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A method to define a typology for agent-based analysis in regional land-use research

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ABSTRACT

Land use/cover change (LUCC) is often the cumulative result of individual farmer's decisions. To understand and simulate LUCC as the result of local decisions, multi-agent systems models (MAS) have become a popular technique. However, the definition of agents is not often based on real data, ignoring the inherent diversity of farmers and farm characteristics in rural landscapes. The aim of this paper is to describe an empirical method that defines an agent typology and allocates agents into the different agent types for an entire region. This method is illustrated with a case study in the Netherlands, where processes of farm expansion and diversification of farm practices take place. Five different agent types were defined and parameterized in terms of views, farm characteristics and location. Despite its simplicity, this empirical method captures several relations between farmers' views, farm characteristics and land-use decisions and strategies. This approach is a step forward in multi-agent systems of land use/cover change (MAS/LUCC) to include the diversity of land-use decisions and strategies in regional studies by empirically defining, parameterizing and allocating different agent types.

1. Introduction

Land-use/cover change (LUCC) is a complex process caused by the interaction between natural and social systems at different temporal and spatial scales (Lambin and Geist, 2001; Rindfuss et al., 2004). In rural areas, LUCC is related to the dynamics of the agricultural sector in general, and those of the farming systems in particular. However, each farming system is different (Köbrich et al., 2003), reflecting the heterogeneity of human's behaviour and decisions. This heterogeneity is not only influenced by the complexity of the human behaviour itself (Simon, 1955; Rokeach, 1968; Ajzen, 1991; Arthur, 1994), but also by both internal and external factors such as land-holders' experience, family structure, economic and technical resources, and the socio-economic context where these decisions occur (Fig. 1) (Gasson, 1973; Ilbery, 1978; Evans and Ilbery, 1989; Willock et al., 1999b; Knowler and Bradshaw, 2007).

An approach to analyse and simulate human decisions in LUCC is the use of multi-agent systems (MAS) (Parker et al., 2003; Brown, 2005; Matthews et al., 2007; Robinson et al., 2007). MAS are modelling tools in which decision-making entities are represented by agents, while the environment is defined by spatial data. This conceptualization of the land-use system explicitly includes interactions between agents and between agents and the environment. Agents in the model can represent individuals or groups of people, institutions, etc. Agents can be designed with different characteristics: they can be heterogeneous (e.g. socio-cultural background, economic situation, perception of the landscape, age, behaviour), autonomous (they take their own land-use decisions based on rational and non-rational rules) and dynamic (they can learn and adapt to different situations) (Ferrand, 1996; Bonabeau, 2002; Parker et al., 2003; Sawyer, 2003; Crawford et al., 2005). By using autonomous and heterogeneous agents, MAS explicitly deal with the diversity of land-use decisions. In this way, MAS cope with the limitation of most of the land-use models implemented at a regional scale (Balmann, 2000; van der Veen and Otter, 2001; Bonabeau, 2002; Sawyer, 2003; Evans and Kelley, 2004; Verburg, 2006), which often use a single response function throughout the study area, assuming that human decision-making is a homogeneous process (e.g. Fohrer et al., 2002; Soares-Filho et al., 2002; Verburg et al., 2002; Luijten, 2003).

Agents can be defined and parameterized in many different ways, depending on the objectives of the MAS itself (Janssen and Ostrom, 2006; Robinson et al., 2007). For example, agents can represent broad groups of stakeholders such as landowners, government or environmentalists (e.g. Ligtenberg et al., 2004; Monticino et al., 2007); socio-economic units such as households (e.g. Evans and Kelley, 2004; Matthews, 2006); or organizational

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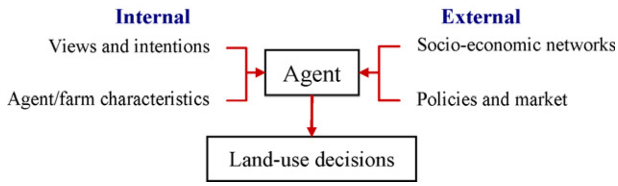

Fig. 1. Influences on agent's land-use decisions.

units such as farms (e.g. Balmann, 2000; Happe et al., 2006). The decision-making process of agents needs to be specifically parameterized by decision rules. These rules can be defined based on either artificial or empirical data. Agent parameterization with artificial data is the more common approach in MAS (Berger and Schreinemachers, 2006). Although improving the theoretical insight into LUCC dynamics, the validity of such artificial agent definition is often difficult to assess (Gimblett, 2002; Parker et al., 2003). On the other hand, agent parameterization with empirical data can facilitate the understanding of real LUCC processes. Still, most studies using empirical data to define and parameterize agents rely on intensive data gathering (e.g. Bousquet et al., 2001; Huigen, 2004; Castella et al., 2005; Jepsen et al., 2006).

At a regional scale, intensive data gathering is limited by the large number of agents. Despite the heterogeneity of farming systems at such spatial scale, general farming strategies can be distinguished, what Bowler (1992) define as ''paths of development'' (see also Wilson, 2007). These general pathways are a simplification of how farming can develop in a certain area (Meert et al., 2005). A relevant approach to analyse the heterogeneity in decision-making of farmers is to formulate typologies (McKinney, 1950; Jollivet, 1965; Escobar and Berdegué, 1990; Perrot and Landais, 1993b; van der Ploeg, 1994). A typology is a tool to simplify the diversity of farmers and farming strategies. This means that a typology is an artificial way to define different groups based on specific criteria in order to organize and analyse reality (McKinney, 1950; Jollivet, 1965). The criteria to construct a typology, as well as to evaluate it, primarily depend on the objectives of its implementation (Escobar and Berdegué, 1990). Different kinds of typologies for agents in rural areas can be distinguished based on their aim. For example, some typologies intend to understand the whole farming process, which include the most relevant farm(er) characteristics (e.g. Escobar and Berdegué, 1990; Perrot and Landais, 1993a; van der Ploeg, 1994). Other typologies aim to analyse the underlying reasons of certain farmers' decisions (e.g. Morris and Potter, 1995; Fish et al., 2003; Guillaumin et al., 2004). Finally, other typologies aim to explain the different production strategies that farmers developed or might develop (e.g. Ondersteijn et al., 2003; de Lauwere, 2005; Vanclay et al., 2006; Van Doorn and Bakker, 2007). Nevertheless, most of the current typologies do not account for the spatial linkage in which land-use decisions are embedded (Landais, 1998).

The aim of this study is to describe an empirical method to define and parameterize different agent types for use in MAS/LUCC at a regional scale. This method first defines an agent typology and subsequently distributes spatially the defined agent types in the entire region. After describing the general method, this paper illustrates the method with a case study in the East of the Netherlands where processes of farm diversification and farm expansion are taking place. Finally, this paper discusses the advantages and the limitation of the proposed method, including its potential applications in MAS/LUCC research and policy-making processes.

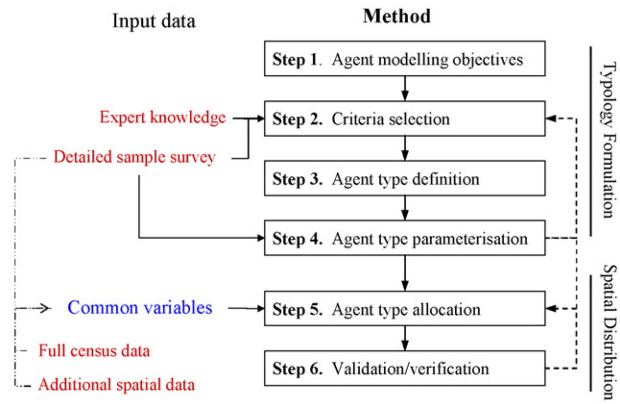

Fig. 2. Diagram of the method.

2. General method

To include the diversity of land-use decisions and strategies at a regional scale in a MAS/LUCC, we need first to simplify the diversity between all individual agents by formulating an agent typology (typology formulation, Fig. 2), and thereafter, we need to distribute spatially the defined agent types in the region (agent type spatial distribution, Fig. 2).

2.1. Typology formulation

In the first part of the method, the diversity of land-use decisions and strategies is simplified by defining and characterizing different agent types in the region based on four steps (Fig. 2).

2.1.1. Step 1. Agent modelling objectives

Before simplifying the diversity of farmers' decisions and strategies, we need to define clearly the aim of such simplification. In the case of MAS at a regional scale, we need to establish what the agent modelling objectives are: do we want to understand and simplify the whole LUCC dynamics of an area? Are we interested only in simulating a particular process? Or are we interested in the reasons to follow a particular land-use management strategy?

2.1.2. Step 2. Criteria selection

The definition of the agent modelling objectives facilitates the selection of different criteria that are used to define and parameterize the agent typology. The selection of these criteria not only reflects the objective of the research and the scientific approach (e.g. Berdegué and Escobar, 1990), but also defines how the diversity of land-use decisions and strategies is simplified and included in MAS/LUCC. Still, such criteria should not rely only on quantitative analyses, but they also need to have a meaning to the social reality of LUCC (Perrot and Landais, 1993b; Landais, 1998). Further, these criteria generally need to describe the views and perceptions of the agent as well as their socio-economic situation and context. Related to views and perceptions, Burton and Wilson (2006) argue that farmers can have different identities (e.g. agricultural producer and diversifier). In this way, a typology can be defined by using a combination of identities. Data to define these identities are often not available for all agents in a large region because restrictions on data accessibility or the data do not even exist. Therefore, such data can be gathered by using a detailed sample survey.

2.1.3. Step 3. Agent type definition

The definition of different agent types primarily depends on the selected criteria. Different methods to construct typologies have been described (e.g. Escobar and Berdegué, 1990; Landais, 1998; van der Ploeg, 2003). For example, a typology can be constructed using qualitative (e.g. Guillaumin et al., 2004; Schmitzberger et al., 2005) or quantitative analyses (e.g. Wilson and Hart, 2000; Köbrich et al., 2003; Kristensen, 2003; de Lauwere, 2005); attitudinal (e.g. Fairweather and Keating, 1994; Morris and Potter, 1995) or socio-economic variables (e.g. Commandeur, 2005; Schmitzberger et al., 2005); and scientist knowledge (e.g. Perrot and Landais, 1993a; van der Ploeg, 1994) or participatory processes (e.g. Girard, 2006). The choice of a particular analysis depends on the selected criteria and the available data.

2.1.4. Step 4. Agent type parameterization

In this step, agent types are described in terms of views and strategies relevant to the MAS/LUCC. This is a step to understand the differences between agent types based not only on views and decisions, but also their socio-economic situation and context. To assess whether these differences are significant, statistical analyses are used. Most of the attitudinal and socio-economic variables used to parameterize agent types are included in the detailed sample survey. Finally, some of these variables can be also used as common variables (see below).

2.2. Agent type spatial distribution

In the second part of the method, all agents in the study area are classified as one of the defined agent types. Further, the method is validated and verified.

2.2.1. Step 5. Agent type allocation

Although full census data of the entire population of a region are often available, the level of detail and/or accessibility of such data are often limited. Therefore, these data are not used to define the different agent types. The use of common variables between a detailed sample survey, full census data and additional socio-economic and biophysical data allows us to classify all agents into one of the defined agent types (Fig. 2). Although spatial variables can be used to define and parameterize the different agent types, it is in this step that agent types are explicitly linked to the landscape. Finally, depending on the available data for the entire study region, different quantitative analyses techniques can be used to classify agents, such as regression, multivariate and probabilistic analyses.

2.2.2. Step 6. Validation/verification

The definition and allocation of the different agent types (step 3 and 5, Fig. 2) may result in some degree of overlap between agent types and consequently uncertainty about the definition of the variables due to both the complexity of land-use decisions and the limited data availability. For this reason, it is necessary to validate these steps and determine the level of uncertainty of the results. Based on this validation/verification process, early steps of the method might need to be modified. Participatory approaches could be used to validate an agent typology (e.g. Girard, 2006). However, agent types are an abstract representation of reality which makes it difficult for people to recognize themselves in the agent types as defined and therefore hampers such a validation.

3. Case study

In this part, the proposed method is illustrated with a case study in the eastern part of the Netherlands, where processes of diversification of farm practices and farm expansion are reshaping the landscape structure.

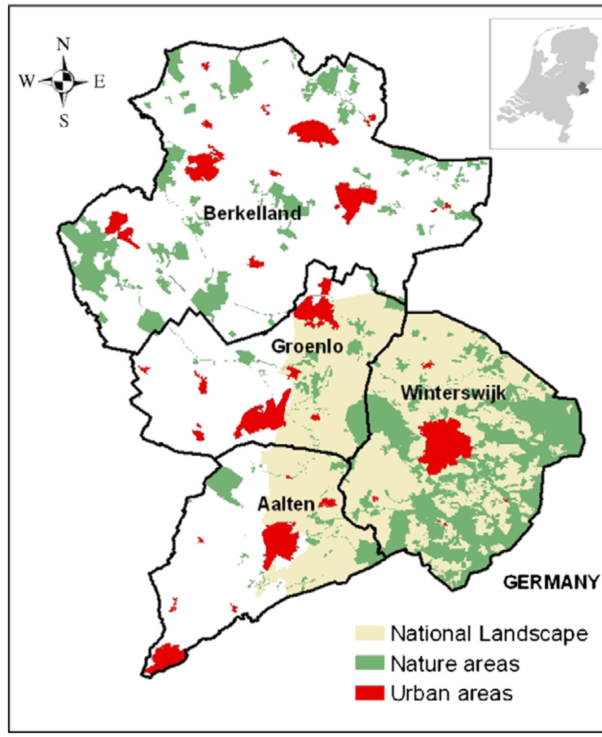

Fig. 3. Study area.

3.1. Study area

The study area is located in the eastern part of the Netherlands and covers an area of approximately 60.650 ha (Fig. 3). By 2005, there were around 2300 agricultural holdings; about 66% of them were livestock farms (Farm Accountancy Data). Part of this area represents a cultural–historic landscape where small-scale agriculture and nature areas are closely related providing a particular cultural, recreational, tourist, ecological and economic value to the region (Provinciale Staten van Gelderland, 2005b). The spatial structure of the landscape has been the result of the interaction between biophysical (e.g. soil characteristics and water availability) and socio-economic factors and processes (e.g. land tenure, accessibility and labour demand) (Benvenuti, 1961; Wildenbeest, 1989; Mastboom, 1996).

In the last decades, social changes such as the increasing environmental awareness and the growing demand for recreation and tourist areas, together with legislative changes such as the establishment of milk quotas, restrictions on manure applications, and compensatory payments for nature and landscape conservation have influenced the rural dynamics not only in the study area (Provinciale Staten van Gelderland, 2005a), but also in most of the rural areas in the Netherlands (van Horne and Prins, 2002; Graveland et al., 2004; Oerlemans et al., 2004; Berkhout and Bruchem, 2005).

3.2. Input data

This study is based on a detailed sample survey carried out during winter 2004 (Jongeneel et al., 2005), full census data of the entire population in the study region (farmer accountancy data) and additional socio-economic and biophysical spatial data. The detailed sample survey included 333 farmers and it was originally carried out to explore the factors that determine the diversification of farm practices including farmer's views (positive, neutral and negative) and structural variables such as the existence or not of a successor, production scale, degree specialization of the farm and past land-use changes (Jongeneel et al., 2005). The full census data include only a limited number of structural variables such as agribusiness type, production scale, cultivated area, head farmer's age and labour, and no attitudinal variables. Finally, additional spatial data include: groundwater table, altitude, proportion of nature and historical areas, farm density, production scale and cultivated area.

To simplify the parameterization and allocation of the different agent types, some variables were grouped. In particular, agribusiness type and category of production scale were defined based on CBS (Statistics Netherlands) terminology. Four main agribusiness types from the Dutch version of the Community Typology were distinguished for the study area: arable, livestock, intensive livestock and other farms. Also, based on the production scale, farms were divided into four main categories: hobby (3–20 dsu), small (20–50 dsu), medium (50–100 dsu) and large farms (>100 dsu). Dsu or Dutch size units represent the economic size of a farm including the amount and use of the land; in 2005, a dsu was equal to 1400 euros.

3.3. Typology formulation

3.3.1. Step 1. Agent modelling objectives

The agent modelling objective is to understand the different strategies that farmers have followed and/or might follow in terms of farm diversification practices and farm expansion.

3.3.2. Step 2. Criteria selection

Because these land-use decisions often depend on individual decisions, the criteria to define this typology should include farmers' views or willingness (Siebert et al., 2006). In particular, views on expansion of production scale as a future alternative, diversification of farm practices as an additional income and participation in compensation schemes for nature and landscape conservation practices were selected. At the same time, socio-economic variables can implicitly represent different farming strategies. This is partly related to the farmer's ability to carry out certain action (Siebert et al., 2006). Specifically, farming is an important source of income for some farmers or it is simply a hobby for others. This distinction has an influence in decisions concerning the diversification of farm practices and the expansion of their holdings (e.g. Primdahl, 1999; Kristensen, 2003; Schmitzberger et al., 2005). Therefore, both socio-economic and attitudinal variables are used as criteria to define the different agent types.

3.3.3. Step 3. Agent type definition

Based on an analysis of the diversity in views and socio-economic conditions, a "classification tree" was chosen as most appropriate method to construct the typology in this case study. This tree is based on Boolean statements defined in the criteria described above: production scale larger than 20 dsu, view on expansion of the production scale and on participating in compensation schemes. The results of this classification tree were supported by explorative analyses, including regression, factor and cluster analysis.

3.3.4. Step 4. Agent type parameterization

After agent types were defined, they were parameterized based on additional variables such as age, education, cultivated area, type of agribusiness, successor, past land-use decisions, membership of different organizations, knowledge about different agricultural projects, etc. To define whether the differences of the metric variables between agent types were significant, analysis of variance (ANOVA) was used.

3.4. Agent type spatial distribution

3.4.1. Step 5. Agent type allocation

In this case study, full census data were available for the entire agent population. This means that socio-economic data of each real agent and its exact location were available. Therefore, a classification of these agents into agent types could be made using the common variables between the detailed survey data and census data. The common variables included: age, agribusiness type, production scale and landscape structure.

The analysis of the landscape structure was carried out at postcode level (average area 550 ha), at which the location of the farms of the detailed survey was known. To calculate the relation between these spatial variables, Pearson correlation analyses were carried out. Finally, to assess whether the landscape structure was significantly related to the agent typology or farming decisions (non-parametric variables), Kruskal–Wallis tests were carried out (for detailed information on these analyses see Legendre and Legendre, 1998; Lesschen et al., 2005).

To classify the different agent types a classification tree was calculated using the CRT growing method (SPSS 15.0). This approach is similar to the one discussed by Speybroeck et al. (2004), who selected as splitting criteria the 'Gini method' because it performs the best. To avoid overfitting the model, the size of parent and child nodes was limited to 20 and 4 respectively. The definition of these sizes was related to both the size of the detailed sample survey and the validation procedure (see below). The advantages of using classification trees are that it allows combining metric and non-metric variables, and including non-linear relationships.

3.4.2. Step 6. Validation/verification

To assess the uncertainty of the classification process, a cross-validation method for the classification tree was implemented (SPSS 15.0). With this method, the dataset was divided into 25 sub-samples. Each sub-sample was classified based on the results of the classification tree of the other 24 samples. The proportion of cases that were correctly classified was calculated for the 25 runs. Further, the classification tree assigns to each agent the probability to belong to each agent type, selecting the type that has the highest probability. To see whether this probability was the same throughout the landscape, a map of the mean highest probability was calculated (ArcMap 9.2).

4. Results

In the study area, there is a tendency towards the reduction of the production scale. While around 7% of farmers belonged in 2005 to a higher category of production scale than in 2001, almost 30% belonged in 2005 to a lower category. Furthermore, according to the CBS data, between 2001 and 2005 there was a decrease of 12% of farm holdings in the entire province (around 1950 holdings).

4.1. Typology formulation

As it was mentioned before, the agent modelling objective in this case study is to understand and simplify the different strategies that farmers have followed and/or might follow in terms of farm diversification practices and farm expansion (step 1).

Two different criteria to define agent types were selected: production scale and farmers' views (step 2). This first distinction reflects to some extent the role of agriculture for a farmer (life-style vs. life-style and production). It also distinguishes farmers with very small farms who might have a relative less relevant role in landscape dynamics than those with bigger farms. This is

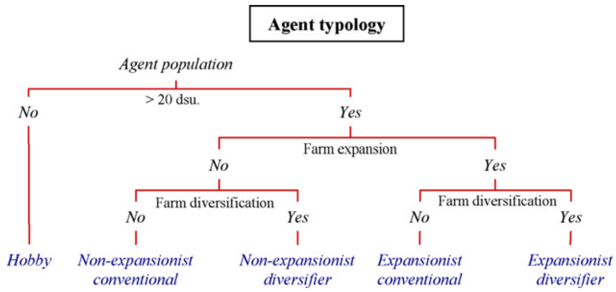

Fig. 4. Agent type definition.

partially reflected by the fact that most farmers with hobby farms (<20 dsu) had similar views: they were not willing to expand their production scale (84%) and they did not have a negative view on compensation schemes for nature and landscape conservation practices (95%).

The second distinction reflects the current and potential probability that a farmer diversifies farm practices and/or expands the production scale of his/her holding. In fact, around 80% of those who think that a future alternative is to increase the production scale have increased the area of their farm and the milk quota between 2001 and 2005. On the other hand, around 17% of those who have a negative view on participating on compensation schemes have diversified farm practices, compared to 32% of those with neutral view and 51% of those with a positive view. However, there were no differences in terms of farm diversification between those farmers with a negative and those with a neutral view on participating on such schemes.

Based on these two criteria and the fact that most farmers did not disagree on seeing diversification of farm practices as a means to obtain more income, five different agent types were defined (step 3): hobby farms (H), non-expansionist conventional (NC); non-expansionist diversifiers (ND); expansionist conventional (EC); and expansionist diversifiers (ED) (Fig. 4).

These agent types can be parameterized based on several socio-economic characteristics (step 4) (Tables 1–4).

- *Hobby farms*: agents with different ages and with different agribusiness types who own very small farms and who normally have an off-farm job. They are unlikely to expand the production scale of their farms. In fact, a relatively high proportion of them have decreased the size of their farm and the milk quota. Moreover, the probability that they would stop farming is relatively high, whereas the probability that they participate in different associations or that they know about different agricultural projects is relatively low. Also, they are unlikely to participate in compensation schemes. However, the probability that they implement other farm practices such as tourism and recreation is relatively high.
- *Non-expansionist conventional*: in general, agents who are not young and who do not own arable farms. They own most of their land and they have different categories of production scale. Still, they are unlikely to expand their production scale. The probability that they stop farming is high and that they

Table 1
Agent type parameterization: production strategies

Agent type	Stop farming	Increase production	Decrease production	Diversify farm practices	Compensation schemes	Tourism and recreation
Hobby farm	+	–	+	–	–	+
Non-expansionist conventional	+	–	+	+/–	+/–	+
Non-expansionist diversifier	+	–	+	+	+	+
Expansionist conventional	–	+	–	–	–	–
Expansionist diversifier	–	+	–	+	+	+

Table 2
Agent type parameterization: age and farm characteristics (mean and standard deviation)

Agent type	No.	Age*	Agricultural income (prop)	Production scale (dsu)	Cultivated area (ha)	Labour (h/week)	Lab. Family (h/week)	Owned land (prop)
H	43	49 (9)	0.58 (0.30)	10.5 (5.1)	15.1 (14.7)	25.6 (15.3)	12.6 (18.6)	0.85 (0.26)
NC	44	52 (11)	0.81 (0.25)	96.4 (61.9)	24.7 (18.0)	40.0 (9.5)	28.5 (24.2)	0.76 (0.32)
ND	34	50 (9)	0.71 (0.34)	77.57 (61.3)	24.0 (14.9)	39.7 (9.0)	17.5 (16.3)	0.70 (0.34)
EC	115	48 (10)	0.71 (0.28)	125.0 (65.2)	36.2 (24.0)	42.3 (6.6)	32.8 (21.6)	0.66 (0.34)
ED	48	48 (12)	0.77 (0.30)	143.2 (78.8)	39.8 (20.6)	41.9 (7.8)	40.1 (24.0)	0.68 (0.26)

* Excluding age, all the variables were significantly different between agent types (ANOVA, $p < 0.05$).

Table 3
Agent type parameterization: education, off-farm job, farm diversification and expansion indicators (numbers indicate percentage of farms belonging to a class, participating in diversification activities or showing respectively an increase or decrease in size)

Agent type	No.	Education: low level	Off-farm job	Divers. farm	Nature and landscape	Tourism-recreation[a]	Farm size[a]		Milk quota[a]	
							Increase	Decrease	Increase	Decrease
H	43	36.8	56.1	22.0	19.5	7.3	7.3	12.2	14.6	22.0
NC	44	35.7	20.5	34.1	31.8	4.5	34.1	11.4	31.8	9.1
ND	34	26.4	23.5	52.9	47.1	5.9	41.2	17.6	26.5	14.7
EC	115	18.7	19.5	21.2	20.4	0.9	66.4	1.8	76.1	0.9
ED	48	10.6	23.4	46.8	46.8	4.3	70.2	0	68.1	4.3

[a] In the last five years.

Table 4
Agent type parameterization: views, membership and acquaintance with projects (percentages)

Agent type	No.	Stop farming	Agriculture organization	Local parties: improve agricultural sector	Agriculture association: nature and landscape management	Acquaintance of different agriculture projects
H	43	34.1	46.3	7.3	24.4	65.9
NC	44	36.4	77.3	6.8	13.6	61.4
ND	34	32.4	76.5	26.5	47.1	88.2
EC	115	6.2	89.4	18.6	16.8	84.1
ED	48	4.3	91.5	34.0	53.2	85.1

participate in different associations or that they know about different agricultural projects is relatively low. Although they do not have a positive view towards compensation schemes, the proportion of diversification of farm practices is relatively higher than that of *hobby farms*.

- *Non-expansionist diversifiers*: agents who are neither young nor old, mainly with livestock and intensive livestock farms. They own small and medium farms, and they normally own most of their land. They are unlikely to expand their production scale, and many of them have decreased their farm size and their milk quota. The probability that they stop farming, that they participate in different associations, that they know about different agricultural projects and that they diversify farm practices is relatively high.
- *Expansionist conventional*: agents with different ages, and with livestock and intensive livestock farms. They own medium and large farms and only half of them own most of their land. The probability that they increase the production scale of their farms is high, and that they decrease the production scale or that they stop farming is low. Their participation in agricultural organizations is high, excluding those for nature and landscape conservation. The probability that they diversify farm practices is low.
- *Expansionist diversifiers*: agents who are relatively young with relatively high level of education. They own medium and large farms with different agribusiness types. The probability that they increase the production scale of their farms is high and that they stop farming is low. Their participation in agricultural organizations is the highest. The probability that they diversify farm practices is also high, mainly their participation in compensation schemes.

4.2. Agent type spatial distribution

The common variables include age, agribusiness type, production scale and landscape structure. In terms of age, around 40% of the agents of type ED are less than 40 years old and of type EC are between 40 and 50 years old. In terms of production scale, almost 42% of agents of type ND own small farms, while more than 60% of type EC and ED own large farms. In terms of agribusiness type,

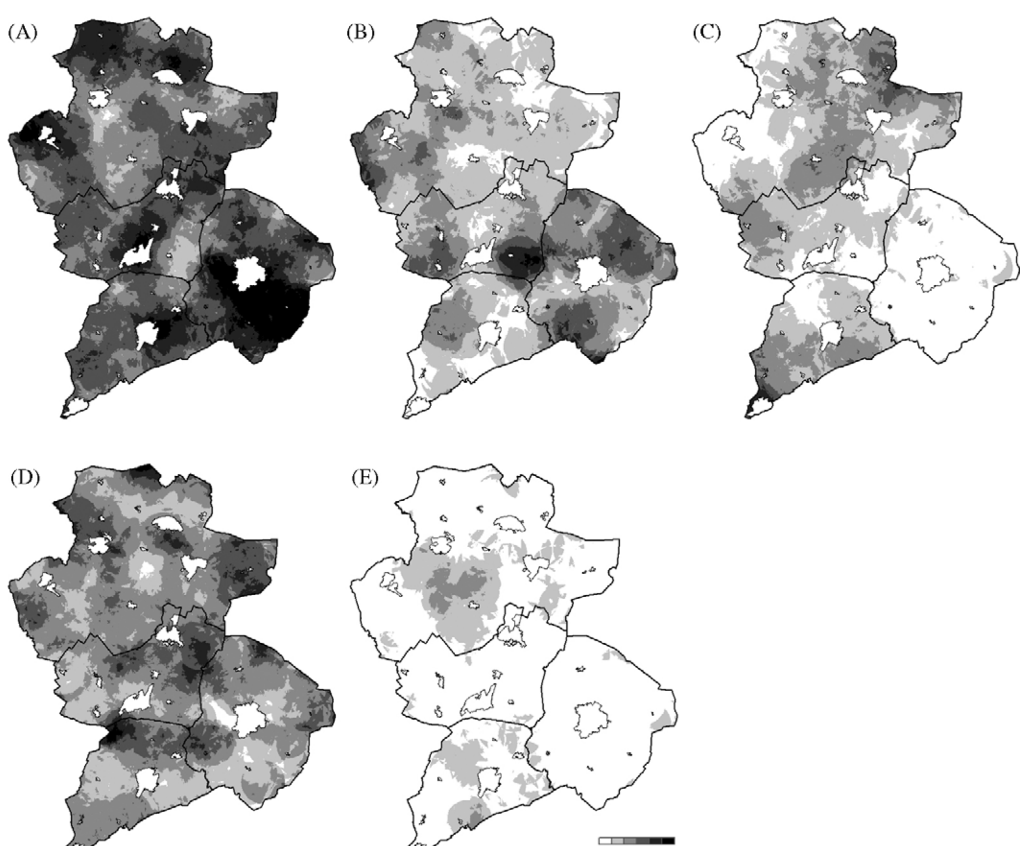

Fig. 5. Densities of each agent type. (A) H, (B) NC, (C) ND, (D) EC, and (E) ED.

most of the arable farms belong to agents of type H, while about 82% of the agents of type EC own a livestock farm and relatively more intensive farms belong to agents of type NC and ND. Finally, about half of the agents of type H are located in postcode areas with a proportion of nature areas between 5% and 20%, while only 29% of the agents of type ED are located in those areas. Also, around 50% of agents of type H and 41% of those of type ND are located in areas with small-scale agriculture—postcode areas where parcels smaller than 2 ha represent more than 20% of the total area—while only 32% of those of type ED are also located in those areas.

The landscape structure is significantly related to the diversification of farm practices. Agents who have diversified farm practices tend to be located in postcode areas higher in altitude ($Z = -1.93$ $p < 0.1$) and with more nature ($Z = -2.02$ $p < 0.05$) where the average parcel size is relatively smaller ($Z = -3.45$ $p < 0.01$) than those who have not diversified. At the same time, some of these variables are correlated. Nature tends to be located in higher areas ($r = 0.54$, $p < 0.01$) where the groundwater table is lower ($r = 0.25$, $p < 0.05$). Also part of the nature areas have a historical value in the study area ($r = 0.36$, $p < 0.01$). On the other hand, postcode areas with a high nature density tend to have a higher farm density ($r = 0.55$, $p < 0.01$), more hobby farms ($r = 0.27$, $p < 0.05$), less intensive livestock farms ($r = -0.26$, $P < 0.05$) and more farms with tourism and recreational facilities ($r = 0.30$, $p < 0.01$).

The classification process shows that each type is not equally distributed throughout the region (step 5). This distribution is partly caused by the spatial structure of the landscape: small-scale agriculture towards the South-West and large-scale agriculture in some parts in centre of the study area (Fig. 5). For example, the density of hobby farms is higher near urban and nature areas (Fig. 5A), where small-scale agriculture often takes place. In contrast, the density of EC and ED is higher in areas where large-scale agriculture occurs (Fig. 5D and E).

Excluding hobby farms, the cross-validation of the classification tree (step 6) shows that around 50% of the agents of the detailed survey were correctly classified using this approach. This percentage is higher than if the entire allocation/classification process is carried out randomly (25%). This degree of uncertainty was mainly caused by the overlap between different agent types. This overlap is related to the distribution of the common variables within each agent type. For example, the overlap between agent types EC and ED was relatively high, making the distinction between these two types less clear than in other cases. This uncertainty is reflected differently among the different agent types. As it was mentioned before, an agent is assigned to the type in which he obtained the highest probability. Thus, the highest probability that an agent belong to a particular type varied among types. In particular, about 66% of the agents of EC had a probability to belong to this agent type lower than 60%, while about 88% of those of ED had a probability higher than 80%. Because the agent distribution is not homogenous throughout the region, then the uncertainty of the classification process throughout the region is also heterogeneous (Fig. 6).

When looking at the relative amount of agents and the means of age, production scale and cultivated area of each agent type in the results of the construction of the agent typology (Table 3) and in the results of the classification procedure (Table 5), several differences can be distinguished. The mismatch between these two set of results indicates that the detailed survey does not completely represent the entire population. In fact, small-scale dairy farms (mainly hobby farms) are underrepresented, whereas large-scale dairy farms and young managers are overrepresented in the survey.

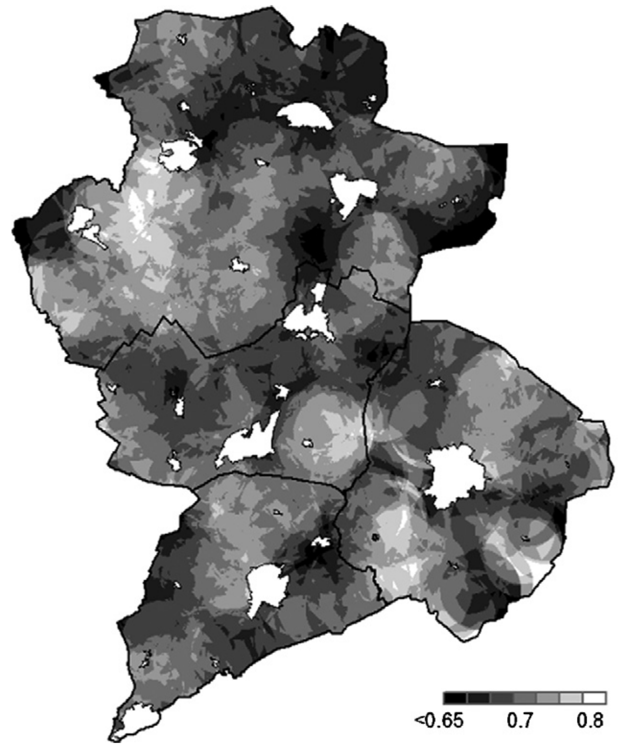

Fig. 6. Highest probabilities to belong to a particular agent type.

Table 5
Average of the means and standard deviation allocated agent types

Agent type	No.	Age	Production scale (dsu)	Cultivated area (ha)
H	735	59 (12)	9.1 (4.5)	6.8 (4.5)
NC	403	54 (12)	69.7 (41.8)	23.5 (14.2)
ND	296	55 (11)	35.3 (10.6)	14.5 (9.6)
EC	522	54 (12)	113.0 (60.3)	38.0 (17.7)
ED	136	52 (11)	126.8 (62.8)	28.8 (21.9)

5. Discussion

The construction of an agent typology is the first step to include the diversity of farmers and/or farming strategies in LUCC research at a regional scale, in particular in MAS. The linkage between this typology to the landscape allows us to combine different kind of data at different scales. These different kinds of data can be also seen as individual empirical methods to define agent-based models, including survey samples, census and GIS data (Janssen and Ostrom, 2006; Robinson et al., 2007). Other empirical methods, such as interviews, experiments and observations could be as well included to define an agent typology. However, it is the combination of these different input data that allows allocating empirically the different agent types through an entire region, where there is normally a lack of detailed data. Consequently, this approach makes it possible to simplify and include the diversity of farming systems and individual decisions in MAS/LUCC at a regional scale.

The method described in this paper has some limitations. The different agent types distinguished in this study overlap in terms of farm(er) characteristics and decisions. Although characteristics such as age and agribusiness type might be important indicators of farmers' views, perceptions and decisions, these are interacting with so many other variables that they are unlikely to discriminate perfectly agent types. In other words, these characteristics make it possible to distinguish general farming strategies at a regional scale, but describing the differences of socio-economic characteristics between these strategies is difficult. This is in line with the statement of Vanclay et al. (2006) that types always overlap because the vast diversity of farm(er)s.

Views and attitudes of farmers are assumed to have a major influence on land-use decisions and strategies (Fairweather and Keating, 1994; Willock et al., 1999a; Busck, 2002; Sharpley and Vass, 2006). However, the data showed exceptions. For example, although some agents were not supposed to diversify their farming practices based on their views, they did it in reality. This supports the claim of Burton and Wilson (2006) that farmers have different identities, depending on the circumstances when they take their decisions. Therefore, typologies do not represent reality perfectly, however, they are relevant tools whose use can facilitate our understanding of land-use dynamics (McKinney, 1950; Jollivet, 1965; Perrot and Landais, 1993a; Fish et al., 2003; Vanclay et al., 2006).

The method presented in this paper depends on the amount and quality of the data. Thus, it requires a set of common variables through which different kinds of data can be linked. In addition, the information that farmers supply to registration systems might not always match with the real data (van der Ploeg, 2003). Related to this, a detailed sample survey that tries to cover a whole region does not necessarily represent the entire population, leading to a mismatch between the detailed sample survey and the statistical data used for allocation/classification.

Nevertheless, the agent typology formulated for the study area included many of the interactions that have been described in literature between farmers' views, farm(er) characteristics and current rural processes such as diversification of farm practices and farm expansion (e.g. Kelly and Ilbery, 1995; Austin et al., 1996; Willock et al., 1999a; Knickel and Renting, 2000; Wilson and Hart, 2000; Ondersteijn et al., 2003; Knowler and Bradshaw, 2007; Jongeneel et al., 2008). Moreover, most of agent types defined in this research are related to one or to the combination of some of the identities that currently define European farmers (Burton and Wilson, 2006). All this suggests that the agent typology presented in this paper has been able to capture the diversity of land-use decisions and strategies occurring in rural landscapes.

The analyses of the case study also confirm previous studies that showed that spatial location of a farm can influence land-use decisions and therefore farming strategies (Bryant and Johnston, 1992; Luttik and van der Ploeg, 2004; Jongeneel et al., 2008). These results also showed that the spatial distribution of such decisions and strategies are not randomly distributed throughout the landscape, which is in accordance with the findings of Köbrich et al. (2003). By defining agent typology and linking it with the landscape, the approach proposed in this paper allows us to link agents' decisions to their environment, which is one of the key aspects of LUCC/MAS (Balmann, 2000; Parker and Berger, 2002; Evans and Kelley, 2004). The empirical definition of an agent typology differs with the agent definition of most MAS that assume more "stereotype" agents that assume very different characteristics and decisions. In fact, the results suggest that defining "stereotype" agents may oversimplify the real diversity in decision-making, restricting their implementation to more theoretical problems.

According to Geertman and Stillwell (2003), Uran and Janssen (2003) and McIntosh et al. (2007), the lack of clarity and flexibility represents a barrier to implement land-use models and decisions support-systems in planning and policy-making processes. Because of its clarity and flexibility, the approach described in this paper moves thus towards a better adoption of MAS/LUCC in such processes. The flexibility of this approach makes it also suitable to be used in different cases studies, where farming systems and rural dynamics might be different.

In conclusion, the method described in this paper is a simple and straightforward approach that combines different empirical methods to built agents-based models. This combination, together with the spatial definition of different agent types, allows us to parameterize, allocate and validate different agent types in an entire region. This empirical method is a step forward to include the diversity of land-use decisions and strategies in MAS/LUCC at a regional scale, as well as the spatial dimension where these decisions take place.

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