

## **CHAPTER 10**

### **ADOPTION AND DIFFUSION PROCESSES IN THE MECHANISATION OF IRISH AGRICULTURE**

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#### **Introduction**

The modernisation of production and the growth of output in the agricultural sector in Ireland, as in many other countries, have been associated with the adoption of many innovations which have contributed to a very significant decline in labour inputs and its replacement by mechanisation. In farming the process of mechanisation can be understood as the adoption of production methods in which human labour and draught animals are replaced to a high degree by technology which can result in greater productivity of both agricultural labour and land. It is part of a wider range of processes which result in a significant level of structural adjustment in the organisation of the total economy. Mechanisation facilitates this adjustment and enables the fewer remaining farmers to achieve higher income levels and an improved standard of living. However, farmers vary in their ability to respond to the requirements of this process for a variety of reasons including economic constraints, demographic factors and in some instances locational disadvantages. The differential impacts of these factors between farmers introduces significant temporal and spatial dimensions into the adoption and diffusion of mechanisation. While there have been many studies of the spatial structure of agricultural production in Ireland (Stamp, 1931; Gillmor, 1977, 1987; Homer *et al.*, 1984; Walsh, 1991) and of the sources of variation in growth rates (Conway, 1975; Cuddy, 1982; Boyle, 1987), there has been surprisingly little systematic analysis of the influences on the adoption and diffusion of innovations in Irish agriculture.

In the 1960s Bohlen and Breathnach (1968) investigated the levels of adoption of seventeen innovatory agricultural practices among a sample of 600 farms which were randomly selected across the 26 counties of the Republic of Ireland. Since the main focus of this sociological research project was on the most useful sources of information at each stage of the adoption process, it did not explore either the scale or the sources of variation in adoption rates between counties (Bohlen and Breathnach, 1970). The influence of demographic and farm-related factors on the adoption of twenty innovations on farms in southeast Galway was reported on in 1982 by Walsh. Studies which have considered locational influences on adoption and diffusion include Higgins' (1977) investigation of the adoption of deep ploughing techniques for land drainage in west Kerry, and Humphrey's (1981) analysis of the spread of

the Small Farm (Incentive Bonus) Scheme among western counties. Countrywide studies have been extremely limited, one of the few exceptions being Homer's (1984) study of the diffusion of credit unions between 1958 and 1982.

This study uses a unique data set extending over sixty years which is finely disaggregated for small geographical units. The data relate to tractors, the adoption of which has been shown to be related to many other agricultural innovations (Horner and Walsh, 1981; Walsh, 1982). The next section provides a brief review of the processes affecting innovation adoption and diffusion which have been identified in the literature. These general processes are brought together in a model which is suggested as appropriate for research in Ireland. The remainder of the paper uses the proposed model as a framework for discussing the spatial diffusion of tractors from the 1920s up to the present.

### **Innovation Adoption and Diffusion Models**

Mechanisation involves several innovations. The processes which influence the adoption of innovations have attracted a considerable amount of attention from researchers in several disciplines who have identified a wide range of processes which affect the rates and patterns of adoption and diffusion (Jones, 1975; Blaikie, 1978; Brown, 1981; Rogers, 1983). Among geographers concerned with spatial diffusion processes, a number of different research traditions have developed (Illbery, 1985). The earliest, associated with Hagerstrand (1952) stressed the role of learning and communication processes. The basic hypothesis in this approach is that increased awareness of new ideas will lead to favourable attitudes towards modernisation which will be conducive to acceptance and ultimately adoption of innovations (Wilkening, 1956; Gartrell and Gartrell, 1977; Hooks *et al.* 1983). This implies that factors related to the effective flow of information are critical. Special significance was given to the distances between potential adopters as well as consideration of other physical barriers and individual sources of resistance which by transforming the information flows influence the morphology of the adoption surface. It was envisaged that diffusion would spread outwards from some initial adopters in a lateral manner until the entire landscape was covered (Hagerstrand, 1952, 1953). According to the Hagerstrand model, the spatial development of many diffusion patterns is characterised by the addition of new adopters around the original nuclei of introduction of the innovation. This contagious growth process was called the neighbourhood effect (Hagerstrand, 1967). This process on its own can only provide a partial explanation for empirically observed diffusion patterns.

An additional process which identifies the role of hierarchical effects in spatial diffusion has been proposed by Hudson (1969, 1972), Pederson (1970) and Berry (1972). In these papers, which are mainly concerned with diffusion of innovations through urban systems, it is envisaged that

the potential adopters can be organised into different hierarchical levels with diffusion taking place between most members of one level before proceeding to the next level. The importance of hierarchical filtering processes is also relevant in an agricultural context where a hierarchy of farms may be identified on the basis of criteria which could include farm size, enterprise specialisation, demographic attributes of the farm household, management skills and motivation, and access to credit (Yapa and Mayfield, 1978; Brown, 1981; Walsh, 1982; Shaw, 1985) These factors are particularly important in rural societies where agriculture is poorly developed and the costs of innovations are high relative to land or labour productivity levels. This is particularly true in the early stages of adoption of expensive items of machinery where the decision to adopt a tractor may also require a commitment to replacing a variety of horse drawn implements. Rates of adoption and diffusion can also be influenced by a variety of other factors including personal, psychological and sociological characteristics of the potential adopters (Jones, 1975).

The processes which contribute to neighbourhood and hierarchical effects are concerned only with the establishment of the demand surface for an innovation. These approaches are complemented by the market/infrastructure perspective which focuses on the supply of innovations to potential adopters (Brown, 1975). Through this approach attention is directed to the policies of diffusion agents. Their locations, targeting strategies, promotional activities and pricing policies may have a considerable influence on the pattern of adoption (Ilbery, 1985; Unwin, 1988). While diffusion agents are concerned with increasing the demand for an innovation, there may be other factors which can distort the diffusion process. In this regard Freeman (1985) has demonstrated how early adopters can, through political processes, become pre-emptors of diffusion so that they can benefit from the excess profits that result from adoption of some innovations. It is the interaction of processes affecting both the demand for and supply of innovations which produces the temporal and spatial patterns of adoption and diffusion.

The foregoing discussion can be summarised in the following model. For the purpose of illustration it is assumed that the potential adopters (farmers) can be classified into a three-level hierarchy consisting of large, medium and small farms which may be defined in terms of size, or some other index of economic potential. In Figure 1(i) there are 60 farms, of which 12 are considered to be large, 20 are medium-sized and the remainder (28) are small. It is also assumed that the spatial distributions of the three categories are neither uniform nor random. The entire region is partitioned into three subregions (A, B, C) with large farms predominating in A, medium-sized in B and small farms in C.

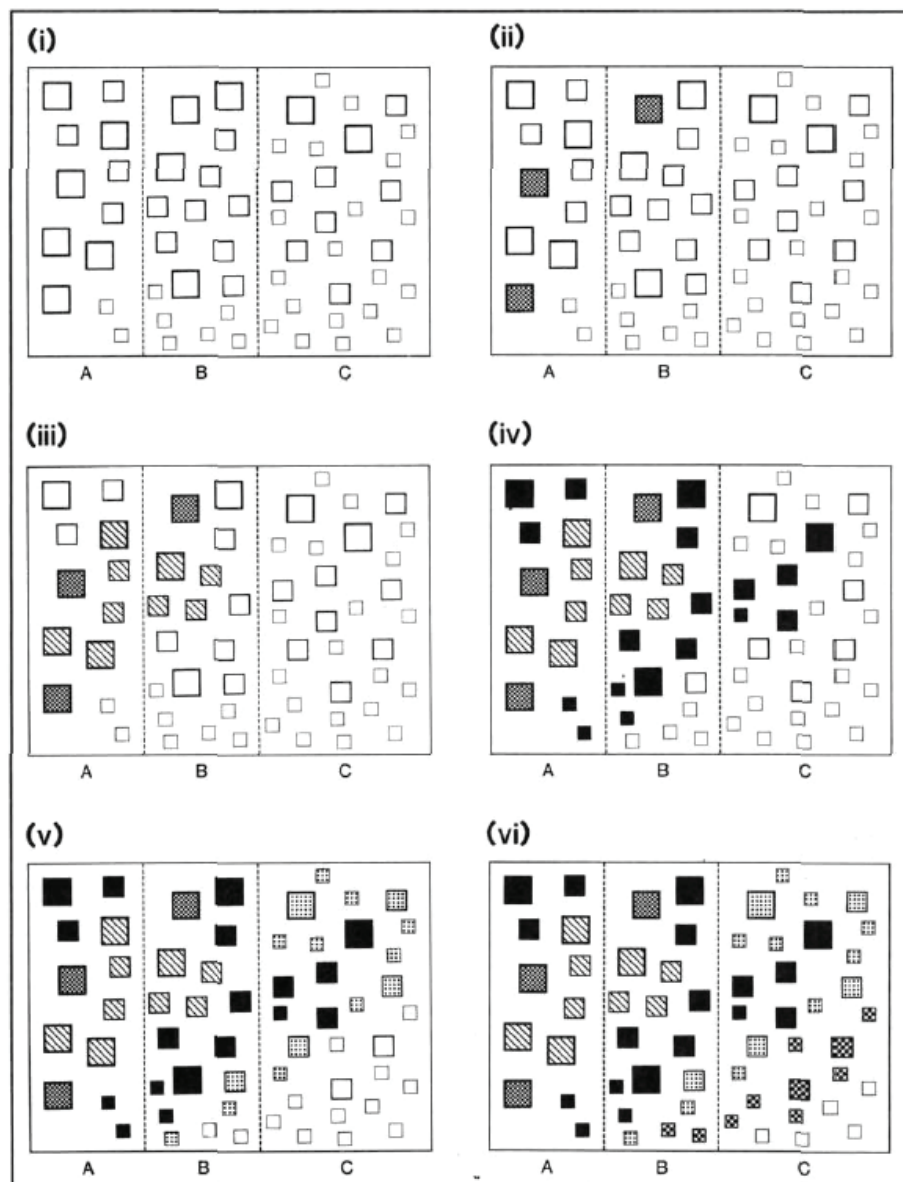
In the initial stages the innovation is most likely to be adopted on some of the largest farms. They are most likely to have the financial resources to purchase the innovation and they are also likely to benefit most from

adoption. At the very early stages the innovation is likely to be available from only a very limited number of outlets (Brown, 1975) and information flows are likely to be restricted to what may be derived from the mass media and more formal channels of a personal kind such as agricultural advisors, and commercial representatives (Jones, 1975). At this stage, while there are likely to be some clusters of adopters where the largest farms are concentrated. There are also likely to be some individual pioneers who may be located some considerable distance from the clusters (Figure 1 (ii)). Those at the top of the farmer hierarchy are likely to be part of geographically extensive social networks so their propensity to adopt innovations is more likely to be influenced by their hierarchical position rather than their location (Smyth, 1975). The small number of outlets at this stage are likely to be restricted to locations in or near the largest cities, in order to take advantage of their superior accessibility. This will be especially the case if the innovation has to be imported. After awareness has been created and evidence is accumulated (either formally or informally) to demonstrate the benefits of adoption the innovation spreads rapidly through the highest level in the hierarchy of potential adopters and begins to filter down to the next level. In Figure 1 (iii) the overall level of adoption is 20% but it has already reached almost 60% among the largest farms. These pioneers correspond with the “early adopters” identified by Rogers (1958). By this stage a strong neighbourhood effect is becoming evident as the increasing density of adopters facilitates more informal information exchanges between farmers in the same locality. The increasing demand for the innovation will be encouraged by a growing number of suppliers or diffusion agents (Brown and Cox, 1971; Brown, 1975) who are likely to form a distribution network that attempts to maximise sales potential. While the response of entrepreneurs at locations that meet the threshold level of sales potential may exhibit a strong random component (Brown, 1981) it is likely to reinforce the neighbourhood effect especially if there are pronounced regional differences in the distribution of potential adopters at each hierarchical level. Apart from the role of suppliers, the rate of adoption can also be influenced by government policies towards agriculture which may have unequal regional impacts.

The diffusion processes continue to operate until almost everybody has adopted. In Figure 1 (iv) while half of all the farms have adopted, the diffusion is complete amongst the large farms and there is over 70% adoption on the medium-size farms. The medium-size farms which have not adopted are located in sub region C where they are furthest away from the initial source of the innovation. Adoption has commenced on some of the smallest farms, but mainly among those located adjacent to the earliest adopters in sub regions A and B. At this stage some additional factors may begin to influence the diffusion process. These include the availability of some low cost second-hand items from the earliest adopters who are already upgrading their technology, and also improvements in the income position of many small farmers who, having

been marginalised rather than modernised, have taken on another occupation. In Figure 1 (v), adoption occurs on most of the remaining medium-size farms and there is a three-fold increase in diffusion among small farms. There is a strong neighbourhood effect in the diffusion at this level due to a combination of the communication and diffusion agency factors. The final stage may be quite slow as it involves adoption by those identified as "laggards" by Rogers (1958), who are mostly imitative in their behaviour (Jones, 1975) and also severely constrained by structural and situations] factors in their ability to adopt the innovation.

Figure 1. Hierarchical and Neighbourhood Innovation Diffusion Model



The temporal dimension implied by this model of diffusion conforms to a logistic growth path (Casetti, 1969). While the timing of the commencement of adoption at any location is influenced by the interaction of processes affecting both the supply and demand for an innovation, the pace of diffusion over time is likely to be influenced by other factors. These include the historical legacy in relation to the structure and distribution of the farm hierarchy, trends in output and incomes which may in turn be influenced by a range of government policies, as well as refinements and improvements to the innovation itself which may make it more attractive to potential adopters.

### **The Adoption and Diffusion of Tractors in Ireland**

This section traces the introduction of tractors into Ireland and their subsequent diffusion throughout the island. The main data sources are the agricultural census enumerations taken in the Republic of Ireland by the Central Statistics Office and by the Ministry of Agriculture in Northern Ireland. These are supplemented by information on suppliers gleaned from the catalogues of the Annual Spring Agricultural Show in Dublin, as well as from interviews with individuals involved in the agricultural machinery trade.

The introduction to Ireland of tractors and other forms of mechanisation came relatively late via a pattern of international diffusion from the United States to Britain. The origins of the tractor can be traced back to the earliest self-propelled steam engines which were developed around 1860 for use on the wheatlands of north Dakota and Minnesota. The weight and cumbersome design of these machines greatly restricted their use to operations such as grain threshing. It was not until 1892 that the first practical self-propelled gasoline tractor was built by John Froelich of Iowa, where in 1905 the first business concerned exclusively with the manufacture of tractors was established by C.W. Hart and C.H. Parr (Rasmussen, 1982). The technology was not transferred across the Atlantic until the early years of this century, so that by 1910 the number of tractors in Britain was probably less than fifty (Cawood, 1980). The threat of food scarcity during the First World War demonstrated the need for Britain to increase its level of domestic agricultural production. A tillage order of 1917 required farmers to substantially increase the amount of ploughed land. In a situation of limited availability of manpower, the only solution was to encourage the adoption of tractors for towing ploughs. At this stage, however, there were only two British firms manufacturing tractors: Saundersons in Bedford and the Austin Motor Company in Birmingham. Since their combined output was not nearly sufficient to supply the expanding market, there developed a high level of dependence on American imports. The British government in 1917 arranged to have 6000 Fords on tractors imported from North America, which enabled Ford to become firmly established in the UK market. They also attempted through demonstrations and competitions

to provide information and instruction on the proper use of tractors for ploughing.

A number of importers and distributors quickly turned their attention to Ireland. It has been estimated that in March 1917 there were only 70 tractors in the whole of Ireland (Martin, 1984). A series of demonstrations, which commenced at Cullybackey near Ballymena in Antrim, was organised throughout Northern Ireland by Harry Ferguson who had developed a revolutionary type of plough (Martin, 1984). The effectiveness of demonstrations as a means of creating awareness and encouraging adoption is evident from the fact that the total number of tractors in Ireland had increased to about 300 by the autumn of 1917 (Martin, 1984). Immediately after the First World War, firms from London, Bedford, Dursley, and Birmingham began to appoint agents in Ireland (all in Belfast and Dublin) for the distribution of tractors and tractor ploughs as well as lubricants. The agents used important public events such as the Annual Spring Agricultural Show organised in Dublin by the Royal Dublin Society to exhibit the new machines and implements. The catalogues for these events in 1919 and 1920 show that no less than eight different models of tractors were on display, most of which were American imports into Britain. The emphasis in some of the early advertisements was on the potential economic gains from adopting the new technology: for example the advert for the Saunderson "Universal" tractor proclaimed in large lettering that "Time,! Money,! Labour,!!! today's most perplexing problems" could be solved by buying one of" their tractors.

Table 1. Number of tractors in the Republic of Ireland, 1928-1988 and Northern Ireland, 1944-1990

Republic of Ireland		Northern Ireland	
Year	Tractors	Year	Tractors
1928	804		
1939	2,067		
1947	5,865	1944	6,789
1950	13,569		
1955	29,744	1954	20,019
1960	43,697	1959	28,930
1965	60,167	1966	35,143
1970	84,349	1972	33,420
1975	114,218	1975	36,898
1980	145,100	1980	47,600
1985	148,100	1984	46,340
1988	147,900	1990	43,700

Source: Central Statistics Office. Dublin, and Ministry of Agriculture for Northern Ireland. Belfast.

The adverts also emphasised the simplicity of the new technology which was described as "absolutely foolproof". However, within a few years most of the tractors exhibited in Dublin in 1920 were no longer available as their American and British manufacturers were put out of business by Henry Ford whose company had been working since 1915 on a model that would dominate the tractor market. A conveyor belt system of production was introduced into Ford's specially designed new plant at Cork in 1917 so that in July 1919 the company could commence producing the "Fordson" on a mass scale, at first solely for the British government. By 1925 the "Fordson" was exhibited at the Spring Show in Dublin by London-based firms. The advertisements for this machine which marked the arrival of the modern tractor (constructed as a unit, totally enclosed, light, speedy and easily manoeuvred) emphasised its economy and labour saving characteristics. The message was simple and direct: "it has been proven that one Fordson tractor does as much work in a day as six horses. Six horses eat not only an immense quantity of provender in the year but the attention they require eats up a great deal of time. Horses simply eat money all the time they stand idle. The Fordson eats nothing and requires no attention when it is not working. Get a Fordson for your farm. Cut out waste and bank the money your horses eat".

#### *The 1920s: Early adoption at key locations*

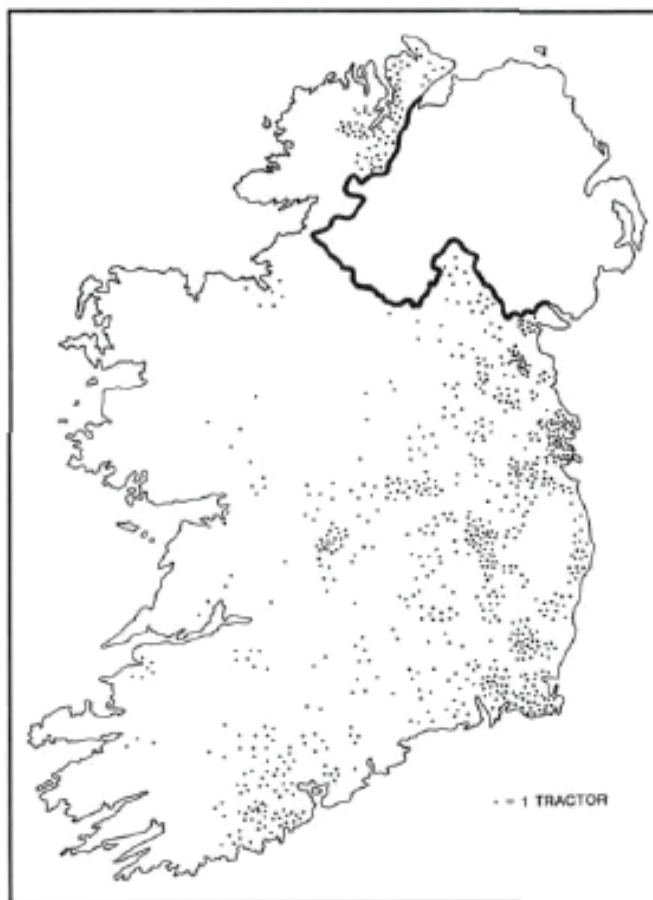
The emphasis in the early Fordson advertisements on the substitution of tractors for horses and labour on the farms was well placed. In 1926 just over half of the labour force in the Republic of Ireland was involved in agricultural occupations which included farmers, farmers' relatives assisting, and agricultural labourers. Around the same time there were approximately 320,000 horses used for agriculture, the maintenance of which would have required at least ten percent of the land used for crops and pasture. While there were probably some tractors imported into Ireland from as early as 1910, it was not until 1928 that the first official enumeration was made by the Central Statistics Office which revealed that there were just over 800 tractors in use on farms. Since then there has been a steady growth in the numbers up to the 1980s with almost three fifths of the total increase concentrated in the period since 1965 (Table 1). In Northern Ireland adoption occurred more quickly, though it is more difficult to trace as there does not appear to be any census data for the period prior to 1944.

The spatial patterns created by the adoption and diffusion of tractors and other items of machinery can be traced in considerable detail from the data compiled for over 2000 District Electoral Divisions and 160 Rural Districts in the Republic by the Central Statistics Office. By 1928 there was already a well-defined geographical pattern (Figure 2). The largest concentrations were in the southeast with 108 enumerated in Wexford alone, and 110 in an arc extending from south Kildare westwards through Mountmellick and Tullamore districts to Borrisokane district in north



Tipperary. The next largest concentration was 92 in county Cork, mostly to the west and north of the city. More localised concentrations were evident around Dublin, Ardee and Dundalk in Louth, and three districts in northeast Donegal. Two-fifths of the tractors were in counties Dublin, Kildare, Wexford and Cork which jointly accounted for about one-fifth of the crops and pasture land. The level of concentration in Donegal was over twice what might have been expected on the basis of its share of crops and pastureland. The level of adoption declined as one moved away from these centres. There were 49 districts without any tractors and another 56 where there were fewer than five. Apart from the Donegal concentration, early adoption in the western counties was mostly confined to districts where the topography is generally fiat, as in east Galway and parts of north Kerry. While the overall pattern demonstrates the existence of a number of key nodes of early adoption it also shows that the pioneers throughout much of the country were widely dispersed, oftentimes at considerable distances from the next adopters. For example, even at this early stage there was some adoption in remote locations such as Ventry in the Dingle peninsula which is over 160 kms from Cork and 350 kms from Dublin.

Figure 2. Distribution of tractors, 1928



A number of explanatory factors can be suggested for this pattern. These include the distributions of tillage, hired agricultural labourers and farm size. Since the early tractors were designed primarily to speed up operations such as ploughing, the distributions of crops such as oats, potatoes, turnips and barley which accounted for almost 88% of the ploughed land is worth noting. Stamp (1931) showed that in 1929 these crops were concentrated mostly in south Leinster (especially Wexford), the lowlying parts of Cork: Louth, Monaghan and east Cavan in the northeast: the lowlands and coastal strips in Donegal: and the well-drained limestone region extending from north Clare through east Galway into Mayo. Of particular significance was the location of commercial crops such as barley in Wexford, the valleys of south Leinster, and county Louth; wheat which was particularly important in Dublin, Wexford and south Cork: and potatoes in parts of Louth, Monaghan and Donegal where the seed crop was highly concentrated. An additional factor in the case of northeast Donegal was its proximity to Derry city which was probably an important centre of supply for farmers throughout the agriculturally fertile lowlands in the Foyle basin. The numbers of hired agricultural labourers were greatest in the areas around Dublin, south Kildare, north Wexford, east Waterford and Cork city, (Meenan, 1970). Their role in the agricultural labour force was particularly low throughout most of the west and northwest (with the exception of east Donegal) where there was a greater involvement of fanners' relatives. This contrast was an important influence on the pattern of early adoption because the labour saving benefits of mechanisation could be best realised on farms where there were hired labourers. The farm size factor which influences the hierarchical effect has consistently displayed a marked gradient from the southeast towards the west and northwest. (Homer *et al.*, 1984). Of particular importance in the early stages of adoption and diffusion of an expensive and revolutionary innovation was the location of large farms, especially those involved in the cultivation of commercial cereals, Jones Hughes (1982) has shown that, for a variety of physical and historical reasons most of the larger farms in the mid-nineteenth century were heavily concentrated in the east and south. Despite the subsequent Land Acts it is likely that many survived into the early decades of this century. While Gillmor (1991) has shown for the Republic of Ireland that in 1931 the mean area of crops and pasture per holding was greatest in counties Kildare, Meath and Wicklow. Freeman (1950) established that in the most fertile parts of Northern Ireland there were local concentrations of farms in excess of 40 ha. The quality of land was another important factor which influenced the distribution of commercial tillage crops. Furthermore, the lighter well-drained soils were much better able to sustain without damage the very heavy early tractors. From this perspective parts of the east and south were again the most favoured (Gardiner and Radford, 1980), while in Northern Ireland the best soils are in parts of counties Down, Antrim and Derry (Symons, 1963; Cruickshank, 1982). Apart from these structural factors, adoption was also likely to occur at an early stage

amongst tillage farmers since they are generally regarded as the most progressive. A final factor which contributed to the evolution of the spatial pattern was the location of major general merchant stores which had already established strong connections with the farming community. Most prominent amongst these were Perry's in Athy and McGee's in Ardee. These types of stores, along with garages which were already selling motor cars were important diffusion agents in the early years.

*1928 - 1939: Intensification and limited expansion*

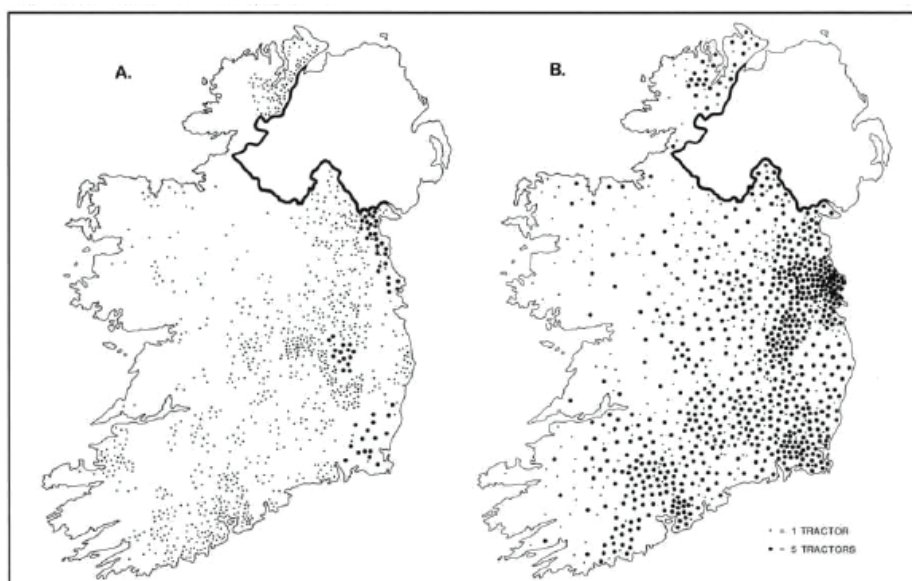
The 1930s was a difficult period for agriculture in the Republic of Ireland with the estimated value of total output in 1934-5 almost 37% less than the estimate for 1929-30 (Meenan, 1970). Even after a recovery in prices towards the end of the decade, the total output estimate for 1938-9 was still 15% less than for 1929-30. This overall situation, which resulted from a trade dispute with Britain and an emphasis by government on a protectionist agricultural policy, was not conducive to a rapid growth in mechanisation. However, of some importance for the geography of mechanisation was the encouragement and assistance given to farmers with land capable of growing wheat or sugar beet. The area under both of these commercial crops expanded from about 10,500 to almost 120,200 ha between 1931 and 1939. Most of this expansion occurred in parts of the eastern and southern counties.

While the general economic situation in the 1930s was not favourable towards investment in machinery, there were two important advances in tractor design which greatly enhanced their capabilities. These were the introduction of pneumatic tyres and hydraulic implement controls. The pneumatic tyre greatly increased the scope of tractor usage by enabling them to move easily and speedily and to act as road haulage vehicles. Their increased speed also meant that they could be used more effectively for operations such as hay mowing and tossing. This broadening in their range of functions also expanded the potential market. The invention of the Ferguson hydraulic three-point linkage mounting system revolutionised the way in which tractors could be used for operations such as ploughing and harrowing. This invention altered the role of the tractor from being essentially a towing machine to the forerunner of the modern highly versatile machine that it is today. By reducing the risk of overturning, which was a fundamental weakness in the early designs, it greatly improved the safety of the driver. These technical improvements were quickly incorporated into the Standard Fordson which was first produced in Cork in 1929. By the late 1930s at least four different tractor models were exhibited at the RDS Spring Show by Dublin-based firms who were also agents for British distributors. In addition a growing number of firms had begun to exhibit tractor drawn ploughs, harrows, mowers, binders and potato diggers. All of the exhibitors were Dublin-based, apart from the Pierce Agricultural Machinery Company of Wexford who in 1940 exhibited a two-furrow tractor plough, and a

Carlow-based firm that had commenced selling all-steel chassis tractor trailers in the late 1930s.

At the next enumeration in 1939 the total had only increased to 2076. Between 1928 and 1939 there occurred an intensification in the areas of early adoption, as well as expansion into surrounding areas where some new adoption centres emerged (Figure 3(a)). The number in county Louth quadrupled from 35 to 145 while a trebling in numbers occurred around Athy and in the hinterland of Cork city (Table 2). In the midland counties of Laois and Offaly the total also trebled with a spectacular increase from 11 to 61 in Mountmellick district. Around Dublin there was considerable expansion in north Kildare, and parts of Meath, while in the southeast important new centres of adoption were established in Carlow and Kilkenny. Elsewhere the districts around towns such as Tralee, Listowel, Waterford, Birr, Abbeyleix, Cavan, and Monaghan were emerging as centres of adoption. Slow progress was experienced in the hinterlands of Limerick and Galway cities, presumably mainly due to the small amounts of tillage and the small scale of farming in these areas. The total in counties Mayo, Roscommon, Leitrim, Longford and Cavan increased from 12 to 83. Nevertheless, there still remained 23 districts, mostly in the northwest, where no tractors had been purchased. Finally, it is useful to contrast the pattern of expansion in Donegal in the 1930s with that in Cork. In Donegal the doubling in the number of tractors did not lead to any extension into new districts (primarily due to the very severe physical and structural constraints in the remainder of the county) whereas in Cork there was diffusion into almost all districts and considerable progress in the districts located on the fringe of the early adoption zone.

Figure 3. Increase in number of tractors (a) 1928-1939, (b) 1939-1947



### *The 1940s: Stagnation and relaunch*

On the eve of World War II there were still approximately 530,000 males engaged in farm work in the Republic of Ireland. In many parts of the state there was also considerable involvement of female members of farm families in work related to farmyard based enterprises (Arensherg and Kimball, 1940). The total number of agricultural horses at this time was about 326,000. During the war years there was very little increase in mechanisation due to difficulties of importing new tractors and spare parts. Apart from a limited number of Fordsons the only new tractors available at this time were some American manufactured Allis-Chalmers models imported by McGee's of Ardee (Neil-Watson, 1991). The situation in Northern Ireland was probably not quite as severe as a result of its political status within the UK which provided a high level of market support and protection for its farmers (Sheehy *et al.*, 1981). The first enumeration of agricultural machinery items in Northern Ireland in 1944 found that there was approximately 6800 tractors. The distribution between counties reveals a density variation from 11.7 per 1000 ha crops and pasture land in county Down to 2.2 in Fermanagh. The degree of localisation in the hinterland of Belfast is evident from the fact that approximately one-third of the tractors were in Down which contained 21CA of the total crops and pasture land. While county Tyrone had an equivalent share of crops and pasture land (most of which was located in the western half of the county) its number of tractors was only about half the total in Down (Table 2). In county Derry the number of tractors was slightly in excess (about 5%) of what might have been expected on the basis of land quality alone. It is very likely that Derry city was a centre of redistribution to suppliers and farmers throughout the fertile Foyle river basin.

In the aftermath of the war, Government policy towards agriculture in the Republic changed from being primarily concerned with supplying the home market to a policy which emphasised improvement and intensification of production for export markets. Indeed, a study on Ireland's potential contribution to the European Recovery Programme emphasised increased agricultural output which would necessitate, among other things, greater mechanisation (Government of Ireland, 1948). The geography of agricultural production had not changed very much by 1946 as indicated by Freeman's (1947, 1949) map of farm types which identified Wexford, parts of the Midlands, the northeast and north Donegal as the principal areas with considerable tillage. Meenan's (1970) maps of the distribution of manpower on farms in 1946 also demonstrate continuing high levels of dependence on hired labourers in the hinterlands of Dublin, Cork and Waterford as well as in south Kildare. The 1946 census of population enumerated 113,800 agricultural labourers and 203,460 farmers' relatives assisting on farms. Significant increases in prices of milk, wheat and sugar beet (the benefits of which accrued mostly to farmers in the east and south) resulted in a rapid growth in the value of total agricultural output so that the estimate for 1947 was twice

that for 1938-9. The increasing returns to farmers were matched by vigorous marketing campaigns by the two main suppliers of tractors - the Ford and Ferguson companies. Ford had an advantage in the early years based on its readymade distribution system through their car dealer network which was established across the entire country. Their advertising campaign continued to emphasise the prospect of labour saving and greater incomes from mechanised farming. For example, the message in their advertisement in the catalogue for the 1950 Dublin Spring Show was "Ford Tractor Less Work More Income per Acre". The first of the famous Ferguson line of tractors was manufactured in Coventry in 1946 (from 1953 these became known as Massey Ferguson tractors following an involvement of the Toronto based Massey Harris harvesting machinery firm with Ferguson). The company in 1946-47 established a network of thirty dealers throughout the Republic of Ireland to sell a variety of models designed to suit the requirements of different users, and also a very wide range of implements and accessories. The adverts for the Ferguson model also emphasised the prospect of greater incomes e.g. one supplier in the southwest used the phrase "It will pay too to farm with Ferguson". Undoubtedly, there was a high level of competition between the Ford and Massey Ferguson dealers which would have helped to keep down prices in an expanding market.

The 1947 agricultural census in the Republic of Ireland enumerated approximately 5900 tractors which represented an increase of 3800 over 1939. The largest increases were in counties Kildare, Wexford, Meath, Dublin and east Cork (Figure 3(b)). There were also significant increases in the hinterlands of towns such as Carlow, Kilkenny, Mullingar, Cashel and Mallow. There remained many districts in western counties where very little increase occurred. Slow progress in adoption and diffusion in western regions may also have been influenced by the prevailing rural social system which resulted in sons replacing fathers on farms and the new families replacing themselves. This system along with informal methods of co-operation in farm work survived until the late 1940s (Hannan and Breen, 1987) and acted as a powerful restraining force on innovation adoption (Hannan, 1972).

#### *The 1950s: Take-off, end of first wave of diffusion*

In the late 1940s and early 1950s there were a number of technical improvements which made the new technology a much more attractive option for farmers. These included improvements in relation to the power take-off systems, which facilitated an expansion in the range of implements that could be used with tractors, as well as the introduction of diesel engines that provided a more economical and reliable source of power than the spark ignition engines which had been in use up to then. There followed a sharp increase in the adoption curve for the Republic (Figure 4). By 1949 the total number of tractors had increased to over 10,100. Over the next three years there was a further increase of 9,000, and by 1955 the total had reached approximately 30,000. The expanding

market was catered for mostly by the Ford and Ferguson companies. The light and versatile Ferguson 20 model, which was fitted with a diesel engine about 1953, was extremely popular among Irish farmers, with one dealer in Cork alone achieving sales of over 1000 Fergusons between 1950 and 1955.

Table 2. Changes in numbers of tractors for selected periods

County	-1928	1928 -1939	1939 -1947	1947 -1953	1953 -1960	1960 -1965	1965 -1970	1970 -1980
Carlow	25	44	102	465	672	253	371	500
Dublin	53	25	264	1008	104	382	54	-78
Kildare	70	126	312	732	789	362	375	879
Kilkenny	32	25	230	855	1230	506	639	1576
Laois	24	92	93	797	904	405	564	1178
Longford	4	4	46	153	237	242	515	1632
Louth	35	110	85	562	575	256	264	201
Meath	54	71	424	733	1035	418	983	1636
Offaly	41	51	104	162	866	337	431	1574
Westmeath	15	18	131	272	370	270	515	1942
Wexford	108	87	378	1375	1937	683	908	1452
Wicklow	36	34	96	482	720	477	361	710
Clare	11	4	26	209	373	607	1311	4227
Cork	92	195	534	1851	3648	2704	3285	6301
Kerry	10	43	23	525	778	787	1459	3941
Limerick	7	32	123	355	701	1123	1757	3155
Tipperary	41	72	305	883	1502	1106	1618	3228
Waterford	18	28	106	468	693	356	436	1012
Galway	16	22	65	586	887	625	1432	5245
Leitrim	0	1	13	139	260	381	833	2140
Mayo	1	22	48	328	488	449	933	5211
Roscommon	2	12	51	276	401	393	961	3613
Sligo	11	2	20	194	259	294	666	2017
Cavan	5	32	51	403	581	933	1544	2665
Donegal	71	78	118	896	1032	1127	1095	3175
Monaghan	22	33	73	711	857	994	872	1596
Republic of Ireland	804	1263	3798	15933	21899	16470	24182	60728

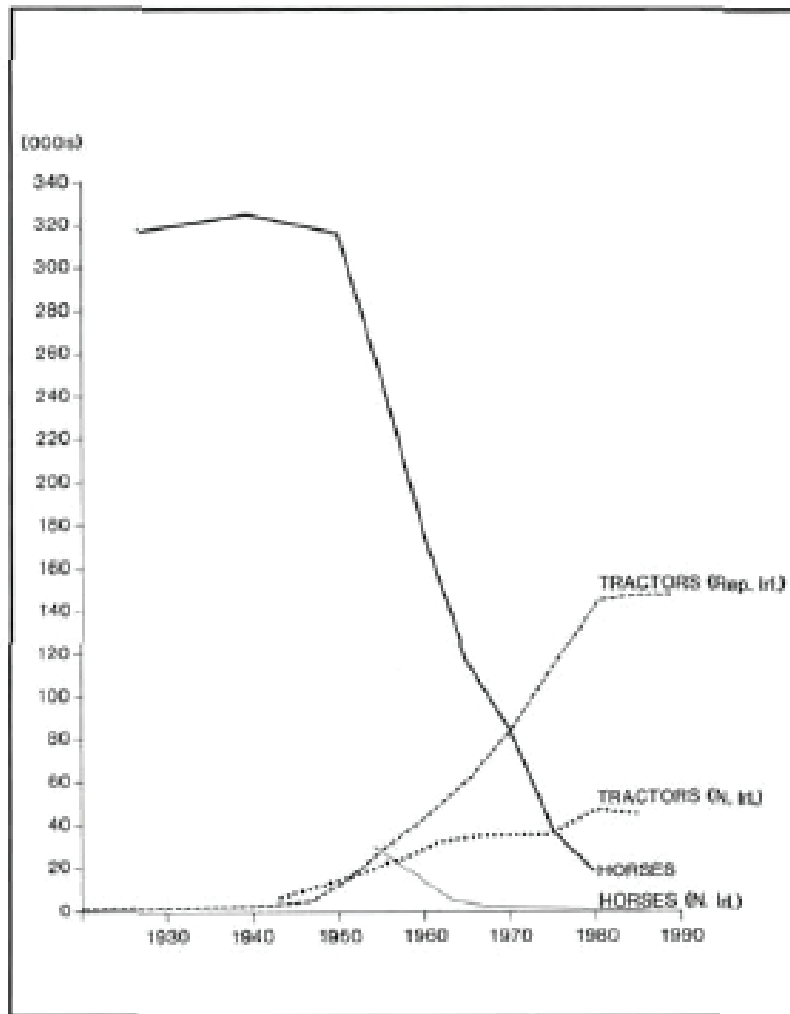
County	-1944	1944 -1954	1954 -1959	1959 -1966	1966 -1972	1972 -1980	
Antrim		1480	3137	2321	1213	-480	2479
Armagh		704	1674	1038	479	-219	2144
Down		2226	3181	1412	1002	-696	2735
Fermanagh		265	740	885	1121	159	1790
Derry		991	2259	1005	905	-352	1842
Tyrone		1123	2239	2250	1493	-135	3190
Northern Ireland		6789	13230	8911	6213	-1723	14180

In order to map the distribution of tractors from the early 1950s it is necessary to switch from dot to choropleth mapping techniques. While a number of ratios are possible, the one chosen relates the number of tractors to the total number of holdings greater than 2 ha. Smaller holdings are omitted since the level of adoption on these is likely to be extremely small. Due to the fact that on a number of large holdings there

may be more than one tractor, the ratio may slightly overestimate the level of ownership in districts where there are a significant number of such holdings. Tractors have had to be related to holdings rather than farms since the agricultural census enumerations are based on the former. The discrepancy between holdings and farms was small in the 1950s but it becomes greater in later years and it is also greater in districts where the average size of holding is small (for distribution maps of holdings and farms by size see Horner *et al.*, 1984: 1987). Hence the choropleth maps presented here probably underestimate the true levels of adoption or ownership of tractors in small-holding districts.

In order to facilitate comparisons between maps a common set of class intervals have been used for the maps covering the period up to 1980.

Figure 4. Trend in numbers of agricultural horses and tractors: Republic of Ireland and Northern Ireland





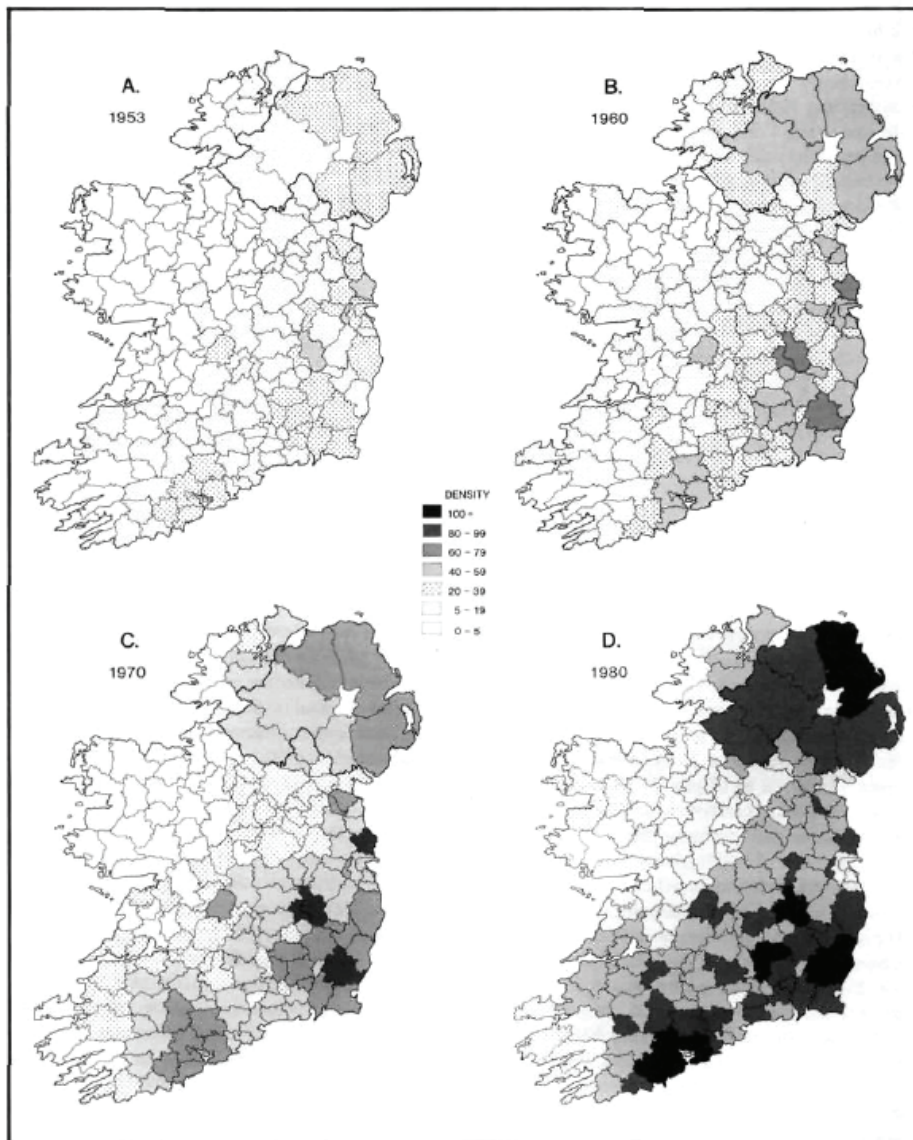
The distribution of tractors in 1953 is shown on Figure 5(a). The density distribution was greatest at 48 tractors per 100 holdings in north Dublin and south Kildare and almost 40 in Enniscorthy district. Density values in the range of 20-29 occurred in the districts around Cork city and further east in many of the districts adjacent to the core areas. While the force of the first "diffusion wave" up to the late 1950s (Hagerstrand, 1952) was felt across most of Leinster and Munster there was still relatively little change throughout most of the western counties apart from northeast Donegal and north Kerry (Table 2). Nevertheless, close examination of the data at district level reveals that some important small centres of adoption and diffusion were emerging in the more remote districts in the southwest, and throughout much of Clare, east Galway, Sligo, south Leitrim and the southern and western parts of Donegal. Significantly, by this time there were some tractors in every district.

In Northern Ireland there were just over 20,000 tractors which represented a density of 30 per 100 holdings greater than 2 ha which is greatly in excess of the value of 9 for the Republic. At county level the densities varied from approximately 40 in Down, Antrim and Derry to about 23 in Tyrone and Armagh, and only 13 in Fermanagh. Thus, when the data are considered for the island as a whole, it is evident that roughly similar levels of mechanisation had been achieved in those parts extending in an arc from the hinterland of Derry eastwards towards Belfast, southwards along an east coast zone which extended inland to Kildare and Kilkenny, and from there southwestwards to the hinterland of Cork city.

By the mid-1950s the Massey Ferguson dealer network based on a strategic selection of nodes was well able to stimulate and cater for the growing demand. In order to increase awareness and encourage adoption field demonstrations of new models and new implements were held regularly across the country, and dealers were motivated to maximise their sales through a system of bonus payments. The largest dealer was in Cork city, to whom just over 600 tractors were supplied between 1954-57. While the average number of sales per dealer over this period was 210 there was a high level of variation with dealers in north Cork, mid-Tipperary, and in counties Louth, Cavan and Donegal each achieving sales of between 330 and 380 tractors, while the dealers in Leitrim, Roscommon, Longford and Westmeath had sales of fewer than 100. Apart from the two major suppliers other firms such as UK-based David Brown International and the Czechoslovakian Zetor manufacturers established subsidiary companies in Dublin, which in turn developed their own distribution networks. These were less extensive with much of the David Brown sales concentrated along the Border counties, while the early Zetor sales were mostly in counties Wexford, Waterford, Cork, Clare and Mayo. One of the first distributors of International tractors outside Dublin was a firm in Kilkenny (Neill-Watson, 1991).

The mid to late 1950s was a period of considerable year to year fluctuations in agricultural output, especially in relation to tillage, which undermined farmers' confidence and slowed down the pace of mechanisation in the Republic of Ireland. During this period there was a trend towards larger and more powerful tractors which could be used to perform an increasing range of tasks, including baling of hay and straw, and harvesting of silage and grain. By 1960 there were 1652 pick-up balers, 690 forage harvesters and 4254 combine harvesters in use. Over 11,300 (26% of the total) tractors had a power rating in excess of 35 horsepower (HP).

Figure 5. Number of tractors per too holdings (a) 1953 (b) 1960 (c) 1970 and (d) 1980



Note: data for Northern Ireland are extrapolated from Table 3.

*The 1960s: Intensification, expansion, hierarchical filtering*

The first direct evidence for the existence of a hierarchical effect in the diffusion is contained in the Report published by the C.S.O. on the 1960 Agricultural Census which includes a set of cross-tabulations based on a 10% sample of the returns. These show that 44% of the tractors were on holdings of at least 40 ha which amounted to only 11% of the total holdings larger than 2 ha. The number of tractors per 100 holdings ranged from 117 for holdings over 120 ha to 49 for those between 40 and 60 ha and 10 for those between 12 and 20 ha (Figure 6). Already approximately 4300 holdings each had more than one tractor. The incidence of multiple ownership declined sharply according to size of holding from 56% for holdings over 120 ha to 19% for holdings between 60 and 80 ha. and under 7% for 20-40 ha holdings.

The importance of the hierarchical effect in shaping the density distribution of the 43,700 tractors enumerated in 1960 is evident from Figure 5(b). When account is taken of the number of holdings with more than one tractor the overall density per 100 holdings in 1960 was 13.5. At district level it is not possible to take account of multiple ownership, hence the ratios for tractors per 100 holdings slightly overstate the number of holdings with tractors. The density varied from over 60 in three districts (reaching a maximum of 67 in Athy) to less than 5 in 23 districts, and as low as 1 in Oughterard and Clifden in west Gal way and Castletown in southwest Cork. By comparison with 1954 the number of districts with densities greater than 40 increased from 2 to 25. The role of towns as locations for suppliers in shaping the spatial pattern of diffusion is evident from the increases around Ballina, Sligo and Donegal in the northwest. The phase of mechanisation between 1946 and 1961 was marked by a reduction of 54,000 (48%) in the number of agricultural labourers and almost 80,000 (39%) in the number of relatives assisting on farms. Between 1950 and 1960 the number of horses used for agriculture declined by 141.3(H) (45%). Nevertheless the total number was still over four times the total tractors.

The rate of expansion in tractor numbers in Northern Ireland in the late 1950s was almost identical to that of the Republic (47% increase between 1954-59 compared with 45%). The highest density per 100 holdings had moved from Down to Antrim where it was 57 (Table 3). The above average growth rates in Tyrone (67%) and Fermanagh (88%) in the southwest are the result of both intensification and spread effects.

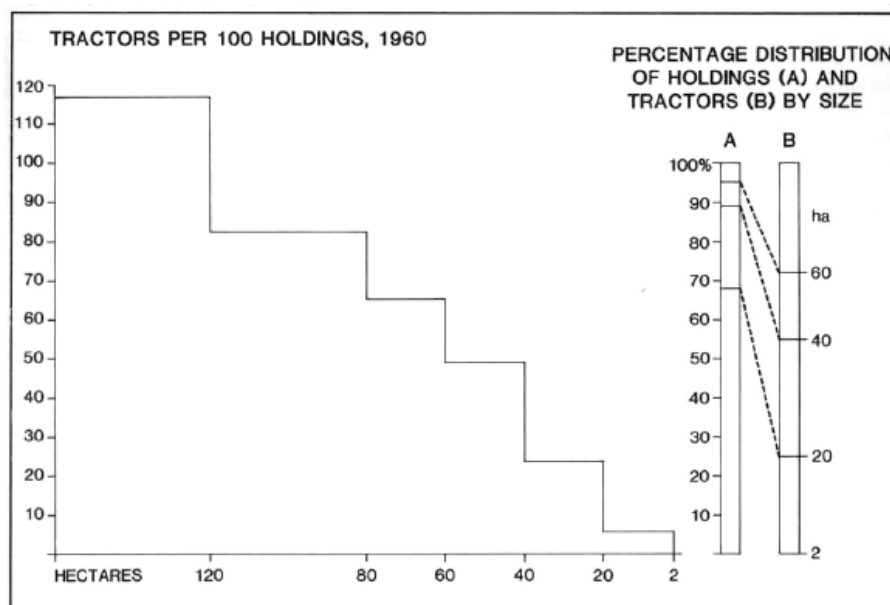
From the end of the 1950s, government policy in the Republic of Ireland towards agriculture has been firmly committed to increasing productivity (Kelleher, 1983). This is just one component of an overall strategy to modernise the economy, which formed the basis of a series of economic plans throughout the 1960s. In order to achieve the objective of increasing agricultural output the state has financed educational, advisory and research services as well as providing price supports for dairying, pig

rearing and some cereals (Government of Ireland, 1964). Consequently, following decades of near stagnation the volume of gross agricultural output finally began to increase around 1960.

Table 3. Tractors per 100 holdings (>2 ha) Northern Ireland

	1944	1954	1959	1966	1972	1980
Antrim	10.5	38.7	56.9	74.6	75.9	108.6
Armagh	6.2	23.2	34.9	45.1	46.7	81.5
Down	14.8	40.8	50.3	63.9	62.5	94.5
Fermanagh	3.0	12.8	24.4	44.6	50.4	83.1
Derry	10.3	39.4	50.1	65.4	66.5	99.9
Tyrone	6.6	22.3	38.5	54.5	58.0	89.8
N. Ireland	8.9	30.1	43.6	59.0	60.9	93.6

Figure 6. Tractors per 100 holdings according to size, 1960



Matthews (1981) estimated that between 1958 and 1963 gross agricultural output increased at a rate of 3.5% per annum. The expansion in output was important in encouraging further mechanisation which in turn facilitated to some extent the intensification process. Another factor in intensification was greater use of artificial fertilisers and lime to improve crop yields.

This was matched by an increase in the number of fertiliser distributors from just over 11,000 in 1960 to 29,100 in 1970. The resultant heavier crops of hay were also more difficult to mow with horse drawn mowers, which in turn encouraged greater adoption of tractor mowers initially

amongst agricultural contractors but later by individual farmers. Thus the number of tractor-mounted mowers increased from under 16,900 in 1960 to over 56,700 in 1970 (Table 4). There was also a rapid growth in the numbers of balers and forage harvesters. Some changes also occurred in relation to the availability of tractors and new implements. Increasingly the main dealers became more specialised agricultural machinery outlets which carried not only a range of implements but also a stock of spare parts and had a skilled workforce of both salesmen and repair mechanics. Not surprisingly, against this background the number of number of tractors increased steadily from 43,700 in 1960 to just over 60,000 in 1965 and over 84,000 in 1970. An important point in the transition from working horses to tractors was reached towards the end of 1970 when the total number of tractors equalled the number of horses used for agriculture in the Republic. This transition point had been reached about 16 years previously in the less diverse and more strongly government-supported agricultural sector in Northern Ireland (Figure 4).

Table 4. Numbers of agricultural machines (000s).

<b>Republic of Ireland 1960-1988</b>						
	1960	1965	1970	1975	1980	1988
Tractors	43.7	60.2	84.3	114.2	145.1	147.9
Mowers	16.9	n.a.	56.7	71.7	83.3	83.8
Fertiliser Distributors	11.1	19.9	29.1	n.a.	60.4	n.a.
Pick-up Balers	1.6	n.a.	8.3	14.2	21.4	22.7
Forage harvesters	0.7	3.3	7.0	8.3	11.1	13.1
Combine harvesters	4.2	5.8	6.3	4.9	5.3	4.9
<b>Northern Ireland 1959-1984</b>						
	1959	1966	1969	1972	1980	1984
Tractors	28.9	35.1	33.1	33.4	47.6	46.3
Mowers	16.9	23.0	22.0	21.2	24.7	20.5
Fertiliser Distributors	8.5	12.3	13.0	14.3	19.7	19.5
Pick-up Balers	1.5	4.7	5.5	6.2	8.4	8.5
Forage Harvesters	0.4	2.5	3.3	4.3	6.8	6.7
Combine Harvesters	0.4	1.8	1.7	1.7	2.0	1.5

When related to the total number of holdings (greater than 2 ha), the overall density in 1970 was almost 33 per 100 holdings. By this stage the density had just exceeded 80 in north Dublin, Enniscorthy and around Athy (Figure 5(c)). There was an extensive area in the southeast and in the hinterland of Cork city where densities exceeded 60. It was in these areas that farmers benefitted most from government policies towards agriculture (Conway, 1975). There was also considerable expansion in the western cattle and sheep grazing region (Gillmor, 1967) so that the number of districts with densities smaller than 10 declined from 60 to 10 over the decade. One of the most striking features of the 1970 distribution is the extent to which the pattern corresponds to the one

established almost fifty years previously when tractors were first introduced to Ireland.

The experience in Northern Ireland in the 1960s was somewhat different to that in the Republic. The level of increase up to the mid-1960s (21.5% between 1959-66) was only about half that in the Republic. This was followed by an even greater contrast - as the number in the Republic grew by 40% between 1965-70, those in the North increased only marginally (1.8%) between 1966-69 before declining by 6.5% (27(H)) over the next three years. The pattern of decline was widespread, especially in counties Down and Antrim: the only county where the number of tractors continued to increase was Fermanagh where farming was least mechanised. The Economics and Statistics Division of the Ministry of Agriculture attributed the decrease to the continuing decline in the number of farm businesses and the trend towards larger and more powerful tractors. By 1972 one-sixth of all tractors had a power rating in excess of 50HP - an identical proportion was recorded for the Republic in 1975 (Walsh and Homer, 1981). At this stage almost 30% of farms had at least two tractors.

*The 1970s: Widespread adoption, second wave of diffusion*

The most significant influence on agricultural production in the 1970s was probably the system of guaranteed prices for most commodities under the European Community Common Agricultural Policy. This contributed to further intensification and greater levels of factor substitution in production (Boyle, 1981). Increased volumes of output and higher prices resulted in a significant improvement in farmers' incomes up to 1978. This resulted in the second wave of diffusion (Table 2) with mechanisation now occurring on farms of all sizes, though there continued to be a pronounced hierarchical effect in the proportion of farmers investing in machinery. The proportions in 1978 ranged from 27% on farms with between 6 and 12 ha to 83% on farms with more than 40 ha (Power, 1980).

The proportions with tractors varied from 97% for farms in excess of 80 ha to 66% for those between 12 and 20 ha and 43% for 6-12 hectare farms. The proportions for the latter two sizes of farms were 42% and 22% in 1973. The increasing number of small and medium-size farms purchasing tractors led to a very high level of dependence on second-hand items as only 5% of first-time buyers purchased new models. The domestic supply of second-hand tractors from large farms where replacement and upgrading were occurring was augmented by imports mainly from the U.K. The acceleration in adoption on small farms in the 1970s was due to a combination of factors including the availability of relatively low-cost second-hand items, improvements in small farmers' incomes due to C.A.P. prices and some off-farm occupation for a growing number of small farmers (Higgins, 1983). While an increasing number of farmers purchased their own tractors, there was also a high

incidence of hiring machinery services from agricultural contractors for specialised operations requiring expensive equipment such as silage making, baling of hay and straw, and combine harvesting of cereals.

Throughout the decade the total number of tractors in the Republic increased at an average annual rate of about 60,000 to a level of just over 145,000 in 1980. Over the same period the number of horses used for agriculture continued to decline so that by 1980 there were fewer than 19,000. Over half of these were concentrated in counties Mayo, Galway, Clare, Kerry and Cork. The amount of labour employed in farming operations also continued to decline with the number of assisting relatives declining by 81% between 1961 and 1981 to 24,200 while over the same period the number of agricultural labourers declined by 70% to less than 18,000. Increased mechanisation and modernisation have also contributed to increased marginalisation (Kelleher and O'Mahony, 1984) and a reduction of about one-third in the number of farmers.

Table 5. Distribution of tractor sizes by region, 1980

Region	Tractor sizes in HP			
	<35	35-50	51-79	80+
Northwest	35.8	47.8	14.5	1.9
West	34.6	50.7	13.5	1.2
Midland & East	19.0	41.3	32.3	7.4
Southwest	18.0	48.0	30.1	4.0
Southeast	14.4	41.6	37.2	6.7
Republic of Ireland	24.3	46.1	25.5	4.1
Northern Ireland	21.5	44.6*	28.6*	5.3

The 1980 density distribution indicates that there were over 100 tractors per 100 holdings in north Wexford, south Kildare, north Kilkenny and in the districts around Cork city (Figure 5(d)). On many of the larger tillage farms in these areas there were three or more tractors. There were 36 districts with densities in excess of 80 compared with only 4 ten years previously. At this stage there were considerable gains throughout most of the western districts as more of the remaining small farms became mechanised. The number of places with densities less than 20 declined from 38 to only 4 which were located in the western small farm fringe (Gillmor, 1967) in parts of west Galway, northwest Mayo and southwest Donegal. Apart from increasing numbers there has been a continuation of the trend towards more powerful and more sophisticated machines (Table 5). The newest and most innovatory items are concentrated mainly in parts of the east and south while older, smaller and less versatile tractors are to be found mostly on farms in western districts (Horner, Walsh and Williams, 1984).

In Northern Ireland also, after 1972 there was a substantial increase in the number of tractors to 47,6000. Since the total number of full-time and part-time farm businesses was approximately 30,300 it is likely that about half of this total had at least two tractors. The trend towards larger tractors continued with 34% over 55HP in 1980 compared with one-sixth over 50HP in 1972.

#### *The 1980s: Stagnation and saturation*

Since about 1978 a number of factors have combined to slow down the pace of intensification (Harte, 1992) and seriously depress real farm incomes (Sheehy, 1988). These changes have curtailed any further expansion in mechanisation. Sample surveys taken on an annual basis by the C.S.O. have confirmed a situation of stagnation in regard to the numbers of several items of farm machinery so that between 1980 and 1988 the number of tractors increased by only about 3,000, with very little variability across regions in levels of increase. A more detailed analysis of the geography of change in mechanisation in the 1980s must await publication of the results of the 1991 agricultural census. Reports from the agricultural machinery traders' association claim that there was a decline in the annual number of tractors purchased from approximately 8,000 around 1980 to 2,200 in the final years of the decade. The levelling off in the number of tractors may be related to an increasing reliance on agricultural contractors to perform tasks such as silage making which require considerable amounts of large and very expensive machinery. It is probably also an indication that market saturation has been reached. One indication that the transition from draught animals to tractors is now virtually complete is that there are fewer than 2,000 agricultural horses left on Irish farms. While there may still be about 190,000 agricultural holdings, the number of household heads described as farmers in 1987 was estimated to be only 135,000 (Department of Agriculture and Food, 1991). Additional purchases in the future will be mostly to replace older stock and/or to provide additional and more sophisticated machines for specialised tasks. For many farmers now the decision is not so much whether to purchase a tractor but rather which make and model. There are now about twenty different makes of tractors comprising some 380 different models available in the Republic of Ireland (Neill-Watson, 1991). The limited data available for Northern Ireland in the 1980s (Table 1) suggests that not only has market saturation been reached but that the total number of tractors is declining as farms are rationalised, operations become more specialised and greater reliance is placed on agricultural contractors.

#### **Conclusion**

A number of conclusions can be drawn from the empirical evidence presented in this paper. These can be discussed in relation to the geography of the transformation of agricultural production, and also in relation to the more general literature on innovation diffusion.



The pattern of adjustment in agriculture has been characterised by a widening division between on the one hand a relatively small, commercially oriented and highly capital intensive modernising sector, and on the other hand a large proportion of farms which are both economically and socially marginalised (Walsh, 1992). While a number of processes have been identified as contributing to a dualistic structure in the post 1960s period it is evident from the maps that the influence of mechanisation on the spatial differentiation of agricultural production can be traced back to the 1920s. A number of factors have been identified as possible influences on the spatial patterns: the distributions of tilled land for commercial crops, hired agricultural labour, and large holdings especially in the early years. Also important was access to suppliers which were mainly distributed in accordance with the principle of maximising sales. In addition, adoption took place earlier and more quickly in some districts along the border with Northern Ireland which suggests that some of the items were brought in from there (possibly as second-hand machines since mechanisation had commenced earlier there).

The model outlined at the beginning emphasised the importance of hierarchical and neighbourhood effects as influences on the demand for an innovation, and the role of diffusion agents in facilitating supply to potential adopters. It also noted the importance of government policies and strategies which may favour more strongly some categories of potential adopters. The data presented provide clear support for the hierarchical hypothesis and strongly suggest the existence of a neighbourhood effect. The interaction of the two effects produced the spatial pattern of adoption and diffusion.

A number of additional factors appear to have influenced the empirical patterns, which may be of relevance to further studies of innovation adoption and diffusion. These include the role of major events in influencing temporal trends (e.g. food scarcity in the UK during the First World War, the economic recovery after the Second World War, accession to the EC); the importance of field demonstrations, and public exhibitions at large meetings; the messages contained in sales advertisements and the role of bonuses as a motivation for salespersons; improvements to the design of the innovation which enhance its range of applications; upgrading by early adopters resulting in a supply of relatively cheap second-hand items for late adopters; government and EC policies which discriminate in favour of some potential adopters at different phases in the diffusion process; and lastly sectoral policies which may indirectly improve the capability of potential adopters to acquire the innovation (e.g. rural-based industrialisation and services which provide off-farm employment opportunities and increase the household income on many small farms).

The interaction of temporal and spatial influences has been emphasised throughout. This approach goes beyond the more restrictive analyses which characterised many of the earlier geographical studies of innovation diffusion (e.g. the studies of the diffusion of tractors in the United States by Casetti and Semple (1969) and Cliff and Ord (1975)). While some limited evidence has been provided on the marketing strategies of the main suppliers, further research is required on this topic. This should involve detailed analysis of company records, and where possible interviews with some of the key individuals involved following the take-off in adoption in the 1950s. The analysis presented here relates specifically to the adoption and diffusion of mechanisation, which represents a fundamental and expensive alteration in work practices for the farmers concerned. As the twentieth century draws to a close, production technologies are being replaced by information technologies which are likely to have far reaching implications for the future of farming and farmers. In the early stages of the diffusion of innovations related to the new technologies, most of the adopters are again likely to be the more advantaged farmers, many of whom are already involved in specialist networks (e.g. cereals growers). Since a strong hierarchical effect is likely to be evident in the diffusion the historical experience in relation to mechanisation suggests that there may be a case for providing some assistance to medium-size commercial farmers so that they do not become technologically disadvantaged and economically marginalised as happened to many small farmers in an era of unregulated diffusion of production technologies.

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## References

- Arensberg, C.M. and Kimball, S.T. (1940) *Family and Community in Ireland*. Harvard: Harvard University Press.
- Berry, B.J.L. (1972) Hierarchical diffusion: the basis of developmental filtering and spread in a system of growth centres In: Hansen, N.M. ed., *Growth Centres in Regional Economic Development*. New York: Free Press.
- Blaikie, P. (1978) The theory of spatial diffusion: a spacious cul de sac. *Progress in Human Geography*, 268-95.
- Bohlen, J.M. and Breathnach, T. (1968) *Study on adoption of farm practices in Ireland*. Dublin: An Foras Taluntais.
- Bohlen, J.M. and Breathnach, T. (1970) Irish farmers' uses of information sources. *Irish Journal of Agricultural Economics and Rural Sociology*, 3(1), 1-28.

- Boyle, G.E. (1981) Input substitution and technical change in Irish agriculture, 1953–1977. *Economic and Social Review*, 12, 149–61.
- Boyle, G.E. (1987) Measurement of the total factor productivity of Irish agriculture 1960–1982. *Irish Journal of Agricultural Economics and Rural Sociology*, 12, 29–49.
- Boyle, G.E. (1987) *How Technically Efficient is Irish Agriculture!* Socio-Economic Research Series. Dublin: An Foras Taluntais..
- Brown, L.A. and Cox. K.R. (1971) Empirical regularities in the diffusion of innovation. *Annals of the Association of American Geographers*, 61, 551–59.
- Brown, L.A. (1975) The market and infrastructure context of adoption: a spatial perspective on the diffusion of innovation. *Economic Geography*, 51, 185–216.
- Brown. L.A. (1981) *Innovation Diffusion: a new perspective*. London: Methuen.
- Casetti, E. (1969) Why do diffusion processes conform to logistic trends? *Geographical Analysis* 1, 101–05.
- Casetti, E. and Semple. R.K. (1969) Concerning the testing of spatial diffusion hypotheses. *Geographical Analysis* 1, 254–59.
- Cawood, C.L. (1980) *Vintage Tractors*. Buckinghamshire: Shire Publications Ltd.
- Central Statistics Office (CSO) (1986) *Statistical Abstract 1982–1985*. Dublin: Stationery Office.
- Cliff, A.D. and Ord, J.K. (1975) Space-time modelling with an application to regional forecasting. *Transactions Institute of British Geographers*, 64, 119–128.
- Conway, A.G. (1975) Inter-farm differences in growth of output, mimeograph. Dublin: An Foras Taluntais.
- Cox, P.G., Higgins, J. and Cuddy, M. (1985) *The Regional (Sub-National) Impact of the Common Agricultural Policy in Ireland*. Report submitted to Directorate General for Regional Policy. Brussels: Commission of the European Communities.
- Cruickshank, J.G. (1982) Soil In: Cruickshank, J.G. and Wilcock, D.N. eds., *Northern Ireland – Environment and Natural Resources*. Belfast and Coleraine: Queen's University of Belfast and The New University of Ulster. 165–84.

Cuddy, M. (1982) A regional analysis of growth rates in agricultural output in Ireland 1968/69 to 1976/77. *Irish Journal of Agricultural Economics and Rural Sociology*, 9(1), 77–89.

Department of Agriculture and Food (1991) *Agriculture and Food Policy Review*. Dublin: Stationery Office.

Freeman, T.W. (1947) Farming in Irish Life. *Geographical Journal*, 110, (1/3), 38–55.

Freeman, T.W. (1949) The agricultural regions and rural population of Ireland. *Bulletin of the Geographical Society of Ireland*, 2, 21–30.

Freeman, T.W. (1950) *Ireland: a general and regional geography*. London: Methuen.

Freeman, D.B. (1985) The Importance of Being First: Preemption by early adopters of farming innovations in Kenya. *Annals of the Association of American Geographers*, 75(1), 17–28.

Gardiner, M.J. and Radford, T. (1980) Soil associations of Ireland and their land use potential. *Soil Survey Bulletin* 36. Dublin: Teagasc.

Gartrell, J.W. and Gartrell, D.C. (1977) Status. Knowledge and Innovation. *Rural Sociology*, 44, 73–94.

Gillmor, D.A. (1967) The agricultural regions of the Republic of Ireland. *Irish Geography*, 5(4), 245–61.

Gillmor, D.A. (1977) *Agriculture in the Republic of Ireland*. Budapest: Akademiai Kiado.

Gillmor, D.A. (1977) The spatial structure of agricultural output in the Republic of Ireland, *Economic and Social Review*, 8(2), 127–42.

Gillmor, D.A. (1987) Concentration of enterprises and spatial change in the agriculture of the Republic of Ireland. *Transactions Institute of British Geographers*, 12(2), 204–16.

Gillmor, D.A. (1991) Land ownership and farm size in the Republic of Ireland: stability and change In: Brunei, P. ed., *Rural France and Great Britain*. France: Université de Caen Presse. 99–122.

Government of Ireland (1948) *The European Recovery Programme*. Dublin: Stationery Office.

Government of Ireland (1964) *Second Programme for Economic Expansion Part II*. Dublin: Stationery Office.

- Gregory, D. (1985) Suspended animation: the stasis of diffusion theory In: Gregory, D. and Urry, J. eds., *Social Relations and Spatial Structures*. London: McMillan. 296–336.
- Hagerstrand, T. (1952) *The propagation of innovation waves (Lund Studies in Geography)*. Lund: Royal University of Lund, Department of Geography.
- Hagerstrand, T. (1953) *Innovations forloppet ur Korologisk Synpunkt*. Bulletin No. 25. Lund: Royal University of Lund, Department of Geography.
- Hagerstrand, T. (1967) *Innovation Diffusion as a Spatial Process*. Translated by A. Pred. Chicago: University of Chicago Press.
- Hannan, D.F. (1972) Kinship. Neighborhood and Social Change in Irish Rural Communities. *The Economic and Social Review*, 3(2), 163–88.
- Hannan, D.F. and Breen, R. (1987) Family Farming in Ireland In: Galeski, B. and Wilkening, E. eds., *Family Farming in Europe and America*. Boulder and London: Westview Press. 39–69.
- Harte, L. (1992) Farm adjustment in Ireland under the CAP. In: Feehan, J. ed., *Environment and Development in Ireland*. Dublin: University College Dublin Environmental Institute. 271–84.
- Higgins, J. (1983) *A study of part-time farmers in the Republic of Ireland*. Socio-Economic Research Series 3. Dublin: Teagasc.  
H\GGMS.T.(WID Research Planning and innovation. Dublin: Stationery Office.
- Hooks, G., Napier, T.L. and Carter, M.V. (1983) Correlates of adoption behaviors: the case of farm technologies. *Rural Sociology*, 48, 308–23.
- Horner, A.A. (1984) Geographical diffusion in Ireland: the example of credit unions 1958-1982 In: Bender, R.J. ed., *Neure Forschungen zur Sozialgeographie von I/land*. Mannheimcr Geographische Arbeiten 17. Mannheim.
- Horner, A., Walsh, J.A. and Williams, J. (1984) *Agriculture in Ireland: A census atlas*. Dublin: University College, Dublin, Department of Geography.
- Horner, A., Walsh, J.A. and Harrington, V. (1987) *Population in Ireland: A census atlas*. Dublin: University College. Dublin, Department of Geography.
- Hudson, J.C. (1969) Diffusion in a central place system. *Geographical Analysis*, 1, 45–58.

Hudson, J.C. (1972) *Geographical Diffusion Theory*. Studies in Geography. Evanstown: Northwestern University Press.

Humphreys, P.C. (1981) The spatial diffusion of a small farm management innovation in the Republic of Ireland (1968 -1974). *Research Discussion Series No. 27*. Dublin: Institute of Public Administration.

Ibery, B.W. (1985) *Agricultural Geography: a social and economic analysis*, Oxford: Oxford University Press.

Johnson, R. and Conway, A.G. (1976) Factors associated with growth in farm output. *Proceedings of Agricultural Economics Society of Ireland*, 52–102.

Jones, G.E. (1975) *Innovation and farmer decision making*. Milton Keynes: D203 Agriculture, Open University. 21–51.

Jones Hughes, T. (1982) The large farm in nineteenth century Ireland In: Gailey, A. and Ó hÓgáin, D. eds., *Gold under the Furze: Studies in Folk Tradition*. Glendale Press. Dublin. 93–100.

Kelleher, C. (1983) Implications of different theoretical development perspectives for policy and interventions. *Irish Journal of Agricultural Economics and Rural Sociology*, 9, 133–60.

Kelleher, C. and O'Mahoney, A. (1984) *Marginalisation in Irish Agriculture*. Dublin: Teagasc.

Kennedy, K.A., Giblin, T. and McHugh, B. (1988) *The Economic Development of Ireland in the Twentieth Century*. London: Routledge.

Martin, B. (1984) *Harry Ferguson*. Ulster Folk and Transport Museum, Northern Ireland.

Matthews, A. (1981) Agriculture In: O'Hagan, J.W. ed., *The Economy of Ireland: Policy and Performance*. Dublin: Irish Management Institute. 257–89.

Meenan, J. (1970) *The Irish Economy since 1922*. Liverpool: Liverpool University Press.

National Economic and Social Council (1992) *The Impact of Reform of the Common Agricultural Policy*. Report No. 92. Dublin: Stationery Office.

Neil-Watson, J. (1991) Pure Nostalgia - Irish Farm Mechanisation... The 1950s... When it all happened. *Irish Farm Machinery Yearbook*, 19–25.

Neil-Watson, J. (1991) Tractor Guide '91. *Irish Farm Machinery Yearbook*, 65–72.

- Pederson, P.O. (1970) Innovation diffusion within and between national urban systems. *Geographical Analysis*, 2, 203–54.
- Power, R. (1980) Past trends and future prospects for investment in farm machinery. Paper presented to An Foras Taluntais Conference on Irish Agriculture within the CAP. December, Dublin.
- Rasmussen, W.D. (1982) The Mechanisation of Agriculture. *Scientific American*, 49–61.
- Rogers, E.M. (1983) *Diffusion of Innovations* (3rd ed.). New York: Free Press.
- Shaw, A.B. (1985) Constraints on Agricultural Innovation Adoption. *Economic Geography*, 61, 25–45.
- Sheehy, S.J., O'Brien, J.T. and McClelland, S.D. (1981) *Agriculture in Northern Ireland and the Republic of Ireland*. Dublin and Belfast: Co-operation North.
- Sheehy, S.J. (1988) Irish Agriculture in the Nineties. *The Irish Banking Review*, 21–32.
- Smyth, W.J. (1975) Continuity and Change in the Territorial Organisation of Irish Rural Communities. *The Maynooth Review*, 1, 51–79.
- Stamp, L.D. (1931) *An Agricultural Atlas of Ireland*. London: Gill.
- Symons, L.J. ed. (1963) *Land Use in Northern Ireland*. London: University of London Press.
- Unwin, T. (1988) Propagation of agrarian change in northwest Portugal. *Journal of Rural Studies*, 4(3), 223–38.
- Walsh, J.A. and Horner, A. (1981) *Agricultural Machinery in the Republic of Ireland 1975: a geographical survey*. Report submitted to National Board for Science and Technology. Dublin.
- Walsh, J.A. (1982) *Structural and demographic influences on the adoption of agricultural innovations*. Dublin: Carysfort College, Department of Geography.
- Walsh, J.A. (1985-86) Uneven Development of Agriculture in Ireland. *Geographical Viewpoint*, 14, 37–65.
- Walsh, J.A. (1991) A regional analysis of enterprise substitution in Irish Agriculture in the context of a changing Common Agricultural Policy. *Irish Geography*, 24(1), 10–23.

Walsh, J.A. (1992) Modernisation and Marginalisation under the Common Agricultural Policy: Irish agriculture in transition In: Flognfeldl, T. and Nordgreen, R. eds., *Proceedings of XI International Seminar on Marginal Regions*. Lillehammer, Norway: Oppland Distriktshogskole.

Wilkening, E.A. (1956) Roles of communication agents in technological change in agriculture. *Social Forces*, 34, 361–67.

Yapa, L.S. and Mayfield, R.C. (1978) Non-adoption of innovations: evidence from discriminant analysis. *Economic Geography*, 54, 145–56.