

## PROJECT NO. 5165: A SPATIAL ANALYSIS OF AGRICULTURE IN THE REPUBLIC OF IRELAND, 1991 TO 2000

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### SUMMARY

By linking farm census and administrative data from the CSO and DAF to a geographic information system and analysing the mapping output, this project shows the continued broad division of farming in the state into marginal farming areas in the north and west and more commercial farming areas in the south and east. While this division was compounded by the 1992 CAP reforms, and commercial farming became more spatially concentrated over the 1990s, the influence of the development in the non-farm economy, particularly in peri-urban rural areas across the state, provided local drivers of change that encouraged enterprise substitution to beef production, the farming system most readily combined by farm holders with another job. A full report on the mapping output will be produced in a forthcoming publication (see publications list).

A local regression technique was employed to assess how the relationships of influential factors on average farm economic scale vary across the state. With the rising importance of the non-farm economy to a greater proportion of farm holders, varying local conditions of accessible urban employment and rural economic diversification will increasingly underpin the geography of Irish agriculture necessitating the use of such statistical models sensitive to changes across space.

### OBJECTIVES

The purpose of this project is to, firstly, provide a detailed empirical analysis of the geography of agricultural production in 2000 and of changes over the dynamic period of the 1990s to update the work of Lafferty *et al.* (1999). The empirical analysis is related to the effects on Irish agriculture from the 1992 reforms of the Common Agricultural Policy by assessing the uptake of selected policy measures. The analysis

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also explores the influence of Ireland's unprecedented economic development, which coincided with the implementation period of the 1992 CAP reforms and compounded the diversity of the spatial consequences, as opportunities in the non-farm economy were unevenly distributed across the state. These analyses show that the CAP reforms and national economic development had different spatial consequences as farm holders in commercial and marginal farming areas responded to them along different trajectories. Findings are synthesised into a typology of five zones that provide an overview of Irish agricultural geography at the turn of the millennium.

Secondly, acknowledging that the geography of Irish agricultural production does not follow neat, administrative boundaries, the project employs the local statistical technique of Geographically Weighted Regression (GWR) to reveal the diversity of local relationships across space, as an aid to policy development.

## **DATA AND METHODS**

The research was based on data from two main sources. The Central Statistics Office (CSO) provided farm data from the Census of Agriculture and the Department of Agriculture and Food (DAF) provided administrative data on selected agricultural policy measures, all at the level of the Electoral Division (ED). In 1991 some 3,100 EDs (out of a total of more than 3,400 EDs in the state) had agricultural activity and this declined to less than 3,000 by 2000, due to the expansion of urban areas, especially in Dublin. The CSO used the same methodology for the Census of Agriculture in 1991 and 2000; this comparability renders spatial farm data compatible at the ED-level, which allowed an investigation into *changes* in farm structures and farming systems at that spatial scale for the first time.

The spatial data were linked to a geographic information system (GIS) and maps of raw data and of derived indices were generated with ArcMap 8.3 for the empirical analysis. Data in most of the maps were classified using the quantiles classification scheme, which allocates an equal number of the spatial units to each of five classes and enhances map-reading accuracy.

In the geostatistical analysis, ordinary least squares (OLS) regression was conducted in SPSS 12.0 to explore the global models, whereby the output was considered to

apply across the state, while GWR 3.0 ([ncg.nuim.ie/ncg/GWR/](http://ncg.nuim.ie/ncg/GWR/)) was used to explore the local models and to reveal spatial variations in the modelled relationships at a local level. Their outputs were combined with the visualization power of the GIS to generate maps of the analytical results for interpretation. Policy relevant variables of average farm economic scale and productivity per land and labour inputs were used as dependent variables in the analysis.

GWR recognises that spatial nonstationarity<sup>3</sup> in processes may exist and extends traditional linear regression by allowing the estimation of local parameters, so that the linear regression equation becomes:

$$y_i = \beta_0(u_i, v_i) + \sum_k \beta_k(u_i, v_i)x_{ik} + \varepsilon_i,$$

where  $(u_i, v_i)$  denotes the coordinates of the  $i$ th point and  $\beta_k(u_i, v_i)$  represents the continuous function of  $\beta_k(u, v)$  at point  $i$  (Fotheringham *et al.*, 2002).

To weight the data, a spatial kernel is placed over each calibration point (ED centroid) and the data around that point are weighted, using a weighted least squares approach, according to the distance-decay curve of the kernel. At the regression point  $i$  (ED centroid), the weight of the data point is unity (equals one); it falls towards zero with increasing distance between the regression point and the data point. Thus, data observations near to regression point  $i$  have a greater influence on the estimated parameters of the relationship being measured at point  $i$  than distant observations. In this way, GWR accounts for the fact that processes and relationships may vary significantly over space related to spatial factors that range from physical, environmental and economic to social, cultural and political.

## RESULTS

Land Inputs: Agricultural area in use in 2000 was almost unchanged at 4.4 million hectares, out of a total of 6.9 million hectares in the state, with over 50 percent of land in most EDs outside of upland areas being used for farm production. But this static impression masks spatial variation in change over the 1990s with increases in

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<sup>3</sup> Whereby the measurement of a relationship is influenced by the location of the measurement.

farmland more likely in the north and west of the state in areas of limited land use ranges. Introduction of area aid system for livestock subsidies in the 1992 CAP reforms, whereby livestock payments are linked to stocking limits based on available forage area, provided an indirect incentive for land reclamation and/or the use of previously unused rough grazing land. The largest percentage declines were recorded in Dublin and the Mid-East counties of Meath, Kildare and Wicklow, linked to population growth and expansion of transport infrastructure. Afforestation grant aid introduced in the 1992 CAP reforms provided another incentive for taking land out of agriculture.

Average farm size (excludes commonage) in 2000 was 31.4 hectares, an increase from 26 hectares in 1991, and maintains its long standing pattern of larger farms in the south and east, underpinned by factors such as larger field systems and superior land use ranges, and in upland areas, where farms are larger to compensate for limiting land resources [Map 1(a)]. Spatial changes over the 1990s reveal a strong southeast to northwest gradient of higher increases, with increases greater than 25 percent more characteristic of Connacht and along the Border, reflecting the smaller average farm sizes in these areas but also the degree of farm enlargement occurring there over the decade.

Considering the sluggish land market in Ireland and the trebling of land prices over the 1990s, renting-in land is probably the most viable strategy for farm enlargement. By 2000, 32 percent of all farmers rented-in land, an increase from 21 percent in 1991. There are higher incidences of farms renting-in land in east Donegal, the north-east, the south-east and the Munster dairying region (44 percent plus), a pattern that reflects the positive association between renting-in land and farms of larger size and economic scale [Table 1]. Nevertheless, increases in the practice occurred across much of the state over the 1990s, with the exception of upland areas, which indicates a rise in land mobility.

**Table 1 Land rented-in by selected farm size (ha) classes, 1991 and 2000**

<i>Size class</i>	<i>Farms with land rented-in (%)</i>		<i>Average area rented-in (ha)</i>	
	<i>1991</i>	<i>2000</i>	<i>1991</i>	<i>2000</i>
Farms <20 ha	13	17	6.1	6.0
Farms ≥50 ha	43	61	33.5	34.5

Derived from: Census of Agriculture 1991 and 2000

The average area of land rented-in by 2000 was 18 hectares, up from 15 hectares in 1991. A comparison of spatial patterns of the average area of land rented-in by farmers and rented-out by farmers, reveals that farmers are more likely to rent out land in the south and east, including east Donegal, while many EDs in the north and west did not enumerate any farmers renting-out land. Thus, both the demand for and supply of rental farmland were greater in the more commercial farming areas of the south, east and east Donegal.

Labour Inputs: Farm labour inputs are measured in Annual Work Units (AWU), where one AWU equals 1,800 hours or more of labour input per person per annum and it accounts for the labour of family members, regular non-family workers and agricultural contractors. The spatial pattern of labour inputs in 2000 reveals that higher values of 1.13 AWU plus are characteristic of the south, east, eastern Donegal and the southern midlands. Declines in AWU were recorded in 88 percent of EDs across the state over the 1990s with the most noticeable exceptions being increases in the mid-east, particularly in east Meath.

In 1991, 73 percent of farm holders described farming as their sole occupation; by 2000, this had declined by 37 percent to 56 percent of all farm holders [Table 2].

**Table 2 Number, proportion and changes in farm holders per occupation category, 1991 and 2000**

<i>Occupation category</i>	<i>Farmers in 1991</i>		<i>Farmers in 2000</i>		<i>Change (%)</i>
	<i>Number</i>	<i>(%)</i>	<i>Number</i>	<i>(%)</i>	<i>Number</i>
Sole occupation	124,746	73	78,723	56	-37
Part-time farm holders <sup>4</sup>	45,147	27	62,619	44	39

Derived from: Census of Agriculture 1991 and 2000

The highest incidences of 59 percent or more of sole occupation farming among farm holders occur in the southern half of the state, in east Donegal and to a lesser degree in the northeast. Large declines of 40 percent plus occur through central Connacht, Cavan and Monaghan, associated with the push factor of small and low income farms in those areas, as well as Dublin, east Meath and north Wicklow, linked to a particularly strong labour market in the region.

Combining farming with other paid work is a long-established strategy among Irish farm holders and households and it became more common over the 1990s. By 2000, 44 percent of all farm holders engaged in gainful non-agricultural activity either on or off the farm, an increase of 39 percent from 27 percent of farm holders in 1991. The highest incidences of such part-time farm holders occur across the northern half of the state, especially the northwest, extending through the midlands into areas west and south of Dublin, as well as the extreme south-west. This reveals regions where farm holders are particularly dependent on gainful non-agricultural activity and thus where investment in the wider rural economy and rural diversification, e.g., in the northwest, midlands and southwest, has the potential to benefit higher proportions of farming families.

There were increases in the number of part-time farm holders over the 1990s throughout the state, signalling the growing and widespread applicability of this income supplementation strategy among farmers. This trend reflects the influence of increased job opportunities in the industry and service sector along with superior wages from such jobs.

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<sup>4</sup> Farm holders reporting gainful non-agricultural activity which includes agricultural contract work.

Mechanisation: While the number of active farms and the numbers employed in the regular farm labour force both fell by approximately 17 percent over the 1990s, total farm labour inputs declined at the higher rate of 33 percent, which suggests the influence of increasing mechanisation.

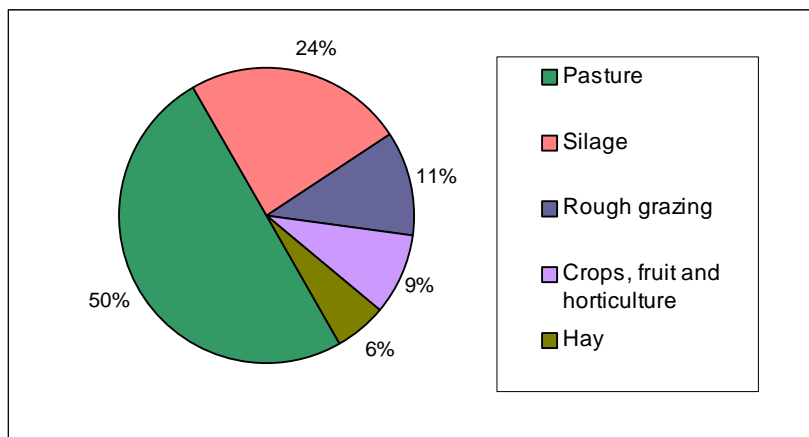
By 2000, there were still farms in Connacht, Donegal and the extreme south-west in particular without a tractor in spite of increases in mechanisation throughout the north and west of the state over the 1990s. Conversely, while areas in the south, east and eastern Donegal were more likely to exhibit at least one tractor per farm in 2000, these areas were also characterised by widespread declines of ten percent or more in the numbers of tractors over the 1990s. These trends are underpinned by the widespread practice of hiring-in tractors, with the exception of much of Donegal, west Galway and Dublin. Hiring-in machinery includes those brought in by contractors, and an assessment of the spatial patterns of hiring-in different types of machinery reflects the distribution of the farming systems with which the equipment is associated. The hiring-in of forage harvesters follows the distribution of specialist dairy farming and was enumerated on over 30 percent of farms in the top quantile. Hiring-in of slurry tankers follows the distribution of cattle farming and silage production and was recorded on 35 percent plus of farms in the top quantile. Hiring-in sowers, distributors and sprayers was enumerated among 28 percent or more of farmers in the top quantile in areas that correspond with arable production. These patterns and rates of hiring-in machinery indicate the widespread input of agricultural contractors to Irish farm labour by 2000.

Farm economic scale: The economic scale of a farm is measured in European Size Units (ESU), where 1 ESU = €1,200 of standard gross margins for farm output or the monetary value of its gross production less specific costs. The spatial pattern for average farm economic scale follows that of average farm size, except in upland areas due to their lower land use ranges [Map 1(b)]. In 2000, the average farm economic scale was 20.7 ESU, an increase of 78 percent from 11.6 in 1991. Values of average farm economic scale of 33 ESU plus are almost exclusively found in the south and east of the State along with eastern Donegal. This spatial pattern reflects the geography of the more lucrative farming systems with an average of 144 ESU among 'other' farms (specialist pig, poultry or horticultural enterprises), followed by

specialist dairy and tillage with averages of 46 ESU and 38 ESU, respectively. In comparison, specialist beef and specialist sheep farms are low-income systems with averages of just nine ESU and ten ESU, respectively, that are most strongly associated with the north-west and upland areas.

The vast majority of EDs underwent increases in the average scale of farm business over the 1990s. The greatest concentrations of EDs that display increases in excess of 80 percent are throughout much of Cavan, Monaghan and Meath as well as most of Connacht. In contrast, EDs in the south and east display comparatively smaller gains in average economic scale of farms.

Land Use and Farming Systems: Pasture remains the dominant land use and takes up 50 percent of farmland. Grass silage occurs on almost one quarter of farmland, followed by rough grazing on 11 percent, crops, fruit and horticulture on nine percent, and hay on just six percent [Figure 1].



**Figure 1 Land use, 2000**

Derived from: Census of Agriculture 2000

The geography of crops, fruit and horticulture reflects that of arable farming with percentages of 16 percent plus in much of the east (except Wicklow) and parts of the south. Only three percent of farms in the state engage in specialist tillage farming<sup>5</sup>.

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<sup>5</sup> A specialist farm is one in which a single farm activity accounts for at least two thirds of the farm's total standard gross margins.



This farming system became more spatially concentrated over the 1990s, with increases of 29 percent plus in its southeastern stronghold, especially Wexford and Carlow, and declines at the margins of arable farming areas, particularly in Meath and Louth. These trends are noteworthy in the context of climate change research by the Environmental Protection Agency, which predicts that reduced rainfall in the southeast will restrict water availability and thus pose a challenge to crop production in Ireland's primary tillage areas.

The distribution of pasture corresponds with areas of cattle farming and ranges from 60 percent plus of farmland from north Munster to the Border dropping to 43 percent or less in upland and arable farming areas. Percentage increases of 25 percent or more over the 1990s are found throughout Donegal, Leitrim, west Connacht and the extreme south-west, which contrast with decreases of seven percent and greater in the east. The western pattern of increases suggest the improvement of rough grazing land. Silage production is associated with dairy farming and makes up 32 percent plus of farmed land in much of Munster and the northeast compared to 18 percent or less in upland and arable farming areas. In response to a series of wet summers and grant aid for storage facilities, increases were widespread over the 1990s with highest values of 64 percent plus in the northwest and extreme southwest. The largest extents of high percentages of hay and permanent meadow (8 percent plus) occur in east Connacht, Longford, west Clare but declines were widespread over the 1990s.

Almost 19 percent of all farms in 2000 were specialist dairy farms. This farming system has two main strongholds: the largest is in Munster extending into south Leinster (35 percent plus of all farms per ED), and the smaller concentration is found in the northeast (22 percent plus). The number of dairy farms declined by 37 percent over the 1990s. Decreases were widespread with noteworthy high declines of 42 percent plus throughout the northeast and in the margins of the Munster stronghold.

In 2000, 51 percent of all farms in the state were in the specialist beef farming system. The largest extents of high incidences (70 percent or more) of specialist beef farms are found among EDs in the north-west: east Mayo, Sligo, Leitrim, Roscommon, Longford and north Galway. There is a second concentration of such high values in Clare that extends into south Galway and west of Galway city. In contrast to the

national decline of 17 percent in the number of farms over the 1990s and declines in all the other farming systems, the number of specialist beef farms actually increased by 0.5 percent. Specialist beef production increased by 40 percent plus in the traditional dairying regions of Munster and the north-east, in east Donegal and in a band from east Galway to the southeast, indicating a dispersal across lowlands beyond its core areas.

Specialist sheep farms comprised over eight percent of all farms in the state in 2000. Sheep farming is associated with the uplands, as well as the lowlands of south Connacht and of south Leinster, where 53 percent plus of farms are engaged in this farming system. The number of specialist sheep farms declined by 18 percent over the 1990s and the pattern of change reveals a retreat of sheep farming from lowland areas.

Table 3 summarizes the number, size, and economic scale of farms across the farming systems found in the state, and how these changed between 1991 and 2000.

**Table 3 Average farm size (ha), economic scale (ESU), farm number and changes by farming system, 1991 and 2000**

<i>Farming system</i>	<i>2000</i>			<i>Change since 1991 (%)</i>		
	<i>Farm number</i>	<i>Average farm size (ha)</i>	<i>(ESU)</i>	<i>Farm number</i>	<i>Av. farm size (ha)</i>	<i>(ESU)</i>
Other	1,752	25.1	144.4	-25	64	386
Specialist beef	72,141	24.2	9.4	0.5	29	141
Mixed grazing livestock	20,729	33.6	17.7	-32	30	103
Specialist dairying	26,292	42.8	45.8	-37	30	86
Specialist tillage	4,736	53.9	37.9	-6	8	58
Mixed crops/livestock	3,644	50.5	32.7	-15	-0.5	54
Specialist sheep	12,233	31.9	10.1	-18	10	16

Derived from: Census of Agriculture 1991 and 2000

Agricultural policy measures: The Early Retirement Scheme (ERS) and the Rural Environment Protection Scheme (REPS) were two of the accompanying measures introduced under the 1992 CAP reforms. The ERS encourages farm transfers to younger farmers to encourage farm development and, between 2000 and 2003,

participation in the scheme continued to exhibit the pattern first noted by Lafferty *et al.* (1999) with higher uptake in the southern half of the state where both commercial farming, and land acquisition through lifetime transfers and purchases, are more common.

The REPS compensates farmers for income loss incurred by farming practices that conserve natural and cultural heritage. An assessment of the uptake of REPS and of farms that availed of headage payments (now the Disadvantaged Area Compensatory Allowances Scheme) around 2000 reveal comparable spatial patterns. Thus, the agri-environmental scheme is particularly attractive to farmers located in Less Favoured Areas of the north and west with natural handicaps to farm production, typified by small-scale cattle enterprises, rather than to farm holders in the more intensive farming regions of the south and east, indicating its role as an income supplement in marginal farming areas. Nevertheless, increases in REPS participation between 1999 and 2003 occurred not only in the north and west, but also along the south and east to Wicklow indicating the rising participation in commercial farming areas.

These schemes reflect the divergent trajectories of Irish farming over the 1990s as the ERS incentivized the transfer of farms to successors in more commercial farming areas in response to rising competitive pressures in the farming sector, while the REPS supplemented farm income on farms in marginal farming areas. Their uptake patterns highlight the continuing divide of more marginal farming in the north and west and more commercial farming in the south and east.

The geographical synthesis: The detailed empirical analyses of the geographies of farm structures, farming systems, agricultural measures and part-time farming were synthesised into a typology of five farming zones to provide an accessible overview [Map 2Map 2(a)]. The three zones in the north and west of the state are: Purple Zone of High Nature Value Farmland, Blue and Green Zones of Agricultural Sustainability through Part-time Farming, with the Green Zone further distinguished as an area of Waste Management Challenge. The two Zones in the south and east are: Orange Zone of Commercial Agriculture and the Red Zone of Threats to Agricultural Sustainability.

Geostatistical analysis: Average farm economic scale per ED measured in ESU was the primary policy relevant dependent variable selected for the regression analysis. Based on the definition of ESU, influential independent variables were selected that represented the type of farmland use, land use intensity, intensive indoor production systems, farm size, farm mechanisation, labour intensity, farm holder age and occupation type, and distance from urban centres.

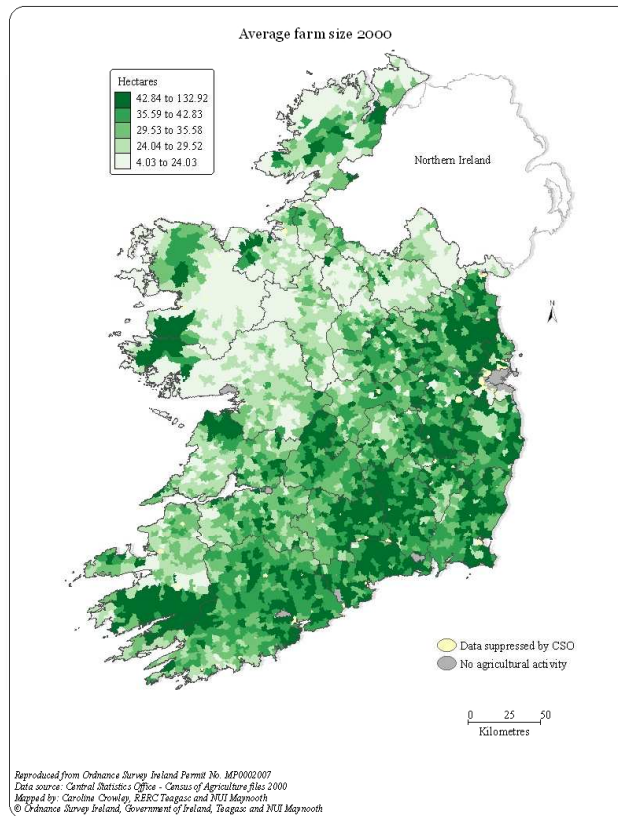
Using stepwise regression, the OLS regression  $R^2$  reached 91 percent with the addition of just three independent variables: land use intensity measured in livestock units per 100 hectares, average farm size and the share of total livestock units represented by dairy cows and dairy heifer-in-calf. This means that 91 percent of the variation in average farm economic scale is associated with these variables. But the global model's residuals exhibited significantly positive spatial autocorrelation (Moran's I: 0.02,  $p \leq 0.01$ ), which means that any inferences drawn from the global model are questionable.

When this model was calibrated in GWR using the same variables, the GWR model delivered an improvement in goodness-of-fit ( $AIC_c$  declined by  $>3$ ). Map 2(b) of local  $R^2$  values across the state reveals that the model performs better from the north-east through the midlands, and from east Connacht to Clare and south to Cork. Relating this pattern to the farming zones typology, the model has lower explanatory power in the Red Zone in the mid-east, the Purple Zone of the west, the Clare/Galway border in the Blue Zone and around Waterford in the Orange Zone. Local factors that may explain the lower explanatory power of the model in these areas include the negative and positive effects, respectively, of the particularly strong labour market and large consumer market in the Red Zone, and the negative effect of peripherality in the Purple Zone. Relatively high percentages of commonage in 2000 along with increases in farm fragmentation over the 1990s are also characteristic of EDs across most of these areas, and may be other influential factors in the spatial pattern. This example highlights how national policies informed by mechanisms expressed in global models may be inappropriate at regional and sub-county level and that GWR models provide a tool to help in the design of location-specific agricultural policies.

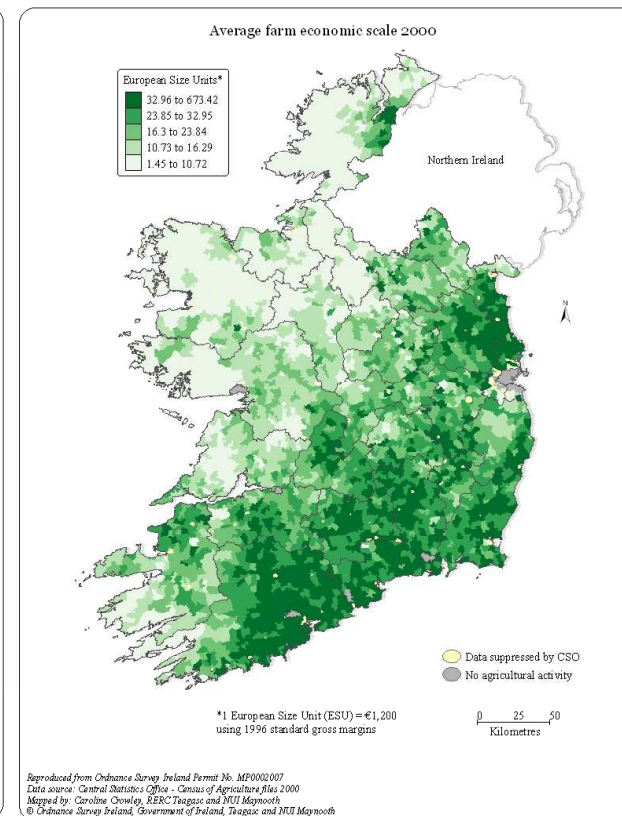
## **KEY FINDINGS**

In terms of the changing geography of Irish agriculture between 1991 and 2000, one of the most important findings is the expansion of beef production, particularly through enterprise substitution on small-scale dairy farms in the dairying regions and mixed grazing livestock farms in lowland sheep farming areas. On dairy farms, this expansion is underpinned by the continued policy restraints on milk production due to the milk quota introduced in 1984, combined with rising competitive pressures on Irish dairy farmers over the 1990s, which drove a decline in specialist dairy farms at over twice the rate of decline in all farms. The transition to specialised beef production also facilitated farm holders to combine farming with another job and thereby take advantage of the unprecedented development in the national economy over the 1990s.

The spatial pattern of changes in combining farming with other work indicate that this income supplementation strategy is being taken up by farm holders across the state, which highlights the need to implement the regional development goals of the National Development Plan through the framework of the National Spatial Strategy and achieve rural diversification under Pillar 2 of the CAP through the national Rural Development Programme. This is confirmed by findings in numerous farmer surveys by both Teagasc and rural development groups of an increasingly negative outlook for the future of farming, especially in comparison to other careers in terms of income potential and living standards, combined with the continued desire among the increasingly well-educated potential farm successors in both commercial and marginal farming areas to continue in farming if local job opportunities and rural services are available. Together, the results highlight how rural development is increasingly important to agricultural sustainability. As a result, the geography of Irish agriculture is likely to become more diverse in response to local socio-economic conditions and the application of GWR in this project shows its potential to help design more territorially-specific agricultural policy and rural development measures.

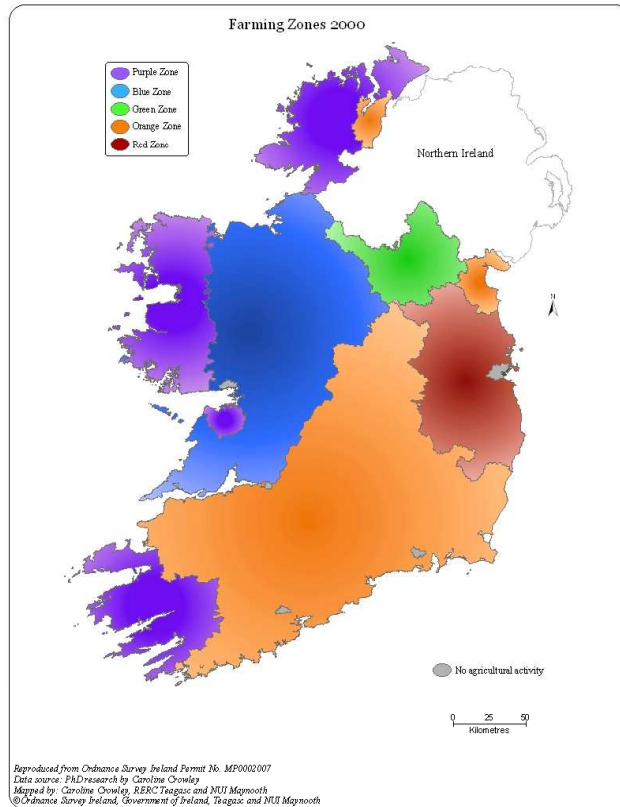


(a)

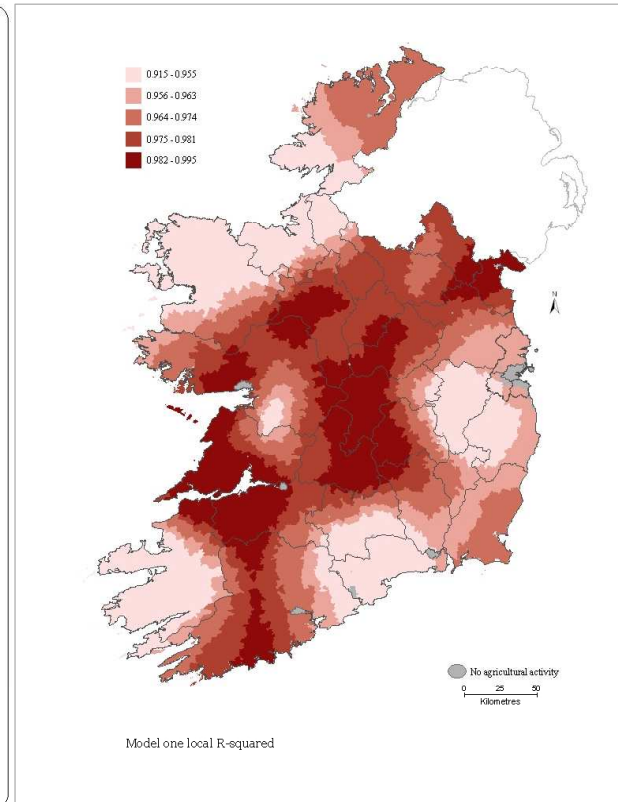


(b)

**Map 1 Average farm size (a) and average farm economic scale (b)**



(a)



(b)

**Map 2 Farming zones (a) and GWR model  $R^2$  (b)**

## REFERENCES

- Fotheringham, A.S., Brunsdon, C. and Charlton, M. (2002) *Geographically weighted regression: the analysis of spatially varying relationships*. Chichester: John Wiley & Sons, Ltd.
- Lafferty, S., Commins, P. and Walsh, J. (1999) *Irish agriculture in transition: a census atlas of agriculture in the Republic of Ireland*. Dublin: Teagasc.

## OUTPUTS

### Publications

- Crowley, C., D. Meredith and J. Walsh (forthcoming). *Irish agriculture at the millennium: a census atlas*. RERC, Teagasc and NUI Maynooth
- Crowley, C., D. Meredith and J. Walsh (2004) *Population and agricultural change in rural Ireland, 1991 to 2002*. In Rural Futures: Proceedings of the Rural Development Conference 2004. Teagasc, Dublin

### Key presentations

#### **Teagasc Rural Development Conference 2007, Mullingar, Westmeath**

*Farming and living in rural Ireland: evidence from the 1990s and implications for the future.*

#### **European Regional Science Association 2006, Volos, Greece**

*Modelling Irish farm census data with OLS multiple regression and GWR.*

#### **Agriculture and Food 2006, Rural Development Tent, Kildalton**

*The geography of Irish farming and the wider rural economy.*

#### **Conference of Irish Geographers 2006, University College Dublin**

*The geography of multifunctional agriculture in Ireland.*

#### **Conference of Irish Geographers 2005, NUI Galway**

*REPS: agricultural or environmental policy?*

#### **Teagasc Rural Development Conference 2004, Tullamore, Offaly**

*Demographic and agricultural change in rural Ireland, 1991-2002.*

#### **Conference of Irish Geographers 2004, NUI Maynooth, Kildare**

*One foot in the farm: the geography of part-time farmers in Ireland, 1991-2000.*