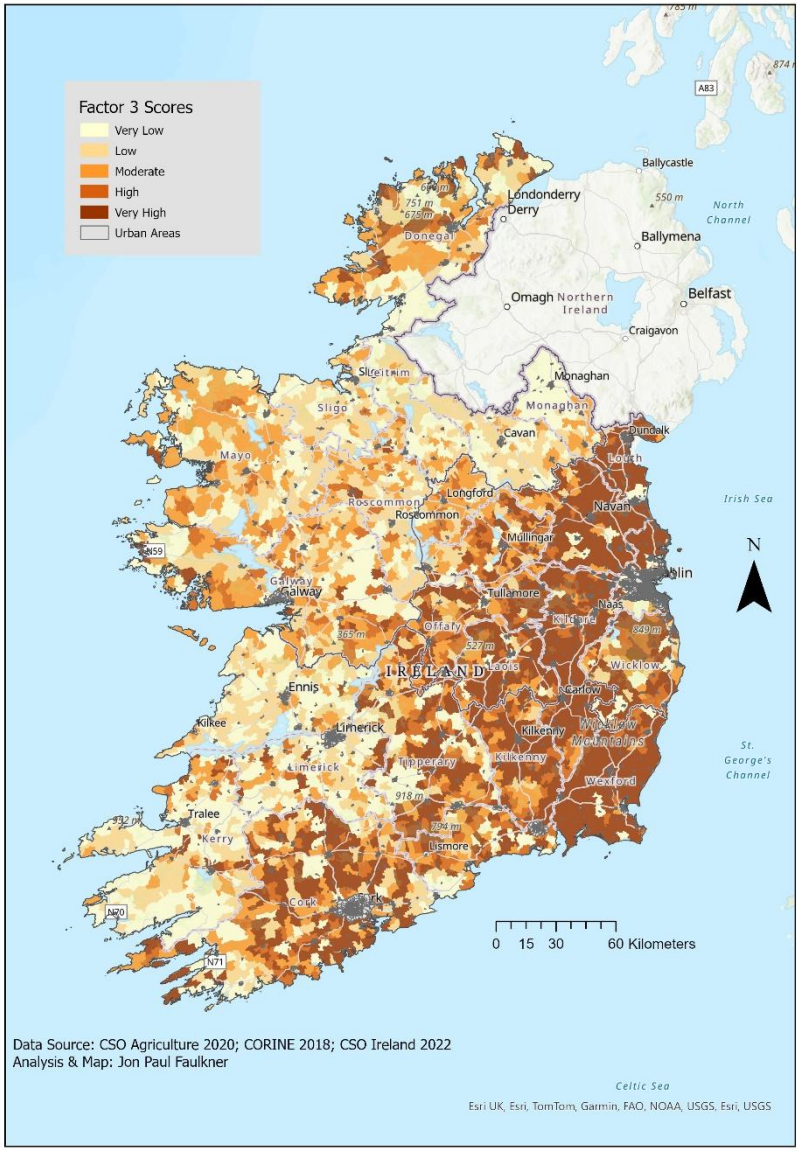
factor 3 exhibits strong positive correlations with professional occupations.

This pattern reflects an ongoing socio-economic transformation, where agricultural regions are diversifying beyond primary farming activities, potentially integrating agri-business, rural enterprise, and service industries into the local economy. These regions may be benefiting from improved infrastructure, education, and access to broader employment opportunities beyond traditional farming occupations. Factor 3 presents a complex educational landscape, with both lower and higher levels of education coexisting. While some educational progress has been made, higher education remains less common in these areas compared to more professionalised farming regions (such as factor 2). The absence of a strong university-educated workforce differentiates factor 3 from the more knowledge-based agricultural hubs characterised in factor 2 regions. Instead, factor 3 is an evolving rural economy where technical education and vocational training may be perceived as more relevant than formal academic pathways.

A key feature of factor 3 is its negative correlation with semi-skilled and unskilled workers, suggesting that these regions are shifting away from labour-intensive employment structures, particularly in agriculture. This contrasts with factor 1 (where agricultural and skilled manual labour is dominant) and factor 5 (representing small-scale livestock farming with a reliance on manual labour). This indicates that factor 3 regions are moving towards a more diversified economy where employment opportunities extend beyond traditional farming and manual labour. The presence of professional and managerial workers suggests that these areas are becoming integrated into broader economic networks, potentially benefiting from proximity to urban

Figure 3: Medium-Small Scale Arable Farming Areas (Factor 3)

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centres, emerging industries, or knowledge-based rural enterprises.

### *Factor 4: Medium-Large Scale Mixed Farming Areas*

Table 8 and Figure 4 show the spatial distribution of factor 4 scores, interpreted as 'Medium-Large Scale Mixed Farming Areas'. The NW region exhibited the highest factor 4 scores, followed by, to a much lesser extent, the Southern region. At county level, Mayo exhibited the highest factor 4 scores, followed by Donegal, with Galway, Cavan, Leitrim and Meath. Other counties with relatively high scores included Sligo and Roscommon.

Factor 4 regions represent medium-to-large-scale mixed farming areas, where livestock and arable farming coexist within a structured, moderately populated rural environment. These areas exhibit a transitional labour market, balancing agricultural employment with non-manual work opportunities, making them distinct from both factor 1's traditional farm-based economy and factor 2's large-scale commercialised sector. Factor 4 represents a rural economy that is evolving beyond traditional agricultural dependency, integrating livestock and crop production with a moderately diversified labour market. These areas are likely to serve as key transitional zones where traditional farming communities adapt to broader economic shifts while maintaining strong agricultural roots.

Factor 4 represents more densely populated regions characterised by a balance between livestock and arable farming, moderate educational

Table 8: Medium-Large Scale Mixed Farming Areas per Region/County

| Scores | Low (%) | Moderate (%) | High (%) |
|---|---|---|---|
| REGION | | | |
| NW | 20.04 | 13.99 | 65.97 |
| Southern | 45.28 | 18.20 | 36.52 |
| EM | 5.03 | 2.02 | 4.06 |
| COUNTY | | | |
| Donegal | 9.40 | 14.77 | 75.84 |
| Sligo | 17.72 | 24.05 | 58.23 |
| Leitrim | 20.55 | 15.07 | 64.38 |
| Cavan | 15.73 | 15.73 | 68.54 |
| Monaghan | 48.57 | 5.71 | 45.71 |
| Galway | 15.42 | 15.89 | 68.69 |
| Mayo | 6.58 | 5.26 | 88.16 |
| Roscommon | 26.36 | 15.45 | 58.18 |
| Clare | 32.21 | 22.15 | 45.64 |
| Tipperary | 34.61 | 16.22 | 49.18 |
| Limerick | 27.41 | 20.74 | 51.85 |
| Waterford | 61.54 | 16.48 | 21.98 |
| Kilkenny | 52.21 | 20.35 | 27.43 |
| Carlow | 75.93 | 9.26 | 14.81 |
| Wexford | 63.71 | 24.19 | 12.10 |
| Cork | 29.41 | 17.34 | 53.25 |
| Kerry | 30.49 | 17.07 | 52.44 |
| Dublin | 85.71 | 4.76 | 9.52 |
| Wicklow | 41.46 | 20.73 | 37.80 |
| Kildare | 76.40 | 13.48 | 10.11 |
| Meath | 23.91 | 15.22 | 60.87 |
| Louth | 51.16 | 16.28 | 32.56 |
| Longford | 37.04 | 9.26 | 53.70 |
| Westmeath | 49.52 | 20.00 | 30.48 |
| Offaly | 50.00 | 15.12 | 34.88 |
| Laois | 62.89 | 16.49 | 20.62 |

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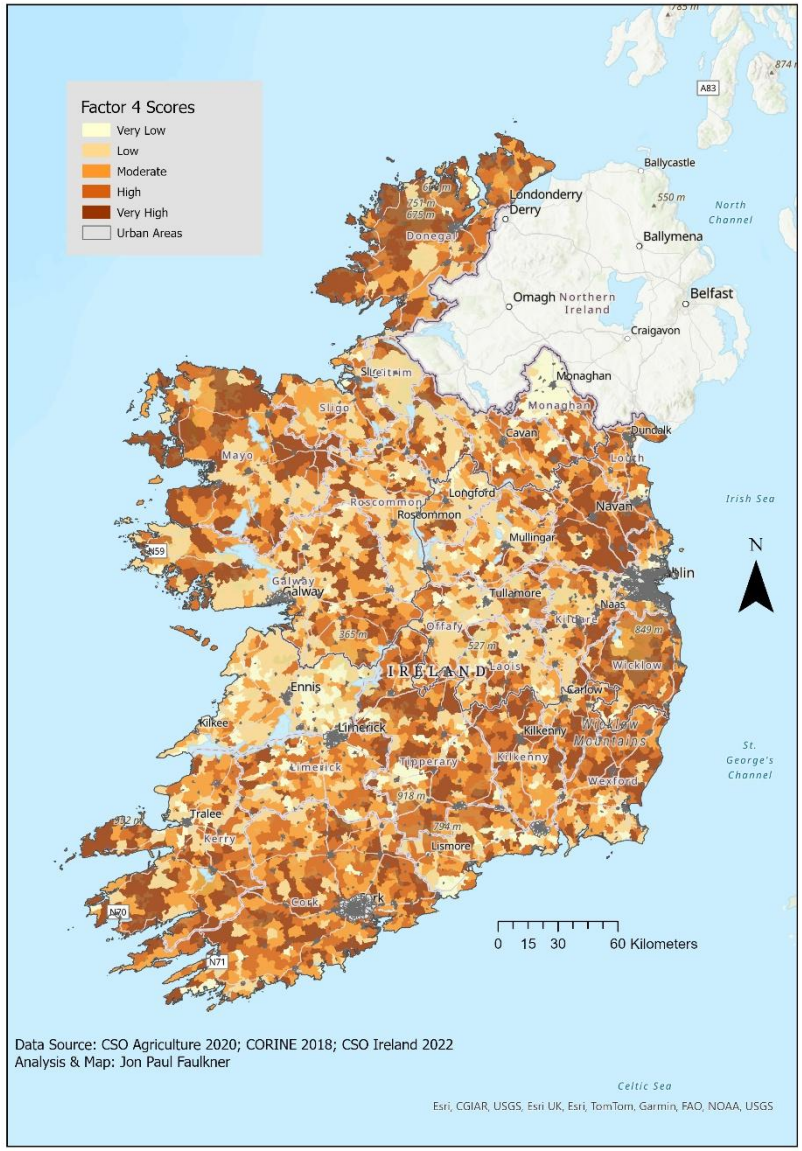
attainment, and a diverse workforce comprising both manual and non-manual occupations. Unlike the traditional farming communities identified in factor 1 or the large-scale commercial farms of factor 2, factor 4 regions exhibit a structured agricultural landscape with a mix of livestock and crop farming alongside a more varied workforce composition. The presence of both cropland and pastureland suggests a diversified farming system, where farmers may engage in both livestock rearing and limited crop cultivation, possibly to support feed supply or rotational farming practices (Lemaire et al., 2015). The more moderate farm size suggests that these areas do not exhibit the extensive, large-scale farming practices seen in factor 2, but neither are they smallholder farms, distinguishing them as medium-large sized agricultural regions with a balanced production system.

The diversified labour force suggests that factor 4 regions are not solely reliant on agricultural employment but also accommodate a mix of secondary and tertiary sector employment. Compared to factor 1, where agricultural labour dominates, and factor 3 where professional and managerial roles are prominent, factor 4 represents a transitional space where both agricultural and non-agricultural employment coexist. The absence of a strong university-educated workforce, as seen in factor 2, suggests that while educational attainment is improving, these regions do not serve as major knowledge hubs or innovation centres. Instead, education may be more applied or vocational, supporting farm management, agribusiness, and other locally relevant industries.

Figure 4: Medium-Large Scale Mixed Farming Areas (Factor 4)

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### *Factor 5: Small-Scale Livestock Farming and Afforested Areas*

Table 9 and Figure 5 show the spatial distribution of factor 5 scores, interpreted as 'Small-Scale Livestock Farming and Afforested Areas'. Factor 5 scores were evenly distributed across regions, with the NW region exhibiting the highest distribution, followed closely by the Southern and EM regions. At county level, Laois exhibited the highest distribution of factor 5 scores, followed by Wicklow, Offaly, Clare and Leitrim. Other counties with relatively high scores included Mayo and Waterford.

Factor 5 represents regions where smallholder farming and traditional rural livelihoods remain central but may be challenged by economic, demographic, and land-use changes. These areas may be at a crossroads between sustaining small-scale farming and transitioning toward forestry and environmental conservation as dominant land-use strategies (Pokorny et al., 2013).

Unlike the diversified and professionalised labour force seen in factor 3 and factor 4, factor 5 regions are characterised by a lower prevalence of skilled workers, semi-skilled and unskilled workers. This suggests that manual labour in non-agricultural industries is less common, and employment opportunities are more concentrated in farming, forestry, or local agrarian economies. The negative association with non-manual workers and university education indicates a lack of professionalised employment sectors, with fewer individuals engaged in tertiary or knowledge-based occupations. Instead, factor 5 regions appear to sustain a workforce that remains attached to traditional agricultural and rural livelihoods, with the potential of limited mobility into higher education and professional careers. This aligns with a high correlation

Table 9: Small-Scale Livestock Farming and Afforestation per Region/County

| Scores | Low (%) | Moderate (%) | High (%) |
|---|---|---|---|
| REGION | | | |
| NW | 47.91 | 20.52 | 31.57 |
| Southern | 54.05 | 14.86 | 31.09 |
| EM | 55.47 | 14.42 | 30.11 |
| COUNTY | | | |
| Donegal | 53.02 | 16.11 | 30.87 |
| Sligo | 27.85 | 36.71 | 35.44 |
| Leitrim | 34.25 | 23.29 | 42.47 |
| Cavan | 51.69 | 23.60 | 24.72 |
| Monaghan | 68.57 | 8.57 | 22.86 |
| Galway | 56.54 | 10.75 | 32.71 |
| Mayo | 36.84 | 22.37 | 40.79 |
| Roscommon | 54.55 | 22.73 | 22.73 |
| Clare | 41.72 | 13.91 | 44.37 |
| Tipperary | 58.36 | 18.19 | 23.45 |
| Limerick | 64.44 | 12.59 | 22.96 |
| Waterford | 40.22 | 19.57 | 40.22 |
| Kilkenny | 61.06 | 8.85 | 30.09 |
| Carlow | 66.67 | 9.26 | 24.07 |
| Wexford | 48.39 | 18.55 | 33.06 |
| Cork | 58.02 | 15.12 | 26.85 |
| Kerry | 47.56 | 17.68 | 34.76 |
| Dublin | 95.24 | 0.00 | 4.76 |
| Wicklow | 37.80 | 15.85 | 46.34 |
| Kildare | 46.07 | 21.35 | 32.58 |
| Meath | 53.26 | 22.83 | 23.91 |
| Louth | 72.09 | 6.98 | 20.93 |
| Longford | 62.96 | 11.11 | 25.93 |
| Westmeath | 54.29 | 20.95 | 24.76 |
| Offaly | 38.37 | 16.28 | 45.35 |
| Laois | 39.18 | 14.43 | 46.39 |

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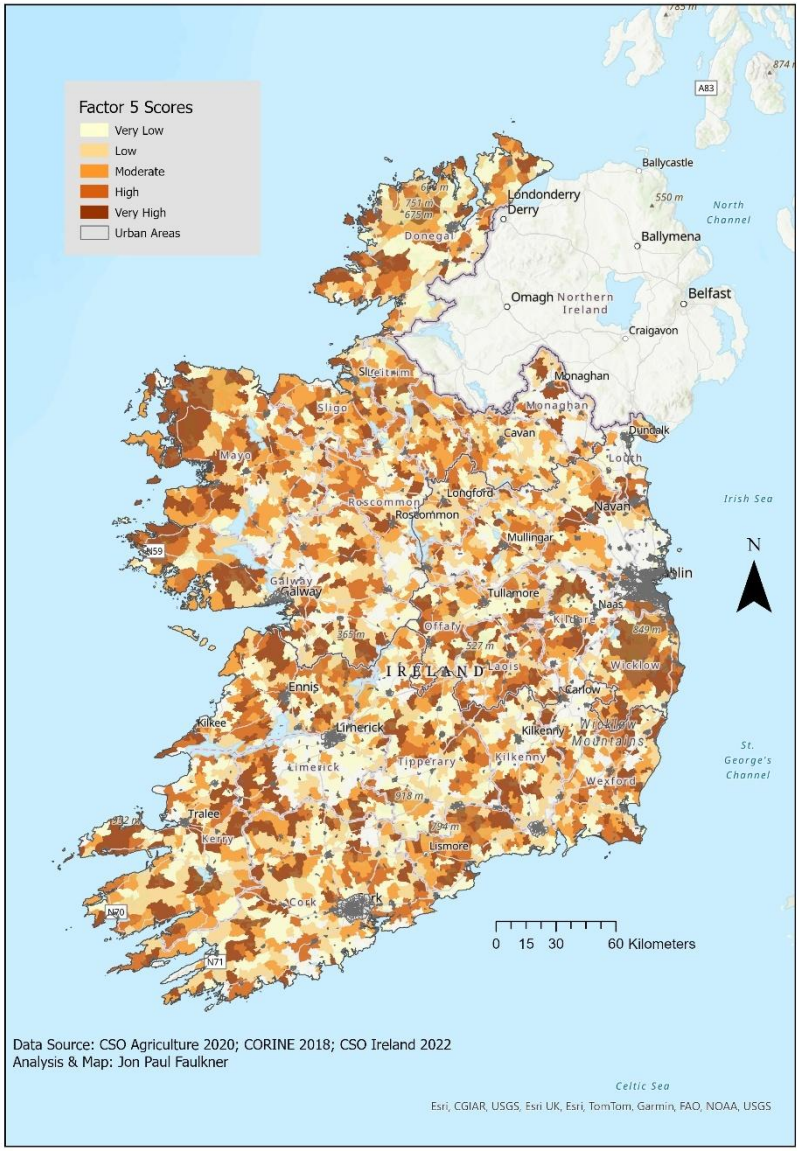
with traditional farming occupations, indicating a workforce that may rely more on experiential knowledge, local agricultural traditions, and generational farming practices rather than formal agricultural training or academic education. The negative correlation with university education further supports this argument, suggesting that higher education opportunities may be limited or less commonly pursued in these regions. This may be due to limited access to educational infrastructure, economic constraints, or a cultural emphasis on inherited farming knowledge rather than formal qualifications. The presence of afforestation, combined with relatively small farm numbers, suggests that factor 5 regions may be experiencing a transition from small-scale, traditional farming to forestry-related activities. This stands in contrast to factor 1, which represents more stable, traditional farming communities, and factor 2, which is characterised by commercialised agricultural regions with large-scale farm operations. This transitional quality may be influenced by environmental policy, economic incentives for afforestation, or challenges associated with sustaining small-scale livestock farms in less productive rural landscapes (Haddad et al., 2021). In this sense, factor 5 regions may represent areas where agricultural land is gradually being repurposed for forestry, conservation, or low-intensity farming activities.

Figure 5: Small-Scale Livestock Farming and Afforested Areas (Factor 5)

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### *Factor 6: Fragmented Cropland and Small Farm Structures*

Table 10 and Figure 6 show the spatial distribution of factor 5 scores, interpreted as 'Fragmented Cropland and Small Farm Structures'. The NW region exhibited the highest factor 6 scores, followed, to a lesser extent, by the Southern region. At county level, Mayo exhibited the highest distribution of factor 6 scores, with Galway and Donegal also exhibiting high scores. Other counties such as Kerry, Clare and Roscommon, also exhibited relatively high scores.

Factor 6 represents rural areas where farming is highly prevalent but lacks large-scale agricultural investment or technical specialisation. These regions likely face structural economic challenges, with barriers to agricultural efficiency, limited investment in vocational training, and fragmented labour markets. While traditional farming persists, it does not dominate the local economy, and a lack of specialisation may hinder long-term rural development and economic resilience.

The presence of 'postgraduate education' alongside 'no formal education' suggests educational polarisation, where some individuals pursue higher education, while a significant segment of the population is characterised by minimal educational attainment. This duality may reflect a divide between rural populations engaged in low-skilled labour and a smaller, mobile professional class that commutes to urban areas for employment opportunities. Unlike factor 2 and factor 3, which represent highly educated professionalised farming regions, factor 6 is more socio-economically mixed, with an absence of strong specialisation in either agricultural or high-skilled sectors. The negative correlation with cropland and average farm size suggests that these regions do not have the agricultural infrastructure to support intensive

Table 10: Fragmented Cropland and Small Farm Structures per Region/County

| Scores | Low (%) | Moderate (%) | High (%) |
|---|---|---|---|
| REGION | | | |
| NW | 15.61 | 26.01 | 58.38 |
| Southern | 38.05 | 23.77 | 38.18 |
| EM | 54.29 | 20.11 | 25.60 |
| COUNTY | | | |
| Donegal | 8.72 | 19.46 | 71.81 |
| Sligo | 15.19 | 26.58 | 58.23 |
| Leitrim | 13.70 | 34.25 | 52.05 |
| Cavan | 14.77 | 36.36 | 48.86 |
| Monaghan | 47.83 | 37.68 | 14.49 |
| Galway | 7.51 | 18.31 | 74.18 |
| Mayo | 5.30 | 7.28 | 87.42 |
| Roscommon | 11.82 | 28.18 | 60.00 |
| Clare | 10.67 | 28.00 | 61.33 |
| Tipperary | 29.39 | 21.49 | 49.11 |
| Limerick | 11.94 | 40.30 | 47.76 |
| Waterford | 26.37 | 35.16 | 38.46 |
| Kilkenny | 51.79 | 25.89 | 22.32 |
| Carlow | 79.63 | 12.96 | 7.41 |
| Wexford | 86.18 | 4.88 | 8.94 |
| Cork | 31.79 | 21.30 | 46.91 |
| Kerry | 14.72 | 23.93 | 61.35 |
| Dublin | 80.95 | 9.52 | 9.52 |
| Wicklow | 31.71 | 12.20 | 56.10 |
| Kildare | 76.14 | 14.77 | 9.09 |
| Meath | 58.70 | 17.39 | 23.91 |
| Louth | 67.44 | 25.58 | 6.98 |
| Longford | 34.62 | 19.23 | 46.15 |
| Westmeath | 35.24 | 41.90 | 22.86 |
| Offaly | 36.47 | 23.53 | 40.00 |
| Laois | 67.37 | 16.84 | 15.79 |

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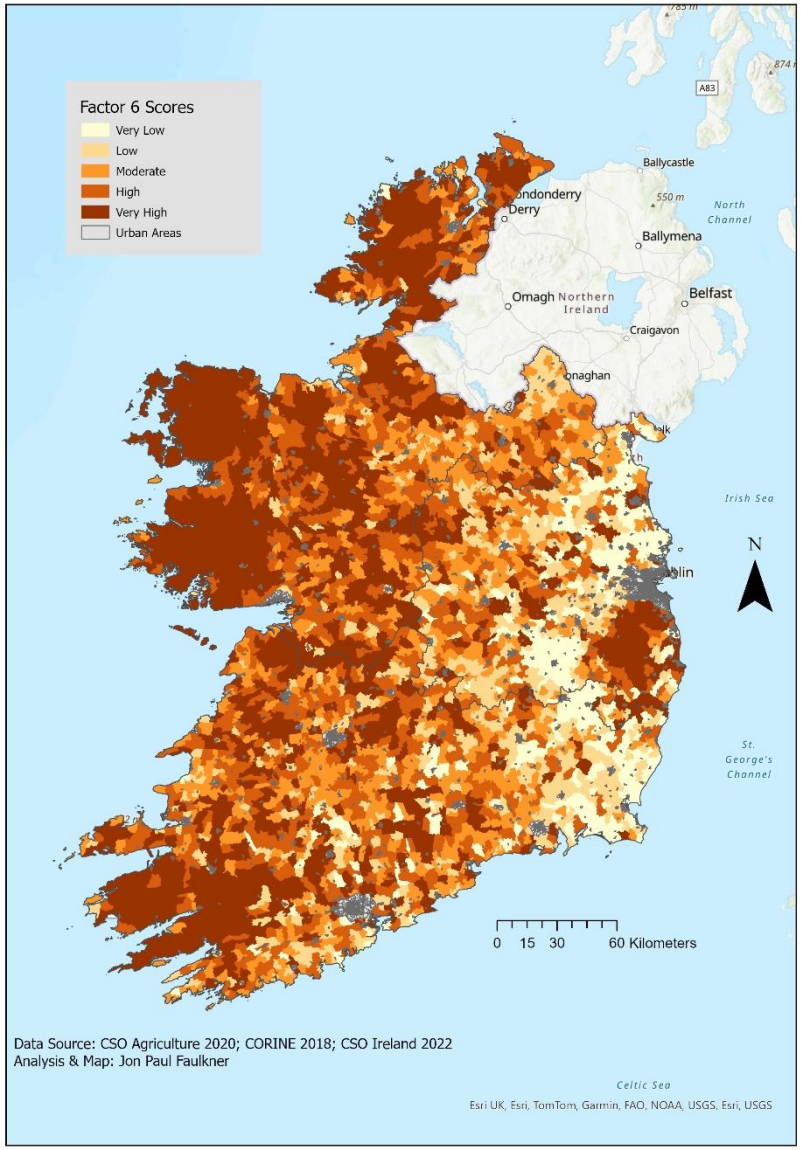
commercial farming, and the workforce structure indicates a dependence on general employment rather than a highly skilled labour force.

The high number of farms combined with small land holdings, low educational attainment, and a mixed workforce suggests that these regions may be experiencing economic stagnation, land-use inefficiencies, or a lack of investment in modern agricultural techniques. Unlike factor 1, which represents traditional farming areas with strong local employment in agriculture, factor 6 suggests regions where farming remains prevalent but is characterised by fragmentation and inefficiency. This could indicate barriers to agricultural modernisation, challenges related to land consolidation, or demographic shifts where younger generations seek non-agricultural employment while older populations maintain small-scale farms (Zmija et al., 2020). The coexistence of professionals and unskilled workers suggests that these regions have diverse but uneven economic opportunities, potentially relying on a mix of local services, small-scale enterprises, and external commuting for employment.

Figure 6: Fragmented Cropland and Small Farm Structures (Factor 6)

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### *Factor 7: Marginal Farming Landscapes*

Table 11 and Figure 7 show the spatial distribution of factor 7 scores interpreted as 'Marginal Farming Landscapes'. The NW region exhibited the highest factor 7 scores. At county level, Monaghan exhibited the highest distribution of factor 7 scores, followed by Mayo and Leitrim. Donegal and Cavan also exhibited relatively high factor 7 scores.

Factor 7 regions appear to be marginal farming landscapes where agricultural traditions may persist in the absence of significant modernisation, professionalisation, or large-scale investment. These regions may require policy interventions focused on land-use management, education accessibility, and small-farm support programs to enhance sustainability and rural resilience (Mihailova et al., 2022).

Factor 7 also exhibits a positive correlation with 'no formal education', suggesting that these regions have a population with lower educational attainment and limited access to structured vocational or technical training. At the same time, negative correlations with 'upper secondary school education' and 'technical education' indicate a workforce with minimal professional or agricultural training, potentially limiting opportunities for farm modernisation, value-added agricultural production, or economic diversification. Unlike factor 2 or factor 4, which represent large-scale, professionalised agricultural economies, factor 7 regions appear to lack the institutional and economic resources necessary to transition toward more specialised or commercialised agricultural sectors. The negative loading on 'own account workers' suggests that self-employment and entrepreneurial activity are less common in these areas.

Table 11: Marginal Farming Landscapes per Region/County

| Scores | Low (%) | Moderate (%) | High (%) |
|---|---|---|---|
| REGION | | | |
| NW | 19.03 | 28.45 | 52.52 |
| Southern | 74.40 | 14.31 | 11.28 |
| EM | 67.52 | 12.14 | 20.35 |
| COUNTY | | | |
| Donegal | 27.52 | 18.12 | 54.36 |
| Sligo | 20.25 | 36.71 | 43.04 |
| Leitrim | 20.55 | 19.18 | 60.27 |
| Cavan | 14.61 | 34.83 | 50.56 |
| Monaghan | 8.57 | 17.14 | 74.29 |
| Galway | 21.96 | 32.24 | 45.79 |
| Mayo | 15.13 | 23.03 | 61.84 |
| Roscommon | 23.64 | 46.36 | 30.00 |
| Clare | 47.02 | 31.79 | 21.19 |
| Tipperary | 82.07 | 6.81 | 11.12 |
| Limerick | 68.89 | 22.96 | 8.15 |
| Waterford | 78.26 | 5.43 | 16.30 |
| Kilkenny | 95.58 | 1.77 | 2.65 |
| Carlow | 83.33 | 7.41 | 9.26 |
| Wexford | 87.90 | 6.45 | 5.65 |
| Cork | 79.63 | 13.27 | 7.10 |
| Kerry | 46.95 | 32.93 | 20.12 |
| Dublin | 66.67 | 0 | 33.33 |
| Wicklow | 78.05 | 9.76 | 12.20 |
| Kildare | 86.52 | 4.49 | 8.99 |
| Meath | 83.70 | 11.96 | 4.35 |
| Louth | 53.49 | 11.63 | 34.88 |
| Longford | 42.59 | 29.63 | 27.78 |
| Westmeath | 73.33 | 17.14 | 9.52 |
| Offaly | 72.09 | 17.44 | 10.47 |
| Laois | 84.54 | 7.22 | 8.25 |

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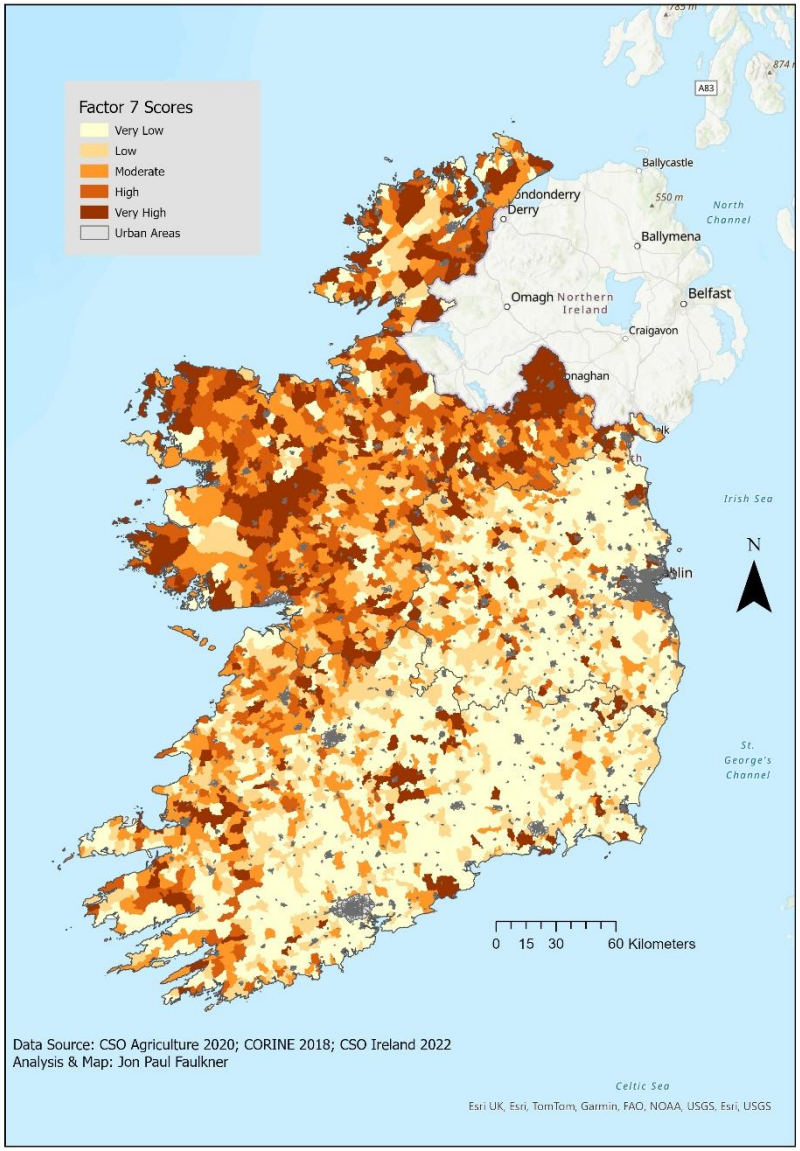
One of the most distinctive features of factor 7 is its strong negative correlation with forestry, which suggests that these regions have little afforestation and are not engaged in forestry-based land use. This stands in contrast to factor 5, which identified small-scale livestock farming regions with strong forestry presence. The absence of forestry suggests that these areas have remained reliant on traditional agricultural land uses, without significant land conversion toward forestry or commercial timber production. However, the coexistence of small-scale, heterogeneous farming and peatlands suggests that these regions face significant agricultural constraints. Unlike the more structured commercial landscapes identified in factor 2 and factor 4, factor 7 regions appear to represent areas where farming is maintained at a subsistence or semi-commercial level, possibly due to limitations in land quality, drainage, or economic opportunities. The low levels of education and absence of structured vocational or professional training further suggest that these areas may struggle with economic diversification, labour mobility, and agricultural innovation. Without access to formal agricultural training or higher education, it is likely that traditional farming techniques persist, with little integration of modern technologies, mechanisation, or agribusiness strategies.

Figure 7: Marginal Farming Landscapes (Factor 7)

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### *Factor 8: Semi-Rural Landscapes with Diversified Agricultural Structures*

Table 12 and Figure 8 show the spatial distribution of factor 8 scores interpreted as 'Semi-Rural Landscapes with Diversified Agricultural Structures. The NW region exhibited the highest factor 8 scores, followed, to a lesser extent, by the EM region. At county level, Leitrim exhibited the highest distribution of factor 8 scores. Monaghan, Cavan and Clare also showed relatively high factor 8 scores.

Factor 8 typifies semi-rural, mixed-use landscapes where agriculture exists alongside a more skilled, professionalised workforce. These regions differ from the intensive farming areas of factor 2 and the fragmented, marginal farming systems of factor 7. Instead, they may reflect a transition toward a more diversified rural economy, incorporating elements of education, self-employment, and managerial occupations alongside multi-functional farming. The moderate population density suggests that these areas may be located near smaller towns or peri-urban zones, with access to education and employment opportunities.

Factor 8 regions are more densely populated than the large-scale farming regions identified in factors 1 and 2. This demographic structure aligns with higher educational attainment. Unlike factor 7, which exhibits lower levels of formal education, these regions show signs of greater human capital development and a workforce with more technical and vocational qualifications. The presence of professional and managerial employment is also notable. These associations suggest that factor 8 regions are not solely dependent on agricultural labour but also accommodate a broader employment base that

Table 12: Semi-Rural Landscapes per Region/County

| Scores | Low (%) | Moderate (%) | High (%) |
|---|---|---|---|
| REGION | | | |
| NW | 55.22 | 11.13 | 33.65 |
| Southern | 74.66 | 10.48 | 14.86 |
| EM | 69.24 | 8.91 | 21.85 |
| COUNTY | | | |
| Donegal | 66.44 | 5.37 | 28.19 |
| Sligo | 60.76 | 15.19 | 24.05 |
| Leitrim | 24.66 | 5.48 | 69.86 |
| Cavan | 43.82 | 16.85 | 39.33 |
| Monaghan | 48.57 | 8.57 | 42.86 |
| Galway | 66.36 | 15.42 | 18.22 |
| Mayo | 70.20 | 11.26 | 18.54 |
| Roscommon | 60.91 | 10.91 | 28.18 |
| Clare | 48.99 | 18.12 | 32.89 |
| Tipperary | 87.81 | 6.51 | 5.69 |
| Limerick | 59.70 | 20.15 | 20.15 |
| Waterford | 73.63 | 12.09 | 14.29 |
| Kilkenny | 85.71 | 7.14 | 7.14 |
| Carlow | 79.25 | 3.77 | 16.98 |
| Wexford | 94.35 | 1.61 | 4.03 |
| Cork | 70.59 | 12.69 | 16.72 |
| Kerry | 71.95 | 12.20 | 15.85 |
| Dublin | 66.67 | 2.38 | 30.95 |
| Wicklow | 60.49 | 9.88 | 29.63 |
| Kildare | 82.02 | 5.62 | 12.36 |
| Meath | 83.70 | 3.26 | 13.04 |
| Louth | 62.79 | 18.60 | 18.60 |
| Longford | 74.07 | 7.41 | 18.52 |
| Westmeath | 77.88 | 13.46 | 8.65 |
| Offaly | 79.07 | 9.30 | 11.63 |
| Laois | 72.16 | 10.31 | 17.53 |

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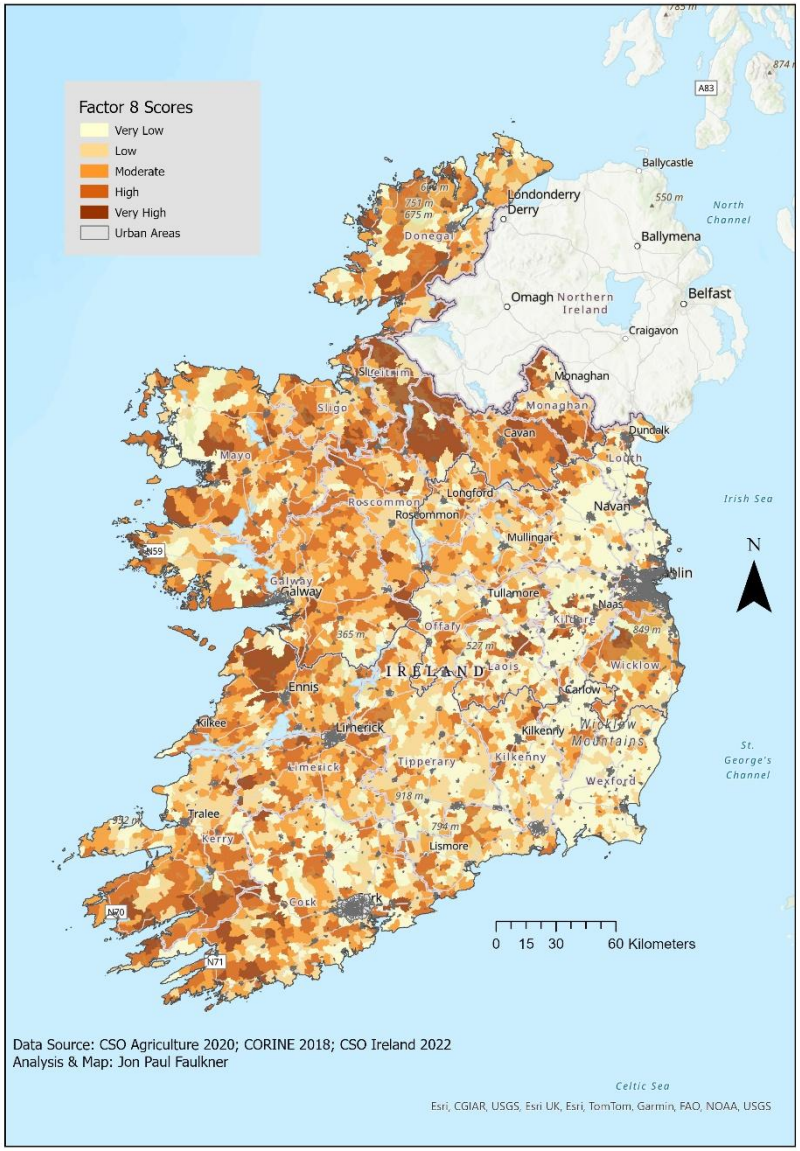
includes business ownership, administrative roles, and skilled labour markets. Additionally, the strong correlation with ‘own account workers’ indicates a high level of self-employment and entrepreneurial activity, which may reflect the presence of small-scale businesses, independent contractors, or local service industries.

Unlike factor 3, which emphasises small-scale arable farming, factor 8 regions appear to have a more mixed and fragmented agricultural economy. Similarly, the negative association with forestry and average farm size suggests that these areas do not engage in large-scale timber production or expansive agricultural enterprises. Instead, they may support smaller, multi-functional farms that integrate a range of land uses, from horticulture and pasture to conservation-oriented agricultural systems. The negative correlation with ‘no formal education’ suggests that factor 8 regions have higher overall educational attainment, distinguishing them from more traditional or marginal agricultural areas, such as those seen in factor 7 areas. The stronger presence of technical education suggests a workforce that may be engaging with modern agricultural techniques, sustainable land management, or specialised rural industries (Carlisle et al., 2019).

Figure 8: Semi-Rural Landscapes (Factor 8)

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### *Factor 9: Environmentally Sensitive Peatland Areas*

Table 13 and Figure 9 show the spatial distribution of factor 9 scores interpreted as 'Environmentally Sensitive Peatland Areas. The NW region exhibited the highest factor 9 scores, followed by the EM region. At county level, Offaly, Donegal, Sligo and Kerry exhibited the highest factor 9 scores, with Galway and Roscommon also showing relatively high scores.

Factor 9 represents ecologically significant landscapes dominated by peatlands, where agricultural productivity is nearly non-existent, forestry has not developed, and land use is shaped by natural and environmental factors rather than human activity. Given the critical role of peatlands in carbon sequestration, biodiversity, and water regulation (Joosten, 2015), these regions should be prioritised for: 1) conservation and climate change mitigation initiatives aimed at preserving peatland ecosystems (Humpenöder et al., 2020); 2) rewilding and biodiversity protection programs (Palmer, 2024); and 3) sustainable land management policies that emphasise environmental preservation rather than economic expansion (Tanneberger et al., 2022).

A notable feature of factor 9 is its negative correlation with forestry. While afforestation has been a major land-use trend in factor 5 regions, these peatland-dominated landscapes have not undergone forest expansion. The environmental conditions of these areas, which likely include high water tables, poor soil fertility, and conservation restrictions, may limit the potential for commercial forestry that could otherwise be present in such peripheral regions. Factor 9 also demonstrates a negative correlation with heterogeneous agriculture, indicating that these areas do not exhibit mixed-use farming systems.

Table 13: Environmentally Sensitive Peatland Areas per Region/County

| Scores | Low (%) | Moderate (%) | High (%) |
|---|---|---|---|
| REGION | | | |
| NW | 58.42 | 12.16 | 29.42 |
| Southern | 73.09 | 10.62 | 16.29 |
| EM | 64.84 | 10.74 | 24.42 |
| COUNTY | | | |
| Donegal | 38.26 | 13.42 | 48.32 |
| Sligo | 45.57 | 10.13 | 44.30 |
| Leitrim | 56.16 | 10.96 | 32.88 |
| Cavan | 85.39 | 7.87 | 6.74 |
| Monaghan | 94.29 | 1.43 | 4.29 |
| Galway | 45.79 | 18.22 | 35.98 |
| Mayo | 47.37 | 24.34 | 28.29 |
| Roscommon | 54.55 | 10.91 | 34.55 |
| Clare | 54.97 | 26.49 | 18.54 |
| Tipperary | 70.92 | 5.00 | 24.08 |
| Limerick | 71.85 | 14.81 | 13.33 |
| Waterford | 78.26 | 4.35 | 17.39 |
| Kilkenny | 94.69 | 2.65 | 2.65 |
| Carlow | 81.48 | 7.41 | 11.11 |
| Wexford | 90.32 | 6.45 | 3.23 |
| Cork | 78.09 | 5.86 | 16.05 |
| Kerry | 37.20 | 22.56 | 40.24 |
| Dublin | 100.00 | 0.00 | 0.00 |
| Wicklow | 58.54 | 13.41 | 28.05 |
| Kildare | 59.55 | 8.99 | 31.46 |
| Meath | 81.52 | 11.96 | 6.52 |
| Louth | 81.40 | 6.98 | 11.63 |
| Longford | 59.26 | 14.81 | 25.93 |
| Westmeath | 54.29 | 15.24 | 30.48 |
| Offaly | 20.93 | 13.95 | 65.12 |
| Laois | 68.04 | 11.34 | 20.62 |

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Unlike factor 7, which represents fragmented, small-scale agricultural landscapes with diverse crop-pasture interactions, factor 9 regions lack such complexity. Instead, they appear to be low-intensity rural environments where agriculture, if present at all, is extremely limited or constrained to marginal land uses. Unlike many of the previous factors, which are strongly associated with different workforce compositions and education levels, factor 9 does not show notable correlations with employment categories or population density. This suggests that these regions are sparsely populated, with little economic activity linked to agriculture, forestry, or professional employment. In contrast to factor 8 regions where semi-rural areas are transitioning toward professionalised employment and diversified land use, factor 9 regions represent areas where economic activity is negligible, and land use is largely dictated by environmental constraints rather than human intervention.

Figure 9: Environmentally Sensitive Peatland Areas

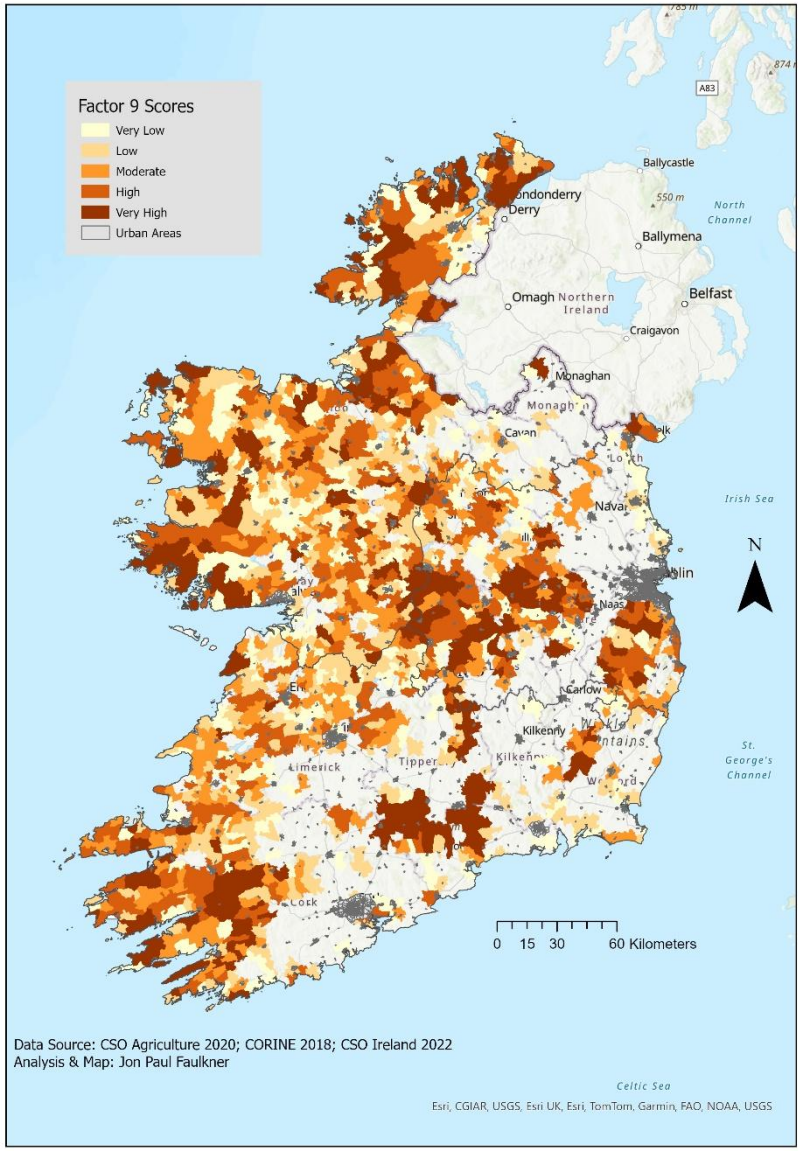


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Table 14 and Figure 10 show the spatial distribution of a typology of land use, farming structure, and socio-economic conditions in rural Ireland generated using a cluster analysis derived from the factors previously described, whereby rural Ireland was classified into 5 clusters: 1) Semi-Rural Landscapes with Arable and Diversified Agricultural Structures; 2) Marginal Agricultural and Rural Transition Zones; 3) Highly Commercialised Large-Scale Farming Areas; 4) Environmentally Sensitive Areas with Small-Scale Livestock Farming; and 5) Medium-Large Scale Traditional Farming in Semi-Rural Landscapes.

### *Cluster 1: Semi-Rural Landscapes with Arable and Diversified Agricultural Structures*

Cluster 1 was most prevalent in the EM region, followed by the Southern region. At the county level, cluster 1 was most prevalent in Wexford, with Meath, Kildare, Louth and Carlow also exhibiting a high prevalence.

Cluster 1 represents semi-rural landscapes which are likely to have experienced significant economic and social change over the past 30 years. Unlike traditional farming communities, these regions are characterised by diversified land use, medium-scale farming, and a highly professionalised workforce. The shift away from manual agricultural labour, higher education levels, and the strong presence of professional and managerial occupations suggests that these regions have evolved towards more service-oriented and knowledge-based economies. While farming still exists in these areas, it is no longer the defining economic activity.

Table 14: Spatial Typology: Clusters as a Percentage of Land Cover per Region/County

| Cluster % | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| REGION | | | | | |
| NW | 5.67 | 16.77 | 22.26 | 21.18 | 34.12 |
| Southern | 28.44 | 8.65 | 24.07 | 12.81 | 26.03 |
| EM | 33.20 | 7.77 | 24.11 | 13.16 | 21.75 |
| COUNTY | | | | | |
| Donegal | 3.46 | 3.21 | 12.85 | 44.46 | 36.02 |
| Sligo | 3.34 | 10.59 | 40.73 | 30.28 | 15.07 |
| Leitrim | 12.02 | 18.85 | 21.80 | 24.12 | 23.22 |
| Cavan | 6.49 | 16.60 | 26.42 | 10.26 | 40.24 |
| Monaghan | 4.30 | 10.10 | 22.95 | 6.86 | 55.81 |
| Galway | 10.75 | 13.42 | 21.35 | 19.28 | 35.19 |
| Mayo | 6.59 | 10.83 | 19.89 | 28.00 | 34.67 |
| Roscommon | 8.38 | 10.60 | 22.06 | 16.22 | 42.75 |
| Clare | 7.75 | 11.92 | 28.15 | 14.61 | 37.57 |
| Tipperary | 14.85 | 8.14 | 23.66 | 10.90 | 42.43 |
| Limerick | 14.18 | 12.26 | 24.51 | 7.17 | 41.87 |
| Waterford | 17.50 | 7.09 | 29.61 | 12.49 | 33.29 |
| Kilkenny | 31.24 | 6.83 | 33.71 | 5.63 | 22.60 |
| Carlow | 49.01 | 3.73 | 23.48 | 6.61 | 17.17 |
| Wexford | 70.86 | 6.24 | 10.88 | 4.96 | 7.49 |
| Cork | 28.00 | 8.68 | 33.11 | 9.77 | 20.46 |
| Kerry | 10.42 | 4.95 | 17.73 | 37.88 | 29.04 |
| Dublin | 28.98 | 16.15 | 17.87 | 16.79 | 20.23 |
| Wicklow | 29.42 | 8.04 | 16.91 | 36.50 | 9.15 |
| Kildare | 54.83 | 5.83 | 17.72 | 8.23 | 13.38 |
| Meath | 56.12 | 5.59 | 16.90 | 8.10 | 13.29 |
| Louth | 51.69 | 6.37 | 18.84 | 9.78 | 13.30 |
| Longford | 15.53 | 7.95 | 25.36 | 10.04 | 41.11 |
| Westmeath | 19.62 | 8.50 | 36.57 | 7.45 | 27.88 |
| Offaly | 19.22 | 4.78 | 34.98 | 11.86 | 29.14 |
| Laois | 23.43 | 6.76 | 31.88 | 9.69 | 28.24 |

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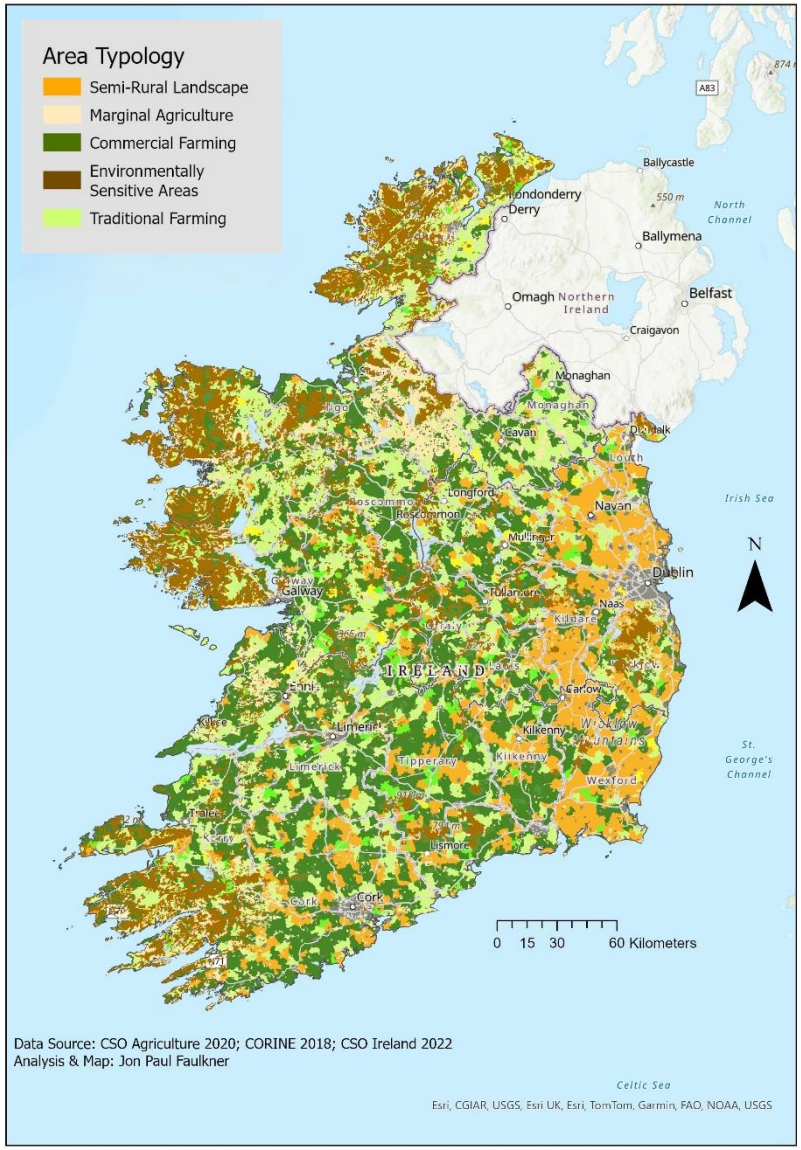
Instead, these regions represent a hybrid of rural and urban economic influences, where agricultural land is repurposed or diversified, and the workforce is engaged in professional and non-manual employment (Acharya, 2021). In many ways, cluster 1 exemplifies the modern rural economy, where traditional farming is supplemented, or even replaced, by new forms of employment, creating a semi-rural, adaptive, and economically diversified landscape.

The educational profile of cluster 1 suggests that basic and vocational agricultural education is less prominent in these areas, with a higher proportion of highly educated individuals compared to traditional farming areas. In terms of workforce composition, these regions do not rely on traditional farming-based employment. Instead, it appears that the workforce in these areas has shifted towards professional, managerial, and knowledge-based occupations. Unlike regions where farming remains the dominant economic activity, cluster 1 appears to be characterised by a more service-based and professional workforce, with fewer people engaged in manual agricultural labour. This suggests that these areas may be benefiting from proximity to urban centres or are experiencing economic diversification, where traditional farming is no longer the primary occupation.

Cluster 1 areas are not dominated by large farms or extensive pasture-based agriculture but are more densely populated than more isolated rural farming areas, indicating a semi-rural character with mixed land use. The presence of some marginal farming landscapes and medium-sized arable farming implies that agriculture is diversified and farming in these areas is adaptive and multifunctional, potentially integrating forestry, small-scale horticulture, or alternative land management practices (Walia and Kaur, 2023).

Figure 10: Spatial Typology of Rural Ireland

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Cluster 1 represents rural areas transitioning away from agriculture-dependent economies. Unlike factor 1, which describes stable, traditional farming regions, or factor 2, which represents highly commercialised agricultural zones, Cluster 1 sits at an intersection between agriculture, rural economic diversification, and professional employment growth.

These areas are characterised by a highly professionalised labour force which may consist of commuters, or remote workers who no longer depend on farming for their primary livelihood. The higher levels of university and postgraduate education further support this hypothesis. The nature of this labour force composition may be influenced by proximity to urban centres, improved infrastructure, or occupation preferences for non-agricultural careers, while farming becomes a secondary or part-time economic activity.

### *Cluster 2: Marginal Agricultural and Rural Transition Zones*

As described in Table 14 and Figure 10, cluster 2 was most prominent in the NW region. At county level, cluster 2 was most prevalent in Leitrim, with areas such as Cavan, rural Dublin, Galway, Limerick, Clare and Mayo showing small-moderate prevalence.

Cluster 2 represents economically and agriculturally marginal regions that do not fit within the framework of structured, productive farming landscapes. Instead, these areas are characterised by: 1) fragmented, heterogeneous small-scale farming practices that are not commercially competitive; 2) low agricultural viability, with peatland and marginal land use restricting large-scale farm development; 3) a mixed workforce, where non-agricultural, lower-skilled employment plays an increasing role; and 4) sparse population and economic stagnation, with limited engagement in commercial farming or high-skilled occupations.

Rather than being defined by robust agricultural economies, cluster 2 represents rural spaces in transition, where farming is either declining or shifting toward non-traditional forms of land use. The weak presence of skilled agricultural labour, combined with low technical education levels, suggests that these areas may struggle with modernisation and economic resilience (Bjørkhaug and Knickel, 2018). They may require targeted policies focused on rural development, economic diversification, and sustainable land-use planning to ensure long-term viability (Rabbinge and van Latesteijn, 1992).

These areas are defined by diverse, small-scale farming practices in environmentally constrained landscapes. The presence of peatland highlights the low agricultural viability of the land due to poor drainage, associated soil conditions, and potential conservation restrictions. Cluster 2 areas are not dominated by forestry or pasture-based farming, and livestock-rearing is not a defining economic activity. Instead, smallholder and subsistence-oriented farming practices may be more prevalent, where households engage in mixed or part-time agriculture rather than full-time commercial farming. Unlike structured farming areas with clear agricultural specialisations, cluster 2 represents a patchwork of marginal agricultural activities, where farms are numerous but small, fragmented, and not economically competitive. The weak association with traditional livestock and afforestation regions further suggests that these areas may have undergone agricultural decline or a shift away from farming altogether.

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The education profile of cluster 2 presents an interesting duality. These regions have lower participation in vocational and technical education, which could impact farm modernisation and diversification, with employment opportunities in these areas extending beyond agriculture and into non-manual and lower-skilled service jobs. The mixed educational and employment profile indicates that these regions may be undergoing a rural-to-non-agricultural transition, where farming is declining, and other forms of employment, particularly in non-specialised labour markets, are emerging. Unlike cluster 1, which is transitioning towards a knowledge-based economy, cluster 2 appears to be more reliant on lower-skilled, service-oriented employment rather than structured professional careers. Cluster 2 regions are relatively sparsely populated, reinforcing their marginal economic status. Unlike traditional farming regions, which maintain a skilled and agricultural workforce, cluster 2's economic base appears dispersed, with a mix of informal, non-agricultural, and low-skilled employment opportunities. The lack of a strong agricultural workforce suggests that many farms in these areas are likely part-time operations, run by individuals who also work in non-agricultural sectors (Madadeniya and Ekanayake, 2021).

### *Cluster 3: Highly Commercialised Large-Scale Farming Areas*

Table 14 and Figure 10 show that cluster 3 was very evenly distributed across regions with the EM region exhibiting the highest prevalence, closely followed by the Southern and NW regions. At county level, Sligo exhibited most prevalence, followed by Westmeath, Offaly, Kilkenny and Cork.

Cluster 3 represents structured, large-scale agricultural regions that maintain a strong farming economy, high levels of formal education, and a workforce deeply tied to primary agricultural production. These areas contrast with more fragmented, marginal, or transitioning rural landscapes and instead reflect a stable, productivity-driven agricultural economy with a strong professional and managerial presence.

The presence of strong positive associations with cropland, forestry, and average farm size highlights the extensive agricultural footprint in these areas. The negative correlation with peatland and heterogeneous agriculture suggests that these regions do not accommodate highly diverse or fragmented agricultural structures. Instead, they are dominated by well-established, large-scale farming systems that prioritise efficiency and productivity.

A notable feature of cluster 3 is its strong association with higher levels of formal education, particularly university and postgraduate education. Unlike clusters where vocational training or informal agricultural knowledge prevails, these regions exhibit a more academically and technically skilled workforce. The presence of employers, managers, and higher professionals suggests that agricultural operations in these areas are more likely to be managed by populations with a professional or business qualification, differentiating them from more traditional, family-run farming systems. Cluster 3 is associated with a structured agricultural workforce that includes skilled workers, agricultural labourers, and farm operators. This indicates that employment in these areas remains tied to primary agricultural activities, with relatively less reliance on low-skilled or unstructured labour markets. The weak association with unskilled and

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semi-skilled workers further supports the idea that these areas maintain a structured and professionalised farming labour force.

Unlike semi-rural or transitioning agricultural landscapes, Cluster 3 regions maintain a relatively low population density, with economic activity centred around agricultural production rather than service-based or urban-oriented employment. The lower association with non-manual occupations and non-agricultural employment sectors suggests that these regions have not undergone the same level of rural economic diversification seen in more transitional rural areas. Unlike cluster 1, which represents semi-rural landscapes undergoing transformation, and cluster 2, which reflects marginal agricultural zones, cluster 3 is defined by its stability and reliance on traditional and commercial farming enterprises. These areas likely benefit from well-developed agricultural infrastructure, established markets, and continued investment in large-scale farming operations. However, they may face challenges related to land consolidation, sustainability, and the need for continued modernisation to remain competitive in evolving agricultural markets (Buckland, 2006).

### *Cluster 4: Environmentally Sensitive Areas with Small-Scale Livestock Farming*

As shown in Table 14 and Figure 10, cluster 4 was most prevalent in the NW region. At county level, cluster 4 was most prevalent in Donegal, followed by Kerry, Wicklow, Sligo and Mayo.

Cluster 4 represents environmental conservation, afforestation, and small-scale livestock farming coexisting in a delicate balance. Cluster 4 represents rural regions where environmental constraints shape agricultural practices, economic structures, and workforce composition. Unlike highly commercialised agricultural clusters, cluster 4 remains tied to traditional rural livelihoods, with limited engagement in knowledge-based industries or intensive farming. This cluster's strong association with environmentally sensitive peatlands highlights its vulnerability to land-use pressures and the need for conservation policies (Chen et al., 2023). Sustainable rural development strategies in these areas need to focus on balancing agricultural viability with environmental preservation, promoting low-impact farming practices, and providing alternative economic opportunities beyond traditional manual labour-based employment (Banks and Marsden, 2000). Policies aimed at rural education, workforce diversification, continued investment in afforestation programs, and sustainable land management will be crucial to ensuring long-term resilience in these regions (Yu et al., 2024).

While peatland dominates, afforestation has played a significant role in shaping the landscape. Rather than being marginal or underutilised, these areas may have witnessed a gradual transition from traditional pastureland toward forestry-based land management, either as a result of deliberate afforestation policies, rewilding initiatives, or land-use diversification strategies (Wang et al., 2025). There is also a lack of diverse farming practices, with land use patterns being relatively homogenous and limited by environmental constraints. Although cluster 4 is not associated with large-scale commercial farming, it does have some presence of livestock farming, particularly smallholder beef/diary and sheep production. Unlike large-scale pasture-based farming areas, these regions likely feature smaller farms operating in

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challenging conditions, where livestock farming is practiced at a lower intensity due to soil and environmental constraints. Agriculture in Cluster 4 appears to be fragmented, with smaller land parcels dedicated to livestock and mixed land uses rather than intensive grazing or crop cultivation. Farms in this cluster are smaller and less commercially oriented compared to more structured farming regions.

Cluster 4 is associated with lower levels of formal education and a workforce structure that leans towards traditional, manual labour-based employment. Higher education and technical training are less prevalent in these regions, suggesting limited professional or knowledge-based employment opportunities. The workforce composition in cluster 4 also reflects a predominantly low-skilled, manual labour economy, and employment in these areas is concentrated in low-skill agricultural or manual work. This contrasts sharply with cluster 3, which represents structured, professionalised farming economies with a highly educated workforce.

Unlike other clusters that exhibit sparse populations (such as cluster 3's commercial farming landscapes), cluster 4 areas support rural communities with relatively higher population densities, despite its low agricultural productivity. The presence of small-scale farming and environmentally sensitive peatlands may contribute to a landscape where traditional rural settlements persist, but with fewer economic opportunities tied to agriculture.

In contrast to cluster 1 which represents transitional rural areas with diversified economic structures, cluster 4 remains deeply embedded in traditional, environmentally constrained agricultural systems. While both clusters 2 and 4 exhibit low-intensity farming, cluster 2 is more defined by fragmented land use and transitions away from agriculture, whereas cluster 4 remains tied to small-scale livestock and peatland conservation. Finally, while cluster 3 represents highly productive, structured farming economies, cluster 4 aligns with low-intensity, small-scale livestock farming in environmentally sensitive landscapes.

### *Cluster 5: Medium-Large Scale Traditional Farming in Semi-Rural Landscapes*

Table 14 and Figure 10 show that cluster 5 was most prevalent in the NW region, followed by the Southern and ME regions. At county level, cluster 5 was most prevalent in county Monaghan, followed by Roscommon, Tipperary, Limerick, Longford and Cavan.

Cluster 5 represents a rural landscape where large-scale, traditional farming persists within a semi-rural economic structure. While these areas are not marginal or fragmented, they also have not fully transitioned into high-tech, commercial agribusiness. Instead, they exhibit a stable, structured farming economy where livestock and grassland farming remain dominant, and where a skilled, but not highly educated workforce, sustains agricultural activity. These regions differ from both highly commercialised agricultural zones, (which exhibit stronger professionalisation), and small-scale, fragmented farming areas, (which are often constrained by environmental or economic challenges). Instead, they function as the heartland of Ireland's traditional farming sector, where large-scale farming remains a way of life, even as the broader rural economy is more focused towards professional and service-based employment.

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The cluster is characterised by a strong association with traditional medium-to-large-scale farming areas, signifying a reliance on established farming systems rather than more specialised or technologically intensive agricultural practices. These regions are home to expansive farm enterprises, yet they may not have fully transitioned into the highly professionalised, large-scale commercial farming structures seen in cluster 3. Instead, farming in these areas is likely rooted in tradition, with a workforce that is primarily engaged in manual and skilled agricultural labour rather than business-driven agribusiness models. Unlike smaller or more marginal farming regions, cluster 5 does not struggle with fragmented landholdings or environmental constraints to the same degree as other clusters. However, its negative association with cropland and forestry suggests that these areas remain primarily focused on livestock farming, particularly cattle and sheep farming, rather than diversified crop production. The absence of strong afforestation trends differentiates this cluster from those that have transitioned towards forestry-based land use, highlighting a continued commitment to pasture-based livestock systems.

The workforce structure in Cluster 5 reflects a semi-rural economic environment that remains closely tied to agriculture but also includes elements of professional employment. Unlike the highly commercialised farming regions that exhibit strong educational attainment and managerial employment, Cluster 5 is marked by moderate levels of secondary and technical education, with a high prevalence of skilled agricultural workers, semi-skilled labourers, and own-account workers. These patterns suggest a workforce that is predominantly engaged in hands-on agricultural activity, with some diversification into rural business and trade a possibility. At the same time, these regions do not exhibit the same level of professionalisation or knowledge-based employment as some of the more urban-adjacent farming areas. While technical education plays a role in shaping the workforce, formal higher education remains less prevalent, suggesting that these are areas where agricultural education is more practical an dis less likely to be pursued through academic pathways. Unlike cluster 1, where professional and managerial employment is dominant, cluster 5 remains anchored in traditional labour structures.

One of the defining features of cluster 5 is its position between large-scale farming and semi-rural economic structures. Unlike cluster 3, which represents highly commercialised farming with a strong managerial and professional workforce, cluster 5's farming economy remains structured around family-run, large-scale agricultural enterprises that may not have fully integrated modern agribusiness models. This distinction suggests that while these regions are not economically marginal, they also do not exhibit the same level of capital-intensive, export-oriented farming seen in Ireland's most commercialised agricultural hubs. The moderate population density in these areas indicates that they are not entirely rural and isolated, yet they also do not share the same degree of urban connectivity as some of the more peri-urban farming landscapes. Instead, these regions function as semi-rural farming communities, where agriculture continues to dominate but where rural economic diversification is occurring gradually. Unlike cluster 4, which is heavily influenced by environmental constraints such as peatlands, farming in cluster 5 regions is not significantly limited by ecological challenges, allowing for more extensive and productive land use. These areas are not oriented

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towards intensive crop farming or forestry but are essentially grassland-dominated livestock farming regions.

## Regional Profile: Informing a Co-Designed Bioeconomy Development Strategy

### *The Northern and Western (NW) Region*

The NW region presents a distinct and multifaceted rural landscape whose bioeconomy potential lies not in high-output commercial agriculture, but in the integrity of its natural assets, the strength of its farming heritage, and the resilience of its rural communities. The region's diverse spatial typology reveals a rural fabric characterised by traditional mixed farming, ecological sensitivity, and structural challenges, including marginality, fragmentation, and low population density. A successful bioeconomy roadmap for the NW must therefore embrace these complexities, building from existing rural strengths while fostering inclusive innovation and ecological protection.

The region's bioeconomy development should be organised around a strategic framework that reflects its spatial and socio-economic diversity as follows:

1. Strategy should focus on enabling grassroots value creation in the NW's traditional farming landscapes. Counties such as Roscommon, Cavan, and Monaghan represent structured, semi-commercial farming areas with stable, medium-to-large-scale agricultural activity. These zones are marked by strong local knowledge, skilled labour, and a persistent, place-based connection to land. While they may lack the capital intensity of Ireland's Agri-Tech centres, they nonetheless possess the productive base needed to anchor bioeconomy activity at a grassroots level. Here, development strategies should support small-scale biorefineries, collaborative livestock systems, and feedstock diversification suited to mixed farming models (Hand et al., 2025). Training initiatives and rural enterprise incubation, which focuses on the targeted support for early-stage businesses (Tutuba and Tundui, 2022), can help to bridge the gap between traditional practice and technical innovation, enabling communities to engage in new forms of value-added production such as anaerobic digestion, fibre and protein valorisation, and renewable energy (Vytvytska et al., 2024). Cooperative supply networks and regional producer groups can also strengthen local capacity to participate in emerging bio-based value chains without requiring disruptive structural change (Ogunlade et al., 2025).
2. Strategy should support rural regeneration and collaboration in fragmented and marginal zones where farming is often characterised by small plots, low mechanisation, and limited economic viability. Areas such as western Galway, Mayo, and Donegal, shaped by factors 6 and 7 and associated with cluster 2, illustrate the challenges of land fragmentation, declining rural infrastructure, and demographic vulnerability. However, these areas also offer opportunities to develop cooperative and community-based bioeconomy models, where collaboration compensates for a lack of individual scale. Shared machinery schemes, community-owned bioenergy facilities, and local food

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hubs can create viable circular systems rooted in trust and social capital (Mukherjee, 2020). These initiatives are particularly important in regions where formal education levels are low but practical and land-based knowledge is strong. A strategy grounded in peer-to-peer learning, technical upskilling, and participatory innovation can build local capacity and resilience (Farrell et al., 2021). At the same time, foundational investments in broadband, rural mobility, and basic services are essential to unlock this potential and ensure that marginal areas are not left behind in the transition to a low-carbon, bio-based economy.

3. Strategy should protect, restore, and monetise the NW region's ecological value, particularly in areas where intensive production is neither appropriate nor sustainable. Counties such as Leitrim, Sligo, Donegal, and parts of Mayo and Galway exhibit strong representation on factor 9 and cluster 4, characterised by environmentally sensitive peatlands, small-scale livestock systems, and low-intensity land use. These landscapes are of national and European ecological importance, offering vital ecosystem services such as carbon sequestration, water regulation, and biodiversity protection (Tanneberger et al., 2021). The bioeconomy strategy here should be conservation-oriented, emphasising nature-based economic models that link ecological value to rural income (Mendum et al., 2024). Payment for ecosystem services (PES) schemes, peatland restoration employment, and low-impact tourism can all form part of an alternative rural economy grounded in environmental protection rather than resource extraction (Kumar et al., 2019). In some cases, controlled development of paludiculture or high-nature-value farming may offer additional opportunities for diversification (Molloy et al., 2024). These areas should also be supported to develop regionally branded products such as traditional crafts, herbal goods, or heritage foods, that reflect their cultural and ecological uniqueness (Sarmokadam and George, 2024).
4. Cluster analysis highlights the NW region's remoteness and low settlement density, which pose real constraints for conventional, centralised bioeconomy infrastructure. As such, decentralised, modular systems such as mobile processing units, farm-based anaerobic digesters, and small-batch biorefineries should be prioritised (Loaiza et al., 2017). Human capital development also demands a tailored approach. While university-level attainment is lower in the NW than in other regions, the prevalence of practical skills and strong community networks offers a valuable foundation for innovation. Bioeconomy training should focus on applied, accessible learning formats such as field-based demonstrations, peer mentoring, and community-led education that match local learning styles and needs (Paris et al., 2023).

The NW region offers a compelling vision for a place-based, ecologically balanced, and socially inclusive bioeconomy. Rather than striving to replicate the capital-intensive models of other regions, it can lead by example in demonstrating how traditional farming, community collaboration, and environmental protection can be woven into a resilient and sustainable rural economy (Šūmane et al., 2018). Through a bioeconomy strategy that promotes grassroots value creation, enables cooperative adaptation, and rewards conservation, the NW region has the potential to become a national exemplar of a regenerative, multi-functional bioeconomy, where economic

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diversification, environmental integrity, and rural identity are mutually reinforcing pillars of long-term sustainability.

### *The Southern Region*

The Southern region represents a high-capacity, high-diversity rural zone, whose bioeconomy strategy must be differentiated yet integrated. It combines the structured strength of Ireland's most commercially productive agricultural counties with areas of environmental sensitivity, smallholder complexity, and emerging rural diversification. The spatial typology reveals both opportunities for industrial-scale innovation and the need for tailored, small-scale, inclusive interventions in more marginal or transitional areas. The Southern region, with its diversity of farming systems, labour profiles, and ecological zones, offers a unique platform to advance a bioeconomy that is technologically ambitious, socially inclusive, and environmentally restorative.

A bioeconomy roadmap for the region should therefore pursue the following strategic framework:

1. Accelerate innovation and scale in commercial farming hubs through investment in infrastructure, research-industry linkages, and supply chain integration (Salihu et al., 2025). Counties of Kilkenny, Wexford, Tipperary, and parts of Cork are marked by large-scale, high-output commercial agriculture, professionalised workforces, and strong educational attainment. They serve as the strategic core of Ireland's agri-food and Agri-Tech economy. These areas should be prioritised for the co-location of bioeconomy infrastructure with existing agri-food value chains, facilitating vertically integrated rural innovation zones (Hamam et al., 2023). Investment should target integrated biorefineries, anaerobic digestion facilities, and nutrient recycling systems capable of handling high-volume biomass inputs (Nunes, 2024). These counties also offer the human capital and institutional networks to act as bioeconomy demonstration zones, suitable for piloting precision agriculture tools, carbon accounting systems, and traceable bio-based product chains (Dietz et al., 2024). With high educational levels and a strong Agri-tech presence, they are ideally positioned to lead on workforce development, vocational training, and technological diffusion to other parts of the region.

2. Support transition and adaptation in fragmented or traditional farming zones by enabling cooperative structures, flexible technologies, and vocational upskilling. Parts of Wexford, Cork, Waterford, and Clare reflect medium-small to medium-large farm structures, where agriculture remains viable but often lacks scale, integration, or diversification. Labour profiles include both skilled and unskilled employment, with varied education levels and growing service-sector participation. These are ideal regions for fostering bio-based diversification, including micro-processing of arable waste (e.g. straw, vegetable residues), feedstock collaboration, and rural enterprise incubation (Tutuba and Tundaui, 2022). Investment should support shared infrastructure models such as machinery rings whereby cooperative organisations allow farmers and rural businesses to share agricultural machinery, labour and services (Başarik and Yildirim, 2015), producer cooperatives, and mobile processing units that enable collective

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scale without land consolidation. Bioeconomy development here should include agri-tourism, local circular economy hubs, and low-capital modular biotechnologies adapted to small farm outputs. Knowledge-sharing networks and peer-led vocational education are critical tools to unlock bioeconomy participation in these landscapes, particularly for younger or returning rural populations.

3. Protect and monetise ecological assets in sensitive landscapes by linking conservation to income, fostering multifunctional land use, and embedding sustainability in rural economic renewal (Ige et al., 2024). Areas within Cork, Kerry, Clare, and Waterford uplands are characterised by small-scale livestock farming in ecologically sensitive areas such as peatlands, Natura 2000 sites, and upland habitats. These landscapes require a conservation-compatible bioeconomy strategy, focused not on production intensification but on ecosystem service monetisation and low-impact land management (Giuntoli et al., 2023). Key initiatives should include agroforestry, silvopasture, wetland restoration (Vidadala, 2024), and nature-based product development (e.g. fibre crops, bio-based crafts, herbal and cultural food products) (Gausa and Tucci, 2024). Financial instruments such as results-based agri-environment schemes, carbon farming payments, and community benefit funds from biodiversity or water-based services are vital to linking environmental value with rural income (deBoe, 2020).

4. The Southern region's spatial proximity to ports, markets, and higher education institutions presents a unique opportunity to create rural-urban bioeconomy linkages, accelerating the movement of knowledge, goods, and people across the value chain. The region's mix of commercial strength and ecological diversity also positions it well for policy piloting, including carbon traceability in farming systems (von Cossel et al., 2019), biogas incentive schemes (Catalano et al., 2024), and green public procurement for bio-based materials (Philip, 2015).

The Southern region provides one of Ireland's strongest platforms for realising a balanced, inclusive, and circular bioeconomy. From its leading commercial hubs to its ecologically rich but structurally fragile landscapes, the region reflects the full spectrum of rural potential. A place-based strategy anchored in innovation, transition, and ecological value can ensure that this potential is realised not just for economic growth, but for long-term resilience, sustainability, and rural well-being. By embracing this integrated approach, the Southern region can serve as a national exemplar of how agricultural innovation, environmental protection, and community vitality can coalesce within a 21st-century bioeconomy.

### *The Eastern and Midlands (EM) Region*

The EM Region occupies a pivotal position in Ireland's rural transformation, acting as a national interface between advanced agricultural production, emergent rural diversification, and metropolitan influence. Its rural landscapes reflect a structural hybridity where modern, large-scale farming coexists alongside smaller, transitioning agricultural areas, and where proximity to urban centres shapes rural labour markets, infrastructure, and land use. A bioeconomy strategy for this region must therefore be responsive to this complexity, supporting the region's commercial productivity while

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enabling inclusive growth, rural innovation, and ecological protection across more transitional and fragmented zones.

A bioeconomy roadmap for the SE region should pursue the following strategic framework:

1. Strategy should focus on accelerating high-tech, scalable bioeconomy development in the region's large-scale commercial farming zones. Counties such as Kildare, Meath, Offaly, Laois, and Westmeath are defined by factor 2 and cluster 3, which identify highly productive agricultural systems characterised by expansive farm sizes, well-educated professional workforces, and a dual model of livestock and arable farming. These counties represent the industrial backbone of the regional bioeconomy and are ideally placed for investment in industrial-scale anaerobic digestion, crop rotation systems for carbon efficiency, and consolidated biomass feedstock supply (Subbarao et al., 2023). Innovation campuses, bioeconomy demonstration sites, and public-private research partnerships should be concentrated in these areas to pilot climate-smart agriculture, digital farm monitoring systems, and circular nutrient recovery platforms (Euston et al., 2024). The region's access to technical expertise, educational institutions, and strong rural infrastructure reinforces its potential to become a national leader in export-grade bio-based products, supply chain integration, and smart logistics.

2. Strategy should also support transitional and hybrid rural economies, particularly in counties such as Louth, Laois, Offaly, and Westmeath, where factor 3 landscapes and cluster 1 dynamics reflect medium-small scale arable farming combined with rising levels of non-agricultural employment and service-sector integration. These areas occupy a structural middle ground, neither fully commercial nor marginal, and are undergoing social and economic rural transition, often marked by fragmented landholdings, growing professionalisation, and spatial links to nearby towns and cities. As such, these regions are appropriate locations for distributed and modular bioeconomy models, including on-farm nutrient recycling, straw and crop residue valorisation, and peri-urban biomass aggregation (Taylor Buck and While, 2021). Investment in these areas should support community-owned bioenergy cooperatives, small-scale fermentation or composting infrastructure, and innovation grant schemes that enable farmer-led experimentation with new bio-based value chains (Celik et al., 2025). These counties can also serve as critical nodes for rural-urban bioeconomy integration, trialling closed-loop systems where agricultural waste is linked to urban bio-waste streams through shared processing, transport, or procurement platforms (Taffuri et al., 2021).

3. Strategy should focus on enhancing viability and resilience in the EM region's more structurally constrained rural zones. In counties such as Longford and parts of Laois and Westmeath, factor 6 and cluster 2 identify areas of high farm density but small farm size, socio-economic vulnerability, and limited access to technical education or capital investment. While these are not areas of high commercial intensity, they possess latent capacity for cooperative development models. The bioeconomy strategy here should enable shared infrastructure for land management, digital platforms for farm clustering, and rural bio-waste processing hubs that build

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collective economies of scale (Celik et al., 2025). Vocational upskilling, especially in areas such as bioenergy system maintenance, composting techniques, or digital land protection, will be essential to improving productivity and sustainability (Sanna and Fenrich, 2020). In these zones, the bioeconomy can become a platform for rural revitalisation, ensuring that smaller-scale farmers and communities are active participants in Ireland's broader transition to a bio-based economy.

4. Additional parts of the region, especially in Offaly and Longford, show moderate representation on factor 5 and cluster 5, indicating landscapes with afforested land, small-scale livestock systems, and semi-traditional agricultural labour structures. These areas present unique opportunities for the development of forest-based value chains, agroforestry, and ecosystem services markets. Strategies here should promote silvopasture, timber product innovation, and biochar production, while also enabling these landscapes to access payments for carbon sequestration, biodiversity enhancement, and water quality improvement (di Sacco et al., 2021). Though these areas are not high-output zones, they hold strategic ecological and land-use potential that can be integrated into a multifunctional bioeconomy (Faucon et al., 2023).

5. At the cluster level, much of the EM region is dominated by cluster 1, typified by semi-rural diversification, peri-urban influence, and a shift away from purely agricultural economies. Counties such as Meath, Kildare and Louth, are particularly illustrative of this transition, where rural labour markets are shaped as much by professional services and urban proximity as they are by farming. These areas are uniquely well-positioned to serve as convergence zones between agriculture, enterprise, and research. Bioeconomy policy here should prioritise investment in innovation accelerators, rural co-working spaces, and public procurement pilots for bio-based goods and services (Brouwer et al., 2023).

6. Across the EM region, the proximity to Dublin and other urban centres creates a strategic advantage in terms of access to research institutions, consumer markets, and transport infrastructure. This spatial positioning enables the development of regional bioeconomy corridors that link innovation sites, processing hubs, and production zones across Ireland. It also reinforces the region's potential to function as a national leader in the deployment of "smart rural" technologies, embedding data analytics, traceability tools, and digital infrastructure into agricultural and land-based systems (Prause and Boevsky, 2019).

The EM region offers a uniquely versatile platform for bioeconomy development in Ireland. Its blend of commercial strength, peri-urban proximity, rural diversification, and ecological opportunity allows for a multi-scalar strategy that aligns innovation, resilience, and inclusion. Through a strategic approach anchored in industrial-scale clustering, transitional rural innovation, and cooperative resilience, the region can become a model for how Ireland's bioeconomy can support both national competitiveness and local vitality. By aligning place-based interventions with the EM region's structural diversity and strategic location, the region is well-positioned to lead the development of a circular, smart, and sustainable rural economy.

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## Conclusion

This report has developed a comprehensive spatial typology of agricultural and socio-economic activity across rural Ireland, using factor and cluster analysis to classify the complexity of land use, farming systems, and rural labour structures. By integrating georeferenced datasets with statistical modelling, the typology identifies nine distinct factors and five spatial clusters that reveal the diverse character of Ireland's rural economy from highly commercialised large-scale farming zones to environmentally sensitive peatland landscapes and fragmented smallholder regions. These classifications offer critical insights into the spatial dynamics of rural Ireland, enabling the design of tailored, place-based bioeconomy strategies that respond to the unique strengths and constraints of each region. By mapping the intersection of environmental conditions, land use, and workforce profiles, the typology provides a robust foundation for informed policymaking, regional development planning, and the equitable advancement of a sustainable, circular bioeconomy across Ireland's rural territories.

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