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Beyond the single farm – A spatial econometric analysis of spill-overs in farm diversification in the Netherlands

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ABSTRACT

Farm diversification is an important component of rural development and policy in Europe. We examine the influence of neighbouring farms on farm diversification decisions. Our analysis investigates spill-over effects between farms and different activities in a spatial econometric framework. Using census data from about 66,000 farms in the Netherlands, we find significant correlations of diversification activities between spatially proximate farms. These are positive for some activities, for example for nature conservation. On a local level, positive spatial dependencies between farms may result from (tacit) cooperation and information sharing within neighbourhoods. However, for other activities, such as on-farm sales, we find negative correlations on a higher spatial level, i.e. within the region, which could result from competition. Spatial aspects of cooperation and competition have important consequences for the success of policies supporting the uptake of farm diversification. Our findings thus reveal that policy measures promoting farm diversification require implementation beyond the scale of individual farms and single activities.

1. Introduction

Farm diversification is an important aspect of agricultural and rural development policy in Europe. It contributes to the stabilization of farm incomes and allows farm households to exploit their resources more broadly. This supports farm survival, creates new economic opportunities and services in rural regions and contributes to the resilience of farming systems (e.g. Meuwissen et al., 2019). Farm diversification thus bolsters the development of rural regions (e.g. Benjamin, 1994; Barbieri and Mahoney, 2009; Heringa et al., 2013; Augère-Granier, 2016). To support further developments in farm diversification, it is essential to understand characteristics of diversified farms and mechanisms driving diversification across space.

In this article, we investigate the importance of the farming neighbourhood on diversification decisions[1] considering a wide set of diversification activities and their interdependencies at the farm-level and across farms using the example of Dutch agriculture.

Decisions of farmers on spatially proximate farms increase or limit economic opportunities of individual farmers (e.g. Beharry-Borg et al., 2012; Läpple and Kelley, 2015; Storm et al., 2015; Peth et al., 2018; Saint-Cyr et al., 2019). We expect that this is also relevant for the decision to diversify, which would have an impact on the success of policies supporting diversification. Yet, while a rich body of literature has addressed determinants of farm diversification (e.g. Mishra et al., 2004; Dries et al., 2012; Meraner et al., 2015) and the impact of socio-economic and physical environment on the emergence of farm diversification has been highlighted in various studies (Ilbery, 1991; Meert et al., 2005; Jongeneel et al., 2008; Barbieri and Mahoney, 2009; Pfeifer et al., 2009; Zasada et al., 2011; Lange et al., 2013; Meraner et al., 2015; Hassink et al., 2016a), the influence of activities and characteristics of neighbouring farms on a farm's decision-making (spill-over effects) has been neglected in the literature on farm diversification.

Characteristics and decisions of spatially proximate farms can be relevant in several forms. *Positive spill-over effects* can be externalities from activities and characteristics of nearby farms. For marketing reasons, it could for example be advantageous to start processing cheese in a neighbourhood, which is known for its pasture-based livestock farms. This advantage can be amplified with the establishment of a joint label

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[1] We focus on farm diversification defined as an on-farm shift in the use of agricultural resources away from the production of traditional agricultural goods (such as food, feed and flower bulbs) towards alternative activities (for example agri-tourism, on-farm sales etc.).

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or a regional brand (Polman et al., 2010) by local farm collaborations (Fischer and Ypma, 2012). Profits from such (tacit or explicit) co-operation apply to the individual farm, but also to other farms neighbouring farms. For example, using a label can be valuable for a single farm, but a farm contributing to the label also increases the value of this label for all contributors and all non-contributors. Positive spill-overs may also result from interactions between farmers (e.g. Case, 1992; Munshi, 2004; Bandiera and Rasul, 2006; Matuschke and Qaim, 2009; Conley and Udry, 2010), as communication with a neighbour can be an important source of information for a farmer (Munshi, 2004) that can reduce transaction costs of adopting a new farm management strategy. *Negative spill-over effects* have been found to be relevant for structural change and development in the agricultural sector (Storm et al., 2015), and can be assumed to exist for diversification as well. For example, strong competition in agri-tourism may reduce the potential for further supply of touristic activities of farms in the neighbourhood (van der Meulen et al., 2014). Moreover, negative externalities can influence agricultural decision-making at the single farm (Läpple and Kelley, 2015). For instance, being situated next to less attractive farm types, such as intensive livestock farms, may reduce the potential utility gain from the adoption of agri-tourism activities. Furthermore, social acceptance of an agricultural practice in the neighbourhood can also contribute to positive and negative spill-over effects (Home et al., 2014; Wollni and Andersson, 2014).

In existing literature, three factors have been identified as crucial for the spatial dependence of the uptake of diversification activities. Firstly, diversification depends less on soil properties than other agricultural activities (Pfeifer et al., 2009). Therefore, opportunity costs of diversification can be different at different locations. Secondly, at sites closer to or within attractive landscapes, farm diversification is observed more often. These sites are especially suited for diversification activities involving farm visitors such as agri-tourism (Walford, 2001; Pfeifer et al., 2009; Lange et al., 2013; Hassink et al., 2016a). Thirdly, diversification activities can (more than other farm activities) gain from the presence of the non-farm population and the proximity of a farm to an urban area influences the uptake of, particularly, on-farm sales activities and care farming (Ilbery, 1991; Zasada et al., 2011; Meraner et al., 2015; Hassink et al., 2016a, b).

We extend this literature by investigating spill-over effects of characteristics and decision-making of nearby farms using a census dataset for all Dutch farms and focussing on multiple diversification activities. More specifically, we account for the influence of farms' and farmers' own characteristics as well as for two processes leading to the emergence of spatially clustered patterns in the uptake of diversification: i) influences of diversification activities of neighbours (endogenous spill-over effects) and of their characteristics (exogenous spill-over effects) on the diversification decision-making on a farm and ii) spatial correlations in the socio-economic and physical environment of farms (e.g. Anselin, 1998; LeSage and Pace, 2009), which includes characteristics and diversification decisions of other farms on a higher spatial level, i.e. the region (Storm and Heckelei, 2018; Saint-Cyr et al., 2019). To address the influence of the farming neighbourhood, we follow Gibbons and Overman (2012) and Halleck Vega and Elhorst (2015), who propose to identify an overall effect of both endogenous and exogenous effects and then discuss which channel of influence is most plausible from a theoretical perspective. This means that an emphasis is on separating spill-over effects from spatial correlation arising from a shared physical or socio-economic environment. This approach allows us to distinguish whether neighbouring characteristics are simply capturing regional socio-economic and physical conditions or whether actual spatial dependencies between neighbouring farms are likely (Storm and Heckelei, 2018; Saint-Cyr et al., 2019. Technically, this means we use a spatial lag of X (SLX) regression framework with two spatial layers and spatial characteristics to identify factors determining farm diversification and to estimate marginal effects. We use agricultural census data of about 66,000 Dutch farms for the year 2013 that includes detailed information on farm-level diversification activities and enrich this dataset with spatially explicit information on soil conditions, landscape attractiveness, population density and regional affiliation.

The remainder of this paper is organized as follows. First, we define farm diversification and give an overview of concepts and literature on farm diversification determinants. We use this to develop hypotheses for the empirical analysis, with a particular focus on spatial and spill-over effects. This is followed by the econometric framework and implementation as well as data used in this research. Next, results are presented and discussed, and finally conclusions are drawn.

2. Determinants of farm diversification

2.1. Diversification activities

Farm diversification implies a shift of farm resources (land, labour or capital) away from the production of crops and livestock to generate additional income (e.g. McNally, 2001; Weltin et al., 2017). In our study, we focus on diversification activities that can be classified as structural diversification and are relevant in Dutch agriculture (those that are used by farms and in the focus of policies). Structural diversification, also referred to as broadening activities, includes non-agricultural activities such as agri-tourism or leasing of buildings and land (Ilbery, 1991; van der Ploeg and Roep, 2003). More specifically, we consider the following activities: nature conservation, agri-tourism, on-farm sales and processing, and care farming (see Table A1 for definitions and Section 4 for more details).

2.2. Influence of farm and farmers' own characteristics

Meraner et al. (2015) and Barbieri and Mahoney (2009) found that younger farmers tend to diversify more often than older farmers because risk reduction might be more important for younger farmers expanding their farm business and because longer planning horizons facilitate investments (Barbieri and Mahoney, 2009). Moreover, farms with more available family labour are more likely to diversify, for example by seeking employment opportunities for family members on the farm (Meraner et al., 2015; Hassink et al., 2016a; Weltin et al., 2017). Additionally, the farm type is found to be relevant for the decision to diversify (Jongeneel et al., 2008; Meraner et al., 2015; Weltin et al., 2017). For example, pasture-based livestock and arable farms more often participate in nature conservation activities because these farms have more land available (Jongeneel et al., 2008; Meraner et al., 2015). The large extent of these farms' land might however also reduce their accessibility for customers and thus lower their potential for other activities such as on-farm sales. Moreover, we expect that complementary diversification activities are more likely to emerge jointly on a farm. For instance, a farm that is engaging in nature-conservation activities might have larger opportunities to start with agri-tourism and sales activities, as nature conservation can be positively perceived by potential customers. Another example could be that a farm that processes its own products, can potentially profit from selling these products (for example home-made jam or cheese).

2.3. Spatial spill-overs within the local neighbourhood

We expect that the uptake of diversification activities is additionally driven by local spill-overs across neighbouring farms. For instance, the presence of multiple farms offering touristic activities is expected to enlarge the local attractiveness, for example through an increased diversity of touristic offers (Fischer and Ypma, 2012). This might increase a farmer's utility of starting with agri-tourism and/or on-farm sales, as potential visitors and buyers might be attracted to the neighbourhood by touristic offers. Furthermore, Fischer and Ypma (2012) highlight that networks are used to transfer knowledge between farmers selling products on their farm. Additionally, several actors may work together by selling, producing and offering touristic attractions under one local brand (Polman et al., 2010). For instance, neighbours having a farm shop might increase possible gains from on-farm processing, when its products can be sold in the neighbour's shop. Also, for care farming spill-over effects might by relevant. Local cooperation alliances for care farming are increasingly embedded in municipalities (Fischer and Ypma, 2012; van der Meulen et al., 2014). Fischer and Ypma (2012) as well as van der Meulen et al. (2014) highlight that the activity nature-conservation differs from other diversification activities as its emergence depends more on subsidies and less on entrepreneurship compared to other activities. However, they emphasize that this support given to agricultural associations might increase learning within a neighbourhood. Generally, acceptance and perceived responsibilities within the local community as described by Home et al. (2014) may further contribute to spill-over effects. Furthermore, there are other characteristics of neighbours that might influence the farmer's decision-making (Läpple and Kelley, 2015; Storm et al., 2015). For example, being surrounded by younger farmers that are found to more often have a farm shop, might increase the level of competition in on-farm sales. Moreover, a small farm surrounded by larger farms might decide to diversify to stay in business. We also expect the predominant farm-type to play a decisive role for the uptake of diversification. For instance, a neighbourhood dominated by intensive livestock farms, could reduce the potential benefit from diversification into agri-tourism. On the other hand, a neighbourhood with pasture-based livestock farms might support the perception of a 'typical Dutch landscape', which could increase the profit of providing a touristic offer.

The consideration of neighbourhoods and spill-over effects is highly heterogeneous in the literature. Table 1 provides an overview of the most important studies on spatial spill-over effects in agricultural decision-making. It shows that neighbourhoods have mostly been defined as all farms within a certain distance from a farm. However, the influence of neighbours may not only be determined by the Euclidian distance between farms, but also by other aspects like the accessibility between them. There may also be physical (e.g. rivers and roads) or institutional (e.g. municipal and province) borders, which might decrease spill-over effects. Finally, spill-over effects might have different weights and directions. There might be role models who have a large impact on the decision-making of their neighbours, but are themselves barely influenced by others.

2.4. Socio-economic and physical environment

The socio-economic and physical environment of a farm is expected to determine the uptake of diversification activities. Environmental variables that have been suggested in earlier literature to influence the uptake of diversification include soil properties, landscape attractiveness and closeness to urban areas. Soil properties are found to influence diversification decisions significantly (Pfeifer et al., 2009; Meraner et al., 2015). More specifically, farms on less productive soils have been found to be more likely engaged in diversification activities due to lower opportunity costs (e.g. Pfeifer et al., 2009; Meraner et al., 2015). Moreover, with proximity to nature sights, diversification is observed more often as it profits from a more attractive landscape (Pfeifer et al., 2009; Lange et al., 2013; Hassink et al., 2016a). Furthermore, farm diversification activities such as on-farm sales and care farming activities profit from proximity to larger markets and customers in urban areas (Meraner et al., 2015; Hassink et al., 2016a). Yet, previous research showed that whether proximity to urban areas supports the uptake of diversification activities also depends on the definition of these urban areas and on the specific type of diversification activity (Zasada et al., 2011; Meraner et al., 2015).

However, including these variables does not explicitly capture other effects emerging from socio-economic, administrative and physical conditions at different spatial levels. More specifically, neighbourhood characteristics can potentially have other (or even) opposite effects due to correlation with omitted variables that work at the regional scale (Storm and Heckelei, 2018). Storm and Heckelei (2018) show in a Norwegian case study that on a local level, higher direct payments have

Table 1
Overview of literature regarding spill-over effects in agricultural decision-making[a].

Author	Subject	Estimation of spatial functional relationship	Country	Aggregation level	Definition of a neighbour
Holloway et al. (2002)	HYV rice adoption	Spatial autoregressive probit model (SAR)	Bangladesh	Single farm	Every other farm in the same village[b]
Nyblom et al. (2003)	Organic farming	Logistic regression	Finland	Single farm	Farms within the distance to the nearest neighbour +1 km
Lewis et al. (2011)	Organic dairy farming	Probit Mundlak-Chamberlain maximum likelihood	USA	Single farm	Within two radii: 5 and 5 – 10 miles
Schmidtner et al. (2012)	Organic farming	SAR	Germany	County level	Common border
Bjørkhaug and Blekesaune (2013)	Organic farming	SAR, Spatial Error Model (SEM)	Norway	Municipality level	Common border, townhalls max. 50 km apart
Wollni and Andersson (2014)	Organic farming	SAR	Honduras	Single farm	Within six radii between 1,5 and 4 km
Allaire et al. (2015)	Organic farming	SAR	France	Based on municipalities and cantons	Common border
Läpple and Kelley (2015)	Organic farming	Spatial Durbin model (SDM)	Ireland	Single farm	Within three radii: 20-, 30-, 50- kilometres
Storm et al. (2015)	Farm exit	Spatially lagged explanatory variable model (SLX), Spatial Durbin error model (SDEM)	Norway	Single farm	Median driving distance to the furthest field in each municipality, within a predefined radius of this distance (max. 20 neighbours)
Läpple et al. (2017)	Technology adaption	SDM, SDEM, SLX	Ireland	Single farm	Inverse distance matrix, with 45 km cut-off[c]
Saint-Cyr et al. (2019)	Farm exit	SLX; Mixture modelling framework	France	Single farm	Farms within same municipality

[a] Note that we focus on literature that defines the neighbourhood in a spatial manner based on census data in contrast to studies that use the social network from survey data (e.g. Bandiera and Rasul, 2006; Matuschke and Qaim, 2009; Conley and Udry, 2010).
[b] Instead of using the village as neighbourhood in a spatial regression model, the village can also be used as a dummy variable in a linear regression.
[c] The relevance of a neighbouring farm is here additionally weighted by its intensity of dairy production (measured in dairy livestock units per hectare).

a negative influence on farm growth, plausibly due to increased competition on the land market. At the regional level however, they find positive effects of direct payments, probably due to economic growth in the region that is not directly observed. Based on this idea, we expect for instance that a neighbourhood with mainly pasture-based livestock farms increases the touristic potential at the local level due to increased attractiveness, but that the presence of a large number of pasture-based livestock farms in the region increases the level of competition between touristic offers.

3. Econometric framework and implementation

We expect that farmers' diversification decision is based on the maximization of expected utility. This choice is a function of different characteristics explaining the binary choice to diversify or not to diversify in a certain activity. We assume that spill-over effects influence the decision to diversify through reduced information costs and through enlarged profits. Following Schmidtner et al. (2012) and Wollni and Andersson (2014), farms take up a diversification activity if and only if:

$$E(U_i^a(\pi_i^a,\ TC_i^a(a_j),\ \Delta(\pi_i^a(a_j)) > E(U_i^{Non-a}(\pi_i^{Non-a})\ ) \tag{1}$$

$$\text{with } \pi_i^a =\ p_i^a(a_j,\ S_i)q_i^a(S_i,\ L_i) -\ C_i^a v_i^a \tag{2}$$

where U_i^a is utility of farm i from activity a, a = one specific diversification activity, Non_a= no diversification in activity a, π_i^a is profit from activity a at farm i, $TC_i^a(a_j)$ is the transaction cost of starting with activity a at farm i depending on the activity choice of the neighbouring farmer, j, $\Delta(\pi_i^a(a_j))$ is the increase in profit experienced by farmer i as a result of farmer j 's activity a choice, p are output prices, q is the production function, S are structural farm characteristics, L are locational factors on the farm, C and v are quantity and prices of inputs used on the farm.

Farmers' diversification decision is modelled as a binary choice probit model, where the observed diversification decision is determined by a latent utility variable y^* that reflects net utility of diversification. We estimate separate models for different diversification activities. We aim to separate the impact of spill-over effects on the local level from farm characteristics and from socio-economic and physical conditions. Two elements are important to notice. Firstly, we do not separately identify endogenous effects of neighbours' diversification decision-making and exogenous effects of neighbours' characteristics, which in many settings is not straight-forward (Manski, 1993; Gibbons and Overman, 2012).[2] We thus identify an overall effect, i.e. including endogenous and exogenous effects. Secondly, spatially correlated (unobserved) effects can potentially bias the identification of spill-over effects. To separate spill-over effects from the effect of the farms' environment, we include environmental, spatially correlated characteristics that, based on earlier literature, are important determinants of diversification. These are soil type, landscape attractiveness and proximity to urban areas. Because we cannot exclude that there are other spatially correlated errors, we follow Storm and Heckelei (2018) and include average farm characteristics on a higher spatial level, i.e. in the region, in our analysis. While Storm and Heckelei (2018) use regional dummy variables, we are also interested in what the effect of average farm characteristics on a regional level is. We thus include regionally lagged variables of farm and farmers' characteristics instead of region dummy variables.

We thus specify y^* to follow a SLX model with two spatial weight matrices:

$$y^* = X_1\beta_1 + W_1X_1\theta_1\ +\ X_2\beta_2\ +\ W_2X_1\theta_2\ +\ \varepsilon \tag{3}$$

We group explanatory variables containing farmers' and farm characteristics as matrix X_1. W_1 is a row standardized spatial weight matrix with the elements $w_{ii} = 0$ and $w_{ij} > 0$ if farm j is in the same neighbourhood (W_1) as farm i, and $w_{ij} = 0$ otherwise. W_1X_1 thus reflects spatially lagged farm and farmers' characteristics in the local neighbourhood. X_2 contains non-lagged variables related to the socio-economic and physical environment (landscape attractiveness, soil type and proximity to urban areas). To better represent socio-economic and physical environment, we additionally include regionally lagged farm and farmers' characteristics with W_2X_1. It should be noted that we do not include variables X_2 as spatially lagged variables since they are usually identical in a spatial neighbourhood (for example, neighbours often share the same soil type). The random error term, ε is assumed to follow a normal distribution and we aim to estimate the unknown coefficient vectors β_1, β_2, θ_1 and θ_2.

There are other models than the SLX for spatial econometric analysis such as the Spatial Autoregressive Model (SAR) and the Spatial Error Model (SEM) (see LeSage and Pace (2009) and Halleck Vega and Elhorst (2015) for overviews). Yet, the SLX model is the only spatial econometric model that allows to use lagged versions only of selected variables. Because of its flexibility, the focus on local spill-overs and the possibility to consider two weight matrices, the SLX model specifically suits our analysis (LeSage and Pace, 2011; Gibbons and Overman, 2012; Halleck Vega and Elhorst, 2015).

We design the local spatial weight matrix W_1 as a k-nearest neighbour definition with 10 neighbours to reflect the local neighbourhood. In the k-nearest neighbour model, every farm has exactly k links to other farms and there is no limitation on the distance of influence of other farms (Fig. A1). This is a somewhat different approach compared to earlier studies on spill-over effects in agricultural decision-making (Table 1), that either choose a distance cut-off or considered administrative boundaries. We chose differently because in most parts of the Netherlands, agriculture is characterised by high farm density, so that most of the Dutch farms have many neighbours within a small radius from their farm. Yet, in some areas with large farms (for example in the Northeast of the Netherlands) very small distances may not allow to capture all relevant neighbours or any neighbours at all (see Fig. A2). Due to this diverse structure across agricultural systems, a non-distance driven definition of neighbours is better suited for our analysis. Nevertheless, to reflect that influences of nearer neighbours might be stronger than those of more distant ones, we weight the links w_{ij} based on the inverse of their distance between i and j. Thus, if a farm has all its k neighbours within a small distance, differences in distance are small and similar weights will thus be assigned to its links. When a farm has some of its k neighbours close by and some far away, the long distances will get relatively low weights. When all of a farm's neighbours are far away, again similar weights will be assigned. Using an inverse distance weighted weight matrix, the weight of an additional neighbour is relatively low. Results for other specifications of W_1 are very similar and lead to identical conclusions (Figs. A3–A5), which is in line with LeSage and Pace (2014) who explain that the influence of the choice of the specification of the spatial weight matrix is low.

The elements of the regional spatial weighting matrix W_2 are specified to be $w_{ij} > 0$ if farm j is in the same agricultural region (*landbouwregio's*) (discussed in detail in the next section) as farm i.

4. Farm diversification in the Netherlands and data

We use Dutch agricultural census data for the year 2013, comprising in total 67,481 farms (Statistics Netherlands, 2016). We find that 2820 farms in the census share a location with at least one other farm, for example due

[2] Manski's reflection problem: when the decision-making of neighbours depends on their characteristics, it is not possible to differentiate if the decision-making of a farmer is influenced by the neighbours' decision-making or by their characteristics. Approaches to overcome this problem and separately identify exogenous and endogenous effects mostly use IV estimation. Most importantly, the model and the weight matrix have to be correctly specified (Halleck Vega and Elhorst, 2015), see for example Bramoullé et al. (2009) and Bramoullé et al. (2014). As we here define the weight matrix spatially (instead of eliciting a social network with a survey), we cannot assume to have correctly specified the weight matrix.

to the division of different farm activities in separate enterprises, legal forms or separate farm holdings at the same address. Because no weights can be assigned to links of length zero, multiple farms on the same location are aggregated, leaving a total of 65,976 farms for our analysis. Important for our analysis is that specific questions on diversification activities on the farm are included in the census data. The inclusion of diversification in the census activities was initiated by the taskforce for multi-functional agriculture (Taskforce Multifunctionele Landbouw) that was set up by the Dutch ministry of agriculture, nature and food quality from the year 2008–2012. This taskforce gave temporary governmental support to diversify the agricultural sector by distributing information and setting up networks (Fischer and Ypma, 2012).[3]

We focus our analysis on the five most important diversification activities in the Netherlands in 2013 (in terms of numbers of active farms), these are on-farm sales ('Sales') and on-farm processing ('Processing'), nature conservation ('NatCons'), agri-tourism ('Tourism'), and care farming ('Care') (for definitions see Table A1). While the uptake of on-farm sales and processing, agri-tourism and care farming is not financially supported, farms potentially obtain financial support granted by agri-environmental schemes for the uptake of nature conservation activities (Meraner et al., 2015; Terwan et al., 2016). More specifically, in 2013 (the year of our study), individual farmers who contributed to the national nature conservation policy, could gain financial support[4] (Terwan et al., 2016; Jongeneel and Polman, 2018). Provincial governments designated areas where gains from nature conservation are high from an ecological perspective, more specifically where farmland birds and ecological corridors are present (Terwan et al., 2016) and thus where farmers could obtain financial support for nature conservation activities. However, we do not have data on where farmers could and could not obtain financial support for nature conservation. This spatially correlated omitted variable possibly influences our estimate of spill-over effects for nature conservation, so the size of effects found for nature conservation could exceed the size of true effects. However, most probably, areas eligible for financial support are partially reflected by our variable for landscape attractiveness (i.e. the proximity to nature areas) as well as by the farm type in the neighbourhood capturing at least part of the omitted variable.

We find that as of 2013, 19 % of all Dutch farms are carrying out at least one of the five diversification activities considered in our analysis. On average, 75.5 % of all Dutch farms have at least one out of their ten nearest neighbouring farms doing one or more diversification activities. We complemented the census dataset with spatial data on soil types as well as population density and nature areas (Statistics Netherlands, 2016).

Table 2 presents summary statistics of all variables used (Table A2 provides an overview of variable abbreviations and descriptions) and Table A3 provides summary statistics separately for individual activities. In order to represent the size of the farm, the variable workforce measured in full-time equivalents is included in our analysis. We opted against the farms' acreage as it is influenced by the farm type and against the standard economic output (SO) as it is not accounting for income from diversification activities (van Everdingen, 2015). Yet, diversification might have an influence on the workforce. We conducted a sensitivity analysis and dropped workforce from the estimated model.[5] We use the Dutch classification of *farm types* and consider horticulture ('Hort'), pasture-based livestock ('Past'), arable farming ('Ara'), perennial farming[6] ('Pere') and intensive livestock ('Inte'). A farm is allocated to a farm type if more than 2/3 of income is generated from this activity and is classified as mixed farm if this is not the case for any category (van Everdingen, 2015).

Table 2
Summary statistics.

	All farms (n = 65,976)		No diversification (n = 53,534)		Diversification (any type) (n = 12,442)	
	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev
Age	55.15	11.61	55.53	11.8	53.52	10.63
Workforce	2.43	7.45	2.46	8.15	2.32	2.97
Past	0.54	0.5	0.52	0.5	0.64	0.48
Ara	0.18	0.38	0.19	0.39	0.15	0.36
Hort	0.13	0.34	0.15	0.35	0.08	0.27
Pere	0.03	0.16	0.02	0.14	0.04	0.2
Inte	0.08	0.27	0.09	0.29	0.04	0.19
Mixed	0.05	0.22	0.05	0.21	0.06	0.24
NatCons	0.12	0.32	0	0	0.59	0.49
Tourism	0.04	0.2	0	0	0.22	0.42
Sales	0.05	0.21	0	0	0.25	0.43
Processing	0.02	0.12	0	0	0.08	0.28
Care	0.01	0.11	0	0	0.07	0.26
PopDens	399.9	492.3	402	490	390.7	502.4
AttrLandsc	317.5	30342.8	203.47	23913.6	798.2	48898.2
Clay	0.35	0.48	0.34	0.47	0.4	0.49
Sands	0.5	0.5	0.52	0.5	0.38	0.49
Peat	0.12	0.33	0.11	0.31	0.16	0.37
Loess	0.02	0.13	0.01	0.11	0.03	0.17
Other soils	0.02	0.15	0.02	0.15	0.02	0.15

We assign all farms a *soil type* and Fig. 1 (left panel) gives an overview of soil types throughout the country. Most of the Dutch farms are located on sand ('Sands') and on clay ('Clay'), which are also the most frequently occurring soil types in the country. Further, 12 % of Dutch farms are located on peat soils ('Peat'). Loess ('Loess') soils are mainly found in the very south of the country. Other soil types in the dataset (water and urban lands) were grouped as 'Others'.

The urban character of the farm's neighbourhood was measured as population density ('PopDense') at the municipal level. We use the population density as an approximation to measure closeness to urban areas. The mean Dutch farm is located in a municipality with 400 inhabitants per square kilometre.

The landscape attractiveness ('AttrLandsc') around a farm was estimated with the Landscape Reilly Index (short: Reilly-index) (e.g. Cotteleer, 2008; Schouten et al., 2013). High scores on the Reilly-index indicate that a farm is close to large nature area such as the national park 'Hoge Veluwe' in the centre of the Netherlands or the dunes along the North Sea (see right panel of Fig. 1, for r = 5 km). Nature areas are defined as areas classified as woods or as open nature and are larger than 10 ha (to exclude very small, single and remote nature areas which do not necessarily contribute to the regional landscape attractiveness). For the Reilly-index, the size of every nature area within a five-kilometre radius around the farm is normalized by the distance from the farm to the nature area. The farm is then assigned a score, which is the sum of all the normalized areas within the radius. The Reilly-index is calculated as follows:

$$R = \sum_{i=1} \sum_{y=1} \frac{\textit{size of nature area y within a radius r of farm i}}{(\textit{shortest distance of firm i to nature area y})^2} \tag{4}$$

Due to the highly skewed distribution and to facilitate the interpretation of the coefficient of the Reilly-index in the regression analysis,[7] a logarithmic transformation is applied (Table A4).

We use the agricultural regions (*landbouwregio's*) (Fig. 2) to specify the regional spatial weighting matrices W_2 in our model. The institute 'Wageningen Economic Research' defined these regions based on soil

[3] After 2012, the Dutch agriculture and horticulture organisation (*Land- en Tuinbouw Organisatie Nederland*, LTO) took over the information distribution tasks of the Taskforce.

[4] In 2016, the Dutch government switched to a system in which only farmer collective actions are supported (Terwan et al., 2016).

[5] Estimating the model without workforce, we find no changes in the sign and significance of the other reported variables.

[6] Includes wine farms, fruit growers and other perennial farming types (van Everdingen, 2015).

[7] This reduces the role of extreme observations and relative instead of absolute impacts of increases in landscape attractiveness are gained.

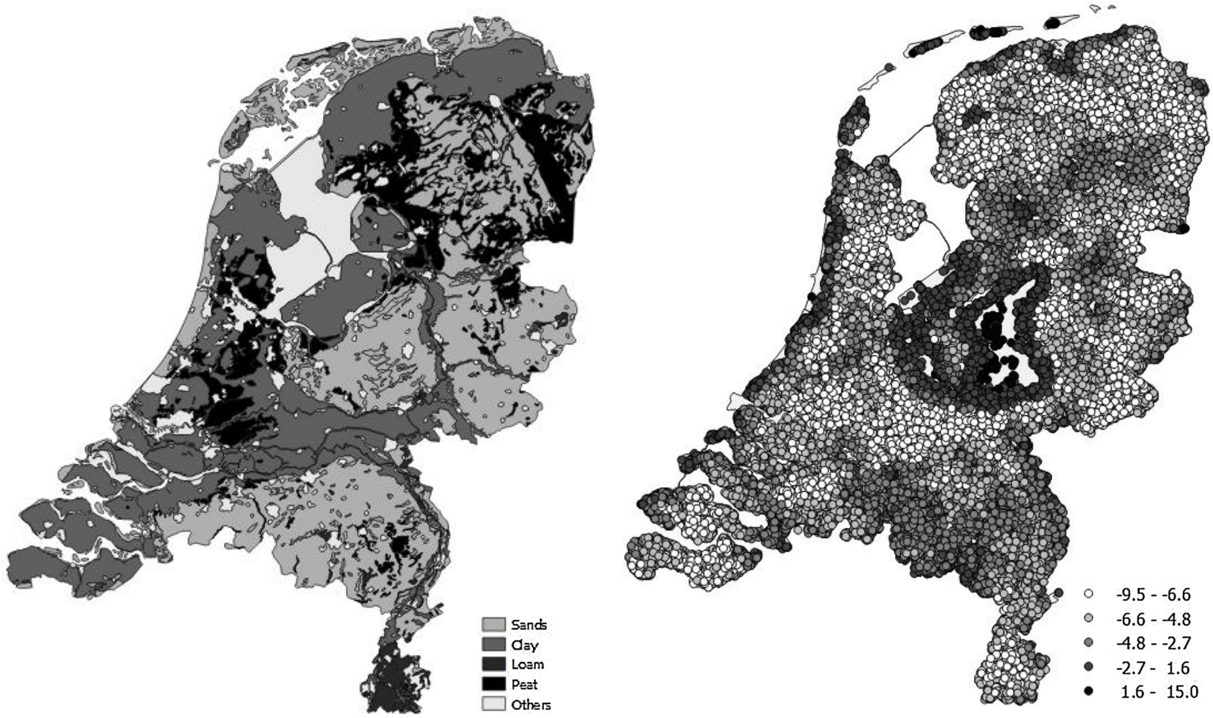

Fig. 1. Soil types in the Netherlands (left) and logarithmic Reilley-index scores of Dutch farms (right).

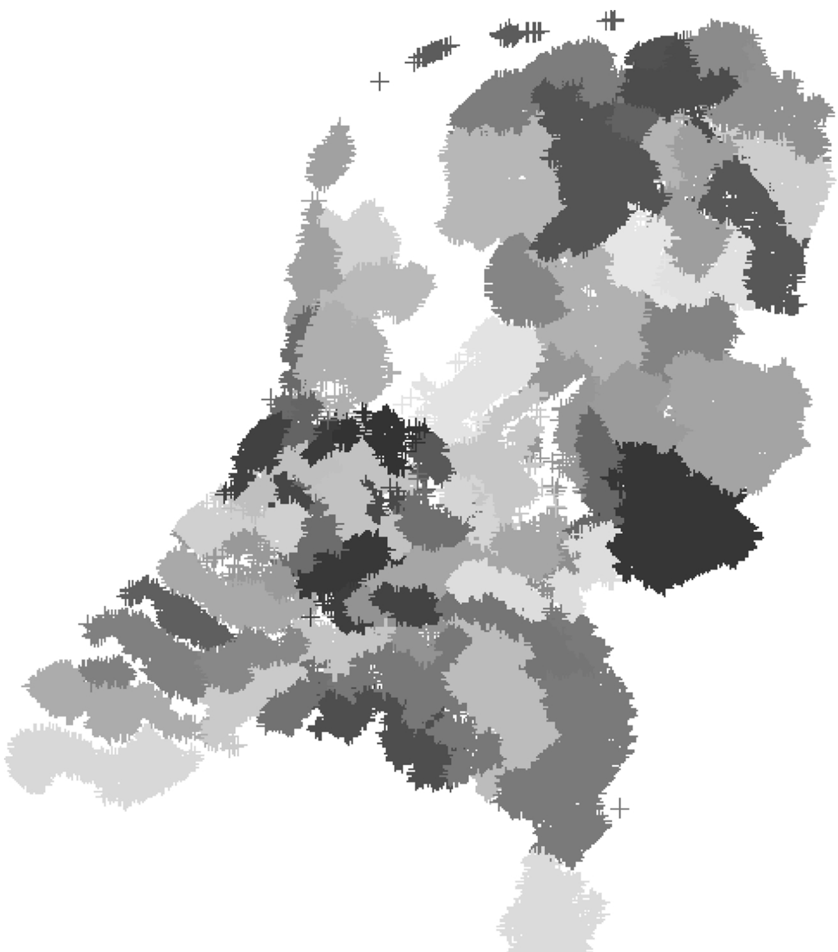

Fig. 2. 66 agricultural regions in the Netherlands (based on Wageningen Economic Research).

type, agricultural practices such as crop specification and on administrative boundaries. By definition there is an overlap between the local and regional neighbourhood, however, the number of farms in each region (minimum 71, on average 1000), substantially exceeds the number of farms considered in the local neighbourhood (10).

5. Results and discussion

The coefficients estimated in the probit models cannot be interpreted directly. Therefore, marginal effects are presented (Table 3). For continuous variables, marginal effects are derived at the mean and for dummy variables at a change from zero to one, while keeping all other variables at their means. Estimates of diversification activities are expressed relatively to farms with no diversification activity. Sandy soils are the reference category for soil type and arable farms for the farm type. Where the signs of the spatially lagged coefficients (effects on the local level) equal the sings of the farm-level effects, the presence of similar farms in the neighbourhood contributes to the uptake of diversification and the spill-over effect is positive. In contrast, when the signs of coefficients are opposite at the farm- and local level, farms rather start with diversification when surrounding farms are different. This would indicate the existence of competition for the uptake of a certain diversification activity. Our results show relevant spill-over effects for the adoption of all diversification activities except for care

Table 3
Marginal effects in %.

	Nature Conservation (n = 7371)			Tourism (n = 2772)			On-farm sales (n = 3113)			Processing (n = 1034)			Care farming (n = 868)		
	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value
Farmers' and farm characteristics															
Age	−0.12	0.01	0	−0.04	0.01	0	−0.05	0.01	0	−0.01	0	0	−0.02	0	0
Workforce	0.05	0.01	0	0.01	0.01	0.08	−0.02	0.01	0.08	0.01	0	0	0.01	0	0.05
Past	1.8	0.3	0	1.03	0.2	0	−2.3	0.22	0	−0.13	0.08	0.11	1.13	0.13	0
Hort	−7.78	0.23	0	−1.65	0.22	0	4.57	0.46	0	−0.14	0.09	0.1	0.35	0.23	0.12
Inte	−4.27	0.34	0	−1.86	0.21	0	0.33	0.3	0.28	−0.38	0.07	0	1.06	0.32	0
Pere	−5.26	0.35	0	0.77	0.52	0.14	13.64	1.17	0	0.52	0.21	0.01	0.6	0.39	0.12
Mix	1.21	0.57	0.03	0.28	0.34	0.41	4.05	0.5	0	0.18	0.13	0.17	2.4	0.48	0
NatCons	–			2.76	0.3	0	2.43	0.32	0	0.37	0.11	0	0.86	0.16	0
Tourism	6.02	0.64	0	–			7.51	0.61	0	2.04	0.27	0	3.67	0.39	0
Sale	5.7	0.72	0	7.67	0.62	0	–			15.47	0.74	0	2.5	0.35	0
Processing	2.63	0.94	0.01	7.65	0.94	0	49.35	1.73	0	–			0.48	0.26	0.07
Care	6.31	1.1	0	12.23	1.18	0	7.76	1.05	0	0.59	0.24	0.01	–		
Neighbourhood characteristics															
LocAge	−0.05	0.02	0.02	0	0.01	0.95	0.03	0.01	0.03	−0.01	0.01	0.23	0	0.01	0.77
LocWorkforce	−0.05	0.05	0.4	−0.06	0.04	0.11	−0.01	0.02	0.67	0	0.01	0.61	0	0.01	0.91
LocPast	6.01	0.66	0	0.07	0.43	0.88	0.08	0.41	0.84	0.02	0.16	0.91	0.07	0.23	0.75
LocHort	−4.1	1.01	0	−0.83	0.58	0.16	−1.33	0.5	0.01	−0.06	0.2	0.75	−0.41	0.3	0.17
LocInte	−3.36	1.17	0	−0.81	0.68	0.23	−0.98	0.65	0.13	0.37	0.26	0.16	0	0.35	1
LocPere	0.5	1.45	0.73	−7.11	1.04	0	−0.01	0.74	0.99	−0.61	0.32	0.05	−0.17	0.5	0.74
LocMix	1.42	1.32	0.28	0.59	0.77	0.45	0.71	0.73	0.33	0.20	0.29	0.49	−0.19	0.44	0.65
LocNatCons	–			0.07	0.44	0.87	−1.52	0.48	0	0.08	0.17	0.65	−0.21	0.22	0.34
LocTourism	1.93	1.08	0.08	–			0.48	0.7	0.49	−0.12	0.27	0.65	−0.34	0.39	0.38
LocSale	−0.84	1.31	0.52	1.68	0.79	0.03	–			0.52	0.26	0.05	0.45	0.41	0.27
LocProcessing	1.88	2.01	0.35	0.73	1.27	0.57	2.19	1.13	0.05	–			0.01	0.68	0.99
LocCare	2.52	2.02	0.21	0.93	1.38	0.5	1.36	1.38	0.32	−0.03	0.54	0.96	–		
Socio-economic and physical environment															
LogPopDens	−0.5	0.16	0	−0.28	0.11	0.01	0.44	0.1	0	0	0.04	0.93	0.15	0.05	0
LogAttrLandsc	0.2	0.05	0	0.39	0.03	0	−0.03	0.03	0.26	0	0.01	0.8	−0.01	0.02	0.37
Clay	3.67	0.33	0	−0.98	0.19	0	0.2	0.2	0.33	0.18	0.08	0.04	−0.18	0.1	0.07
Peat	5.26	0.44	0	−0.94	0.2	0	−0.56	0.22	0.01	0.16	0.11	0.14	−0.03	0.11	0.83
Loam	17.69	1.73	0	−0.76	0.43	0.08	0.57	0.58	0.33	−0.04	0.21	0.83	−0.34	0.21	0.1
Other soils	0.89	0.82	0.28	0.3	0.48	0.53	0.45	0.48	0.35	−0.06	0.17	0.71	0.49	0.3	0.1
RegAge	−0.4	0.14	0	0.52	0.09	0	0.35	0.09	0	−0.05	0.04	0.14	0.06	0.05	0.21
RegWorkforce	0.32	0.23	0.16	−0.11	0.14	0.45	−0.21	0.1	0.04	−0.08	0.04	0.03	0.09	0.06	0.14
RegPast	7.87	1.61	0	1.86	1.02	0.07	−0.55	0.96	0.57	−0.79	0.38	0.04	−0.45	0.54	0.4
RegHort	−3.14	2.13	0.14	3.13	1.27	0.01	0.86	1.06	0.42	0.52	0.43	0.22	−0.67	0.65	0.3
RegInte	−23.37	2.59	0	0.54	1.57	0.73	−1.47	1.53	0.33	−1	0.64	0.12	−0.29	0.81	0.72
RegPere	−8.57	3.3	0.01	5.83	2.09	0.01	−3.27	1.85	0.08	0.51	0.78	0.51	0.33	1.1	0.76
RegMix	−58.63	10.73	0	18.13	6.23	0	16.14	5.7	0	−1.23	2.48	0.62	−2.36	3.4	0.49
RegNatCons	–			−1.71	1.12	0.13	1.48	1.2	0.22	0.91	0.46	0.05	−0.08	0.59	0.89
RegTourism	21.14	4.73	0	–			−1.63	3.11	0.6	0.89	1.15	0.44	−3.68	1.88	0.05
RegSale	52.33	10.19	0	14.65	6.27	0.02	–			−4.39	2.39	0.07	1.39	3.3	0.67
RegProcessing	84.77	13.2	0	48.22	9.43	0	−23.91	9.76	0.01	–			3.02	4.97	0.54
RegCare	5.25	18.36	0.77	−16.8	14.37	0.24	14.79	14.05	0.29	6.76	5.07	0.18	–		

See Table A2 for an overview of abbreviations and variable descriptions.

farming.[8] Additionally, our results indicate that socio-economic and physical conditions on a regional scale are important. Results for local effects do not differ when including regional dummy variables or regional farm characteristics (Table A5).

5.1. Farmers' and farm characteristics

Our results on the effects of farmers’ and farm own characteristics on the uptake of farm diversification are largely in line with findings from earlier literature. We for example find that younger farmers engage more in diversification activities (Jongeneel et al., 2008; Barbieri and Mahoney, 2009; Meraner et al., 2015; Weltin et al., 2017). Compared to earlier studies on diversification in Dutch agriculture, the direct effect of the workforce on diversification is relatively small (Jongeneel et al., 2008; Pfeifer et al., 2009; Meraner et al., 2015). Using arable farming as reference category, we find that the effect of farm types differs strongly across diversification activities. Additionally, we find that a farm’s probability to start any diversification activity is greater when it is already conducting another diversification activity, independent of the type of activity. The largest interdependences are found between on-farm sales and on-farm processing. More specifically, our results indicate that half of the farmers with on-farm sales activities additionally engage in processing activities. In reverse, we find that farmers that engage in on-farm processing are very likely to also have on-farm sales activities. This hints towards positive synergies between these two. Our results also show similar positive interdependencies between agri-tourism and care farms. Farmers that are already used to people from outside to come to the farm and are already including a hospitality aspect in their diversification activity are more likely to expand that. Nature conservation farms are also more likely to start a second activity but no activity clearly stands out most.

5.2. Insights in spill-over effects

We find spill-over effects within the farm’s neighbourhood. Agri-tourism activities are often taken up by young farmers at diversified arable and pasture-based livestock farms, who are located in a neighbourhood with farms with these same characteristics. This could mean that there is a certain level of cooperation between farms with agri-tourism activities at the local level. Furthermore, agri-tourism activities are less favoured if there are perennial, intensive livestock and horticultural farms neighbouring. Thus, it is possible that the attractiveness of the neighbourhood is not only dependent on the attractiveness of nature areas, but also on the attractiveness of the surrounding farm types. Moreover, we find agri-tourism activities more likely to occur in neighbourhoods with on-farm sales activities. This can be explained by the importance of other activities (tourists who sleep at farms might also buy products at farms and vice versa) (Fischer and Ypma, 2012; van der Meulen et al., 2014).

Our results show that having older neighbours only has a (negative) influence on the uptake of nature conservation. The negative impacts of having older neighbours on the uptake of nature conservation supports findings of Home et al. (2014), who mention that older neighbours can decrease the local social acceptance of a new activity in a neighbourhood, leading to lower adoption. More generally, the uptake of nature conservation is more likely when surrounding farmers and farms are similar, i.e. when young neighbours have pasture-based livestock farms. This is probably a result of the governmental selection of designated areas for nature conservation (Terwan et al., 2016), which go beyond the scale of a single farm. More specifically, a nature conserving farm is more likely to be situated in a selected area when neighbours are also suitable for nature conservation. From the five activities, estimated spill-over effects are the largest for nature conservation. However, estimated spill-over effects could be upwards biased by the spatially dependent availability of financial support, for which we cannot fully account.

Regarding on-farm sales, we find that neighbours with nature conservation are associated with a lower uptake of on-farm sales. This could result from lower accessibility of farms surrounded by farms with extensive land. Moreover, on-farm sales is less likely to emerge in neighbourhoods with horticultural and intensive livestock farms. More generally, we find that many coefficients have opposite signs for the local compared to the farm level for the emergence of on-farm sales. This could indicate that there is competition between farm shops. For example, while on-farm sales is taken up by younger farmers, it is advantageous to be located in a neighbourhood where other farmers are older. Yet, for on-farm sales, we find that the effects of mixed farms (positive) and workforce (negative) have the same signs at the farm and the local level. Farmers with a farm shop might not only sell their own products, but also local products produced by their neighbours. The presence of other mixed farms could contribute to a larger diversity of products to sell. Moreover, local on-farm sales networks have been setup by the Taskforce of the Dutch government (Fischer and Ypma, 2012), which could have contributed to a certain level of cooperation between on-sale farms. Additionally, we find positive correlations between on-farm sales and processing farms. Neighbours with on-farm processing activities increase the probability of a farm to start with on-farm sales more than vice versa. It is possible that both activities can profit from the same cooperations as for example local brands. Our results reveal no significant spill-over effects for care farms. However, our results show that the presence of surrounding care farms has positive indirect effects on the uptake of other diversification activities.

5.3. Socio-economic and physical environment

Our results show that a farms’ socio-economic and physical environment also matters in the adoption of diversification activities. In general, the level of diversification in the region influences the probability of a farm to diversify. For example, in regions with higher shares of agri-tourism, sales and processing activities, farms have a higher likelihood of taking up nature conservation. Moreover, higher regional shares of on-farm sales and processing activities are beneficial for the uptake of agri-tourism. We, however, find negative correlations between on farm-sales and processing on a regional level. This indicates that while there seems to be cooperation between on-farm sales and processing on a local level, there may be competition on a higher spatial level. Additionally, for agri-tourism, we find opposite coefficient signs on the local and on the regional level. While cooperation between agri-tourism farms seems to exist within the neighbourhood, competition may be present at the regional level.

The average age of farmers in the region has ambiguous effects on the uptake of diversification. While a lower average age of farmers in the region has positive effects on the uptake of nature conservation, having young farmers in the region decreases the chance of uptake of agri-tourism and on-farm sales. Moreover, agri-tourism and on-farm sales emerge in regions with smaller farms. Furthermore, the main farm type in the region matters for the uptake of diversification. We find that the presence of pasture-based livestock farms is important for nature conservation. Moreover, agri-tourism is less likely to emerge in regions with arable and intensive livestock farms and on-farm sales is mostly present with mixed farms in the region.

In line with earlier findings, our results indicate that on-farm sales and care farming activities are more likely to emerge in densely populated areas. These activities profit from larger markets and smaller distances to customers. Furthermore, we find that nature conservation and agri-tourism are more often found in less populated areas (Ilbery, 1991; Pfeifer et al., 2009; Zasada et al., 2011; Meraner et al., 2015).

[8] Note that regional variables have comparably high coefficients because a small change in the average at the regional level implies a change that is going on at many farms.

Additionally, we find that landscape attractiveness increases the likelihood to start with these two activities, but we find no significant effect on the adoption of other activities. These results confirm findings by Pfeifer et al. (2009) that attractive landscapes contribute to the emergence of agri-tourism and nature conservation activities. Especially providing agri-tourism activities is profitable when people are attracted by the landscape (Pfeifer et al., 2009). For nature conservation, however, this correlation could result from the financial support available for nature conservation for farms located close to nature areas. Furthermore, we find that loess soils are positively correlated with the adoption of nature conservation if compared to sandy soils (the reference category). Nature conservation also occurs more often on farms located on peat soils, reflecting that nature conservation emerges more often on less productive soils where opportunity costs are lower (Pfeifer et al., 2009). In contrast, peat soils are negatively correlated with agri-tourism and on-farm sales. Our results reveal that farms located on sandy soils are rather not starting with nature conservation activities, but are most likely to engage in agri-tourism activities. Farmers on clay soils are slightly more likely to start with on-farm processing.

6. Conclusion

We analyse the uptake of farm diversification in the Netherlands using a spatial regression framework. Our results show that neighbourhood and regional effects are important in the emergence of agricultural farm diversification. Spill-over effects are found to be especially important for nature conservation and agri-tourism.

The identified spill-over effects might affect the effectiveness of support programs, as the characteristics and diversification decision of a farmer seem to influence the decision-making of its neighbours. Thus, policies that aim to develop rural areas and foster nature conservation are more efficient if accounting for spill-overs and designing policies beyond the level of single farms. Diversification promotes not only income diversification of single farms, but also creates economic opportunities for farms in the neighbourhood. Thus, policies focusing on the development of certain regional hotspots of diversification activities are affected by and lead to significant spill-over effects. Not accounting for spill-over effects across farms could result in an incorrect estimation of the costs required to establish successful farm diversification patterns. We conclude that cooperation plays an important role for farm diversification. Diversified farms contribute to the attractiveness of regions, which increases the benefit of diversification for other farms in the neighbourhood. Moreover, diversified farms reduce the information costs for other farms in the neighbourhood, easing the uptake of diversification on other farms. This implies that the creation of local brands can exploit the potential of spill-over effects across diversifying farms. However, our results also indicate that competition is an important component in the emergence of diversification activities. For example, competition at the regional level constrains the uptake of agri-tourism, on-farm sales and on-farm processing.

Future research should investigate the size and structure of local social networks to better understand spill-over effects. We suggest that a definition of networks based on activities and interactions of farmers will allow to better capture spill-over effects, for example by accounting for farmers' participation in local collaborations, cooperatives or associations. A social network analysis for example could also account for spatial borders (such as rivers and mountains), farm accessibility and the influence of opinion leaders. Moreover, an investigation of the spatial development of diversification over time, i.e. panel data, would support further research on interactions between farms. Future research would also benefit from more general indices for landscape attractiveness also accounting for the attractiveness of dominant farm types in the region. In addition, with increasing importance of diversification activities, there is a need for the assessment of an additional type of an economic size variable, i.e. one which includes standardized outputs from diversified activities. We focused on the analysis of specific diversification decisions and estimated spill-over effects for each activity separately. Further research should include a binary first step in a double hurdle framework, where a farm-level diversification decision precedes the analysis of the specific interrelated activities to gain a more holistic picture.

CRediT authorship contribution statement

Willemijn Vroege: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Visualization, Validation, Writing - original draft, Project administration. **Manuela Meraner:** Conceptualization, Writing - review & editing. **Nico Polman:** Conceptualization, Investigation, Resources, Writing - review & editing. **Hugo Storm:** Conceptualization, Methodology, Writing - review & editing. **Wim Heijman:** Conceptualization, Writing - review & editing. **Robert Finger:** Conceptualization, Methodology, Resources, Writing - review & editing.

Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A

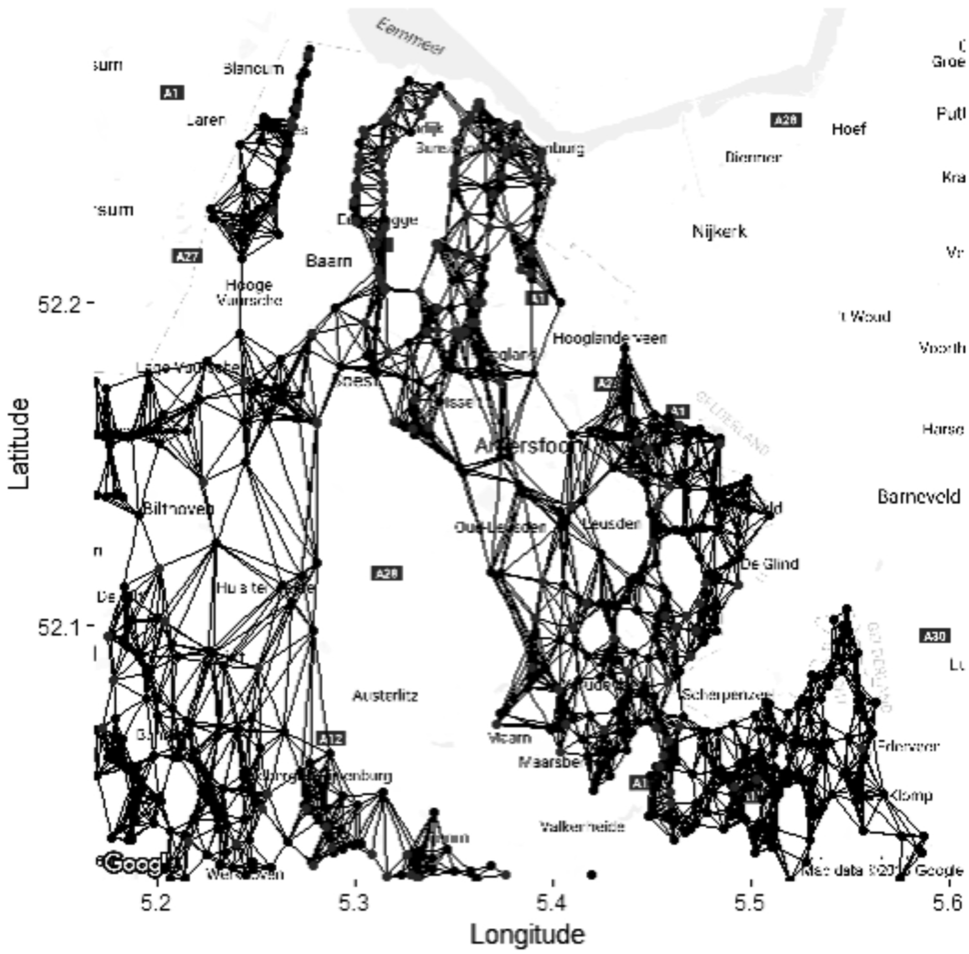

Fig. A1. 10 nearest neighbours network Province Utrecht.

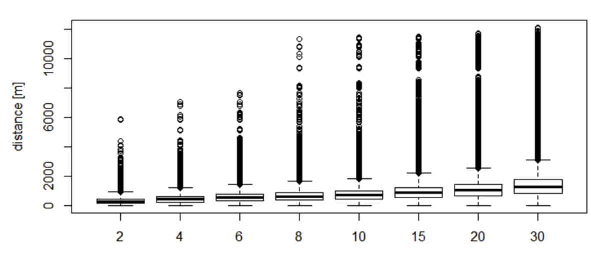

Fig. A2. Distances to neighbours for different k's[1].

[1]The isolated farm on the Island Vlieland in the North Sea is excluded as it has no neighbours within a comparable distance.

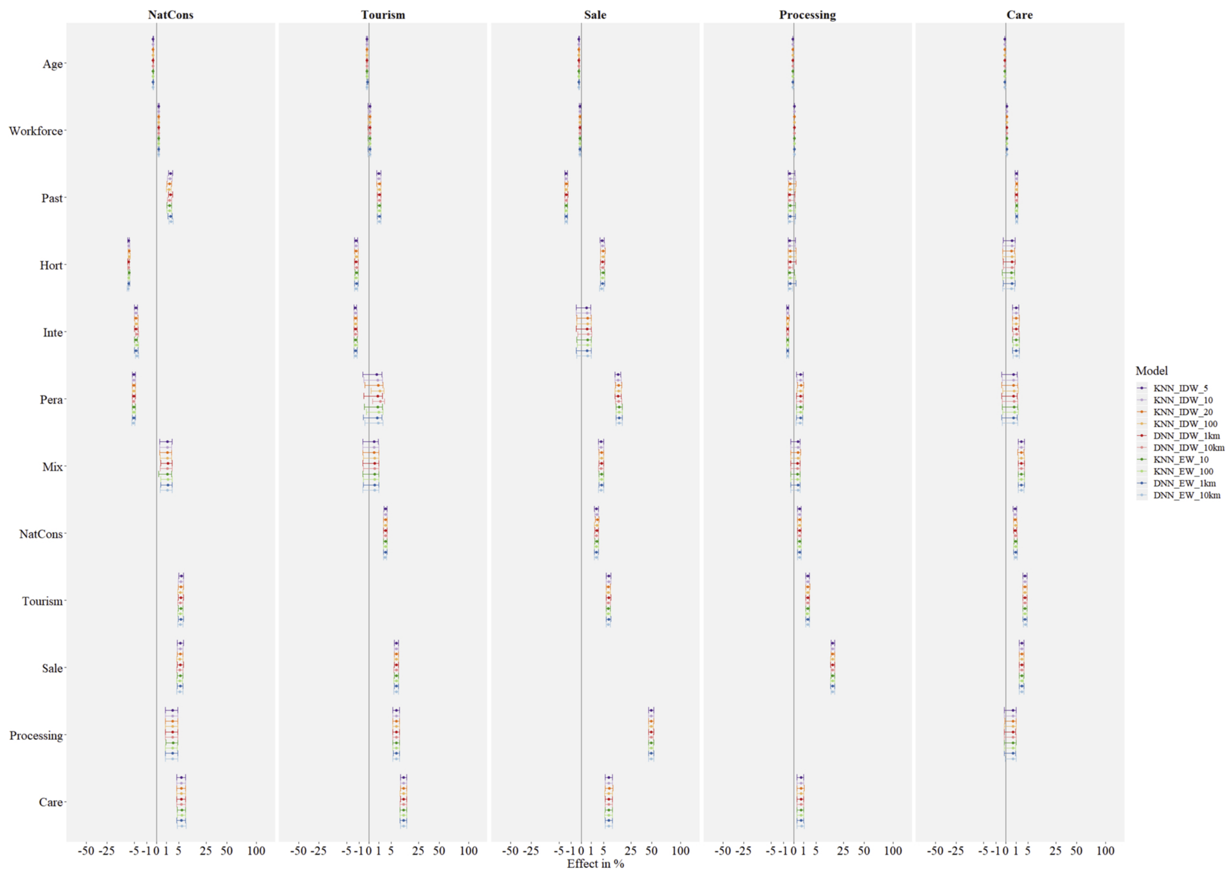

Fig. A3. Coefficient plot of farm and farmer characteristics. Mean and 95 % confidence interval of effects with ten different spatial weight matrix specification. Results are highly robust. The following models are ordered top down.
k nearest neighbours, inverse distance weighted, 5 neighbours (KNN_IDW_5),
k nearest neighbours, inverse distance weighted, 10 neighbours (KNN_IDW_10),
k nearest neighbours, inverse distance weighted, 20 neighbours (KNN_IDW_20),
k nearest neighbours, inverse distance weighted, 100 neighbours (KNN_IDW_100),
distance based neighbours, inverse distance weighted, 1km radius (DNN_IDW_1km),
distance based neighbours, inverse distance weighted, 10km radius (DNN_IDW_10km),
k nearest neighbours, equally weighted, 10 neighbours (KNN_EW_10),
k nearest neighbours, equally weighted, 100 neighbours (KNN_EW_100),
distance based neighbours, equally weighted, 1km radius (DNN_IDW_1km),
distance based neighbours, equally weighted, 10km radius (DNN_IDW_10km).

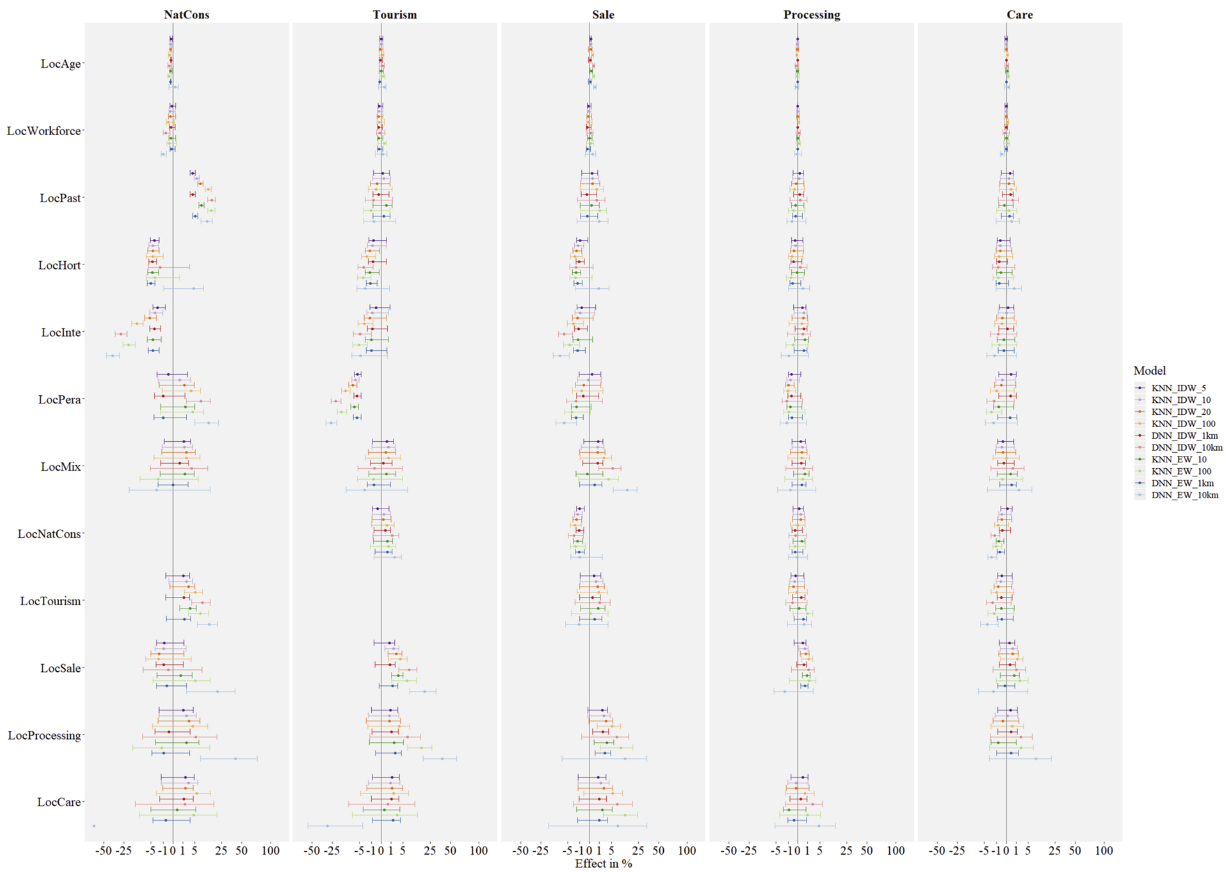

Fig. A4. Coefficient plot neighbourhood characteristics. Mean and 95 % confidence interval of effects with ten different spatial weight matrix specification. Results are highly robust. For model descriptions see Fig. A1.

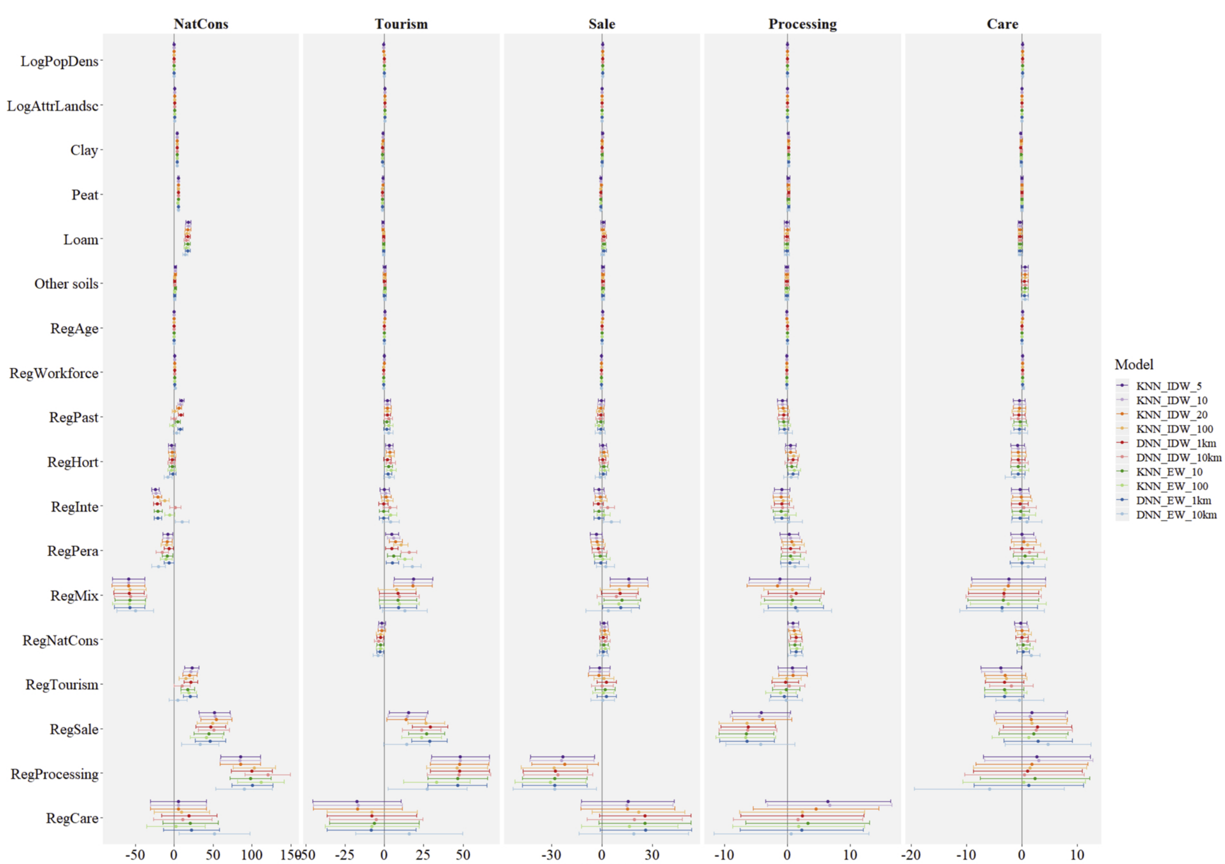

Fig. A5. Coefficient plot socio-economic and physical environment. Mean and 95 % confidence interval of effects with ten different spatial weight matrix specification. Results are highly robust. For model descriptions see Fig. A1.

Table A1
Definitions of diversification activities.

Activity	Definition
Nature conservation	Conservation of nature on the farm area, for example a flower strip at a field border
Tourism	Offer recreational services with daily and/or accommodational purposes, for example farmer golf, horse riding, bed and breakfast or camping sites
On-farm sales	Direct sale of agricultural products to consumers, catering and hotels
On-farm processing	Processing of agricultural products on the farm, for example cheese, butter, wine or jam
Care farming	Offer care services to different target groups, for example daily activities or farm residence

Adapted from Van der Meulen et al. (2014) and Meraner et al. (2015).

Table A2
Variable overview.

Abbreviation	Description
Age	Age of farm manager in years
Workforce	Workforce in full-time equivalents (farm size)
Past	Pasture-based livestock farm
Ara	Arable farm
Hort	Horticultural farm
Pere	Perennial farm
Inte	Intensive livestock farm
Mix	Mixed farm
NatCons	Nature Conservation
Tourism	Agri-tourism
Sale	On-farm sales
Processing	On-farm processing
Care	Care farming
LocAge	Average age of farm managers in the neighbourhood
LocWorkforce	Average farm size in the neighbourhood in full-time equivalents
LocPast	Share of pasture-based livestock farms in the neighbourhood
LocAra	Share of arable farms in the neighbourhood
LocHort	Share of horticultural farms in the neighbourhood
LocInte	Share of intensive livestock farms in the neighbourhood
LocPere	Share of perennial farms in the neighbourhood
LocMix	Share of mixed farms in the neighbourhood
LocNatCons	Share of farms in the neighbourhood with the activity nature conservation
LocTourism	Share of farms in the neighbourhood with the activity agri-tourism
LocSale	Share of farms in the neighbourhood with the activity on-farm sales
LocProcessing	Share of farms in the neighbourhood with the activity on-farm processing
LocCare	Share of farms in the neighbourhood with the activity care farming
PopDens	Closeness to urban areas measured as population density of the municipality, logarithmic scale
AttrLandsc	Landscape attractiveness estimated with Landscape Reilly Index: Total size of nature areas (> 10ha) within a five-kilometre radius around the farm, normalized by the distance from the farm to each nature area, logarithmic scale
Clay	Clay soil
Sands	Sandy soil
Peat	Peat soil
Loam	Loam soil
Other soils	Other soils
RegAge	Average age of farm managers in the agricultural region
RegWorkforce	Average farm size in the agricultural region in full-time equivalents
RegPast	Share of pasture-based livestock farms in the agricultural region
RegAra	Share of arable farms in the agricultural region
RegHort	Share of horticultural farms in the agricultural region
RegInte	Share of intensive livestock farms in the agricultural region
RegPere	Share of perennial farms in the agricultural region
RegMix	Share of mixed farms in the agricultural region
RegNatCons	Share of farms in the agricultural region with the activity nature conservation
RegTourism	Share of farms in the agricultural region with the activity agri-tourism
RegSale	Share of farms in the agricultural region with the activity on-farm sales
RegProcessing	Share of farms in the agricultural region with the activity on-farm processing
RegCare	Share of farms in the agricultural region with the activity care farming

Table A3
Summary statistics for specific activities.

	Nature Conservation		Tourism (n = 2’772)		Sale (n = 3’113)		Processing (n = 1’034)		Care (n = 868)	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev
Age	53.74	10.92	53.52	10.26	52.62	10.09	51.66	9.77	51.74	9.07
Workforce	1.95	1.49	2.36	2.63	3.12	4.53	3.63	4.59	2.78	2.66
Past	0.79	0.41	0.64	0.48	0.3	0.46	0.44	0.5	0.7	0.46
Ara	0.13	0.34	0.17	0.37	0.16	0.37	0.17	0.38	0.05	0.22
Hort	0.01	0.11	0.07	0.25	0.23	0.42	0.15	0.36	0.07	0.26
Inte	0.02	0.15	0.03	0.18	0.07	0.25	0.03	0.18	0.06	0.24
Pere	0.01	0.1	0.04	0.2	0.13	0.34	0.12	0.32	0.03	0.17
Mix	0.04	0.2	0.07	0.25	0.12	0.32	0.11	0.31	0.09	0.29
NatCons	1	0	0.23	0.42	0.16	0.37	0.23	0.42	0.26	0.44
Tourism	0.09	0.28	1	0	0.17	0.38	0.27	0.44	0.24	0.43
Sales	0.07	0.25	0.19	0.39	1	0	0.65	0.48	0.21	0.41
Processing	0.03	0.17	0.1	0.30	0.21	0.41	1	0	0.09	0.29
Care	0.03	0.17	0.08	0.27	0.06	0.24	0.08	0.27	1	0
LogPopDense	5.54	0.76	5.59	0.83	5.73	0.82	5.68	0.83	5.73	0.86
LogAttrLandsc	−4.9	2.42	−4.18	2.81	−4.74	2.30	−4.63	2.39	−4.94	2.17
Sands	0.32	0.46	0.5	0.5	0.43	0.5	0.38	0.49	0.49	0.5
Clays	0.41	0.49	0.34	0.47	0.42	0.49	0.45	0.5	0.32	0.47
Peat	0.22	0.42	0.1	0.3	0.08	0.28	0.12	0.32	0.14	0.35
Loess	0.03	0.18	0.03	0.17	0.04	0.19	0.03	0.16	0.02	0.13
Others	0.02	0.13	0.03	0.17	0.03	0.17	0.03	0.16	0.04	0.2

Table A4
Overview of Reilley-index statistics.

	Total number	Median	Median absolute deviation
All farms	65,976	0.00488	0.00605
Non-diversified farms	53,535	0.00495	0.00615
Diversified farms	12,442	0.00455	0.00554
NatCons	7371	0.00383	0.00444
Tourism	2772	0.00788	0.0105
Sales	3113	0.00524	0.00652
Processing	1034	0.00518	0.00642
Care	868	0.00411	0.00487

Table A5
Marginal effects in % with regions as dummy variables.

	Nature Conservation (n = 7’371)			Tourism (n = 2’772)			On-farm sales (n = 3’113)			Processing (n = 1’034)			Care farming (n = 868)		
	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value
Farmers' and farm characteristics															
Age	−0.12	0.01	0	−0.04	0.01	0	−0.05	0.01	0	−0.01	0	0	−0.02	0	0
Workforce	0.05	0.01	0	0.01	0.01	0.08	−0.02	0.01	0.09	0.01	0	0	0.01	0	0.06
Past	1.72	0.3	0	1.04	0.2	0	−2.24	0.21	0	−0.13	0.07	0.09	1.09	0.19	0
Hort	−7.65	0.23	0	−1.57	0.22	0	4.39	0.44	0	−0.13	0.07	0.08	0.35	0.22	0.12
Inte	−4.27	0.32	0	−1.82	0.21	0	0.33	0.3	0.27	−0.33	0.06	0	1.01	0.33	0
Pere	−5.2	0.33	0	0.75	0.52	0.15	13.39	1.15	0	0.46	0.19	0.02	0.52	0.37	0.16
Mix	1.01	0.55	0.07	0.31	0.34	0.36	3.99	0.49	0	0.15	0.12	0.21	2.33	0.54	0
NatCons	–			2.73	0.3	0	2.34	0.31	0	0.34	0.1	0	0.82	0.18	0
Tourism	6.17	0.64	0	–			7.41	0.6	0	1.85	0.25	0	3.6	0.56	0
Sale	5.65	0.72	0	7.7	0.62	0	–			14.98	0.73	0	2.44	0.45	0
Processing	2.58	0.93	0.01	7.78	0.95	0	49.45	1.73	0	–			0.47	0.26	0.07
Care	6.13	1.09	0	12.23	1.18	0	7.9	1.05	0	0.56	0.23	0.01	–		
Neighbourhood characteristics															
LocAge	−0.07	0.02	0	0	0.01	0.76	0.03	0.01	0.02	−0.01	0	0.2	0	0.01	0.52
LocWorkforce	−0.04	0.05	0.48	−0.06	0.04	0.1	−0.01	0.02	0.8	0	0.01	0.64	0	0.01	0.99
LocPast	5.42	0.66	0	−0.19	0.43	0.66	0.17	0.40	0.67	−0.02	0.15	0.91	0.09	0.22	0.67
LocHort	−4.90	1	0	−0.51	0.58	0.38	−1.26	0.49	0.01	−0.1	0.17	0.57	−0.35	0.29	0.23
LocInte	−4.17	1.14	0	−0.77	0.67	0.25	−0.96	0.64	0.14	0.26	0.23	0.27	−0.01	0.33	0.98
LocPere	0.52	1.43	0.72	−7.66	1.03	0	0.11	0.73	0.88	−0.59	0.28	0.03	−0.26	0.48	0.58
LocMix	1.1	1.3	0.39	0.59	0.77	0.45	0.69	0.72	0.34	0.13	0.26	0.63	−0.2	0.42	0.63
LocNatCons	–			−0.02	0.44	0.96	−1.66	0.47	0	0.03	0.16	0.83	−0.22	0.21	0.31
LocTourism	1.79	1.07	0.1	–			0.33	0.69	0.63	−0.14	0.25	0.57	−0.37	0.37	0.33

(*continued on next page*)

Table A5 (*continued*)

	Nature Conservation (n = 7′371)			Tourism (n = 2′772)			On-farm sales (n = 3′113)			Processing (n = 1′034)			Care farming (n = 868)		
	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value
LocSale	−1.54	1.3	0.23	1.66	0.78	0.03	–			0.47	0.24	0.05	0.51	0.4	0.21
LocProcessing	1.7	2	0.4	0.87	1.27	0.5	2.25	1.12	0.04	–			0.1	0.65	0.88
LocCare	1.9	2	0.34	1.35	1.35	0.32	1.77	1.35	0.19	−0.19	0.49	0.7	–		
Regional dummies															
Achterhoek	−5.84	0.46	0	1.67	1.48	0.26	0.43	0.39	0.97	−0.04	0.4	0.93	−0.56	0.2	0
Alblasserwaard en Vijfherenlanden	2.03	1.61	0.21	−0.61	1	0.54	−0.33	0.54	0.7	0.68	0.91	0.46	−0.15	0.35	0.67
Amstelland en Aalsmeer	−1.51	1.92	0.43	2.16	2.38	0.36	0.79	0.87	0.43	0	0.58	0.99	0.28	0.74	0.71
Biesbosch	−5.62	0.72	0	1.11	2.3	0.63	0.7	1.44	0.88	0.65	1.2	0.59	−0.55	0.37	0.14
Bollenstreek	−0.80	1.71	0.64	2.06	2.01	0.31	0.63	0.61	0.27	1.21	1.32	0.36	−0.38	0.33	0.25
Bommelerwaard	−4.54	0.79	0	−0.78	1.15	0.5	−0.39	0.58	0.39	0.46	0.83	0.58	−0.36	0.32	0.26
Boskoop en Rijneveld	−1.56	1.64	0.34	0.76	1.72	0.66	0.5	1.13	0.69	0.19	0.66	0.77	−0.55	0.26	0.04
Centraal Tuinbouwgebied in Utrecht	−5.87	0.75	0	−0.86	1.97	0.66	−0.57	1.3	0.34	−0.34	0.35	0.33	−0.59	0.37	0.11
Centraal Weidegebied in Groningen	0.2	1.41	0.89	−1.21	0.85	0.15	−0.18	0.13	0.64	0.17	0.6	0.78	−0.48	0.23	0.04
De Kempen	−6.86	0.23	0	1.85	1.64	0.26	0.48	0.42	0.88	−0.15	0.33	0.64	−0.54	0.2	0.01
De Marne	−0.07	1.91	0.97	−0.48	1.51	0.75	−0.36	1.13	0.79	0.65	1.11	0.56	−0.73	0.19	0
De Wouden	0.38	1.29	0.77	−1.29	0.74	0.08	−0.11	0.06	0.39	−0.12	0.35	0.74	−0.58	0.18	0
Drentse Veenkoloniën en Hondsrug	−6.15	0.34	0	0.23	1.28	0.86	0.2	1.09	0.94	−0.19	0.32	0.55	−0.25	0.33	0.45
Eemland	4.16	2.24	0.06	0.6	1.6	0.71	0.42	1.13	0.41	−0.16	0.4	0.69	−0.35	0.33	0.3
Eilanden	26.29	5.57	0	19.14	5.81	0	0.02	0.01	0.64	0.14	0.74	0.85	−0.84	0.04	0
Goeree-Overflakkee	−6.81	0.23	0	2.69	2.21	0.22	0.6	0.5	0.7	0.99	1.2	0.41	−0.17	0.46	0.71
Groninger zuidelijk Westerkwartier	0.15	1.43	0.91	−1.26	0.86	0.14	−0.18	0.12	0.73	0.15	0.6	0.81	−0.59	0.19	0
Haarlemmermeer	−6.49	0.42	0	0.92	1.89	0.63	0.57	1.18	0.42	0.56	0.96	0.56	0.29	0.74	0.69
IJsselstreek	−3.86	0.8	0	1.8	1.77	0.31	0.56	0.55	0.79	−0.07	0.44	0.87	−0.64	0.18	0
Kennemerland	−3.37	1.23	0.01	6.49	3.29	0.05	0.32	0.16	0.29	−0.37	0.21	0.08	−0.56	0.27	0.04
Krimpenerwaard en Oostelijk Rijnland	3.63	1.85	0.05	−0.8	0.96	0.41	−0.33	0.39	0.41	2.57	2.01	0.2	−0.51	0.22	0.02
Kromme Rijn-streek en Heuvelrug	−5.08	0.58	0	2.58	2.01	0.2	0.51	0.4	0.86	−0.03	0.45	0.94	−0.31	0.32	0.33
Land van Breda	−6.44	0.36	0	−0.6	1.15	0.6	−0.36	0.7	0.27	0.46	0.81	0.57	−0.61	0.21	0
Maaskant en Land van Cuijk	−5.6	0.46	0	0.57	1.32	0.67	0.38	0.88	0.8	−0.27	0.25	0.28	−0.47	0.23	0.04
Midden-Noord-Brabant	−6.62	0.28	0	3.05	1.89	0.11	0.33	0.2	0.4	−0.17	0.31	0.6	−0.43	0.24	0.07
Noord-Limburg	−5.79	0.48	0	0.61	1.27	0.63	0.38	0.8	0.56	−0.21	0.28	0.46	−0.48	0.23	0.03
Noordelijk Friesland	−0.19	1.28	0.88	−1.33	0.76	0.08	−0.11	0.06	0.59	0.13	0.54	0.81	−0.67	0.16	0
Noordelijk Zeeland	−3.62	0.89	0	9.22	3.39	0.01	0.06	0.02	0.99	0.09	0.53	0.87	−0.78	0.14	0
Noordoost-Overijssel	−6.76	0.22	0	1.62	1.62	0.32	0.51	0.51	0.76	−0.13	0.36	0.72	−0.33	0.28	0.25
Noordoostelijke Polder	−6.45	0.3	0	−0.02	1.25	0.99	−0.01	1.24	0.09	1.38	1.36	0.31	−0.64	0.19	0
Noordwesthoek	−3.63	0.95	0	−1.83	0.77	0.02	−0.03	0.01	0.61	−0.12	0.4	0.75	−0.58	0.24	0.01
Oostelijk Hogeland	−3.54	0.95	0	−1.73	0.8	0.03	−0.05	0.02	0.88	−0.2	0.36	0.59	−0.6	0.22	0.01
Oostelijke Betuwe en Nijmegen	−3.92	1.21	0	0.73	1.97	0.71	0.52	1.4	0.74	0.1	0.65	0.88	−0.72	0.19	0
Oostelijke Bouwstreek in Groningen	−2.58	1.02	0.01	−1.1	0.9	0.22	−0.25	0.2	0.54	0.17	0.59	0.77	−0.61	0.19	0
Oostelijke Langstraat	−5.4	0.52	0	−0.31	1.2	0.79	−0.25	0.95	0.47	0.04	0.51	0.94	−0.26	0.34	0.44
Oostelijke Veluwe	−5.19	0.51	0	1.03	1.45	0.48	0.49	0.69	0.84	−0.4	0.14	0	−0.64	0.17	0
Rotterdam en omgeving	−5.96	0.57	0	1.82	2.16	0.4	0.73	0.86	0.65	0.48	0.91	0.6	−0.1	0.52	0.84
Salland	−6.44	0.28	0	1.14	1.45	0.43	0.49	0.63	0.79	0	0.44	1	−0.57	0.19	0
Smilde en Centraal Zandgebied in Drenthe	−6.32	0.3	0	1.21	1.57	0.44	0.53	0.69	0.49	0.07	0.52	0.89	−0.61	0.19	0
Texel en Land van Zijpe	−0.64	1.35	0.63	11.99	3.75	0	0.02	0.01	0.98	0.72	0.95	0.44	−0.54	0.21	0.01
Twente	−6.79	0.32	0	2.29	1.63	0.16	0.37	0.26	0.28	0.07	0.47	0.88	−0.56	0.2	0
Veluwezoom en Betuwe	−4.65	0.62	0	0.78	1.37	0.57	0.44	0.78	0.97	0.19	0.56	0.74	−0.44	0.24	0.06
Voorne-Putten en Hoeksche Waard	−5.93	0.41	0	−0.51	1.1	0.64	−0.33	0.71	0.26	0.04	0.49	0.93	−0.49	0.25	0.05
Walcheren en Zuid-Beveland	−4.96	0.6	0	13.08	3.91	0	0.01	0	0.8	0.08	0.5	0.87	−0.66	0.17	0
Waterland en N.-Hollandse Droogmakerijen	2.78	1.68	0.1	0.9	1.41	0.52	0.47	0.73	0.94	−0.05	0.42	0.91	0.1	0.45	0.82
Weidegebied in Overijssel	−5.48	0.46	0	0.02	1.12	0.99	0.02	1.1	0.33	−0.17	0.32	0.59	−0.53	0.2	0.01
Weidegebied van het Noorderveld	−6.13	0.39	0	0.93	1.81	0.61	0.56	1.1	0.17	0.08	0.66	0.91	−0.54	0.26	0.04
Weidestreek in Friesland	0.79	1.35	0.56	−0.16	1.06	0.88	−0.14	0.93	0.69	−0.33	0.2	0.09	−0.71	0.15	0
West-Friesland en omgeving	−2.36	1.04	0.02	0.2	1.26	0.87	0.18	1.1	0.13	1.33	1.29	0.3	−0.27	0.31	0.38
Westelijk Peelgebied	−6.74	0.32	0	0.92	1.34	0.49	0.45	0.66	0.69	0.23	0.58	0.69	−0.49	0.22	0.03
Westelijk Rijnland	1.79	1.68	0.29	2.89	1.98	0.15	0.42	0.29	0.69	1.85	1.61	0.25	−0.68	0.16	0

(*continued on next page*)

Table A5 (*continued*)

	Nature Conservation (n = 7′371)			Tourism (n = 2′772)			On-farm sales (n = 3′113)			Processing (n = 1′034)			Care farming (n = 868)		
	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value	Est.	Std. Err.	p-value
Westelijk Weidegebied in Utrecht	0.66	1.36	0.63	1.25	1.45	0.39	0.49	0.56	0.88	1.05	1.1	0.34	−0.6	0.18	0
Westelijke Langstraat	−5.74	0.47	0	0.64	1.52	0.67	0.43	1.02	0.3	0.09	0.55	0.87	−0.61	0.2	0
Westelijke Veluwe	−5.42	0.49	0	1.6	1.53	0.29	0.47	0.45	0.59	−0.25	0.26	0.35	−0.56	0.19	0
Westelijke Zandgronden	−6.41	0.31	0	−0.12	1.17	0.92	−0.11	1.08	0.15	−0.12	0.35	0.73	−0.26	0.32	0.41
Westerwolde en Groninger Veenkoloniën	−4.82	0.66	0	−0.63	1.13	0.57	−0.36	0.65	0.1	0.42	0.8	0.6	−0.38	0.32	0.23
Westland en Zuidhollandse Droogmakerijen	−3.82	0.87	0	−0.09	1.19	0.94	−0.08	1.12	0.13	0.11	0.53	0.83	−0.36	0.29	0.2
Wieringen en Wieringermeer	−5.36	0.55	0	−0.29	1.22	0.81	−0.23	0.99	0.09	1.47	1.43	0.31	−0.59	0.21	0.01
Zandgebied in Utrecht	−4.84	0.68	0	2.62	2.13	0.22	0.57	0.46	0.71	−0.02	0.51	0.96	−0.38	0.31	0.21
Zeeuwsch-Vlaanderen	−4.73	0.63	0	2.45	1.85	0.19	0.45	0.34	0.92	0.25	0.62	0.69	−0.45	0.25	0.07
Zuid-Limburg	3.99	1.86	0.03	4.45	2.27	0.05	0.22	0.11	0.15	−0.09	0.37	0.81	−0.52	0.21	0.01
Zuidelijk Gelderland	−5.87	0.4	0	2.13	1.75	0.22	0.47	0.39	0.37	−0.04	0.42	0.93	−0.58	0.19	0
Zuidelijk Zandgebied in Drenthe	−5.88	0.39	0	−1.02	0.95	0.29	−0.29	0.27	0.9	−0.34	0.22	0.12	−0.58	0.2	0
Zuidelijke IJsselmeerpolders	−6.07	0.37	0	−0.18	1.2	0.88	−0.16	1.06	0.01	1.5	1.43	0.29	−0.39	0.29	0.17
Zuidwestelijk Weidegebied in Drenthe	−6.26	0.3	0	1.62	1.63	0.32	0.52	0.53	0.65	0.18	0.6	0.76	−0.39	0.26	0.13

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.landusepol.2020.105019.

References

Allaire, G., Poméon, T., Maigné, E., Cahuzac, E., Simioni, M., Desjeux, Y., 2015. Territorial analysis of the diffusion of organic farming in France: between heterogeneity and spatial dependence. Ecol. Indic. 59, 70–81. https://doi.org/10.1016/j.ecolind.2015.03.009.

Anselin, L., 1998. Spatial Econometrics: Methods and Models. Kluwer Academic Publishers, Dordrecht, Netherlands.

Augère-Granier, M.-L., 2016. Farm Diversification in the EU. Retrieved from. http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/581978/EPRS_BRI(2016)581978_EN.pdf.

Bandiera, O., Rasul, I., 2006. Social networks and technology adoption in Mozambique. Econ. J. 116, 869–902.

Barbieri, C., Mahoney, E., 2009. Why is diversification an attractive farm adjustment strategy? Insights from Texas farmers and ranchers. J. Rural Stud. 25, 58–66. https://doi.org/10.1016/j.jrurstud.2008.06.001.

Beharry-Borg, N., Smart, J.C.R., Termansen, M., Hubacek, K., 2012. Evaluating farmers' likely participation in a payment programme for water quality protection in the UK uplands. Reg. Environ. Change 13, 633–647. https://doi.org/10.1007/s10113-012-0282-9.

Benjamin, C., 1994. The growing importance of diversification activities for French farm households. J. Rural Stud. 10, 331–342.

Bjørkhaug, H., Blekesaune, A., 2013. Development of organic farming in Norway: a statistical analysis of neighbourhood effects. Geoforum 45, 201–210. https://doi.org/10.1016/j.geoforum.2012.11.005.

Bramoullé, Y., Djebbari, H., Fortin, B., 2009. Identification of peer effects through social networks. J. Econom. 150, 41–55. https://doi.org/10.1016/j.jeconom.2008.12.021.

Bramoullé, Y., Kranton, R., D'Amours, M., 2014. Strategic interaction and networks. Am. Econ. Rev. 104, 898–930. https://doi.org/10.1257/aer.104.3.898.

Case, A., 1992. Neighborhood influence and technological change. Reg. Sci. Urban Econ. 22, 491–508.

Conley, T.G., Udry, C.R., 2010. Learning about a new technology: pineapple in Ghana. Am. Econ. Rev. 100, 35–69. https://doi.org/10.1257/aer.100.1.35.

Cotteleer, G., 2008. Valuation of Land Use in the Netherlands and British Columbia; a Spatial Hedonic GIS-based Approach. Retrieved from. Wageningen University, Wageningen. http://library.wur.nl/WebQuery/wurpubs/fulltext/122030.

Dries, L., Pascucci, S., Gardebroek, C., 2012. Diversification in Italian farm systems: Are farmers using interlinked strategies? New Medit 4.

Fischer, M., Ypma, T., 2012. Vier jaar impuls voor de multifunctionele landbouw: inzet Taskforce Multifunctionele Landbouw 2008-2012. Retrieved from. https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/brochures/2012/04/12/vier-jaar-impuls-voor-de-multifunctionele-landbouw/vier-jaar-impuls-voor-de-multifunctionele-landbouw.pdf.

Gibbons, S., Overman, H.G., 2012. Mostly Pointless Spatial Econometrics? J. Reg. Sci. 52, 172–191. https://doi.org/10.1111/j.1467-9787.2012.00760.x.

Halleck Vega, S., Elhorst, J.P., 2015. The slx model. J. Reg. Sci. 55, 339–363. https://doi.org/10.1111/jors.12188.

Hassink, J., Agricola, H., Thissen, J., 2016a. Participation rate of farmers in different multifunctional activities in the Netherlands. Outlook Agric. 45, 192–198.

Hassink, J., Hulsink, W., Grin, J., 2016b. Entrepreneurship in agriculture and healthcare: different entry strategies of care farmers. J. Rural Stud. 43, 27–39. https://doi.org/10.1016/j.jrurstud.2015.11.013.

Heringa, P.W., van der Heide, C.M., Heijman, W.J.M., 2013. The economic impact of multifunctional agriculture in Dutch regions: an input-output model. Njas - Wageningen J. Life Sci. 64–65, 59–66. https://doi.org/10.1016/j.njas.2013.03.002.

Holloway, G., Shankara, B., Rahman, S., 2002. Bayesian spatial probit estimation: a primer and an application to HYV rice adoption. Agric. Econ. 27, 383–402.

Home, R., Balmer, O., Jahrl, I., Stolze, M., Pfiffner, L., 2014. Motivations for implementation of ecological compensation areas on Swiss lowland farms. J. Rural Stud. 34, 26–36. https://doi.org/10.1016/j.jrurstud.2013.12.007.

Ilbery, B., 1991. Farm diversification as an adjustment strategy on the urban fringe of the West Midlands. Journal of Rural Studie 7, 207–218.

Jongeneel, R., Polman, N., 2018. Farmer groups as a device to ensure the provision of agri-environmental services in the Netherlands: a procurement perspective. In: Paper Presented at the Agricultural Economics Society Annual Conference. University of Warwick.

Jongeneel, R., Polman, N.B.P., Slangen, L.H.G., 2008. Why are Dutch farmers going multifunctional? Land Use Policy 25, 81–94. https://doi.org/10.1016/j.landusepol.2007.03.001.

Lange, A., Piorr, A., Siebert, R., Zasada, I., 2013. Spatial differentiation of farm diversification: how rural attractiveness and vicinity to cities determine farm households' response to the CAP. Land Use Policy 31, 136–144. https://doi.org/10.1016/j.landusepol.2012.02.010.

Läpple, D., Kelley, H., 2015. Spatial dependence in the adoption of organic drystock farming in Ireland. Eur. Rev. Agric. Econ. 42, 315–337. https://doi.org/10.1093/erae/jbu024.

Läpple, D., Holloway, G., Lacombe, D.J., O'Donoghue, C., 2017. Sustainable technology adoption: a spatial analysis of the Irish Dairy Sector. Eur. Rev. Agric. Econ. 44, 810–835. https://doi.org/10.1093/erae/jbx015.

LeSage, J.P., Pace, R.K., 2009. Introduction to Spatial Econometrics. CRC Press, Boca Raton, Florida.

LeSage, J.P., Pace, R.K., 2011. Pitfalls in higher order model extensions of basic spatial regression methodology. Rev. Reg. Stud. 41, 13–26.

LeSage, J.P., Pace, R.K., 2014. The biggest myth in spatial econometrics. Econometrics 2, 217–249. https://doi.org/10.3390/econometrics2040217.

Lewis, D.J., Barham, B.L., Robinson, B., 2011. Are there spatial spillovers in the adoption of clean technology? The case of organic dairy farming. Land Econ. 87, 250–267.

Manski, C.F., 1993. Identification of endogenous social effects: the reflection problem. Rev. Econ. Stud. 60, 531–542.

Matuschke, I., Qaim, M., 2009. The impact of social networks on hybrid seed adoption in India. Agric. Econ. 40, 493–505. https://doi.org/10.1111/j.1574-0862.2009.

00393.x.
McNally, S., 2001. Farm diversfcation in England and Wales - what can we learn from the farm business survey? J. Rural Stud. 17, 247–257.
Meert, H., Van Huylenbroeck, G., Vernimmen, T., Bourgeois, M., van Hecke, E., 2005. Farm household survival strategies and diversification on marginal farms. J. Rural Stud. 21, 81–97. https://doi.org/10.1016/j.jrurstud.2004.08.007.
Meraner, M., Heijman, W., Kuhlman, T., Finger, R., 2015. Determinants of farm diversification in the Netherlands. Land Use Policy 42, 767–780. https://doi.org/10.1016/j.landusepol.2014.10.013.
Meuwissen, M.P.M., Feindt, P.H., Spiegel, A., Termeer, C.J.A.M., Mathijs, E., Mey, Yd., 2019. A framework to assess the resilience of farming systems. Agric. Syst. 176, 102656. https://doi.org/10.1016/j.agsy.2019.102656.
Mishra, A.K., El-Osta, H.S., Sandretto, C.L., 2004. Factors affecting farm enterprise diversification. Agric. Financ. Rev. 64, 151–166. https://doi.org/10.1108/00214660480001160.
Munshi, K., 2004. Social learning in a heterogeneous population: technology diffusion in the Indian Green Revolution. J. Dev. Econ. 73, 185–213. https://doi.org/10.1016/j.jdeveco.2003.03.003.
Nyblom, J., Borgatti, S., Roslakka, J., Salo, M.A., 2003. Statistical analysis of network data—an application to diffusion of innovation. Soc. Networks 25, 175–195. https://doi.org/10.1016/s0378-8733(02)00050-3.
Peth, D., Mußhoff, O., Funke, K., Hirschauer, N., 2018. Nudging farmers to comply with water protection rules – experimental evidence from Germany. Ecol. Econ. 152, 310–321. https://doi.org/10.1016/j.ecolecon.2018.06.007.
Pfeifer, C., Jongeneel, R.A., Sonneveld, M.P.W., Stoorvogel, J.J., 2009. Landscape properties as drivers for farm diversification: a Dutch case study. Land Use Policy 26, 1106–1115. https://doi.org/10.1016/j.landusepol.2009.01.007.
Polman, N., Poppe, K.J., van der Schans, J.-W., van der Ploeg, J.D., 2010. Nested markets with common pool resources in multifunctional agriculture. Rivista di economia agraria 65, 295–318.
Saint-Cyr, L.D.F., Storm, H., Heckelei, T., Piet, L., 2019. Heterogeneous impacts of neighbouring farm size on the decision to exit: evidence from Brittany. Eur. Rev. Agric. Econ. 46, 237–266. https://doi.org/10.1093/erae/jby029.
Schmidtner, E., Lippert, C., Engler, B., Häring, A.M., Aurbacher, J., Dabbert, S., 2012. Spatial distribution of organic farming in Germany: does neighbourhood matter? Eur. Rev. Agric. Econ. 39, 661–683. https://doi.org/10.1093/erae/jbr047.
Schouten, M., Opdam, P., Polman, N., Westerhof, E., 2013. Resilience-based governance in rural landscapes: experiments with agri-environment schemes using a spatially explicit agent-based model. Land Use Policy 30, 934–943. https://doi.org/10.1016/j.landusepol.2012.06.008.
Statistics Netherlands, 2016. StatLine. Retrieved from. http://statline.cbs.nl/Statweb/.
Storm, H., Heckelei, T., 2018. Reducing omitted-variable bias in spatial-interaction models by considering multiple neighbourhoods. Spat. Econ. Anal. 1–16. https://doi.org/10.1080/17421772.2018.1468571.
Storm, H., Mittenzwei, K., Heckelei, T., 2015. Direct payments, spatial competition, and farm survival in Norway. Am. J. Agric. Econ. 97, 1192–1205. https://doi.org/10.1093/ajae/aau085.
Terwan, P., Deelen, J.G., Mulders, A., Peeters, E., 2016. The Cooperative Approach under the New Dutch Agri-Environment-climate Scheme. Background, Procedures and Legal and Institutional Implications. Retrieved from The Hague, Netherlands. .
van der Meulen, H.A.B., Dijkshoorn-Dekker, M., Jager, J., Schoorlemmer, H., Schoutsen, M., Veen, E., et al., 2014. Kijk op multifunctionele landbouw: Omzet en impact 2007-2013. Retrieved from Den Haag, Netherlands. http://edepot.wur.nl/317952.
van der Ploeg, J.D., Roep, D., 2003. Multifunctionality and rural development: the actual situation in Europe. In: V. H. G, Durand, C. (Eds.), Multifunctional Agriculture: a New Paradigm for European Agriculture and Rural Development. Ashgate, Aldershot, Hampshire, England, pp. 37–54.
van Everdingen, W., 2015. NSO-typering: typering van agrarische bedrijven in Nederland. Retrieved from. http://library.wur.nl/WebQuery/wurpubs/fulltext/347875.
Walford, N., 2001. Patterns of development in tourist accommodation enterprises on farms in England and Wales. Appl. Geogr. 21, 331–345.
Weltin, M., Zasada, I., Franke, C., Piorr, A., Raggi, M., Viaggi, D., 2017. Analysing behavioural differences of farm households: an example of income diversification strategies based on European farm survey data. Land Use Policy 62, 172–184. https://doi.org/10.1016/j.landusepol.2016.11.041.
Wollni, M., Andersson, C., 2014. Spatial patterns of organic agriculture adoption: evidence from Honduras. Ecol. Econ. 97, 120–128. https://doi.org/10.1016/j.ecolecon.2013.11.010.
Zasada, I., Fertner, C., Piorr, A., Nielsen, T.S., 2011. Peri-urbanisation and multifunctional adaptation of agriculture around Copenhagen. Geografisk Tidsskrift-Danish Journal of Geography 111, 59–72. https://doi.org/10.1080/00167223.2011.10669522.