



HAL
open science

Operational modelling of peri-urban farmland for public action in Mediterranean context

Esther Sanz Sanz, Davide Martinetti, Claude Napoleone

► To cite this version:

Esther Sanz Sanz, Davide Martinetti, Claude Napoleone. Operational modelling of peri-urban farmland for public action in Mediterranean context. *Land Use Policy*, 2018, 75, pp.757-771. 10.1016/j.landusepol.2018.04.003 . hal-01794795

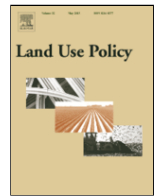
HAL Id: hal-01794795

<https://hal.science/hal-01794795>

Submitted on 26 Jul 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Operational modelling of peri-urban farmland for public action in Mediterranean context

Esther Sanz Sanz*, Davide Martinetti, Claude Napoleone

Institut National de la Recherche Agronomique (INRA), Unité de recherche Ecodéveloppement, France

ARTICLE INFO

Keywords:

Peri-urban
Agriculture
Spatial mapping
Characterisation
Food planning
Land use
Policy

ABSTRACT

Awareness of peri-urban farmland multi-functionality and social concern for food security have prompted public action for the preservation of farmland around cities. A growing literature on peri-urban farming characterises its dynamics and quantifies urban pressure and farmland consumption by urban sprawl. However, such research requires expensive surveys and comprehensive databases that are usually inaccessible to planners and public-policy analysts.

This paper presents an analytical framework for peri-urban farmland characterisation that is operational for public action. Based on in-depth analysis of a Mediterranean local case study using surveys, on-site landscape reading, remote sensing analysis and interviews, we classed peri-urban farming into spatial units of peri-urban agriculture (USAPU). The classification obtained over seven municipalities was later used to train a fractional regression model, which was then tested on the rest of this French *département* (similar to NUTS-3 level), to predict the presence and actual proportion of each USAPU in the total agricultural land of each municipality. Furthermore, we drew up categories of municipality according to USAPU distribution that open perspectives for public action on peri-urban farming. We discussed whether such a model could be used as an instrument for decision-making on food planning, rather than simply for fairly reliable future predictions. This work is the starting point for the development of a methodology characterising complex peri-urban areas, simple to handle and hence operational for policy-makers and planners.

1. Introduction

1.1. Context

Growing cities are encroaching onto farmland all over the world, especially in developing countries. This is particularly true in the Mediterranean basin, with new and promising opportunities to trade land for urban development (Chanel et al., 2014; Darly and Torre, 2013; Gant et al., 2011). In addition, urban growth can influence peri-urban farms' structure by providing opportunities to specialise in short food supply chains for urban consumers (Aubry and Kebir, 2013a; Filippini et al., 2016). Furthermore, proximity to the city has an impact on farmers' lifestyle, since greater pluri-activity tends to decrease the agricultural intensity of labour (Ilbery, 1991; Lange et al., 2013; Primdahl, 1999).

From the perspective of land-use planning, metropolitan farmland contraction has precipitated social demand for preserving productive peri-urban agriculture. On the one hand, agriculture's multi-functionality is credited with providing tangible benefits for ecological and economic territorial dynamics, at both local and regional levels (Fürst et al., 2010; Guillaumin et al., 2008; Helming and Pérez-Soba, 2011). On the other hand, social concerns over food security (Sonnino, 2016; Morgan, 2009) legitimate interest in peri-urban farmland preservation. This is both a valid and a valuable question, expected to have major relevance for land-use planning and management¹ in peri-urban landscapes, where land-use trade-offs are proving urgent and especially difficult to resolve (Geneletti et al., 2017; Scott et al., 2013). Cities are beginning to assume a key policy role, especially concerning food issues (Sonnino, 2016).

Mediterranean landscapes and agri-food systems are intrinsically complex and diverse (Barton et al., 2010; Ortiz-Miranda et al., 2013),

* Corresponding author at: Institut National de la Recherche Agronomique (INRA), Unité de recherche Ecodéveloppement, 228 route de l'aérodrome, CS 40509, Domaine St Paul - Site Agroparc, 84914, AVIGNON Cédex 9, France.

Email address: esther.sanz-sanz@inra.fr (E.S. Sanz)

and meeting social expectations from land-use regulation requires a suitable methodology. Our aim here is to define a methodological framework usable by public bodies to characterise peri-urban agriculture for purposes of spatial and strategic planning. We are focusing our approach in the occidental and European part of the Mediterranean basin. Going beyond the Mediterranean context, we seek to test a prototype of a tool that could, with minor adaptations, be applied to other similar territorial contexts.

In most European countries, land-use planning tools are principally based on zoning provisions (Healey and Williams, 1993; Reimer et al., 2014). However, planning in itself –by means of zoning arrangements– is not effective in preserving farmland near cities (Abrantes et al., 2016). Moreover, suburbanisation and reduced urban density are worldwide phenomena (Angel et al., 2010). In Europe, urban areas have increased 80% over the last 50 years, roughly twice faster than population growth (EEA, 2006). Hence, urbanisation mainly occurs on farmland (Chanel et al., 2014), and it is particularly alarming in Europe, since cities are historically located in fertile regions (Ceccarelli et al., 2014; Greene and Harlin, 1995). For instance, 318,000 ha of agricultural land were lost in France between 2000 and 2010,² with peri-urban areas developing four times faster than urban zones (Piore et al., 2011). “It is evident that physical land-use plans do not prevent urban intrusion and are not sufficient if productive farmland is to be preserved” (Paül and McKenzie, 2013, p. 96). There needs to be a sustainable food strategy and farmland preservation plan (Bousbaine and Bryant, 2016; Jarrige et al., 2009), where short supply chains and food production to feed cities can play a role. Thus, scientific research on food production is moving its focus from agriculture and rural development to also embrace consumption and urban areas.

Urban food planning calls for spatial and food-chain integration as well as a holistic approach to peri-urban farming, including environment, economics, quality, recreational activities, and so on (Moragues-Faus, 2016). Yet there are still few operational frameworks considering all the issues specific to peri-urban agriculture and practices (Galli et al., 2010). Peri-urban agriculture is usually considered in terms of distance from city-centres, in a gradient inspired by Von Thünen’s conceptual model (Sinclair, 1967; Bryant, 1992) where the relationship with the city is correlated with distance (Nahmias and Le Caro, 2012). But distance alone is not enough to characterise peri-urban agriculture, which is diverse, plural and dynamic (Bryant, 1997; Paül Carril, 2006; Soulard et al., 2016).

1.2. State of the art

Research in several fields has analysed peri-urban farming in Western Europe. Furthermore, scientific knowledge provides manifold frameworks for agriculture modelling and assessment oriented to environmental evaluation for land use planning (Burel and Baudry, 2004; Helming and Pérez-Soba, 2011; Schaldach and Priess, 2008; Termorshuizen and Opdam, 2009) and rural development (Groot et al., 2009; Lardon, 2012; Véron, 2003; Waldhardt et al., 2010; Wiggering et al., 2006). Nevertheless, agriculture has rarely been considered in interaction with urbanised zones, even if research started addressing ecosystem-services issues in peri-urban planning for food (Tedesco et

al., 2017). Nevertheless, attempts to build a peri-urban agriculture typology are rare. Some economic studies are based on Von Thünen’s model of agricultural land-use, which classifies farming in four rings depending on distance from city-centre (Von Thünen et al., 1826). According to this rationale for land-use distribution and spatial-economic relationships, adjacency to the urban market determines the profitability of agriculture, measured in terms of transport cost and locational rent, hence the location of each farming type. In addition, geographers have described diverse dynamics and typologies from the analysis of case studies, focusing on the heterogeneity and dynamism of peri-urban farming (e.g. Jones and Bryant, 2016; Marraccini et al., 2013) or on the relation between farming activities and landscape changes (e.g. Kizos and Kristensen, 2011). They show that different forms of agriculture coexist on the urban-rural fringe and can be divided into two main categories: a) “independent” farms that are not constrained by the urban influence to define their business strategy; and b) farms that are functionally linked to the city or that have appeared with it. In the first category (a), we can further distinguish two major typologies: a.1) profitable and non-dependent on the local market, historical farms that have become peri-urban because of nearby urban expansion (Pérez, 2007); and a.2) stable farms with long-term intensification and/or specialisation strategies, aware of marketing strategies, selling on both long and short supply chains, and dependent on international pricing rather than on the urban market (Aubry and Kebir, 2013b). Within the category of farms under urban influence (b), we can distinguish four major types: b.1) those specialised in high value-added products selling mainly on short supply chains (Zasada, 2011; Zasada et al., 2013b) sometimes oriented to public canteen food supply (Darly and Aubry, 2014; Morgan and Sonnino, 2010); b.2) farms with a short-term extensification strategy based on opportunities offered by subsidy policies (e.g. subsidies to durum wheat under the Common Agricultural Policy, CAP) and which cultivate a variable number of temporarily available land plots, usually pending their conversion from agricultural to developable land-use (eg. residential, commercial, etc.), a situation of extreme insecurity for farmers concerning cultivable land-plots availability (Geniaux et al., 2011; Jouve and Napoléone, 2003; Soulard, 2014); b.3) farms with diversification and pluri-activity strategies seeking additional sources of income to compensate for lack of profitability from an intersectorial strategy (Lange et al., 2013), offering services that respond to the urban demand for recreational and environmental farming (Bailey et al., 2000; Ilbery, 1991; Wilson, 2007), including : b.3.1) horse-keeping and equine services (Elgåker, 2012; Zasada et al., 2013a), b.3.2), the so-called “lifestyle farming” best known in its part-time form (Primdahl, 1999; Zasada, 2011) and b.3.3) agri-tourism or accommodation facilities (Sharpley and Vass, 2006; Yang et al., 2010); and finally, b.4) small and medium-sized unstructured, non-dynamic and non-competitive farms, often devoted to retirement farming and hobby farming (Busck et al., 2008; Præstholm and Kristensen, 2007).

These studies are based principally on thorough field-work and interviews, combined with statistical analysis of census data. As such, they usually require major financial and time investments, which limits their potential as a support for planning usable by policy makers and stakeholders. An alternative approach proposed by urban economists is to implement accurate peri-urban farm location models based on exhaustive databases and complex mathematical tools (Cavailhès and Wavresky, 2007; Geniaux et al., 2011). The drawback of this approach is that it requires highly detailed (plot-level) databases that are usually unavailable in most countries, and analytical skills that are beyond the reach of many public non-research institutions. Furthermore, aggregated patterns discovered in *département*-level (similar to NUTS-3 level) agricultural census data cannot encompass the great diversity of individual farms, so that substantial amounts of valuable information are missing (e.g. Clark et al., 2007). Moreover, simplified models are un-

¹ Land-use planning refers to a future desired vision of an area, while land-use management is the process of managing the use and development of land resources. Land-use planning often leads to land-use regulation, which typically encompasses zoning to regulate the types of activities that can be accommodated on a given piece of land. On the other hand, land management practices describe the way that land is managed, the means by which a land use outcome is achieved.

² http://agriculture.gouv.fr/sites/minagri/files/documents/pdf/140514-ONCEA_rapport_cle0f3a94.pdf

able to disentangle diverse farming strategies, which are not mutually exclusive and can be related to different adaptation strategies (Smithers et al., 2004). Field-work and interviews are therefore still key to understanding farming dynamics at *département*-level.

The key research objective of this paper is to define a systemic and generic methodology, operational for public land-use managers and landscape planners and potentially usable in different peri-urban areas. Here, agriculture is considered in its productive dimension and not only as open green space, as is often the case in landscape planning.

We propose in Section 2 a methodology to situate, characterise and represent peri-urban agriculture that aims at integrating agricultural issues into urban and regional planning and identifying actionable elements of public action. We also apply statistical modelling to extend the findings from the case study area to a larger geographical scale. Section 3 presents and discusses the results of this generalisation with a view to future application to urban and regional planning. Section 4 concludes the paper with a discussion and final considerations.

2. Material and methods

In the following section, we describe the methods applied in three successive stages. First, we carried out a comprehensive spatial analysis at local level of the urban area of study to delimit and characterise peri-urban agriculture. Various methods were used: on-site landscape reading, field-work and interviews, photo-interpretation and diachronic remote-sensing analyses of land-use changes. The result of the first stage is the classification of peri-urban agriculture into spatial units (USAPU). Second, we characterised the USAPU classification with respect to a set of variables concerning farming arrangements and dynamics. Third, we extended the results of the USAPU classification to a larger geographical scale (from local level to *département* level –similar to NUTS-3-) by means of a modelling approach.

2.1. Study area

The exhaustive analysis was carried out in the peri-urban area around the city of Avignon in Southern France (more than 200,000 inhabitants spread over 385 Km² and 16 municipalities, with an average density of 518 inhabitants by km² - see Fig. 1). Following Forman (2008), we defined a study region recognised under local planning as urban³, composed of a group of municipalities. Actually, “the urban region is the unit and the scale where existing landscape ecology/urban planning principles apply especially effectively” (Forman, 2008, p. 253). The Avignon peri-urban area shares typical features with other Mediterranean regions, such as heterogeneous morphology, diversity of cultivated crops and diverse farming systems (Grasso and Feola, 2012; Ortiz-Miranda et al., 2013). This area has experienced strong population growth (80% increase between 1962 and 2008)⁴ leading to leapfrog development around city centres, based on scattered housing development (AURAV, 2012).

³ The French National Institute of Statistics and Economic Studies (INSEE) in 2010 defined the Avignon urban area (*Aire urbaine* no. 016) as composed of 97 municipalities. An *Aire urbaine* is defined by INSEE as a set of municipalities, continuous and without enclaves, consisting of an urban pole (urban unit) of more than 10 000 jobs and rural municipalities or urban areas (peri-urban crown) where at least 40% of the resident employed population work in the pole or in surrounding municipalities. For this study, we chose seven municipalities representative of the Avignon peri-urban area with similar geographical conditions and located less than 45 minutes from employment clusters (i.e. the areas where most employment is located, following the Avignon planning agency (AURAV, 2011)).

⁴ The demographic growth of Avignon urban area is stronger than that of Provence-Alpes-Côte d’Azur *région* (+ 73 %) or that of metropolitan France (+ 34 %).

2.2. Conceptual framework

We departed from the hypothesis that both peri-urban farming activities and their spatial arrangement and landscape dynamics are heterogeneous, as is typically true of Mediterranean medium-sized cities like Avignon (Debolini et al., 2018; Marraccini et al., 2015). Moreover, we considered peri-urban agriculture to be part of what we call the “agri-urban system”, since cities need the goods and services provided by farming (Soulard et al., 2016). Besides, “agricultural landscapes, which occupy more than 40% of the European Union and more than 30% of the contiguous American states, are arguably the largest urban land-use, since the functional ecosystems of cities extend to agricultural watersheds that provide potable water and other ecosystem services, and the supply chains of urban food processing and consumption begin in agricultural landscapes” (Nassauer, 2012, p. 223). From this perspective, the agri-urban system places agriculture at the heart of the analysis, from the viewpoint of its multifaceted relations with the urban system, through farming practices and the flow of goods and services. Geographers have proposed several frameworks to explain the internal and external driving forces defining the business strategy of peri-urban farmers. Based on case study analysis, these frameworks either focus on farm behaviour and adaptation to external forces (Bousbaine et al., 2015; Bryant, 1992; Heimlich and Anderson, 2001; Robineau, 2013), or highlight internal forces and the relationships between the farm’s business and household, in the case of family farms (Bertoni and Cavicchioli, 2016; Lobley and Potter, 2004; Shucksmith and Herrmann, 2002; Smithers and Johnson, 2004). In addition, we assumed that competition assigns peri-urban land to the most profitable activity (Debolini et al., 2018; Napoléone, 2005; Wibberley, 1960).

Formally, we sought a conceptual framework for the external and internal driving forces shaping farming system dynamics in the peri-urban context. We schematized the components of the agri-urban system by discriminating between prevailing internal elements of peri-urban farming and external drivers contributing to its evolution (Fig. 2). This framework is adapted to global North context. We identified several external forces: the European Common Agricultural Policy -CAP- (Bartolini et Viaggi, 2013; Overmars et al., 2013; Viaggi et al., 2013); standardisation and commodification of agricultural goods, new marketing devices and globalised marketing of foodstuffs (Lobley and Potter, 2004); climate change and adaptation of cropping and livestock farming systems (Bryant et al., 2016; Section Production animale de l’Académie d’agriculture, 2016); regional agriculture sectorial organisation (Bryant, 1997); the urban demand for food security and sovereignty (Condon et al., 2010; Connell et al., 2013). On the other hand, two types of internal forces determine peri-urban farming: the business and the farming household. The first group of factors includes land quality and location, fragmentation and possible atomisation of crop plots, farm size, degree of specialisation, enterprise cycle and debt, tenancy system covering farmed areas, etc. (Bryant, 1992; Heimlich and Anderson, 2001; Heimlich and Brooks, 1989; Morlon et al., 2006; Vidal, 2011; Zasada et al., 2013b). The factors affecting farming family households include farmer age and background, children and potential successors to continue the farming business, type of work force employed, farming philosophy, etc. (Bessière and Gollac, 2014; Clark et al., 2007; Lataste and Chizelle, 2014; Paranthoën, 2014; Smithers and Johnson, 2004). These characteristics can be summarised as follows:

- Farm structure:
 - o Production means: land quality, size, type, equipment (green-houses, agricultural machinery), irrigation facilities (canal/well), crop-plot fragmentation (adjoining/scattering).

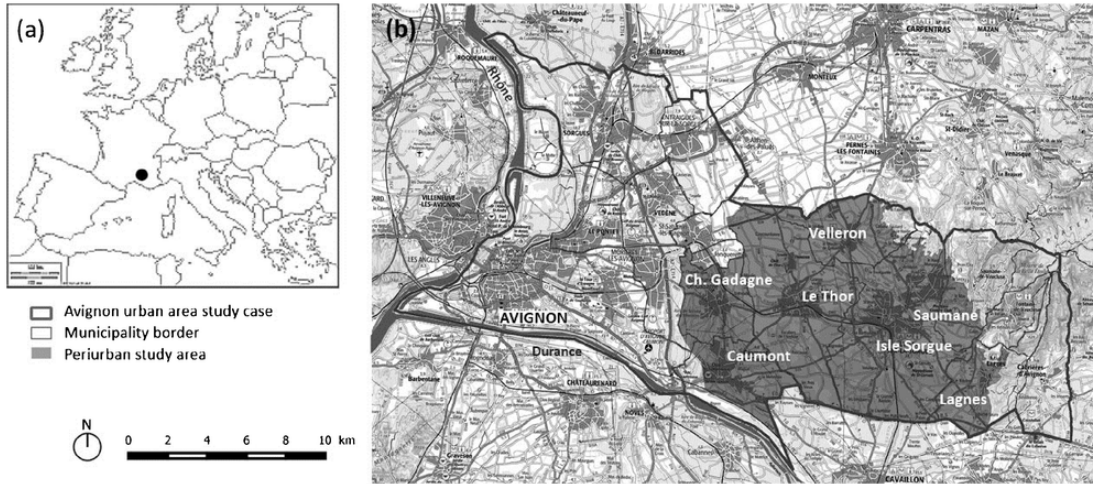


Fig. 1. The geographical location of Avignon (a) and the study area (b).

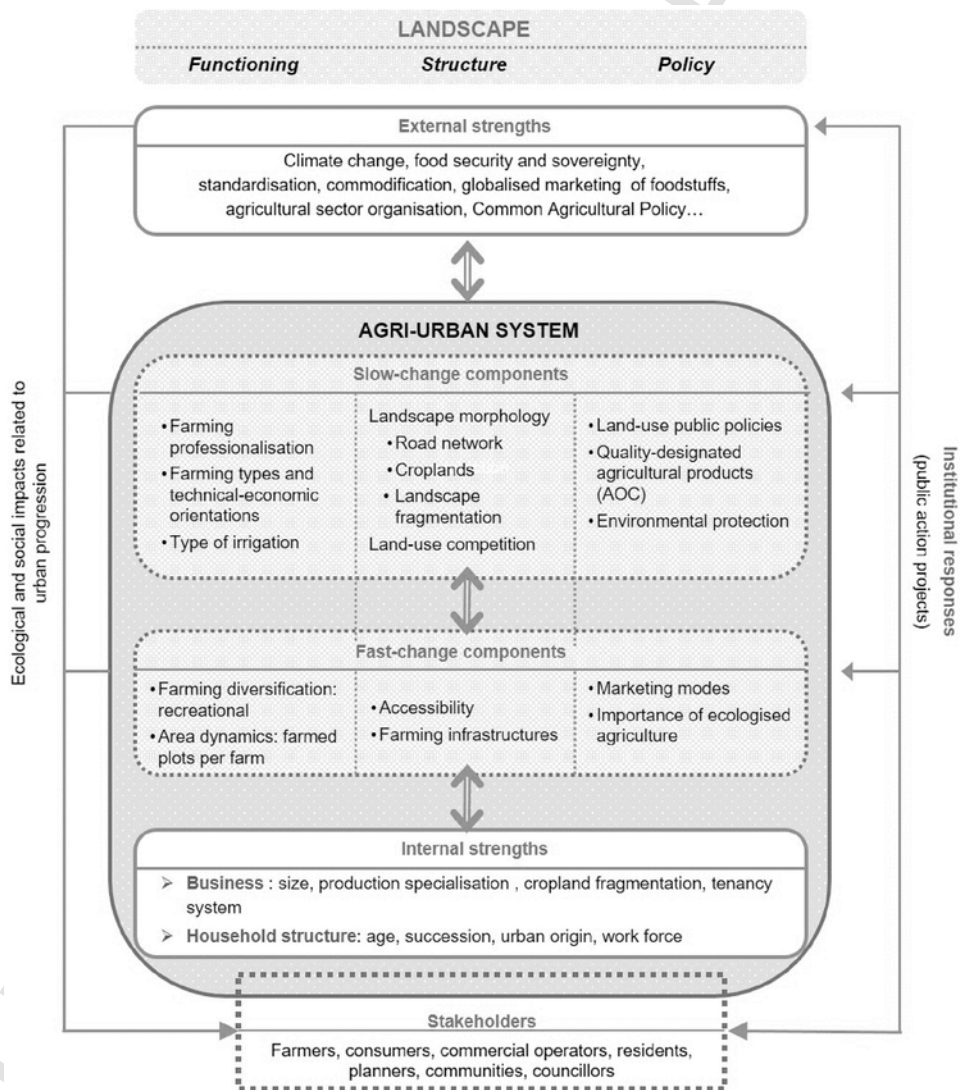


Fig. 2. Conceptual framework of external and internal forces shaping agri-urban system components.

- o Production strategy: scale of production (current crops and size in ha), production intensity (crop rotations and inputs), production modes (conventional versus organic).

- o Labour: permanent and temporary employees, family participation in on-farm work, full/part-time/hobby farming.
- o Management: marketing modes (long versus short supply chains), land tenure modes (rental versus purchase of farmland), urban-oriented marketing strategies (e.g. processing of farm products to increase added value).
- Head of the exploitation trajectory: background, education, life-course (length of professional farming experience), age, children, succession plans, farming and life-style philosophy, objectives, reasons for becoming a farmer, whether satisfied or not, perceived obstacles to farming profession.
- Business trajectory and adjustments: expand and intensify, on-farm diversity and urban-oriented marketing, off-farm work, replace hired farm labour with owner-exploitation, no change, downsize, hobby-farming, exit. Indicating:
 - o past crops and size (ha) to measure changes in farm holding size
 - o motivation to change crops, e.g. new crops or livestock to sell to new urban consumers
- Metropolitan forces (local community farm system): agricultural support infrastructure at local scale, accommodations made to satisfy urban neighbours (ex. crop spraying modified to reduce drift/smells), land-use values and restrictions, pressures for non-farm development, local-labour markets and alternative job and life-style opportunities, tradition/norms, tourism potential, policies supporting agriculture decided at provincial and European scales and applied locally.
 - o Local-community relationships: grassroots organisations, neighbourhood associations, socio-economic composition, information networks.

The combination of internal and external driving forces shapes the three attributes related to the peri-urban agricultural landscape (Piore, 2003; Sanz Sanz, 2016): landscape structure (urban and farming spatial configuration), landscape functioning (farming practices and farming business model) and landscape policy (preservation regulations), as shown in Fig. 2.

2.3. Methodology

Our methodology consists of three steps at two levels of public action (from local to provincial level, Fig. 3).⁵ At the case-study area level, our in-depth empirical analysis included 1) a comprehensive analysis using fieldwork, interviews and spatial analysis to identify the types of peri-urban agriculture and their drivers and 2) a statistical analysis. Then, at the provincial level, we took 3) a probabilistic approach based on regression models, aimed at predicting the types of peri-urban agriculture likely to be observed. Steps 1) and 2) involved fine spatial analysis at crop-plot scale, whereas step 3) was performed from localised results at municipal level.

2.3.1. Empirical analysis at local level

Our goal was to construct spatial units of peri-urban agriculture (USAPU) that could be used as a tool for policy makers and stakeholders. USAPU are local spatial entities bigger than farms (in the case study area, covering between 20 and 40 Km², not necessarily continuous) that are homogeneous in terms both of farming and urban uses and of layout. They were defined statistically by combining variables describing different features of plots and farms (geography, economics, agronomy, regional politics), to characterise and map peri-urban agriculture. Thus, USAPU characteristics and locations evolve with changes

⁵ Full details of methodological development and techniques used are in the PhD thesis of Esther Sanz Sanz (2016) – see <http://www.theses.fr/2016EHES0115>.

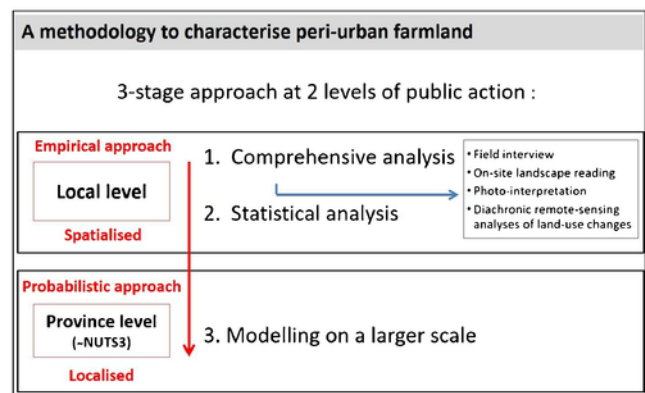


Fig. 3. Steps in the implementation of the methodology to characterise peri-urban farmland.

in local characteristics (e.g., land prices, public policy, proportion of organic farming), so they do not simply represent a fixed zoning. USAPU can therefore be used in an adaptive way to highlight areas experiencing changes or risks that call for public or social action. We place our work in the framework of geo-agronomy (Deffontaines et al., 1995; Rizzo et al., 2013).

2.3.1.1. Comprehensive analysis To construct USAPUs, we analysed the peri-urban agriculture of our study case in two steps:

- First, we performed a multi-temporal spatial analysis of the land-use and land-cover changes (LULCC) over the last four decades in order to identify hot-spots of change during the peaks of urban sprawl that started in the late seventies (AURAV, 2013; Grosso et al., 1993). LULCC was semi-automatically characterised through remote sensing for three dates (1973, 1987 and 2011) and for five land-cover classes: urban, agriculture, natural vegetation and woods, bare soil (natural and artificial) and water. We used Landsat data because they have been recorded since the seventies, are free of charge and are suitable for regional analysis (Wulder et al., 2008). In addition, to test reliability and validate the classifications, we carefully compared them visually with complementary data sources such as *Corine Land Cover* (EEA, 2012), aerial ortho-photography and *Google Earth* photos.
- Second, we undertook a morphological and functional spatial analysis combining various methods: photo-interpretation, on-site landscape reading, spatial database analysis and interviews. The goal was to locate and identify in the landscape recurrent patterns of observable activities (e.g. grazing) and structural elements (e.g. the presence of horse shelters and fencing). This process involved several iterative stages to visually examine the indicators of cover, use and farming practices (e.g. road network, irrigation system, crop type, land-tenure system, crop-plot layout) at different scales, ranging from the whole study case to 1:5000 detail. Furthermore, we interviewed 14 farmers, 3 municipal councillors and 3 local experts (farmers' representatives or technical advisers), seeking to better understand both the factors shaping farms' evolution and the drivers of farmers' strategies. The interviews were semi-structured and lasted about one hour. They were recorded, anonymised and analysed following the grid shown in Box 1. The quantitative and qualitative data were mapped⁶ at 1:10,000 detail.

⁶ Interviews with councillors and experts were conducted using maps. This allowed us to spatially locate their responses. On the other hand, interviews with farmers were reported to the extent of their farms.

Box 1. Interview analysis grid.

Interviews with farmers

Questions about professional life and farm evolution aimed at tracing their trajectory. The goal was to identify the drivers of changes explaining the current strategy of the farms. Analysis grid:

Farmer - Municipality - Internet- Age - Birthplace - Strategy - Social environment - Schooling - Length of farming career - Full-time/part-time - Reasons for becoming a farmer - Satisfied/not satisfied - Successors - Formal/informal associations - Farming equipment System of land tenure - Farm fragmentation - Relationship with local government - Relationship with provincial government - Subsidies (CAP) - Professional impediments - Irrigation methods - Crops (ha) - Previous crops (ha) - Reasons for crop-change - Organic/conventional - Production intensity / rotations - Production strategy - Workforce: employees / family / seasonal - Marketing

Interviews with municipal councillors

Questions about local public action in the municipality and about local impact of national and European policies (e.g. CAP). The goal was to understand how public action was evolving and how these organisations were adapting to new policies. Analysis grid:

- Decision-maker - Local public action - Local impact of higher-level policies - Public action evolution - Adaptation of organisations

Interviews with local experts

Questions about policies concerning territorial development, agriculture and conservation of natural areas and biodiversity, to trace their evolution. The goal was to highlight significant events in peri-urban farming evolution that have shaped the current situation and to compare local experts' responses with events identified in the literature review. Analysis grid:

- Type of expert - Territorial development policies - Natural area policies - Agricultural policies - Evolution

We then overlaid these analysis using GIS. This comprehensive and qualitative analysis allowed us to visually identify eight homogeneous entities (USAPU) in terms of landscape features, agricultural land use and dynamics (Fig. 4): USAPU-A consisting of marketing-aware horticultural farms surrounding built-up areas; USAPU-B of "opportunistic" CAP-driven cereal crop farming; USAPU-C of small, highly-diversified and fragmented farms; USAPU-D of historical green-belt horticulture; USAPU-E of historical fruit arboriculture; USAPU-F of recreational agriculture; USAPU-G of quality wine growing and USAPU-H of low-mountain crop/livestock farming.

2.3.1.2. Statistical analysis The next step was to analyse the USAPU classification with respect to a set of 75 variables concerning data from several sources.⁷ All variables were available from existing maps and databases for the entire study-region and with sufficient spatial resolution. We carried out iterative analysis (correlation matrix and multiple

correspondence analysis –MCA–) to reduce the number of statistically significant variables explaining the variance between the USAPUs.⁸ The resulting twenty variables are listed here, grouped by the landscape attribute they are related to (Table 1):

- Landscape structure: density of road network, crop-plot shape, location of farmstead and farm buildings, border relationship with urban zones, nearby urban fabric morphology and built-up land use evaluated from remote sensing analysis in 1987 and 2011.
- Landscape functioning: proportion of farmed area declared to the agricultural social security (*Mutuelle Sociale Agricole*, MSA), percentage of declared farmed areas with no defined type of crop, dynamics of cropland on each farm (number of farms that expanded or reduced cultivated area and proportion of increased cultivated area on existing farms between 2004 and 2006, analysed based on declarations to MSA), percentage of leased land, diversification by type of farming (*orientation technico-économique*, OTEX), type of irrigation, proportion of professional farmers out of the total, as defined both by the 2010-farming-census⁹ condition of a minimum cultivated area for statistical inclusion and by the minimum area required by the Chamber of Agriculture.¹⁰
- Landscape policy: size of areas classified as agricultural or natural by the municipal land-use plan (*Plan Local d'Urbanisme*, PLU) and proportion of farms containing plots covered by a protected designation origin (AOC) vineyard.

2.3.2. Modelling at provincial level

In this section we propose a methodology to extend the results on farm USAPU classification to a wider geographical scale, such as the whole *Vaucluse département* (similar to NUTS3 level), to predict the types of peri-urban farming activities likely to be found in the rest of the region. We chose a modelling approach to avoid a costly and time-consuming replication of the first part of this research (comprehensive survey and interviews) with the 151 municipalities of the *Vaucluse*. We were therefore obliged to extract all useful information from the classification of our study area's seven municipalities, comparing it with available data at the municipal and *département* level. The main drawback was the quality of the data for the rest of the region, with only aggregated information available at the municipal level. We therefore exploited the 2010 agriculture census (*Recensement Général Agricole* - RGA) database, containing information at municipal aggregated level on the proportions of land dedicated to several land-use types, distance from amenities and services and other features relevant to characterising peri-urban agriculture in the *Vaucluse département*. Table 2 contains descriptions and statistics for the 18 explanatory variables used in the model specification.

We trained a regression model on the seven municipalities of the case study and then applied it to the rest of the *département* in order to predict the presence and current proportion of the eight USAPUs in the total Utilised Agricultural Area (UAA) of each municipality. Before giving details of the regression model, it is worth mentioning the type of data-handling this involved. Since the information in the *Vaucluse* was only available at aggregated municipal level, we first had to rescale and normalise the presence and surface area of each USAPU such that,

⁸ The set of 75 variables is briefly presented in Sanz et al., 2017 and Sanz Sanz et al., 2016. They are described in detail in the PhD thesis of the first author.

⁹ In France, the farming census *Recensement Général Agricole* (RGA, general agriculture survey) specifies certain conditions on minimum single farm area for statistical inclusion: at least 1 hectare of utilised agricultural area (UAA) or failing this, at least 0.2 hectares of specialised crops.

¹⁰ In France, the Chamber of Agriculture of each *département* defines the minimum farming area (*Surface Minimale d'Exploitation*, SMI) for each farm type conferring entitlement to join the agricultural social security system.

⁷ Landsat imagery from 1987 and 2011; orthophotography from 1973, 1987 and 2011; 2014 geo-referenced aerial photos; land cadastre; geographical shapes from *Institut National d'Information Géographique et Forestier* (IGN) and *Centre Régional de l'Information Géographique en Région Provence-Alpes-Côte d'Azur* (CRIGE PACA); *Institut National de l'Origine et de la Qualité* (INAQ) - AOC wine quality zoning; *Géorisques*, national governmental database; *Mutuelle Sociale Agricole* (MSA), database for farms in *Vaucluse département*; local land-use plans (PLU); inter-municipal strategy plans (SCoT).

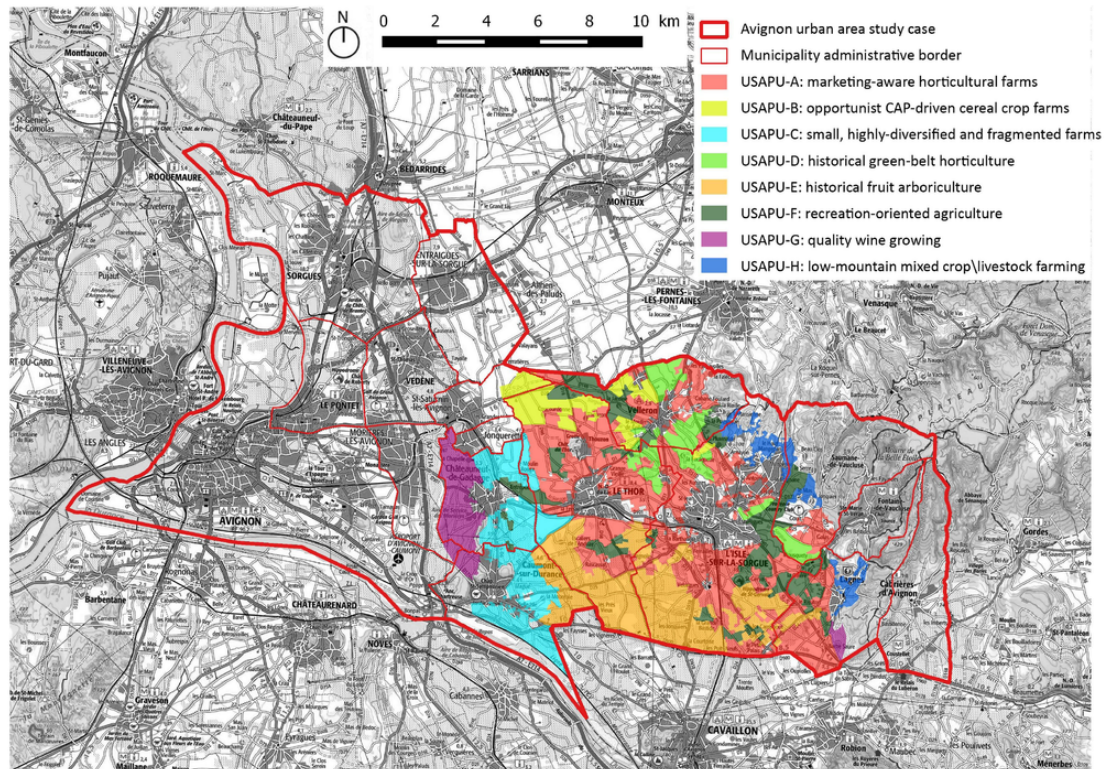


Fig. 4. USAPU mapping in Avignon study area.

for each of the seven municipalities, we had a vector (y_A, \dots, y_H) representing the proportion of each USAPU in the total UAA of the municipality. Table 3 shows the observed proportions of the eight USAPUs in the seven municipalities.

Data presented in this way are usually referred to as compositional or fractional data, meaning that the value y_{ic} (c in $\{1, \dots, m\}$, i in $\{1, \dots, n\}$) represents the share that observation i has allocated to the corresponding category c , under the constraints that $0 \leq y_{ic} \leq 1$ and $\sum_{c=1}^m y_{ic} = 1$, for any i in $\{1, \dots, n\}$. In our study, y_{ic} represents the proportion of the total UAA of a municipality i that is classified under USAPU c . Commonly, these data are transformed in various ways (e.g. isometric, additive log-ratio or centred transformations) and then analysed by means of log-ratio analysis, as pioneered by Aitchison (1982). Alternatively, Campbell and Mosimann (1987) proposed a Dirichlet distribution. We chose Dirichlet regression and its implementation in the R software under the DirichletReg library (Maier, 2015). This regression model allows a different set of explanatory variables to be specified for each category of the compositional data and we took advantage of this feature when it came to choosing the explanatory variables: having advance expert information on the prominent attributes that defined each of the USAPUs (see Table 1), we chose to explain the share of the different categories by the most meaningful variables. For example, we explained the proportion of USAPU A (horticultural farms surrounding built areas) in a municipality by means of the area dedicated to vegetable production, plant nursery, and greenhouses; the proportion of USAPU B (“opportunist” CAP-driven cereal crop farming) by means of the area dedicated to cereal crops and the number of farms that were recognised as primary economic activities. In the same vein, USAPU C (highly-diversified and fragmented farms) is characterised by distance from the city centre and proportion of land dedicated to diversified production, USAPU D (historical horticulture) by the number of farmers registered in the national agricultural survey and the area dedicated to vegetable production, USAPU E (similar to

USAPU D but for fruit production) by the area dedicated to fruit production, USAPU F (recreational-oriented, especially equestrian centres) by distance from the city centre and area dedicated to horse boarding and riding, USAPU G (protected-designation wine production) by agricultural land prices and the area dedicated to wine production and finally USAPU H (low-mountain traditional crop-livestock farming) by the mean slope of the municipality and the area of natural land. The model parameters estimated and the variables chosen for each USAPU are shown in Table 3; the values fitted on the training set are in the coloured columns, next to their respective observed values. It should be noted here that our aim was not to find the model that best fits the observed data, but rather to produce an expert-informed model, capable of predicting USAPU proportions in municipalities outside the study region, as the following section shows.

3. Results

Local-level analysis resulted in the identification of 8 USAPUs characterised by a set of homogeneous variables in terms of arrangements and dynamics:

- USAPU-A: small and medium-sized farms fragmented in several land plots at different geographic locations, mainly engaged in horticulture under shelter, and combining several market strategies, from on-site selling to distribution abroad.
- USAPU-B: farming geared to short-term “opportunist” CAP-driven cereal crops (e.g. durum wheat) on large land plots formerly partitioned by East-West trees-hedgerows intended for horticulture or permanent crops, some fragments of which remain.
- USAPU-C: small, highly-diversified and very fragmented farms, not operating on a standard agricultural basis and probably dependent on an outside salary, composed of small land plots of vineyard, vegetables and annual crops, in the immediate vicinity of built-up areas.

Table 1
Significant variables explaining USAPU variance at local level.

Item	Description	Whole study area	USAPU A	USAPU B	USAPU C	USAPU D	USAPU E	USAPU F	USAPU G	USAPU H
Landscape structure	Road network density (YES, NO)		YES	NO	YES	NO	YES	NO	NO	NO
	Crop plot shape (C, F, I) ^a		F	C	F	C	I	I	I	C
	Location of farmstead (A, N) ^b		A	N	A	A	A	A	N	A
	Built land use in 1987 (0, 1, 2, 3, 4) ^c		4	1	2	1	2	3	3	3
	Built land use in 2011 (0, 1, 2, 3, 4)		4	1	4	1	3	4	4	4
	Border relation between farming and urban zones (J, I, N) ^d		JI	N	JI	J	N	J	J	JI
	Nearby urban fabric morphology (1, 2, 3, 4) ^e		1	4	2	3	4	3	1	2
Landscape functioning	Officially declared farmed area (%)	0,60	0,55	0,80	0,42	0,87	0,78	0,52	0,62	0,16
	No defined type of crop (%)	14	0	6	28	7	13	14	25	11
	Farms with expanded farmed area (%)	0,2	0,08	0,00	0,07	0,05	0,06	0,06	0,06	0,00
	Farms with reduced farmed area (%)	0,004	0,11	0,06	0,13	0,14	0,06	0,17	0,03	0,00
	Increase in farmed areas (%)	0,06	0,008	0,000	0,005	0,001	0,003	0,007	0,003	0,000
	Tenant farmed land (%)	80	77	90	74	83	77	84	71	76
	Main type of farming (%)	25	29	39	29	40	46	30	29	57
	Professional farmers according to census area criterion (%)	0,66	0,60	0,77	0,67	0,63	0,76	0,54	0,77	0,77
	Professional farmers according to Chamber of Agriculture (%)	0,19	0,14	0,14	0,08	0,18	0,33	0,05	0,08	0,03
	Type of irrigation (I, N, D) ^f		N	D	N	I	I	N	D	D
Landscape management	Agricultural areas in land-use plan (%)	87	88	97	68	98	99	83	93	33
	Natural areas in land-use plan (%)	9	2	0	23	0	0	9	5	59
	Farms with protected-designation wine production (%)	3	1	0	20	2	0	0	50	0

^a C: compact, F: fragmented, I: irregular.

^b A: crop plots located around farmstead, N: without nearby farm-buildings.

- c 0: no buildings embedded in farmland, 1: very few buildings embedded, 2: several buildings embedded, 3: many buildings embedded, 4: groups of several buildings embedded.
 d J: juxtaposition, JI: juxtaposition and imbrication, N: no contact.
 e 1: continuous urban fabric, 2: discontinuous urban fabric, 3: leapfrog development, 4: scattered buildings.
 f I: irrigated land, N: non-irrigated but irrigable land, D: dry-land farming.

Table 2
 Explanatory variables at provincial level.

Name	Description	Min	Median	Mean	Max
Prop_land	Proportion of land use in the categories:				
- p_agri	- Agricultural	0.18	0.74	0.64	0.86
- p_nat	- Natural				
- p_urb	- Urban				
		0.01	0.09	0.20	0.74
		0.05	0.13	0.14	0.25
Crop	Proportion of agricultural land dedicated to				
- hort	- Horticulture	0.00	0.02	0.03	0.05
- green	- Greenhouse				
- nurs	- Plant nursery				
- cere	- Cereal				
- legu	- Legume crops				
- fru	- Fruits				
- wine	- Wine				
- horse	- Horses				
- poly	- Polyculture				
		0.00	0.02	0.03	0.08
		0.00	0.02	0.01	0.03
		0.00	0.07	0.11	0.23
		0.00	0.02	0.03	0.08
		0.08	0.17	0.23	0.43
		0.02	0.05	0.10	0.25
		0.00	0.02	0.02	0.05
		0.37	0.40	0.44	0.62
N_RGA	Number of farms surveyed	18	32	43	88
SMI	Number of professional farmers (Proxy for professionalisation of farms)	3	14	19	49
Evol_urb	Proxy for urban evolution	223	304	326	489
Price_agri	Price of agricultural land	15	12	19	30
CBD	Distance from closest central business district	20	44	41	63
Slope	Slope	0	1	2	8

- USAPU-D: historical green-belt horticulture composed of medium-sized land plots around a farmstead combining open-air and under-shelter vegetable cropping, mingled with some elongated plots bordered with hedges formerly used for fruit growing (in the seventies).
- USAPU-E: historical fruit arboriculture composed of orchard ribbon plots (40×200m long) bordered by trees-hedgerows to protect crops from Mistral winds.
- USAPU-F: recreational-oriented agriculture, especially equine services (horse-boarding and horse-riding facilities) and agri-tourism. This USAPU is not clearly structured, being composed of small patches interwoven with other USAPUs in the surrounding urban and built-up areas. It is characterised by high density of equestrian centres and horse stables surrounded by cultivated grasslands and hay meadows, mingled with plots of vegetable crops, orchards, fallow land and wild land.
- USAPU-G: wine-growing under protected designation of origin (French label *Appellation d'Origine Contrôlée*, AOC) either on large cropping plots (400m side) around a farmstead on a discontinuous hedgerow landscape, or on irregular and broken-up medium-sized plots (about 100×250m) surrounding urban areas on a dense bocage with scattered abandoned vineyards and wild land.
- USAPU-H: mixed crop/livestock farming on low-mountain slopes, historically cultivated on step terraces still visible on the landscape, although most today are wild land and wooded.

The spatial layout of these eight USAPUs (Fig. 4) is not solely based on distance from the city centre, as in the framework proposed by the Von Thünen conceptual model (market-gardening located very close to

the city and less profitable farming activities farther away). For example, the wine-growing USAPU is located close to the urban centre of Avignon. This is consistent with findings from other studies (e.g. Marraccini et al., 2015).

At provincial level, after training the regression model on the seven case-study municipalities, we tested it on the rest of the *département* (151 municipalities). The results of the prediction for each municipality are graphically represented with pie charts on the map of Vaucluse (Fig. 5). We can identify several categories of municipality from a visual analysis of the predicted distribution of agricultural areas according to USAPUs:

- In the Northwest of the *département*, USAPU-G (AOC wine) is the most widely represented type of agriculture, matching almost perfectly the municipalities situated in highly-valued wine-growing areas;
- In the East of the *département*, where the municipalities are classified as “mountain area¹¹” or are in “areas facing natural or other specific constraints¹²” other than mountain areas, the most widely

¹¹ The European definition of «mountain area» was constructed in the CAP context to consider the natural and structural disparities among various agricultural zones (Cf. 75/262/CCE directive of 28 April 1978 and article 8 of regulation EU No 1257/1999).

¹² The Areas facing Natural or Other Specific Constraints (ANCs) others than mountains areas present “biophysical” or other specific constraints for agricultural production; but the areas should be maintained for the reasons of environmental protection or improvement, maintenance of the countryside, preserving touristic potential or protection of the coastline. Before the 2013 CAP reform, the ANCs areas were known as ‘Less Favoured Areas’ (LFAs). (Cf. 75/262/CCE directive).

Table 3

Top of the table: regression parameters of the estimated Dirichlet model. Bottom: observed and predicted proportions of the 8 USAPUs in the 7 case-study municipalities.

	USAPU A		USAPU B		USAPU C		USAPU D		USAPU E		USAPU F		USAPU G		USAPU H	
	Var.	Coeff.	Var.	Coeff.	Var.	Coeff.	Var.	Coeff.	Var.	Coeff.	Var.	Coeff.	Var.	Coeff.	Var.	Coeff.
		1.66														
<i>Inter.</i>		39.04	<i>Inter.</i>	-1.63	<i>Inter.</i>	-3.66	<i>Inter.</i>	-0.66	<i>Inter.</i>	-0.75						
<i>Hort</i>		-16.24	<i>SMI</i>	-0.01	<i>CBD</i>	-0.44	<i>RGA</i>	-0.04	<i>SMI</i>	0.02	<i>Inter.</i>	0.05	<i>Inter.</i>	-3.17	<i>Inter.</i>	0.01
<i>greennurs</i>		35.72	<i>cere</i>	7.11	<i>poly</i>	4.21	<i>p_agri</i>	0.02	<i>p_agri</i>	0.01	<i>CBD</i>	0.02	<i>Price</i>	0.17	<i>p_natu</i>	0.08
<i>p_urb</i>		-0.09	<i>p_agri</i>	0.02	<i>Evourb</i>	0.01	<i>legu</i>	44.28	<i>fru</i>	3.91	<i>horse</i>	18.36	<i>wine</i>	3.94	<i>slope</i>	-0.29
	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.
Caumont	0.000	0.016	0.000	0.018	0.600	0.549	0.000	0.019	0.222	0.072	0.000	0.036	0.178	0.233	0.000	0.056
Ch	0.000	0.054	0.000	0.019	0.493	0.471	0.000	0.019	0.000	0.029	0.066	0.035	0.441	0.352	0.000	0.023
Gadagne																
Isle	0.407	0.307	0.006	0.032	0.000	0.034	0.044	0.089	0.292	0.333	0.139	0.137	0.000	0.025	0.112	0.043
Sorgue																
Lagnes	0.297	0.321	0.000	0.018	0.000	0.005	0.000	0.039	0.043	0.115	0.096	0.142	0.036	0.019	0.527	0.341
Saumane	0.080	0.035	0.000	0.016	0.000	0.006	0.048	0.048	0.000	0.012	0.055	0.058	0.000	0.025	0.818	0.801
Le Thor	0.472	0.399	0.099	0.131	0.060	0.070	0.039	0.017	0.249	0.146	0.081	0.144	0.000	0.035	0.000	0.059
Velleron	0.305	0.329	0.130	0.139	0.000	0.059	0.226	0.210	0.000	0.043	0.201	0.146	0.000	0.020	0.138	0.054

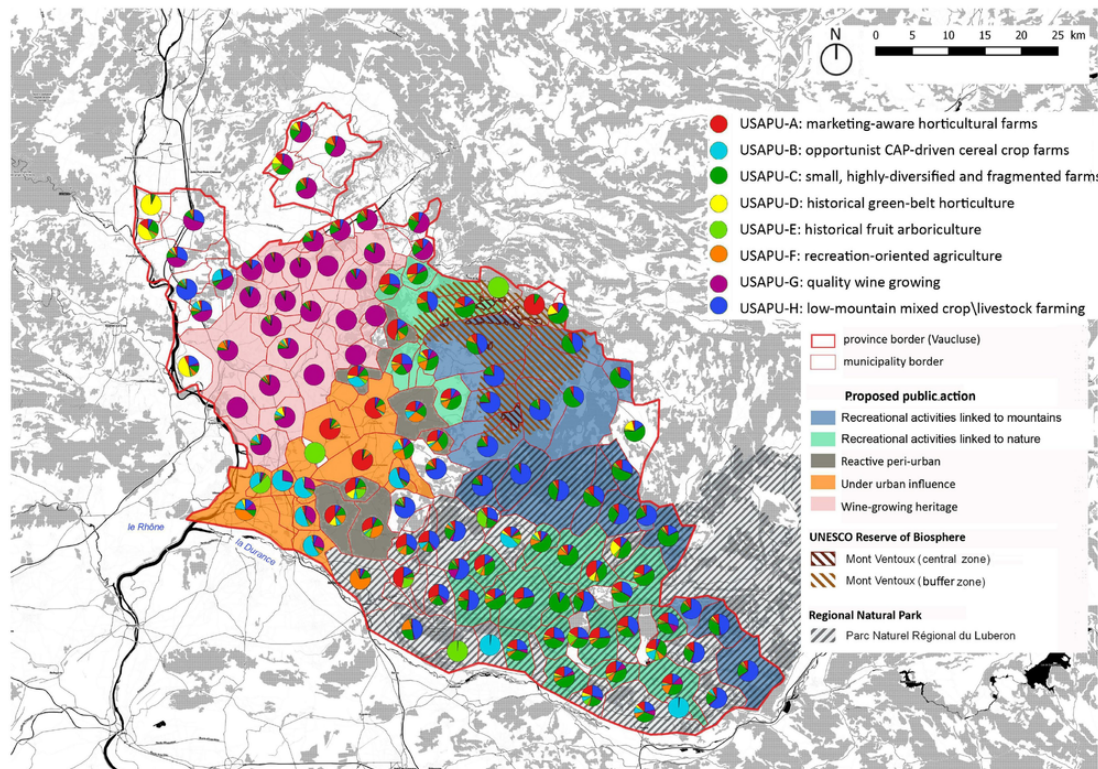


Fig. 5. Predicted distribution of agricultural areas in Vaucluse municipalities according to model.

represented types of peri-urban agriculture are USAPU-H (low mountains) and USAPU-F (recreational);

- c) In the South, the municipalities with a high proportion of USAPU-F currently fall under environmental-protection zoning (either the *Luberon* regional natural park or the *Mont Ventoux* UNESCO biosphere reserve), and generally have a high proportion of farms offering agro-tourism services and other diversification activities¹³.

Similarly, we tested for any possible correspondence between, on the one hand, USAPU distribution and the individual municipalities' predominant farming-type (the *orientation technico-économique* -OTEX- defined by the 2010 farming-census), and on the other hand, the zoning produced under public policies linked to inter-municipality cooperation¹⁴ and even the Vaucluse landscape units¹⁵; however, we found no relationship.

The predictions of the model show some inconsistencies, where municipalities with particular features were not well represented in the training set. For instance, the predictions for 3 municipalities (*Brantes*, *Puget* and *Saint Leger du Ventoux*) estimated only one type of USAPU because they have very few listed farmers. For the remaining municipalities, the predicted values were confirmed by expert knowledge and by superposition with other parameters that were not considered in the model (to avoid endogeneity), both for census data and for public zoning. Once again, we found that the distribution of USAPUs in the municipalities is not based on distance from urban centres of reference. This corroborates the results of local-level USAPU analysis: other drivers explain USAPU location, such as agro-ecological and historical conditions or political choices and environmental regulations.

¹³ Source: *Agrreste, Recensement Général Agricole* (RGA 2010).

¹⁴ Thus, we analysed the territorial coherence schema zoning (SCOT) and the inter-municipality cooperation public institutions (ECPI).

¹⁵ Source: *Agence Paysages* et al. (2013).

Furthermore, the five categories of municipality that we identified according to USAPU distribution open perspectives for public action on peri-urban farming (Fig. 5). What is more, the USAPU distribution could be linked to the ecosystem services framework by unifying and streamlining terminology into implementable programs and schemes. This could be useful to make a bridge between environmental and food planning which remains a challenge for sustainable development of urban peripheries (Geneletti et al., 2017; Viljoen and Wiskerke, 2012). For the category linked to wine-growing heritage, where USAPU G is exclusive or in the majority, public action should be strongly linked to local landscape and environment potential. For those municipalities where agriculture is oriented toward recreational activities involving either mountains (USAPU H) or existing environmental protection zoning (USAPU F), political action should respond to the social demand for quality products, environment and landscape preservation, e.g. by providing public support for agriculture and territorial development in the face of market-dominated CAP policies and sectorial policies at national level. Beyond existing actions in support of local short supply chains in these regions, policies should also create new forms of governance between farmers and other local stakeholders, to define a territorial project supporting these new agricultural activities. This might take the form of developing partnerships with sectorial institutions around quality local products (*produits du terroir*), or promoting innovation in energy production from local agricultural resources adapted to rough and hilly regions. Moreover, the municipalities where agriculture is oriented toward recreational activities could exploit local potential and expertise by creating complementary craft or tourism activities in connection with existing policy devices (mountain zone and regional natural park). For example, horse-boarding and horse-riding facilities could be coupled with tours introducing local products. Finally, we distinguished two categories of municipalities where agriculture is under urban pressure, and therefore public urban action should support local production. The category "active peri-urban" encompasses municipalities with a balanced distribution of USAPUs and lo-

cated close to urban centres, where farming is not fully influenced by market strategies. Here, there is room for institutional projects, such as food planning actions, to relocate the urban food supply. On the other hand, the category “under urban influence”, with high proportions of USAPU A or USAPU C, would benefit from urban projects preserving farmland and supporting farming activities. For those municipalities where the USAPUs are mainly driven by agricultural market strategies (USAPU D and F), we do not suggest any particular political action.

4. Discussion

This paper proposes an operational modelling approach that could be used to support decision-making on farmland management in peri-urban areas. In addition, our proposal covers both farm and regional level: the USAPUs are constructed using indicators concerning farm structure and management decisions. In this section, we consider whether such a model could be used as an instrument for decision-making on food planning, rather than simply for fairly reliable future predictions. Firstly, we present the implementation of our predictive model on the seven municipalities of the case study, to illustrate its potential efficiency in a dynamic perspective. Secondly, we discuss the relationship between farm-system spatial patterns and food systems. Finally, we address the issue of the planning framework and the scales of policy-making required for effective food planning.

4.1. An illustrative simulation of the dynamics of peri-urban agriculture types

We applied the predictive model to the seven case-study municipalities to simulate how changes in the explanatory variables of the estimated Dirichlet model would impact the predicted distribution of agricultural land. Our intention was both to validate the proposed methodology and to illustrate the dynamics of peri-urban agriculture types, rather than to propose quantified results. Actually, the model is not accurate enough: conclusions cannot be drawn from results for less than a 5% change in predicted agricultural land. The results are usable in regional planning but need to be completed with fieldwork to be usable in spatially explicit planning or landscape or land-use management. Therefore, we designed three simulation scenarios considering those variables most likely to be influenced by planning policies and regulations, namely land use and land price. This enabled us to simulate the impact on the distribution of agricultural land w.r.t. USAPUs over a period of 20 years according to three scenarios (Fig. 6): a) a 23% increase in artificial areas at the expense of farmland, the current trend in land use evolution in France¹⁶; b) a radical 50% conversion of urban areas to agricultural land¹⁷, to test the accuracy of the model; and c) a 54% price increase per hectare of farmland, following the trend of the past 20 years¹⁸. Simulations show that land artificialisation (a) would reduce USAPU-A, largely consisting of horticulture and market gardening small and medium-sized farms surrounding built-up areas. On the other hand, the conversion of formerly urban land to agricultural land (b) would increase USAPU-A farmland. This mechanical conclusion is interesting if we consider that distance from urban areas is not among the variables that characterise USAPU-A in the estimated model; it also

¹⁶ The mean yearly evolution of artificialised land is 1.05%. We can assume that artificial areas increase at the expense of farmland decreasing by 0.13% every year. Furthermore, forest and scrublands remain stable (+0,01%). Source: CETE Nord-Picardie, from DGFIP 1994–2011 aggregated land-use data.

¹⁷ Urban agriculture could be considered as an example of conversion from artificial to agricultural land use.

¹⁸ Source : SAFER, 2017. Le prix des terres. Synthèse. L'essentiel des marchés fonciers ruraux en 2016. Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt.

proves the robustness of the model against unrealistic scenarios. Finally, in a context of stable land-use distribution and rising agricultural land prices (c), USAPU-G, containing profitable quality-wine farms, would increase at the expense of USAPU-C, consisting of highly diversified small farms in the immediate vicinity of built-up areas. This finding shows that interactions between peri-urban farming systems are not solely linked to urban drivers. Furthermore, policy can benefit from identifying ‘hot-spots’ of synergies and trade-offs between peri-urban farming systems, as well as hot-spots of change and vulnerability (Moreira et al., 2016; Verburg et al., 2009). This is especially relevant in the Mediterranean context, that is very likely to be impacted by climate change (Grasso and Feola, 2012; Malek and Verburg, 2017).

4.2. Relationship between farm-system spatial patterns and food systems

The USAPU methodology can be used to characterise and map different peri-urban farm systems and to link them to a singular spatial pattern. Classifying peri-urban agricultural landscapes through their probability of hosting differing agricultural activities as connected with local urban markets provides useful input for policies on feeding the city. In this sense, the methodology provides a tool for eliciting information on the complex relationship between land use and local and regional food systems. Our study case illustrates the three main difficulties involved in conducting such comprehensive field studies. Firstly, there are countries where this type of research remains difficult, especially due to the geo-political situation limiting access to data or to the field for direct observation. Secondly, funds are limited, necessitating a streamlined approach over a relatively short period of time. Thirdly, some landscapes (e.g. Mediterranean) are intrinsically complex and characterised by the complementarity of different agricultural systems (Caraveli, 2000), which makes it difficult to simplify the relationship between agriculture and local food. The USAPU methodology is easy to apply if data can be obtained either by remote sensing analysis or from a national census at municipal level. Only this last point remains a real challenge; however, the USAPU methodology could be applied for an organised overview of the complex mosaic of peri-urban farm systems, leading to further, more thorough, research.

4.3. Which scales to consider for effective food planning?

Classification of USAPUs according to their sensitivity to urban influence puts the focus on actionable issues, for public planning at two levels: local (spatial planning, for instance) and provincial (strategic landscape planning). Our classification highlights areas where it may be socially desirable to manage trends in land-use patterns to support an enhancement of sustainable agriculture and correlated food systems, and where public action is more likely to be efficient. In this sense, our approach raises the question of food production scales (Watts et al., 2005) and the territorial planning suitable for the metropolitan agri-food system (FAO, 2011) or “urban food system” (Viljoen and Wiskerke, 2012).

From an agricultural perspective, the Mediterranean region has a long history of varied production of food. The current agricultural systems and the complementarities between crops are somewhat complex, inherited from a long history of purely Mediterranean agricultural and cultural traditions (Zeder, 2008). Several agricultural practices are known to produce food while remaining desirable, for instance, in terms of proper ecosystem functioning. Policy-making, to enhance food planning, requires insight into the complex dynamics of farming systems at local and regional level.

It might be interesting, in future research, to examine the assumption that diversifying farm systems has the potential to develop local food systems (i.e., a homogeneous area of monospecific agriculture does not usually favour the integration of new farming systems). Fur-

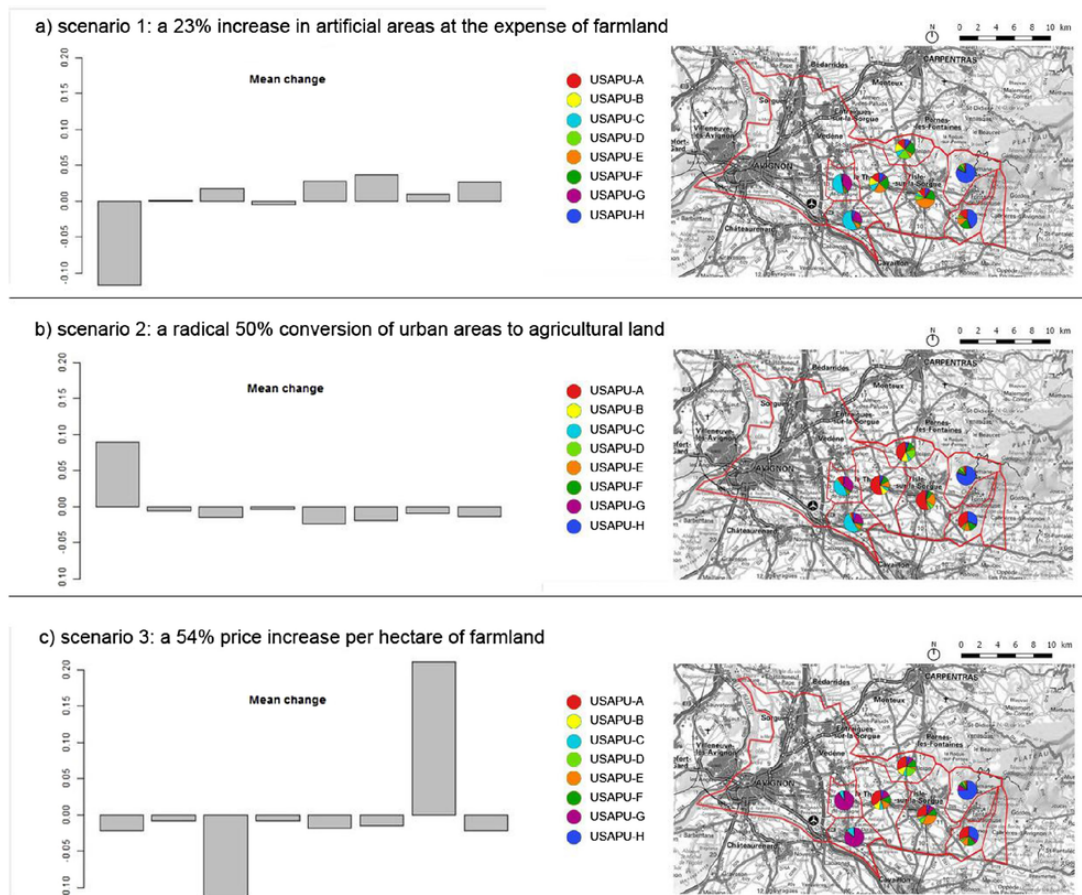


Fig. 6. Illustrations of peri-urban agricultural type dynamics.

ther research should allow us to pinpoint areas with pronounced agricultural diversity, where it should be feasible to enhance local food systems. This also requires testing the sensitivity to changes in selected variables of different types of peri-urban agriculture. As such, it would be interesting to consider the metropolitan agri-food system, a food supply network for urban consumption, systematically including areas devoted to local food production and others aimed at global markets (Wascher et al., 2014). Indeed, these two systems are complementary and interact so complexly that their analysis requires the inclusion of multi-scale decision-making (Bousbaine and Bryant, 2016; Veldkamp and Lambin, 2001).

A last question is the level of generality of our model. It was constructed in a Mediterranean context, and would therefore require adjustments before being applied to other natural or social environments. For instance, an explanatory variable such as “wine” would be meaningless in Northern Europe, and the number of non-professional farmers would not be a suitable variable to characterise a global-trade-oriented farming area. However, other studies at a more global scale highlight a small set of common characteristics prevailing in the dynamics of farms in peri-urban settings (e.g. the landscape structure, reflecting the fragmentation of farmland generally heightened by urban expansion (Lange et al., 2013; Piorr, 2003). Hence, the next step in our work will be to transpose and test our model first in other locations in the Mediterranean Basin¹⁹ and then in a different context.

¹⁹ In the European research program Arimnet2/ DIVERCROP – see <http://www.agence-nationale-recherche.fr/?Projet=ANR-16-ARM2-0003>

5. Conclusion

In the current context of awareness of agricultural multifunctionality and social concerns about food security and quality, more insights are needed into the role of urban-rural linkages for the management and planning of landscapes across multiple geographical contexts (local, regional). Actually, agriculture and food production should play a key role in urban and regional planning. This paper explicitly aimed to present a methodology to situate, characterise and represent peri-urban agriculture in order to integrate agricultural issues into landscape and land planning. The key research objective of the paper was to define a systemic and generic methodology that can be used by public managers and planners for different cases or territorial levels. Based on a strong empirical and comprehensive method developed at local level from a study case, we develop a methodology that can be easily applied elsewhere at provincial level, without being too time- or resource-consuming.

In peri-urban areas, the relation between different scales, from local to regional, is a central question for food planning. The scales need to be linked, to connect regional policies with the local vision of stakeholders. However, there are no integrated tools usable at public policy scale that account for these interactions of agricultural models at the farm/local level (e.g. yields, agricultural plot patterns, stakeholders' activities) and regional level (e.g. food security, energy flows). From a planning perspective, the issue at stake is how to combine the two approaches so as to provide significant levels of precision in a tool usable at the policy level. Using the USAPU for the characterisation and spatial mapping of peri-urban farmland can help identify priority areas for

intervention and context-specific public action opportunities. The methodology proposed in this paper could offer an instrument for decision support concerning food planning, a novel approach in regional science relevant beyond the scope of the case study presented here. Furthermore, the findings presented here could be of much wider relevance generally, in areas where trade-offs between urban and agricultural development persist. Importantly, the spatial layout of the USAPU is not solely based on distance from the city centre, as in the framework proposed by the Von Thünen conceptual model. Interactions between farming systems (either coexistence or confrontation) also need to be taken into account. Actually, changes affecting dominant agricultural practices, e.g. family farming vs. corporate agriculture (Bontkes and van Keulen, 2003) or intensification of agricultural activities (Ruiz-Martinez et al., 2015) are intertwined with interactions between peri-urban agriculture and the surrounding expanding city. In order to support food planning, an overall understanding of the feedback mechanisms and of the human-environment interactions at this level is needed (Foley, 2005). In other words, food planning requires both land-use regulations and sectorial politics to promote the desired farm systems bearing participation and decision co-construction. Furthermore, incentives to shift practices and attitudes could help to change management of peri-urban agriculture.

Acknowledgements

Esther Sanz Sanz is supported by the ANR and *Agence Paysages* in the framework of CIFRE n°2012/0608. Davide Martinetti is supported by the EU in the framework of the Marie-Curie FP7 COFUND People Programme, through the award of an AgreenSkills Fellowship under grant agreement 267196. The research reported in this work was partially supported by projects URBANSIMUL and EPIDEC. We would like also to thank the *Ot-Med* Labex for supporting this research.

References

- Abrantes, P., Fontes, I., Gomes, E., Rocha, J., 2016. Compliance of land cover changes with municipal land use planning: evidence from the Lisbon metropolitan region (1990–2007). *Land Use Policy* 51, 120–134. <https://doi.org/10.1016/j.landusepol.2015.10.023>.
- Agence Paysages, DIREN, DDE, Conseil Général Vaucluse, 2013. Atlas des paysages de Vaucluse. Conseil Général de Vaucluse - DREAL PACA. In: <http://paysages.vaucluse.fr/wp-content/force-download.php?file=uploads/2017/Atlas-Paysages-2017.pdf>, (last accessed 31/08/2017).
- Aitchison, J., 1982. The statistical analysis of compositional data. *J. R. Stat. Soc. Ser. B (Methodological)* 139–177.
- Angel, S., Parent, J., Civco, D.L., 2010. The Fragmentation of Urban Footprints: Global Evidence of Sprawl, 1990–2000. Lincoln Institute of Land Policy, Cambridge, USA.
- Aubry, C., Kebir, L., 2013. Shortening food supply chains: a means for maintaining agriculture close to urban areas? The case of the French metropolitan area of Paris. *Food Policy* 41, 85–93. <https://doi.org/10.1016/j.foodpol.2013.04.006>.
- Aubry, C., Kebir, L., 2013. Shortening food supply chains: a means for maintaining agriculture close to urban areas? The case of the French metropolitan area of Paris. *Food Policy* 41, 85–93. <https://doi.org/10.1016/j.foodpol.2013.04.006>.
- AURAV, 2013. Retour sur l'évolution démographique dans l'espace Rhône-Avignon-Vaucluse. Chroniques (périurbaines) d'un territoire attractif (No. 4). Les publications de l'agence, Avignon (France). In: www.aurav.org/Ressources/Files/aurav-evolutiondemographique.pdf, (last accessed 31/08/2017).
- AURAV, 2012. L'aire urbaine d'Avignon : une nouvelle échelle de réflexion territoriale. Premiers éclairages (No. 1). Les publications de l'agence. Agence d'urbanisme Rhône Avignon Vaucluse (AURAV), Avignon (France). In: www.aurav.org/Ressources/Files/aurav-aireurbaine.pdf, (last accessed 31/08/2017).
- AURAV, 2011. Identification des bassins de vie en Vaucluse. Agence d'urbanisme Rhône Avignon Vaucluse, Avignon (France).
- Bailey, A., Williams, N., Palmer, M., Geering, R., 2000. The farmer as service provider: the demand for agricultural commodities and equine services. *Agric. Syst.* 66, 191–204. [https://doi.org/10.1016/S0308-521X\(00\)00047-0](https://doi.org/10.1016/S0308-521X(00)00047-0).
- Barton, C.M., Ullah, I.I., Bergin, S., 2010. Land use, water and Mediterranean landscapes: modelling long-term dynamics of complex socio-ecological systems. *Philos. Trans. R. Soc. A Math. Phys. Eng. Sci.* 368, 5275–5297. <https://doi.org/10.1098/rsta.2010.0193>.
- Bertoni, D., Cavicchioli, D., 2016. Farm succession, occupational choice and farm adaptation at the rural-urban interface: the case of Italian horticultural farms. *Land Use Policy* 57, 739–748. <https://doi.org/10.1016/j.landusepol.2016.07.002>.
- Bessière, C., Gollac, S., 2014. Des exploitations agricoles au travers de l'épreuve du divorce: rapports sociaux de classe et de sexe dans l'agriculture. *Sociétés contemporaines* 96, 77. <https://doi.org/10.3917/soco.096.0077>.
- Bontkes, T.S., van Keulen, H., 2003. Modelling the dynamics of agricultural development at farm and regional level. *Agric. Syst.* 76, 379–396.
- Bousbaine, A.D., Bryant, C.R., 2016. The integration of action research and traditional field research to provide sustainable solutions to maintaining periurban agriculture: action research and traditional field research. *Geogr. Res.* 54, 176–186. <https://doi.org/10.1111/1745-5871.12134>.
- Bousbaine, A.D., Nguendo-Yongsi, B., Bryant, C., 2015. Les agricultures urbaines (y compris les agricultures périurbaines) des villes du Nord et du Sud : une conceptualisation des dynamiques et des défis. le 9-11 juin 2015, Paris, France. Presented at the Colloque international Villes et campagnes en relations : regards croisés Nords-Suds.
- Bryant, C.R., 1997. L'agriculture périurbaine. L'économie d'un espace innovateur. *Cahiers Agric.* 125–130.
- Bryant, C.R., 1992. Farming at the urban fringe. Chapitre 10. In: Bowler, I.R. (Ed.), *The Geography of Agriculture*. Routledge (première édition de 1992 publiée par Longman), London & New York, pp. 275–304.
- Bryant, C.R., Vasseur, L., Bellichi, A., Soulard, C., 2016. Conclusion. In: Bryant, C.R., Mammadou, A.S., Kénel, D. (Eds.), *Agricultural Adaptation to Climate Change*. Springer International Publishing, pp. 225–232.
- Burel, F., Baudry, J., 2004. Landscape ecology: concepts, methods, and applications. Science Publ., Enfield, NH, [u.a.].
- Busck, A.G., Kristensen, S.P., Præstholm, S., Primdahl, J., 2008. Porous landscapes – the case of Greater Copenhagen. *Urban For. Urban Green.* 7, 145–156. <https://doi.org/10.1016/j.ufug.2007.05.002>.
- Campbell, G., Mosimann, J.E., 1987. Dirichlet covariate models for random proportions. *Computer Science and Statistics: Proceedings of the 19th Symposium on the Interface*. 93–101.
- Caraveli, H., 2000. A comparative analysis on intensification and extensification in Mediterranean agriculture: dilemmas for LFAs policy. *J. Rural Stud.* 16, 231–242.
- Cavalières, J., Wavresky, P., 2007. Les effets de la proximité de la ville sur les systèmes de production agricoles. *Agreste Cahiers* 2, 41–47.
- Ceccarelli, T., Bajocco, S., Perini, L., Salvati, L., 2014. Urbanisation and land take of high quality agricultural soils - exploring long-term land use changes and land capability in Northern Italy. *Int. J. Environ. Res.* 181–192.
- Chanel, O., Delattre, L., Napoléone, C., 2014. Determinants of local public policies for farmland preservation and urban expansion: a French illustration. *Land Econ.* 90, 411–433.
- Clark, J.K., Jackson-Smith, D., Sharp, J.S., Munroe, D.K., 2007. The geography of US peri-urban agricultural adaptation. Washington, DC, 24–26 September. TransAtlantic Land Use Conference.
- Condon, P.M., Mullinix, K., Fallick, A., Harcourt, M., 2010. Agriculture on the edge: strategies to abate urban encroachment onto agricultural lands by promoting viable human-scale agriculture as an integral element of urbanization. *Int. J. Agric. Sustain.* 8, 104–115. <https://doi.org/10.3763/ijas.2009.0465>.
- Connell, D., Bryant, C., Caldwell, W., Churchyard, A., Cameron, G., Johnston, T., Margulis, M., Ramsey, D., Marois, C., 2013. Food sovereignty and agricultural land use planning: the need to integrate public priorities across jurisdictions. *J. Agric. Food Syst. Commun. Dev.* 1–8. <https://doi.org/10.5304/jafscd.2013.034.011>.
- Darly, S., Aubry, C., 2014. La demande en produits locaux de la restauration collective: quels liens avec l'offre de proximité dans une région d'agriculture industrielle?. le cas de l'Île-de-France la demandfour 89, 145–157.
- Darly, S., Torre, A., 2013. Conflicts over farmland uses and the dynamics of “agri-urban” localities in the Greater Paris region: an empirical analysis based on daily regional press and field interviews. *Land Use Policy* 33, 90–99. <https://doi.org/10.1016/j.landusepol.2012.12.014>.
- Debolini, M., Marraccini, E., Dubeuf, J.P., Geizendorffer, I.R., Guerra, C., Simon, M., Targetti, S., Napoléone, C., 2018. Land and farming system dynamics and their drivers in the Mediterranean Basin. *Land Use Policy*.
- Defontaine, J.P., Thenail, C., Baudry, J., 1995. Agricultural systems and landscape patterns: how can we build a relationship?. *Landsc. Urban Plan.* 31, 3–10. [https://doi.org/10.1016/0169-2046\(94\)01031-3](https://doi.org/10.1016/0169-2046(94)01031-3).
- EEA, 2006. Urban sprawl in Europe: the ignored challenge. European Environment Agency. Office for Official Publications of the European Communities, [distributor], Copenhagen, Denmark; Luxembourg. In: https://www.eea.europa.eu/publications/eea_report_2006_10, (last accessed 31/08/2017).
- EEA, - European Environmental Agency, 2012. Corine land cover 2012 raster data. In: <http://www.eea.europa.eu/data-and-maps/data/clc-2012-raster>, (last accessed 31/08/2017).
- Elgäker, H.E., 2012. The new equine sector and its influence on multifunctional land use in peri-urban areas. *GeoJournal* 77, 591–613. <https://doi.org/10.1007/s10708-010-9398-y>.
- FAO, 2011. Food, agriculture and cities. Challenges of food and nutrition security, agriculture and ecosystem management in an urbanizing world, Rome (Italie) www.walnap.org/resource/6272, (last accessed 31/08/2017).
- Filippini, R., Marraccini, E., Lardon, S., Bonari, E., 2016. Is the choice of a farm's commercial market an indicator of agricultural intensity? Conventional and short food

- supply chains in periurban farming systems. *Italian J. Agron.* 11, 1. <https://doi.org/10.4081/ija.2016.653>.
- Foley, J.A., 2005. Global consequences of land use. *Science* 309, 570–574. <https://doi.org/10.1126/science.1111772>.
- Forman, R.T.T., 2008. The urban region: natural systems in our place, our nourishment, our home range, our future. *Landsc. Ecol.* 23, 251–253. <https://doi.org/10.1007/s10980-008-9209-8>.
- Fürst, C., König, H., Pietzsch, K., Ende, H.-P., Makeschin, F., 2010. Pimp your landscape—a generic approach for integrating regional stakeholder needs into land use planning. *Ecol. Soc.* 15, 34.
- Galli, M., Lardon, S., Marraccini, E., Bonari, E., 2010. Agricultural management in peri-urban areas. The experience of an international workshop. Land Lab—Scuola Superiore Sant'Anna (Italy), INRA et AgroParisTech-ENGREF, UMR Métafort Clermont Ferrand (France). Felici Editore, Ghezzeno, Italy.
- Gant, R.L., Robinson, G.M., Fazal, S., 2011. Land-use change in the “edgelands”: policies and pressures in London's rural–urban fringe. *Land Use Policy* 28, 266–279. <https://doi.org/10.1016/j.landusepol.2010.06.007>.
- Geneletti, D., La Rosa, D., Spyra, M., Cortinovis, C., 2017. A review of approaches and challenges for sustainable planning in urban peripheries. *Landsc. Urban Plan.* 165, 231–243. <https://doi.org/10.1016/j.landurbplan.2017.01.013>.
- Geniaux, G., Ay, J.-S., Napoléone, C., 2011. A spatial hedonic approach on land use change anticipations. *J. Reg. Sci.* 51, 967–986. <https://doi.org/10.1111/j.1467-9787.2011.00721.x>.
- Grasso, M., Feola, G., 2012. Mediterranean agriculture under climate change: adaptive capacity, adaptation, and ethics. *Reg. Environ. Change* 12, 607–618. <https://doi.org/10.1007/s10113-011-0274-1>.
- Greene, R.P., Harlin, J.M., 1995. Threat to high market value agricultural lands from urban encroachment: a national and regional perspective. *Soc. Sci. J.* 137–155.
- Groot, J.C.J., Rossing, W.A.H., Tichit, M., Turpin, N., Jellema, A., Baudry, J., Verburg, P.H., Doyen, L., van de Ven, G.W.J., 2009. On the contribution of modelling to multi-functional agriculture: learning from comparisons. *J. Environ. Manage.* 90, 147–160. <https://doi.org/10.1016/j.jenvman.2008.11.030>.
- Grosso, R., Galas, J., Locci, J.-P., Clap, S., 1993. Histoire de Vaucluse. Les Vauclusiens, des campagnes à la ville, vol. 2, Éditions A. Barthélemy, Avignon (France).
- Guillaumin, A., Dockès, A.-C., Tchakerian, E., Daridan, D., Gallot, S., Hennion, B., Lasnier, A., Perrot, C., 2008. Demandes de la société et multifonctionnalité de l'agriculture: attitudes et pratiques des agriculteurs. *Courrier de l'environnement de l'INRA.* 45–66.
- Healey, P., Williams, R., 1993. European Urban planning systems: diversity and convergence. *Urban Stud.* 30, 701–720. <https://doi.org/10.1080/00420989320081881>.
- Heimlich, R.E., Anderson, W.D., 2001. Development at the Urban Fringe and Beyond: Impacts on Agriculture and Rural Land (No. AER-803). U.S. Dept. of Agriculture, Economic Research Service. <http://ageconsearch.umn.edu/bitstream/33943/1/ae010803.pdf>, (last accessed 31/08/2017).
- Heimlich, R.E., Brooks, D.H., 1989. Metropolitan growth and agriculture: farming in the city's shadow. *Agricultural Economic Report* 619. 26 <http://nalcd.nal.usda.gov/nalcd/download.xhtml?id=CAT10407751&content=PDF>, (last accessed 31/08/2017).
- Helmig, K., Pérez-Soba, M., 2011. Landscape scenarios and multifunctionality: making land use impact assessment operational. *Ecol. Soc.* 16 (1), 50 <https://www.ecologyandsociety.org/vol16/iss1/art50/>, (last accessed 31/08/2017).
- Ilbery, B.W., 1991. Farm diversification as an adjustment strategy on the urban fringe of the West Midlands. *J. Rural Stud.* 7, 207–218.
- Jarrige, F., Thimon, P., Delay, C., Montfrais, P., 2009. L'agriculture s'invite dans le projet urbain. Le schéma de cohérence territoriale de Montpellier Agglomération. *Innovations Agronomiques.* 41–51, <http://prodinra.inra.fr/ft?id={32857FF9-5349-41CA-9E85-EBFA94BD9FB6}> last accessed 31/08/2017).
- Jones, R., Bryant, C.R., 2016. Participatory action research for rural and regional development: participatory action research for rural and regional development. Editorial of special issue articles. *Geogr. Res.* 54, 115–117. <https://doi.org/10.1111/1745-5871.12185>.
- Jouve, A.M., Napoléone, C., 2003. Stratégies des agriculteurs et réorganisations spatiales sous contrainte de la périurbanité: étude du pays d'Aix-en-Provence. In: Elloumi, M., Jouve, A.-M. (Eds.), *Bouleversements Fonciers En Méditerranée. Des Agricultures Sous Le Choc de L'urbanisation et Des Privatisations*, Paris, pp. 143–172 http://www.iamm.ciheam.org/ress_doc/opac_css/index.php?lvl=notice_display&id=13098, (last accessed 31/08/2017).
- Kizos, T., Kristensen, L.S., 2011. The “good farmer”: studies of farm management practices and landscape change. Editorial of special issue. *Geografisk Tidsskrift-Danish J. Geogr.* 111, 105–106. <https://doi.org/10.1080/00167223.2011.10669526>.
- 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>.
- Lardon, S. (Ed.), 2012. *Géoaquonomie, paysage et projets de territoire. Sur les traces de Jean-Pierre Deffontaines, Indisciplines*. Editions Quae - NSS Dialogues, Paris.
- Lataste, D., Chizelle, B., 2014. Une lecture psychosociologique des difficultés d'accès au métier d'agriculteur pour les candidats hors cadre familial: la confiance au cœur du processus de transmission-reprise?. *Pour* 224, 15. <https://doi.org/10.3917/pour.224.0015>.
- Lobley, M., Potter, C., 2004. Agricultural change and restructuring: recent evidence from a survey of agricultural households in England. *J. Rural Stud.* 20, 499–510. <https://doi.org/10.1016/j.jrurstud.2004.07.001>.
- Maier, M.J., 2015. DirichletReg: Dirichlet Regression in R. R package version 0.6-3. In: <http://dirichletreg.r-forge.r-project.org/>, (last accessed 27/04/2016).
- Marraccini, E., Debolini, M., Moulery, M., Abrantes, P., Bouchier, A., Chéry, J.-P., Sanz Sanz, E., Sabbatini, T., Napoleone, C., 2015. Common features and different trajectories of land cover changes in six Western Mediterranean urban regions. *Appl. Geogr.* 62, 347–356. <https://doi.org/10.1016/j.jageog.2015.05.004>.
- Marraccini, E., Lardon, S., Loudiyi, S., Giacchè, G., Bonari, E., 2013. Durabilité de l'agriculture dans les territoires périurbains méditerranéens: enjeux et projets agriurbains dans la région de Pise (Toscane, Italie). *Cahiers Agric.* 22, 517–525 [revues.cirad.fr/index.php/cahiers-agricultures/article/download/31060/30820](http://www.revues.cirad.fr/index.php/cahiers-agricultures/article/download/31060/30820), (last accessed 31/08/2017).
- Moragues-Faus, A., 2016. Revisiting food studies from a political ecology perspective: lessons from Mediterranean Agri-food systems. In: Ioris, A.A. (Ed.), *Agriculture, Environment and Development*. Springer International Publishing, Cham, pp. 59–90.
- Morgan, K., Sonnino, R., 2010. The urban foodscape: world cities and the new food equation. *Camb. J. Reg. Econ. Soc.* 3, 209–224. <https://doi.org/10.1093/cjres/rsq007>.
- Morlon, P., Soulard, C., Trouche, G., 2006. L'organisation spatiale des chantiers dans les exploitations de grande culture: les nouveaux enjeux de la logistique. *FASADe Résultats des recherches du département INRA – SAD No. 24*, 4, <http://prodinra.inra.fr/ft?id={1F0037B9-80DE-45E4-9464-BE1BBA50EC28}> (last accessed 31/08/2017).
- Nahmias, P., Le Caro, Y., 2012. Pour une définition de l'agriculture urbaine: réciprocity fonctionnelle et diversité des formes spatiales. *Environnement urbain/Urban Environ.* 6, 1–16 <https://eue.revues.org/437>, (last accessed 31/08/2017).
- Napoléone, C., 2005. *Prix fonciers et immobiliers, et localisation des ménages au sein d'une agglomération urbaine*. Doctoral thesis on Economics. Ecole des Hautes Etudes en Sciences Sociales.
- Nassauer, J.I., 2012. Landscape as medium and method for synthesis in urban ecological design. *Landsc. Urban Plan.* 106, 221–229. <https://doi.org/10.1016/j.landurbplan.2012.03.014>.
- Ortiz-Miranda, D., Moragues-Faus, A., Arnalte-Alegre, E., 2013. Chapter 1 introduction: reframing agriculture in Mediterranean Europe. In: Ortiz-Miranda, D., Moragues-Faus, A., Arnalte-Alegre, E. (Eds.), *Research in Rural Sociology and Development*. Emerald Group Publishing Limited, pp. 1–8.
- Paranthoën, J.-B., 2014. Déplacement social et entrées en agriculture: Carrières croisées de deux jeunes urbains devenus maraîchers. *Sociétés contemporaines* 96, 51. <https://doi.org/10.3917/soco.096.0051>.
- Paül Carril, V., 2006. L'Ordenació dels espais agraris metropolitans: plans, gestió i conflictes territorials a la regió de Barcelona. Doctoral thesis. Universitat de Barcelona. Departament de Geografia Física i Anàlisi Geogràfica Regional, Barcelona, 1138p.
- Paül, V., McKenzie, F.H., 2013. Peri-urban farmland conservation and development of alternative food networks: insights from a case-study area in metropolitan Barcelona (Catalonia, Spain). *Land Use Policy* 30, 94–105. <https://doi.org/10.1016/j.landusepol.2012.02.009>.
- Pères, S., 2007. *La vigne et la ville: forme urbaine et usage des sols*. Doctoral thesis. Université Montesquieu-Bordeaux IV, 387 <https://tel.archives-ouvertes.fr/tel-00448670/document>, (last accessed 31/08/2017).
- PLUREL projet. In: Piorr, A., Ravetz, J., Tosics, I. (Eds.), *Peri-urbanisation in Europe: Towards European policies to sustain Urban Rural Futures*. University of Copenhagen/Academic Books Life Sciences, Frederiksberg, p. 2011. 142 http://www.openspace.ea.edu.ac.uk/wp-content/uploads/2015/12/Peri_Urbanisation_in_Europe_printversion.pdf, (last accessed 31/08/2017).
- Piorr, H.-P., 2003. Environmental policy, agri-environmental indicators and landscape indicators. *Agric. Ecosyst. Environ.* 98, 17–33. [https://doi.org/10.1016/S0167-8809\(03\)00069-0](https://doi.org/10.1016/S0167-8809(03)00069-0).
- Præstholm, S., Kristensen, S.P., 2007. Farmers as initiators and farms as attractors for non-agricultural economic activities in peri-urban areas in Denmark. *Geografisk Tidsskrift-Danish J. Geogr.* 107, 13–27. <https://doi.org/10.1080/00167223.2007.10649566>.
- Primdahl, J., 1999. Agricultural landscapes as places of production and for living in owner's versus producer's decision making and the implications for planning. *Landsc. Urban Plan.* 46, 143–150.
- Reimer, M., Getimis, P., Blotvogel, H.H. (Eds.), 2014. *Spatial planning systems and practices in Europe: a comparative perspective on continuity and changes*. Routledge, New York, NY.
- Rizzo, D., Marraccini, E., Lardon, S., Rapey, H., Debolini, M., Benoît, M., Thenail, C., 2013. Farming systems designing landscapes: land management units at the interface between agronomy and geography. *Geografisk Tidsskrift-Danish J. Geogr.* 113, 71–86. <https://doi.org/10.1080/00167223.2013.849391>.
- Robineau, O., 2013. *Vivre de l'agriculture dans la ville africaine: une géographie des arrangements entre acteurs à Bobo-Dioulasso, Burkina Faso*. Doctoral thesis. Université Paul Valéry-Montpellier III. <https://hal.archives-ouvertes.fr/tel-00917958v2/document>, (last accessed 31/08/2017).
- Ruiz-Martinez, I., Marraccini, E., Debolini, M., Bonari, E., 2015. Indicators of agricultural intensity and intensification: a review of the literature. *Italian J. Agron.* 10, 74. <https://doi.org/10.4081/ija.2015.656>.
- Sanz Sanz, E., 2016. *Planification urbaine et agriculture. Méthodologie systémique de caractérisation de l'agriculture périurbaine à partir d'une recherche empirique en France et en Espagne*. International doctoral thesis on Geography and on Urban Stud-

- ies. Ecole des Hautes Etudes en Sciences Sociales and Universidad Autónoma de Madrid, 454 <http://www.theses.fr/2016EHES0115>, (last accessed 31/08/2017).
- Schaldach, R., Priess, J.A., 2008. Integrated models of the land system: a review of modelling approaches on the regional to global scale. *Living Rev. Landsc. Res.* 2, 1 <http://www.livingreviews.org/lrlr-2008-1>, (last accessed 13/05/2013).
- Scott, A.J., Carter, C., Reed, M.R., Larkham, P., Adams, D., Morton, N., Waters, R., Collier, D., Crean, C., Curzon, R., Forster, R., Gibbs, P., Grayson, N., Hardman, M., Hearle, A., Jarvis, D., Kennet, M., Leach, K., Middleton, M., Schiessel, N., Stonyer, B., Coles, R., 2013. Disintegrated development at the rural–urban fringe: re-connecting spatial planning theory and practice. *Prog. Plan.* 83, 1–52. <https://doi.org/10.1016/j.progress.2012.09.001>.
- Section Production animale de l'Académie d'agriculture, 2016. L'avenir de l'élevage en France Un des enjeux majeurs de la réforme territoriale. *Revue de l'Académie d'agriculture française*. 17–23.
- Sharpley, R., Vass, A., 2006. Tourism, farming and diversification: an attitudinal study. *Tourism Manage.* 27, 1040–1052. <https://doi.org/10.1016/j.tourman.2005.10.025>.
- Shucksmith, M., Herrmann, V., 2002. Future changes in British agriculture: projecting divergent farm household behaviour. *J. Agric. Econ.* 53, 37–50. <https://doi.org/10.1111/j.1477-9552.2002.tb00004.x>.
- Smithers, J., Johnson, P., 2004. The dynamics of family farming in North Huron county, Ontario. Part I. Development trajectories. *Can. Geogr./Le Géographe Canadien* 48, 191–208. <https://doi.org/10.1111/j.0008-3658.2004.00055.x>.
- Smithers, J., Johnson, P., Joseph, A., 2004. The dynamics of family farming in North Huron County, Ontario. Part II. Farm–community interactions. *The Can. Geogr./Le Géographe canadien* 48, 209–224. <https://doi.org/10.1111/j.0008-3658.2004.00056.x>.
- Sonnino, R., 2016. The new geography of food security: exploring the potential of urban food strategies. *Geogr. J.* 182, 190–200. <https://doi.org/10.1111/geoj.12129>.
- Soulard, C., Valette, , Perrin, C., Abrantes, P., Banzo, M., Bendjaballah, O., Chia, E., 2016. Durabilité des agricultures urbaines en Méditerranée. Rapport du Projet ANR-10-STRA-007 DAUME (Annexe scientifique No. ANR-10-STRA-007). 102p.
- Soulard, C.-T., 2014. Les agricultures nomades, une caractéristique du périurbain. *Pour* 224, 151–158. <https://doi.org/10.3917/pour.224.0151>.
- Tedesco, C., Petit, C., Billen, G., Garnier, J., Personne, E., 2017. Potential for recoupling production and consumption in peri-urban territories: the case-study of the saclay plateau near Paris, France. *Food Policy* 69, 35–45. <https://doi.org/10.1016/j.foodpol.2017.03.006>.
- Termorshuizen, J.W., Opdam, P., 2009. Landscape services as a bridge between landscape ecology and sustainable development. *Landsc. Ecol.* 24, 1037–1052. <https://doi.org/10.1007/s10980-008-9314-8>.
- Veldkamp, A., Lambin, E.F., 2001. Predicting land-use change. *Agric. Ecosyst. Environ.* 85, 1–6. [https://doi.org/10.1016/S0167-8809\(01\)00199-2](https://doi.org/10.1016/S0167-8809(01)00199-2).
- Véron, F. (Ed.), 2003. Les cahiers de la multifonctionnalité n.2. Propositions de recherche soutenues par le dispositif INRA-CEMAGREF-CIRAD sur la multifonctionnalité de l'agriculture et des espaces ruraux. INRA Editions <http://agritrop.cirad.fr/516489/>, (last accessed 31/08/2017).
- Vidal, R., 2011. Construire des territoires partagés entre la ville et l'agriculture, in: *Entre Ville et Campagne, Un Paysage À Inventer, Ateliers Techniques Du Paysage*. Conseil régional de Bretagne, Rennes, 13–36.
- Viljoen, A., Wiskerke, J.S.C. (Eds.), 2012. Sustainable food planning evolving theory and practice.. Wageningen Academic Publishers, The Netherlands, 590p.
- Von Thünen, J.H., 1826. *Der Isolierte Staat in Beziehung auf landwirtschaft und Nationaleconomie* (Hamburg). [Von Thünen, J. H. (1826 (reedition 1966)). Von Thunen's isolated state. Glasgow, Pergamon press].
- Waldhardt, R., Bach, M., Borresch, R., Breuer, L., Diekötter, T., Frede, H.-G., Gäth, S., Ginzler, O., Gottschalk, T., Julich, S., 2010. Evaluating today's landscape multifunctionality and providing an alternative future: a normative scenario approach. *Ecol. Soc.* 15 (3), 30 <https://www.ecologyandsociety.org/vol15/iss3/art30/>, (last accessed 31/08/2017).
- Wascher, D., van Eupen, M., Jansma, J.-E., Corsi, S., Sali, G., Zasada, I., 2014. Metropolitan foodsheds as spatial references for a landscape-based assessment of regional food supply. Leeuwardem (The Netherlands). Finding Spaces for Productive Cities. Presented at the 6th AESOP Sustainable Food Planning Conference 31–47.
- Watts, D., Ibbery, B.W., Maye, D., 2005. Making reconections in agro-food geography: alternative systems of food provision. *Prog. Hum. Geogr.* 29, 22–40. <https://doi.org/10.1191/0309132505ph526oa>.
- Wibberley, G.B., 1960. *Agriculture and Urban Growth. A study of the competition for rural land*. Michael Josep, London.
- Wiggering, H., Dalchow, C., Glemnitz, M., Helming, K., Müller, K., Schultz, A., Stachow, U., Zander, P., 2006. Indicators for multifunctional land use—linking socio-economic requirements with landscape potentials. *Ecol. Indic.* 6, 238–249. <https://doi.org/10.1016/j.ecolind.2005.08.014>.
- Wilson, G.A., 2007. *Multifunctional agriculture: a transition theory perspective*. CABI, Cambridge, MA, 385p.
- Wulder, M.A., White, J.C., Goward, S.N., Masek, J.G., Irons, J.R., Herold, M., Cohen, W.B., Loveland, T.R., Woodcock, C.E., 2008. Landsat continuity: issues and opportunities for land cover monitoring. *Remote Sens. Environ.* 112, 955–969. <https://doi.org/10.1016/j.rse.2007.07.004>.
- Yang, Z., Cai, J., Sliuzas, R., 2010. Agro-tourism enterprises as a form of multi-functional urban agriculture for peri-urban development in China. *Habitat Int.* 34, 374–385. <https://doi.org/10.1016/j.habitatint.2009.11.002>.
- Zasada, I., 2011. Multifunctional peri-urban agriculture—a review of societal demands and the provision of goods and services by farming. *Land Use Policy* 28, 639–648. <https://doi.org/10.1016/j.landusepol.2011.01.008>.
- Zasada, I., Berges, R., Hilgendorf, J., Pierr, A., 2013. Horsekeeping and the peri-urban development in the Berlin metropolitan region. *J. Land Use Sci.* 8, 199–214. <https://doi.org/10.1080/1747423X.2011.628706>.
- Zasada, I., Loibl, W., Köstl, M., Pierr, A., 2013. Agriculture under human influence: a spatial analysis of farming systems and Land use in European rural-urban-regions. *Eur. Countryside* 5, 71–88. <https://doi.org/10.2478/euco-2013-0005>.
- Zeder, M.A., 2008. Domestication and early agriculture in the Mediterranean Basin: origins, diffusion, and impact. *Proc. Natl. Acad. Sci.* 105, 11597–11604. <https://doi.org/10.1073/pnas.0801317105>.