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Adoption of payments for ecosystem services: An application of the Hägerstrand model

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ABSTRACT

Many governments are now offering incentive payments to private land owners to adapt their management of the land in such a way as to safeguard or enhance ecosystem service provision. These payments are offered to individual land owners, whose decisions may be influenced by economic rationality, but also other factors. Understanding factors such as social capital and neighbourhood networks is particularly relevant as these can help to create local patterns of high and coordinated uptake. This is important because the delivery of many ecosystem services depends on spatial patterns of interventions at the landscape scale, i.e. at spatial scales of multiple farms. To date little empirical work has been carried out to estimate the extent and relative importance of local land owner networks on entry into ecosystem services payment schemes. This study demonstrates a method to detect possible relationships between farm locations and the time of adoption. Based on Thorsten Hagerstrand's model of innovation diffusion as a spatio-temporal process, a simulation approach is used to detect spatio-temporal clustering in the uptake of a case study ESP scheme, the Environmentally Sensitive Area (ESA) scheme in Scotland. The analysis reveals clear spatio-temporal uptake patterns at different spatial scales and in different types of rural spaces. It is argued that these findings have relevance for local adaptation of policies, both to liaise more effectively with sections of the farming community, and to achieve better uptake patterns at the landscape scale.

Introduction

In recent years there has been much work to develop models that can inform policy makers on where and how to intervene in the landscape in order to conserve biodiversity and sustain the provision of ecosystem services (e.g. Andersson, Barthel, & Ahrne, 2007; Norderhaug, Ihse, & Pedersen, 2000; Van der Horst & Gimona, 2005). These models are now extended to take (in addition to the benefits) also the costs of conservation into account (e.g. Messer, 2006; Naidoo et al., 2006; Van der Horst, 2007; Wunscher, Engel, & Wunder, 2008) so that conservation policies at the landscape scale can be more efficient.

Such methods may be directly suitable to design command and control measures such as the delineation of new conservation areas, or the compulsory purchase of private land. However on many occasions the policy makers seek to achieve conservation goals through collaboration with willing land owners. This more collaborative approach is informed amongst others by the costs of top-down measures such as buy-out and the allure of the concept of multi-functional land use for policy makers who must balance multiple interests (including the vested interests of the farming sector) in a pluralist democratic society. Financial incentives are currently the most widely used policy instrument for conserving biodiversity in the agricultural landscapes of Europe. The design of such incentive policies, traditionally called Agri-Environmental Schemes (AES) in the EU, but now increasingly designed to provide Ecosystem Service Payments (ESP), requires (a) knowledge of potential biodiversity conservation gains from different land management decisions and (b) understanding of what it takes to motivate farmers (and other land managers) to participate in these policies. In recent years there has been a growing body of literature about the conservation gains from agri-environmental schemes, including both empirical studies to assess the impacts on the ground of schemes that have been in place for a number of years (e.g. Feehan, Gillmor, & Culleton, 2005; Kleijn & Sutherland, 2003) and simulation or modelling studies to assess the potential impacts of proposed or ongoing schemes (e.g. Haines-Young, Watkins, Wale, & Murdock, 2006; Van der Horst, 2007). Also on farmer behaviour there has been a growing body of literature (see further down), focussing strongly on the factors influencing the choices made by *individual* farmers to join or opt out of AES. These studies employ either survey methods to assess behavioural patterns (of

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representative samples) of the farmer population, or qualitative approaches to develop a more in-depth understanding of values and motivations underpinning behavioural choices.

Uptake of amongst individual farmers is not by itself sufficient to guarantee the delivery of enhanced habitat structure and connectivity at the landscape level. A well designed AES, combined with a very high uptake by individual farmers, may guarantee the delivery of conservation benefits. However when uptake is not very high or when uptake in some areas is much more beneficial for conservation than in others (i.e. when conservation benefits are spatially heterogeneous), then it becomes important to ensure that uptake takes place in a *coordinated* way across multiple neighbouring farms that constitute an area of high conservation value. Whilst the successes and failures of collaborative or collective action have been studied for common property regimes such as common grazing land, wildlife and fishery management (e.g. Berkes; 2009; Ostrom, 1990), its application is still a rarity within a European agricultural setting that is dominated by privately owned farms (see also Franks & McGloin, 2007; Hodge, 2001; Hodge & McNally, 2000). This is not to say that in existing AES, decision making by farmers is completely individualistic, mutually independent and uncoordinated, but rather that the social settings of farmer decision making have been underplayed both in scheme design and in the evaluation of scheme uptake. Whilst research into farmer motivation has revealed the importance of informal and often local networks (see further down), the aggregate effects of such factors on collective uptake within a locality have been little studied.

In short, there are currently shortcomings in policy design and in empirical research on the spatial pattern of uptake of AES schemes. With regards to current policy design, it tends to focus on farm-level interventions, whilst the provision of many ecosystem services depends on processes that take place at the landscape scale. With regards to empirical research, there have been very few studies of the landscape scale patterns of uptake of AES schemes. The reasons for this lack of attention to spatial heterogeneity and spatial scale in policy appraisal and evaluation, lies perhaps in the traditional dominance of conventional economic thinking in the shaping of policy interventions. The legacy of quantitative geography is of course prominent in regional science, but this heterodox approach has long been ignored by 'mainstream' economics.There have only been a few occasions when leading 'mainstream' economists have borrowed from the classical tradition of quantitative geography, with Nobel laureates Tinbergen (on international trade) and Krugman (on new economic geography) as perhaps the most notable examples.[1] The rapid development of IT in general and GIS in particular, together with a growing attention to the challenge of sustainable resource use, has created a more dynamic research environment for interdisciplinary research since the 1990s, yielding hybrid sub-disciplines such as ecological economics and spatial econometrics. The legacy of quantitative geography is now visible in hybrid concepts such as spatial discounting (Brown, Reed, & Harris, 2002; Hannon, 1994; Kozak et al., in press) and the use of gravity models in travel cost estimates of the non-market value of recreational sites (Brainard, Lovett, & Bateman, 1999). More generally, GIS is now widely used to map values of nature (e.g. Bateman, Jones, Lovett, Lake, & Day, 2002, 2003; Eade & Moran, 1996; Sherrouse et al., in press; Van der Horst, 2006, 2007). This paper draws on the work of the Swedish geographer Thorsten Hägerstrand, another 'classical' quantitative geographer, to explore its contemporary value in sustainable land use policy. Hägerstrand (1967) used a mathematical model to explore the extent to which innovation diffusion takes place as a spatial process. Observing a clear occurrence of a neighbourhood or proximity effect in the spatio-temporal pattern of adoption, he was able to conclude that for the adoption of subsidised grazing-improvement and other cases of innovation in agricultural management by Swedish farmers in the 1930s, communication within the local farming community was a more powerful agent of diffusion than public announcements which disperse information in a more even pattern across rural space.

Although Hägerstrand's work was focused on the diffusion of 'productive' farming innovations, there is no reason why it cannot be used to examine the diffusion of sustainable farming innovations to produce non-market goods and ecosystem services. In view of the current policy agenda for sustainable and multi-functional rural land use, and the provision of financial incentives to farmers to produce other ecosystem services in addition to growing food, it is relevant to ask how, where and when the innovation diffusion of AES takes place. The aim of this paper is to demonstrate how his model, now largely forgotten as a research tool,[2] can be relevant today in studies on the uptake of ecosystem service payments.

In order to illustrate what Hägerstrand's model could bring to appraisal or evaluation of policies for ecosystem service payments, this paper will utilise a particular AES case study, namely the Environmentally Sensitive Area (ESA) scheme in Scotland. The ESA Scheme is an agri-environmental scheme which aims to protect flora and fauna, geological and physio-graphical features, buildings and other objects of archaeological, architectural or historic interest in an area or protect and enhance the natural beauty of that area through payments made to farmers to maintain or alter their current practices. The ESA Scheme applies only to certain designated areas. These are often areas characterised by traditional agricultural systems and especially areas where this traditional agriculture is threatened by rural depopulation or agricultural intensification (for more details, see Wilson, 1997a; b). The ESA Scheme is voluntary, offering incentive payments to entice farmers to join. The ESA Scheme is a European scheme, first implemented in the UK in 1986. In total, 43 ESAs have been designated in the UK and 10 of these are located in Scotland (Fig. 1), covering 19% of Scotland's land area.

The remainder of this paper is structured as follows. First an overview is provided of the literature on farm adoption of agri-environmental schemes, showing that spatio-temporal patterns of uptake have sometimes been observed but that these have received very limited attention as a key focus of analysis. Subsequently, the use of Hägerstrand's model to explore these patterns is described in the methodology section. The results of the analysis are then presented, describing observed spatio-temporal patterns and exploring possible factors of influence. Subsequently, the limitations of the method are discussed, along with options for further development and application. The paper concludes with a reflection on the importance of analysing spatio-temporal patterns of uptake for understanding farmer behaviour, and for the effective delivery ecosystem services through voluntary payment schemes.

The ESA scheme; factors known to influence the uptake

An extensive literature exists on farmers' motivation and factors influencing farmers' decision to join an AES. Entry decisions have been found to be highly influenced by the

[1] Krugman (1995, p. 33) once observed that "there is almost no spatial analysis in mainstream economics".

[2] Since the 1980s there seem to have been only a handful of studies which drew on this model, e.g. Allaway, Berkowitz, and D'Souza (2003) used it to examine the uptake of loyalty schemes in retail; and Erlingsson (2008) used it to examine party political entrepreneurs in local government in Sweden.

Fig. 1. Location of Environmentally Sensitive Areas (ESAs) in Scotland.

consequences for farm income and farmers with fewer financial constraints are much more likely to be influenced by potential conservation considerations (Morris, Mills, & Crawford, 2000). The degree to which the scheme prescriptions fit the existing farm system, determines its 'popularity' with farmers, i.e. farmers are more likely to enter the scheme when only minimum effort would be required (Wilson, 1997a). Wynn, Crabtree, and Potts (2001) observed that the ESA Scheme in Scotland (discussed in more detail below) favoured extensive farms as the prescriptions with minimal opportunity costs (eg stock management, herb-rich grassland, woodland, and wetland) applied especially to these extensive farms; in addition some of these prescriptions included improved fencing, which reduced the input costs to agriculture. CEAS (1997) also found that the main factors determining entry to ESAs were the level of payments and the changes required to the farm. In addition, they found entrants to be marginally older and more environmentally concerned than non-entrants. The issue of age raises the question of who the farm will be passed on to. Potter and Lobley (1992) observed that farmers without successors were most likely to be disengaging from full-time agriculture or extensifying (i.e. reducing the input of labour or capital). The importance of conservation concerns was also noted by Morris and Potter (1995), who subdivided adopters of the ESA scheme into passive and active, with passive farmers joining for business reasons and active ones being more motivated by the environmental objectives of the scheme.

The importance of the source of information on farmers' decision to enter is stressed by a number of authors. McHenry (1995) found that farmers tend to suffer from a lack of information and make decisions based upon rumour. Moss (1994) noted that channels of information differed between non-participants and participants with the latter most likely to have heard about the scheme through farming advisory staff and public meetings. For the adoption of organic farming, Burton, Rigby, and Young (1997) noticed that the uptake increased if the farmer obtained information primarily from other farmers. Skerratt's (1994) found that both the farm advisors and the neighbourhood network play an important role in the adoption decision. Some farmers may be perceived as 'leaders' by their neighbours and their participation can accelerate the uptake by other farmers in the area (Wilson, 1997b). Other farmers have a more cautious 'wait and see' attitude and they may postpone their decision until they learn of other farmers' experiences with the scheme (Wynn et al., 2001). Adoption or non-adoption cannot be reduced to a single dichotomous decision taken at one point in time (Skerratt, 1994). Adoption should be seen as a process, in which both formal and informal communication can play an important role at different stages (Taylor & Miller, 1979).

Temporal trends of uptake have received attention in a number of studies. Fisher, Arnold, and Gibbs (1996) concluded that the rate at which information becomes available is a critical factor in the adoption decision and the speed of that decision. Moss (1994) found that 40% of the farmers applied to the scheme as soon as it was brought to their attention; for the remainder there was a 6 months time lag. Evans (1997) examined the uptake levels for three different types of AES and he concluded that selective targeting of large farms and active early promotion could result in a strong initial uptake rate which then declined over time. Skerratt (1994) suggests that farmers would not have joined, or would have taken much longer to join had the agricultural advisor not possessed his negotiating skills and the ability to appreciate both the farming and the conservation objectives of the scheme. The work of Morris and Potter (1995) leads one to expect differences in the motivation of early and late adopters. Fisher et al. (1996) suggest that a Beyesian learning model would be well suited to account for the time lag between when farmers first hear about an innovation and the time when they adopt it; a model which can be used to observe laggards and partial adopters.

Empirical work on the spatial patterns of uptake of agri-environmental schemes is less common. Battershill and Gilg (1996) have studied the role of geographical location on the uptake of a number of voluntary conservation schemes (including ESAs) in south-west England. Location and attitudes were found to be far more important as determinants of adoption than socio-economic characteristics. Wilson (1997a) found that farmers located in the centre of ESAs were more likely to sign an agreement than those farmers located on the boundaries.

The above literature presents a variety of factors which influence the entry decision and the speed with which that decision is taken. Many of these factors differ from place to place and also over time. It is therefore expected that if entry is influenced by such factors, this may manifest itself in patterns of uptake that are not evenly spread across space and time. So far, little empirical research has been carried out to investigate such patterns. In the following section, we discuss how Hägerstrand's model can be used to detect and explore spatio-temporal patterns of uptake.

Methodology

The methodology consists of two stages. Firstly, and very similar to Hägerstrand's original approach, quantitative indicators of spatio-temporal clustering are applied to each ESA. Secondly, the ESAs for which these indicators suggest a possible occurrence of neighbour networks, are subjected to a closer, visual study. A Geographical Information System (ArcView 3.1) is used to display the farm locations on a map (a farmers's postal address is translated into x,y coordinates using Ordnance Survey's Address-Point database) with the time of entry printed at each farm's location. For the illustrative purpose of this paper, the most prominent clusters and outliers are identified through 'eyeball analysis' (Chorley & Haggett, 1965) of the map. Whilst lacking the methodological rigour of statistical methods, this intuitive approach is widely used in practice and fit for purpose if the data is suitable (Belperio, Harvey, & Bourman, 2002). In this particular case, the explorative value of eyeball analysis can be enhanced by adding further topographical data to the farm points with date of-entry labels. Data layers such as shore-lines, rivers and road-networks provide information about connectivity, and may thus be useful as potential proxy indicators for the likelihood of frequent face to face interactions between farmers.

Since this is a desk-based study to demonstrate the use of the Hägerstrand model, it cannot reveal the actual rationale for each farmer who is found within an observed cluster. However where available, the analysis is supplemented by a few comments from the regional farm advisors[3] to demonstrate the importance of subsequent qualitative assessment.

It could be argued that evidence of temporal clustering of uptake is a better indicator of network effects than spatial clustering. There are two reasons for this. The farmer can freely choose the time of entry, whereas he/she cannot chose the farm location. This makes entry time a stronger indication of the decision making process a farmer goes through. And secondly, unlike spatial distance, temporal distance has a set direction, suggesting who may influence who. The latter could aid in the identification of a network as it suggests who may be an early adopter or leader and who may be followers.

A simple measure of temporal clustering is the coefficient of variation of the entry time, i.e. the average entry time, divided by the standard deviation. More close-knit communities are expected to have a more temporally clustered uptake.

Evidence of spatio-temporal clustering of uptake can be used as a quantifiable indicator of a possible neighbour network effect. The choice of method for the measurement of spatio-temporal patterns of entry depends on the characteristics of the dataset. The most conventional methods to measure spatio-temporal clustering might be some type of cluster analysis, possibly preceded by a semi-variate approach. These methods are deemed unsuitable in this case study application because of the diverse geography of Scotland and the differences between separate ESA areas, which range from coherent geographical areas such as Loch Lomond, to separate mountain valleys in the Highlands, to dispersed islands and a long and thin strip of coastal land along the Western Isles. As a result, the distance over which farmers may influence each other and the 'following time' (between adoption by a 'leader' and adoption by a 'follower') are expected to vary strongly and unpredictably, with temporally or geographically out-lying farms creating a 'noisy' data set. An additional problem is that single observations in each dataset cannot be assumed to be independent of each other. A simulation approach is therefore needed to test for the significance of association between temporal and spatial pattern of uptake. A simulation method appropriate for this type of problem is the Mantel test (Sokal & Rohlf, 1995. p. 815), which is widely used in evolutionary ecology to examine spatio-temporal

[3] These comments were supplied by Dr Gerard Wynn (pers. Com.), who had interviewed farmers and farm advisors.

Table 1
Uptake statistics for each Scottish ESA.

Environmentally Sensitive Areas (ESA) in Scotland	Total ESA area (ha)	Date of first entrant	Number of entrants	Average time of entry since scheme started	Coeff. of Var.	*Mantel P***
Western Isles Machair	18,110	14/06/90	172	Day 396	0.58	0.98
Argyll Islands	264,050	21/12/94	168	Day 458	0.73	0.99
Breadalbane	181,207	27/08/88	83	Day 499	0.71	0.99
Central Southern Uplands	273,317	25/10/93	155	Day 591	0.62	0.28
Central Borders	35,125	27/07/94	72	Day 602	0.50	0.86
Stewartry	60,312	05/05/89	151	Day 609	0.59	0.28
Cairngorm Straths	236,138	30/09/94	76	Day 609	0.55	0.99
Western Southern Uplands	220,500	16/12/93	100	Day 624	0.65	0.31
Loch Lomond	49,687	07/05/88	34	Day 632	0.74	0.76
Shetland Islands	146,478	23/06/94	172	Day 776	0.38	0.23

patterns (e.g. Dybdahl & Lively, 1996; Le Corre, Dumolin-Lapègue, & Kremer, 1997). The Mantel test is used to estimate the association between two independent dissimilarity matrices and test whether the association is stronger than one would expect from chance. This method permits to test for association between a 'euclidean distance matrix' (X_{ij}) and a 'difference in entry time matrix' (Y_{ij}) for any set of farms ($N > 7$) under the null hypothesis that no association exists. The observed Z statistics, for the test is computed by multiplying two matrices with each other, and summing the results:

$$Z_o = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} X_{ij} Y_{ij} \tag{1}$$

After a random permutation of the elements of one matrix, the Z value is re-calculated. By repeating this procedure 1000 times, a reference distribution of simulated values, Z_s, is obtained. Z_o (Equation (1)) is then compared to the distribution of Z_s to assess if the observed level spatio-temporal clustering is stronger ($Z_o > Z_s$) or weaker ($Z_o < Z_s$) than the level of spatio-temporal clustering that is likely to occur by chance.

Results

Comparisons between ESAs

Table 1 lists the results of the statistical analysis for each ESA. The coefficient of variation records the degree of temporal clustering about the average entry time. The higher the values for the coefficient of variation, the stronger the temporal clustering is. Mantel p measures the level of spatio-temporal clustering in comparison to a random distribution, with $p > 0.5$ indicating stronger clustering and $p < 0.5$ indicating weaker clustering than what could be expected by chance. Table 1 shows that the Western Isles have the fastest average entry time from the start of the scheme, and the Shetlands the slowest. With the exception of the Shetlands, temporal clustering is or exceeds 0.5 – although it never exceeds 0.74. Spatio-temporal clustering can be much stronger, reaching 0.098 or 0.99 for four out of ten ESAs. However for four other ESAs it is significantly below what may be expected from chance (0.23–0.31).

Local clustering within ESAs

Following on from the statistical indicators of clustering calculated across all entrants of each individual ESA, four ESAs are selected for closer, 'eyeball' examination of the patterns of uptake by zooming in on the GIS maps on screen: Western Isles Machair, Cairngorm Straths, Argyll and the Shetlands. The Shetlands are selected because of the out-lying and conflicting clustering indicators. The others three ESAs are selected on the basis of their high p score (significant spatio-temporal clustering). Breadalbane was at first also selected on that basis but a visual analysis revealed only one, relatively minor cluster. Table 2 contains an overview of the main clusters identified in these ESAs. A number of clear clusters are identified on a number of the smaller Argyll islands (Coll and Tyree, Colonsay, Lismore, see Fig. 2), parts of the Western Islands (northern Barra) and valleys of the high Cairngorm mountains. The selected ESAs are discussed in turn below.

The uptake pattern on the Shetlands is quite irregular and can be subdivided into three subsets. The first subset (days 0–707) is actually significantly unclustered ($p = 0.09$). The exceptionally slow rate of uptake in the first year (13 entrants) is blamed by the local farm advisor on negative local media publicity at the scheme launch. Farmers belonging to sub-set 1 are scattered all over the Shetland Islands with the exception of the southern part of Mainland (Shetlands' main island). One notable spatio-temporal cluster is identified within sub-set 1: this is a cluster of 8 farms (5% of all entrants at 1997) on Fair Isle, a remote island lying halfway between Shetland and Orkney. This cluster clearly suggests a collective approach or response by the farmers on this very remote island, who are responding in a manner that is quite contradictory to the pattern found at the same time in the rest of the Shetland islands. Subset 2 (days 708–1013) is significantly clustered at $p = 0.05$. This sub-set contains a third of all entrants in Shetland. More than half the entrants from this sub-set live on the island of Unst or on the western part of Mainland where they make up half the total number of entrants. That this sub-set represents a cluster could be explained by a rush of entrants after the initial unfoundedly negative publicity subsided – yet their peculiar spatial pattern (Unst and western Mainland) suggests the

Table 2
Spatio-temporal clusters identified through 'eyeball analysis' of GIS maps.

ESA	Area of cluster	Farmers in entry cluster/total no. of farmers in area	Entry days
Cairngorm Straths	Glen Avon	10/10	941–1113
	Dee valley	5/7	336–465
Argyll Islands	Coll	7/8	46–175
	Tyree	15/16	769–1029
	Colonsay	5/8	62–86
Breadalbane	Strath Ardle	9/14	208–364
Western Isles Machair	Barra/Eolaigearraidh	4/5	883–878
	Barra/Aird Mhor	11/11	105–457
	South Uist	6/13	569–650
Shetland Islands	Fair Isle	8/9	523–564
	Mainland south of Stove	8/10	1103–1208

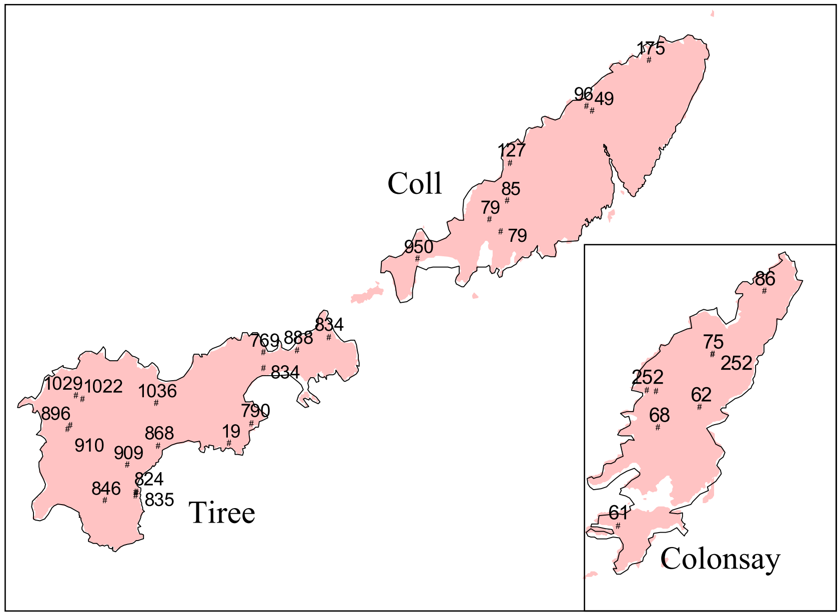

Fig. 2. Example of the GIS maps produced for eyeball analysis (part of the Argyll islands ESA). Dots indicate the location of the farms that joined the scheme, with a number indicating the day of entry since the scheme was opened.

possibility of neighbourhood networks that would have to be investigated in the ground. Subset 3 (day 1082–1226) is randomly distributed ($p = 0.5$). Of the 37 entrants in this sub-set, 15 are concentrated on the southern part of Mainland (south of Lerwick) where they make up about 50% of all entrants.

As with Fair Isle, the smaller Argyll islands have a highly clustered uptake patterns. Isolated from other islands and only 4 km apart, the two island communities of Coll and Tiree respond quite differently to the scheme (see Table 2 and Fig. 2). According to the farm advisor, the difference in entry time of almost three years was a result of the more sceptical attitude of the crofters on Tiree who only joined after the prescribed time of haycutting had been adjusted in their favour. On Coll the farmers are not traditional crofters and were much quicker to join. The farming communities on both islands responded as one group (clustered in time) with only one outlier. On Coll this outlier (entry day 950) is a farm run by RSPB (the Royal Society for the Protection of Birds). This national conservation NGO can clearly be seen as an outsider to the community. There is also some evidence to suggest that farm size can be a predictor to the time of entry. The first five entrants (day 62–86) on Colonsay have relatively big farms (400–1300 ha), the two entrants who joined at day 252 have around 25 ha while the last joiner (day 658) has only 7 ha. The financial benefits of joining are higher for larger farms, whilst the transaction costs (i.e. the hassle of form-filling) do not differ so much between large and small farms.

For the Western Isles, larger clusters are only identified at the northern tip of the island of Barra where two crofting communities only 3 km apart join the scheme more than 400 days apart. There was no information from the local advisor to explain this pattern. In the western isles there is a temporally clustered sub-set of entrants between day 548 and 715 which is spatially significantly clustered ($p = 0.01$). Visual analysis reveals that almost 60% of the entrants of this sub-set are found on the island of South Uist. Again, this eyeball analysis can provide guidance for targeted interviews with local farmers to explain the processes that produced the spatial pattern.

The significant clustering ($p = 0.99$) in the entrants dataset for the Cairngorm Straths ESA can be explained by both large and small clusters. Surrounded by Britain's highest mountain range, these three valleys represent geographically separated farming communities. However the explanation of the difference in uptake time may also lie in the mode of operation of the regional advisors. The three valleys belong to three different regional offices of farm advisors. The advisor for Strath Avon explained that he made use of existing farm networks to persuade farmers to join. The highly concentrated time of entry suggests he was successful.

Discussion

By demonstrating the utilisation of Hägerstrand's spatial model of innovation diffusion in a case study application, the ESA scheme in Scotland, this paper has yielded some strong and diverse evidence of spatio-temporal clustering of farmer decisions to join a voluntary agri-environmental scheme. This discussion section is structured as follows. First the tentative interpretations of the clustering are explored, then opportunities for extending and improving the analysis are identified, and finally the policy relevance of the model and the findings are discussed.

It is not easy to draw generic conclusions from the patterns of clustering – for two different reasons of (spatial) scale. With regards to assessment at the inter-ESA scale, similar trends or their absence may be found in different local circumstances as all ESAs differ from one-another and all have their own unique circumstances and local histories. With regards assessment at the intra-ESA scale, the trends found at the population level (all entrants of each separate ESA) are not always recognisable on the ground, where micro-clusters may be encountered, or larger trends may be harder to spot.

However there are some tentative conclusions we can draw from the analysis. It is noted with respect to Table 1 that uptake in the six later ESA schemes (designated 1993–1994) is neither quicker nor more clustered than that of the four earlier ESA schemes (designated 1988–1990), suggesting that favourable opinions and information do not easily cross separate (spatial) ESA designations over time. Cairngorm Straths, Argyll, Breadalbane and

Western Isles all have a positive association between location of farms and time of entry significant at the 95% level of confidence. By contrast, three of the four southern ESAs score very similarly with an observed association which is less positive than what would be expected from random ($p = 0.28–0.31$). It could be hypothesised that this may have something to do with the very different socio-economic and geographical nature of the farming communities in the south which are (by comparison) highly accessible and close to major cities. These communities are much larger, and much more diverse, giving farmers more opportunity for off-farm earnings, more farm-diversification options and more/diverse sources of information to individual farmers. Collective or identical decision making is less likely to take place here and spatio-temporal clustering in the pattern of uptake are less likely to be found.

The frequent occurrence of micro-clusters in the more remote ESAs suggests strongly that neighbourhood effects can be more prominent in small and remote communities. Statistical or map analysis does not yield information about the personal motivations and group/community dynamics on the ground, but two related explanations may be proffered. The first explanation is that group deliberation and collective decision making is taking place in these relatively tight-knit communities which are remote from other communities and small enough to make people more collaborative with, reliant on and trusting towards their neighbours. On small remote islands or in isolated mountain valleys, people are more likely to form island communities in a physical, socio-economic and cultural sense. The second explanation relates to the role of the farm advisor in information provision and 'selling' the scheme. This too could be an important explanatory variable for the observed pattern of uptake in these remote areas where a trusted farm advisor may act as a (surrogate) 'leader'. This would be consistent with Skerratt's (1994) suggestion that some farmers would not have joined, or would have taken much longer to join, had the agricultural advisor not possessed the necessary negotiating and trust building skills. A similar observation was made for advisers in community energy projects in rural Scotland (Van der Horst, 2008); the advisors were local people who were embedded in relatively small and remote communities so that the atomised distinction between principal and agent faded and made way for collaborations that were based on trust, social capital and a strong ethos of knowledge sharing.

It could be hypothesised that promotion is more critical in remoter areas, because of the opportunity for exploiting neighbour networks and because of fewer opportunities for farmers to access information through a range of different channels. The impact of negative local publicity on the uptake in the Shetlands is an indication of the high impact of localised information provision, resulting (in that case) in collective inaction by the farmers on the Shetland islands, but apparently not affecting the out-lying Fair Isle.

In this illustrative case study, available farm data was very limited, consisting only of size (ha), location (x & y coordinates) and time of entry to the scheme. Thus it was not possible to try to account for farm type in observed spatial clusters of uptake. It would be logical to expect that neighbours are more likely to reach similar conclusions and influence each other's decision making if their farms are more similar. Wynn et al. (2001) reported that farmers with more rough grazing had the tendency to join *earlier* and that this was associated with relatively attractive ESA payments for conservation measures on rough grazing land. Since extensive farms, e.g. those associated with more rough grazing, are found in similar biophysical environments and are thus likely to be spatially related, observed *spatial* clusters of uptake do not (by themselves) necessarily constitute convincing evidence of neighbourhood networking. The analysis of spatio-temporal clustering should ideally account for both biophysical farm type and the level of economic benefit offered by the agri-environmental scheme. However whilst higher economic incentives may result in more neighbouring farmers making identical *individual* decisions to join, it can also be hypothesised that in relatively close-knit communities, relatively lower economic incentives may result in less individualistic responses and discussions through neighbour networks may play a more important role in shaping farmer decisions. Also, when farms are similar and marginal, it may be more tempting to reduce the administrative burden associated with form-filling through collaboration. Actual proof of these processes can only come from subsequent empirical fieldwork.

The analysis presented here has been limited to a statistical and eyeball examination of spatio-temporal clustering of a particular farmer decision. There is clearly much scope for extending the analysis in future studies. It would require a combination of the quantitative and top-down analysis presented here (extended with data on farm typology, the exact measures adopted, as well as data on non-entrants), and local qualitative and in-depth fieldwork to really unpack the patterns of adoption of agri-environmental measures and to account more realistically and accurately for the role of neighbourhood networks on farmer decision making to join a particular PES scheme. However the analysis presented here is a quick and useful step to identify clustering of uptake and can help guide a more time and resource intensive qualitative study of farmer behaviour. Fig. 2 illustrates that dependent on the data and geography, some clusters and outliers can be very easily identified by eyeball. Eyeball analysis is relatively quick and intuitive and it can always be supplemented or followed up by more statistically rigorous methods. Cluster analysis could for example be useful for comparing uptake of two different schemes in the same farming area.

This draws attention to the policy relevance of utilising the Hägerstrand model. In order for incentive policies (like PES schemes) to be effective, they must be designed in a way that encourages widespread uptake/diffusion. In order for them to also be efficient, they must be designed in a way that encourages rapid diffusion without offering unnecessarily generous financial incentives or without costing too much money to advertise and administer. Existing farmer networks offer a potential channel for rapid and 'cheap' innovation diffusion of AES. Existing studies of farmer motivation have yielded evidence that farmer networks can be important channels for distributing information and influencing decisions, but the pattern and consequences of this network effect were not clear. It could be argued that utilising the Hagerstrand model as a tool to evaluate AES, offers two particular benefits. Firstly, it fills a knowledge gap by revealing spatio-temporal patterns of AES uptake. In the application presented here, it was shown that in some areas clustering is very strong. This offers useful insights into the patterns of successful information dissemination in specific communities/farming areas, which in turn can provide pointers for the development of more targeted dissemination and influencing strategies in the future. For example the findings from the ESA case study suggest that farm advisors in remote rural areas can utilise existing farmer networks to encourage and 'bundle' local uptake.

Secondly, in the specific case of PES, it is important to note that spatial clustering of uptake is very important for securing the delivery of ecosystem services. This is because many non-provisioning ecosystem services (e.g. water quality, landscape aesthetics, recreational opportunities, habitat connectivity to support populations of valued wildlife species) cannot be effectively delivered through land use interventions at the field scale or the farm scale, but need a spatial patterns of uptake at the landscape scale. In this case, strong spatial clustering of uptake can by itself be an indicator of the potential environmental benefit provided by the AES.

Conclusions

This paper has sought to illustrate that the model developed by Hägerstrand for Swedish farming in the 1930s, can have relevance for a very contemporary land management challenge; the design of incentive policies to enhance the delivery of ecosystem services in agricultural landscapes. In addition to arguing for the revival of a 'classical' but now largely dormant quantitative geography model, this paper is also novel in that it utilises a statistical method (the Mantel test) that is widely used for spatio-temporal analysis but not by geographers and in that it yields clear evidence of spatio-temporal patterns of AES uptake – a finding which is not surprising (given existing interview-based studies) but nevertheless novel and insightful. The identification of these patterns offers the opportunity to engage with more 'bottom up' empirical studies on farmer behaviour, both by drawing on existing studies to identify possible explanations for the clustering observed, and by steering/targeting new fieldwork to interview members of specific clusters or outliers in order to better understand the linkages between (more aggregate) observed patterns of uptake and the process of decision making by individual farmers. Understanding the processes that produce these patterns, can be very useful for the design of policies that can achieve higher take-up without necessarily having to offer higher financial incentives. In other words, the combined use of the Hägerstrand model and fieldwork, can help to target both incentives and engagement strategies, and thus help infuse economic models of 'rational' farmer behaviour with a rich fabric of local knowledge, social relations and other location specific context (see Blair and Carroll, in press).

The results from the analysis of the case study clearly demonstrate that geographically separated communities can respond very differently to incentives that look roughly similar on paper. Using the Hägerstrand model to study farmer uptake of a voluntary PES scheme, is not only useful in highlighting the need for much more flexible and area specific approaches to the design and promotion of PES schemes, it also offers a tool to assess the level of cohesion within farmer communities with regards to adopting more sustainable land management options. PES schemes are exposed to a systemic mismatch of scale, since they seek to encourage interventions at the scale of private land holdings, in order to yield ecosystem benefits at wider landscape scales. There are no conventional economic models to explore to what extent current PES schemes produce appropriate spatial patterns of uptake at the landscape scale. The old Hägerstrand model has a new role to play in addressing this contemporary research challenge.

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