UNIVERSITÉ DE STRASBOURG

ÉCOLE DOCTORALE AUGUSTIN COURNOT ED 221

BUREAU D'ÉCONOMIE THÉORIQUE ET APPLIQUÉE UMR 7522

THÈSE

pour l'obtention du titre de Docteur en Sciences Économiques

Présentée et soutenue le 24-06-2024 par

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Incentives and spatial heterogeneity on organic farming development

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Préparée sous la direction de Anne STENGER et Phu NGUYEN-VAN

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Remerciements

Cette thèse n'aurait jamais vu le jour sans le soutien de nombreuses personnes que je tiens à remercier.

En premier lieu, je voudrais exprimer ma sincère reconnaissance envers mes directeurs de thèse, Anne Stenger et Phu Nguyen-Van, qui m'ont accompagné tout au long de ce processus. Alors que je n'avais pas comme projet de faire de la recherche, l'opportunité de faire un stage avec vous m'a donné envie de poursuivre vers cette voie. Malgré un début de thèse marqué par le confinement et la mutation de Phu à Nanterre, vous avez continué à m'encadrer. Vous avez su me guider tout en acceptant les orientations que je souhaitais apporter à mes recherches. Le projet "Dis-Bio" avec l'INRAe et l'Agence Bio nous permettra de continuer à collaborer.

Je tiens également à remercier tous les membres de mon jury: Marie-Laure Breuillé et Alexandre Sauquet, Raja Chakir et Bertrand Koebel, d'avoir accepté cette invitation. Je vous remercie d'avoir consacré du temps à la lecture de mon travail.

Je souhaite exprimer toute ma gratitude à Julie Le Gallo, Laurent Piet et Jens Abildtrup, membres du comité de thèse, pour leurs précieux conseils et commentaires. Je suis profondément reconnaissant envers Jens pour ses conseils pertinents depuis mon mémoire de recherche de M2. Quant à Laurent, je lui suis très reconnaissant pour son invitation à Rennes et pour son expertise dans le domaine du foncier agricole qui m'ont aidé à améliorer le troisième chapitre.

Je tiens à remercier le Bureau d'Économie théorique et appliquée (BETA), l'École doctorale Augustin Cournot et la Chaire Renel pour les moyens intellectuels et financiers qu'ils ont mis à ma disposition afin que je puisse réaliser mes travaux. Je désire tout particulièrement exprimer ma gratitude envers Amélie Barbier-Gauchard, Bertrand Koebel, Samuel Ligonnière et Marie Boltz pour leur aide scientifique ainsi que leurs conseils concernant mon avenir académique. Je souhaite aussi remercier la Maison Interuniversitaire des Sciences de l'Homme d'Alsace pour son soutien financier et la mise à disposition de box CASD, en particulier Eric Wiest et Jean-Yves Bart.

Je tiens aussi à remercier mes collègues doctorant.e.s et ami.e.s, qui ont rendu ces quatre années de thèse très agréables. L'aile Ouest du PEGE, le RU, le bureau 154 et ses marmites de café auront toujours été des raisons de sortir du lit. Merci aux membres de mon bureau, qui ont enduré mes blagues et mon anglais bancal. Merci Agathe, et ces deux écrans, une microsim sur l'un, le dernier ragot sur messenger de l'autre. Merci à Guillaume, qui est à la fois d'une rigueur scientifique irréprochable, et en même temps le producteur de fake news le plus prolifique (de José Bové à Matt Pokora). Merci à Enrico pour ton aide en économétrie. Merci à Shengxi, j'arrive soon à Pekin, et à Diletta, soon calcio pepe devant le Buco della serratura dell'Ordine di Malta. Au doctorants qui seront encore là dans ce bureau, Mathilde, Xiaomei et Arnaud, et à ceux qui les suivront, je vous souhaite tout le courage nécessaire pour la suite. Prenez soin des plantes et de la cafetière!

Je veux aussi remercier les autres docs, Antoine et Anne-Gaëlle (meilleure présidente des ACDD), mes compagnons depuis l'avant COVID. Je vous attends de l'autre côté! Merci aux ancien.nes doc qui rayonnent désormais hors les murs, Ben Dich, Pierre Peltouz, Kenza, Yann. Merci aux actuel.le.s doc qui convergent vers un rayonnement encore plus intense, Romane et son armée de stagiaire, Jérôme et ses frites, Ioannis et ses "ptit clopes", Théo et son phrasé, le JB's et son baudard, Eva et son revenu universel pour faire le tour du monde, et tous les autres membres participants au confort de travail de ce labo.

Cette thèse conclut également ma parenthèse strasbourgeoise, qui aura été l'occasion de rencontrer mes ami.es et aussi l'amour (voir ci-après). Ces amitiés se sont développées dans le même lieu que ce manuscrit à la Fac d'Eco en master MPE. Merci à ces amitiés que j'espère maintenir avec des alsaciens, qui par définition, ne sont pas les plus mobiles, Arnaud, Antoine & Carla, Corentin, Erwan, Manon, Heloïse et Jiji. Merci mes ami.e.s de toujours qui ont toujours été là, malgré un pote moins dispo pour faire le barbischtroumpf. Charles-Max & Emma (les parisiens), Pauline & Simon (les malaisiens), Mélo & Alban (les Rétais Canadiens), Loudana, Cédric & Pauline, Dominique Fev, Dylan.

Je remercie les membres de ma famille pour tout le soutien et l'amour qu'ils m'ont apportés. Je ne saurais jamais assez remercier mes parents pour les sacrifices qu'ils ont faits pour que je puisse me concentrer sur mes études (et un peu sur la fête). Leurs engagements tout au long de mon parcours universitaire ont été un véritable moteur. Ils ont été essentiels pour la rédaction de cette thèse, car travailler dans le domaine de l'agriculture me permet de rester connecté à mon bocage normand. Merci à ma mamie Paulette, d'être là, forte, drôle, résiliente et un puit sans fond (mais non moins dénué de fond) d'expression. Merci à mon frère Germain et sa copine Selene, toujours précieux d'avoir un grand frère. Et puis leur petit Nathan, mon neveu que j'adore qui est né alors que je préparais mon audition pour la bourse doc. Quand tu auras l'âge de lire cette thèse, j'espère que le monde sera plus apaisé et en meilleure santé. Si ce n'est pas le cas, tu pourras te dire que Tonton et Tata auront essayé...

Et enfin merci à Cloé, d'avoir été un soutien sans faille, ton aide a été et sera toujours précieuse. J'ai hâte de notre vie parisienne ainsi que toutes les autres aventures qui nous restent à vivre.

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Table 1: List of abbreviations

AEI	Area of Ecological Interest
AES	Agri-environmental schemes
Loc AES	Agri-environmental and climate measures for land Localised in area with issue
HPS AES	Agri-environmental and climate measures for Herb and Pasture System
ANC	Payment for Areas facing Natural Constraints
CAP	Common Agricultural Policy
CBD	Central Business District
CF	Conventional Farming
DID	Differences-in-Differences Method
DVF	Demand for Land Value, list of French land transactions
EC	European Commission
LPIS	Land Parcel Identification System, French LPIS refers to the database *Graphic Parcel Register* (RPG)
OF	Organic Farming
OLS	Ordinary Least Squares Econometric Method
PDO	Protected Designation of Origin
PSM	Propensity Score Matching
RDD	Regression Discontinuity Design
SDM	Spatial Durbin Model
UAA	Utilized Agricultural Area
WCA	Water Catchment Area
#	Number

Table 2: Liste des abréviations

AAC	Aires d'Alimentation de Captage
AB	Agriculture Biologique
AC	Agriculture Conventionnelle
AOP	Appellation d'Origine protégée
CAB	Conversion à l'Agriculture Biologique
DID	Méthode des doubles différences
ICHN	Indemnité Compensatoire de Handicaps Naturels
MAB	Maintien à l'Agriculture Biologique
MAEC	Mesures Agro-Environnementales et Climatiques
MCO	Méthode économétrique des Moindres Carrées Ordinaire
PAC	Politique Agricole Commune
RDD	Méthode économétrique de la Régression sur Discontinuité
RPG	Registre Parcellaire Graphique
SAU	Surface Agricole Utile

General introduction

Context and literature

How can we produce more, while producing enough food to sustain an ever-growing population ? Agricultural production must meet the challenges of sustainable food system, defined by the Food and Agriculture Organization of the United Nations (FAO) as *"a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised"* (Von Braun et al., 2021). Agricultural practices must be adapted to produce enough food for the population while minimising the pressure on water, air, soil and biodiversity. According to IFOAM Organics International (2019), promoting organic farming (OF) can help countries achieve 8 of the 17 sustainable development goals. Based on the scientific literature, IFOAM Organics International (2019) reports that OF responds to environmental issues by improving water and air quality and reducing pressure on marine and terrestrial biodiversity. Socially, it contributes to an increase of the wages, to the promotion of sustainable consumption, and to the fight against hunger.

While the European and national targets for growth in OF, respectively 25% of utilised agricultural area (UAA) by 2030 (European Commission, 2020) and 18% by 2027 (Ministère de l'Agriculture et de la Souveraineté alimentaire, 2022) have been posted. The development of OF in France, the region analysed in this thesis, is slowing down. In fact, the amount of land converted has decreased by 0.9% in 2021 and 24.2% in 2022 (Agence Bio, 2023). To understand the dynamics of this slowdown and trying to relaunch it, it is necessary to identify the differences between OF and conventional farming (CF). This will help us identify the challenges involved in their development.

The practice of OF differs from that of CF in that it is governed by European specifications[1]. OF productions defined by its rigorous principles: natural products (no added colouring or flavours), respect for animal welfare (outdoor access, ban on certain methods of animal mutilation), no use of chemicals or genetically modified organism (ban on synthetic products and a strict list of authorised natural products), and the promotion of agri-environmental practices. Among the agri-environmental techniques that are encouraged, we find the inclusion of crop diversity, the introduction of long-term crop rotations with permanent plant cover, and the use of mechanical weed control methods. These different practices lead to yield differences compared to CF.

According to Meemken and Qaim (2018), OF systems only use green manure to improve soil quality, which is not enough to provide phosphorus and nitrates for crop growth. The lack of chemical inputs also limits their growth potential. In addition, the absence of pesticides makes organic crops easy prey for a pests and diseases, which can result in a significant drop in yield. At the end, according to the three main meta-analyses (Seufert et al., 2012; Ponisio et al., 2015; De Ponti et al., 2012), which compare yield between OF and CF on a global scale, an organic farmer's yields between 9% and 25% lower than those of a conventional farmer who grows the same crop on the same area. The average yield gap varies depending on the type of crop. For cereals, the yield loss is about 22%, while it is only 3% for orchard crops (Seufert et al., 2012). When the analysis level changed from the crop level to the farm level, the authors find that, for a farm of the same area, the total yield gap between the OF and CF farms is only 10%. This decrease can be explained by the greater use of permanent cover in OF. It allows for longer harvesting periods and more diverse production than in CF.

OF has a lower yield than CF, meaning that more farmland is needed to produce the same amount. Two other factors explain the increased need for land in OF. Firstly, the introduction of *nitrate-fixing intermediate crops* (such as leguminous crops) into rotations improves soil fertility by increasing the level of nitrogen, however, these are not used directly for human consumption (fodder crop). Secondly, animals raised organically live longer on average, requiring more feed and more land. For example, according to Treu et al. (2017), the production area required for organic dairy products (such as butter and cheese) is 40% larger than that for CF. Finally, according to Muller et al. (2017), if all agriculture were organic, the amount of arable land needed to produce the same amount of food would have to increase by 33%.

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[1] In the EU, OF is governed by European Regulation (EU) 2018/848

The comparison between OF and CF practices should not be limited to yield differences. Indeed, the practices defined in the OF specifications allow for limiting pressure on the environment and even improving its ecological status. OF generates higher number of positive externalities than CF. These externalities can be divided into three categories: environmental, health, and social. These are very well described in the report by Sautereau and Benoit (2016), as well as in the meta-analysis carried out by Meemken and Qaim (2018).

OF has a negative impact on soil quantity compared to CF. However, its positive impact on soil quality is much greater. Agri-environmental practices in OF help to improve soil structure and the amount of biomass. This drastically reduces the potential for eutrophication[2] and erosion of the soil (Tuomisto et al., 2012). OF also contributes to the provision of essential ecosystem services, such as carbon storage (Gattinger et al., 2012). OF has a different impact on water resources than CF. It uses less water and retains it better (Fleury, 2011), which helps to preserve both the quantity and quality of this resource. Improved soil permeability in OF increases water storage capacity. During periods of drought, this reduces the risk of water stress for crops, leading to higher yields in OF compared to CF (Lotter et al., 2003; Gomiero et al., 2011).

In terms of air quality, CO_2 emissions are lower in OF than in CF (Mondelaers et al., 2009; Tuomisto et al., 2012). As for biodiversity, OF practices lead to a significant increase in the diversity and abundance of species (Bengtsson et al., 2005; Gomiero et al., 2011), while encouraging positive phenomena such as pollination (Andersson et al., 2012). These results can be explained by the absence of the use of synthetic pesticides, and by agri-environmental practices (ecological infrastructure, meadows, diversified rotations) favourable to the return of biodiversity (Sautereau and Benoit, 2016).

The gap in the production of ecosystem services between organic and conventional farming has been well documented in the scientific literature. Nevertheless, these non-visible aspects may not be recognised by the farmers themselves and therefore not valued by them. To verify this, we will examine in Chapter III whether the agricultural land market takes into account the positive externalities of AB practices in the price of land. Is the value of organic land higher than that of conventional

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[2] A process of nutrient accumulation (mainly nitrogen and phosphorus) caused by intensive farming, which alters the biological balance of aquatic environments (fish kills, deterioration in water quality)

land ?

In addition to its environmental benefits, OF also addresses public health issues. A diet based on OF products appears to have positive health effect, with convincing results revealed by the huge survey called 'BIO Nutrinet' (Kesse-Guyot et al., 2013). The study, which was launched in 2009, involved more than 54,000 volunteers. It revealed many health benefits associated with the consumption of organic products. The results showed a reduced risk of cancer (among regular consumers), as well as a reduced risk of obesity (in line with the study by Bhagavathula et al. (2022) in the United States), and a lower prevalence of type 2 diabetes. According to Barański et al. (2014), these results can be explained by the fact that organic products contain four times fewer pesticides than conventional products, and have lower nitrate levels and higher antioxidant levels. The latter is associated with a reduced risk of cancer and cardiovascular disease. For Kesse-Guyot et al. (2013), there may be confounding factors that explain the differences in health levels between regular consumers of organic produce and others. These two groups differ in terms of their living conditions and diets. Organic product consumers have a more balanced diet, rich in fiber and leguminous plants, and they consume less animal protein. These factors could also explain the differences in health status and diseases exposure.

OF limits the negative impact of farming on the environment, biodiversity, and human health. However, worldwide, its development is limited (2% of the world's agricultural land according to Willer et al. (2024) in 2022) and low in France (9.2% of agricultural land in 2021). Identifying the determinants of the adoption of OF practices that are already known, as well as highlighting any missing elements, could help accelerate its development.

To understand the development of OF, we will examine how agricultural innovation diffuses and how it fits into a farmer's agronomic trajectory. Then, we will look in more detail at the attributes identified in the literature that encourage farmers to make the transition to OF.

Padel (2001) applies Rogers's theory of the diffusion of innovations (Rogers, 1983), applying it to the diffusion of OF. The authors consider that the adoption of an innovation follows a long process in which certain individuals, the pioneers, quickly adopt it and are gradually imitated by others. Other authors (Bellon and Lamine, 2009; Sutherland et al., 2012) contribute to this subjects by showing that the innovation fits into different agronomic trajectories. These trajectories can be divided into two categories. The first, called *input substitution*, is based on the theory of incremental change. In this case, farmers gradually move towards OF. The second, called *system redesign*, is triggered by an event making the change in practice imperative for the farmer. Sutherland et al. (2012), defines this trajectory as follows: *"The farm manager of the existing 'path dependent' system encounters [...] one or more triggers leading to a 'trigger event': the realisation that system change is necessary to meet his/her objectives, and/or exploit new opportunities"*. The triggering event for each farmer is different. While some begin conversion due to a short-term economic opportunity that allows them to increase their profits by charging higher prices (Merot et al., 2020). Others convert because of health problems (disease diagnosis) or a desire to limit their impact on the environment.

In their article, Schmidtner et al. (2012) define an equation that is derived from the utility function of agriculture. They present a calculation whereby the farmer will convert when the gains associated with OF exceed the cost of conversion. In other words, the farmer will convert when the expected utility gains from OF are greater than those from CF. This empirical model illustrates the theory of incremental change. The literature on the determinants of adoption of OF practices aims to identify the characteristics and marginal changes that influence the difference between organic and CF practices. The objective is to identify the profiles of farmers most likely to convert to OF.

We can distinguish three sources that influence a farmer to convert to organic farming: itself (its characteristics, its farm), public policy, and the local environment. Certain characteristics of the farmer may encourage him to switch to organic farming. The farmers whom are the most likely to make this switch are young farmers with agricultural or general education and those who are sensitive to environmental issues (Padel, 2001; Genius et al., 2006; Geniaux and Latruffe, 2010). Lapple (2010) also found a negative relation between farm size and the probability of conversion. At the same time, public policy has a crucial role to play in the decision to adopt OF practices, through the implementation of regulations and monetary or non-monetary incentive schemes. According to Genius et al. (2006) and Kumbhakar et al. (2009), in Greece and Finland, subsidies received by organic farmers played an important role in their decision to convert their land. Nevertheless, Geniaux and Latruffe (2010) concludes that the available studies cannot be generalised, as their results depend on the regional and temporal context. The impact of one characteristic may vary from one country to another and from one time period to another. For example, Gardebroek (2003) found that between 1994 and 1999, extensive dairy farmers in the Netherlands had a higher probability of conversion. The effect was negative for soybean farmers in the USA in 2006 (McBride and Greene, 2009).

The third source of influence is the farmer's local environment, the environment in which the farmer operates. In this space, social, economic and natural environmental interactions can influence the farmer's decision to convert. The influence of this environment on the farmer's practice depends on two components. Firstly, the agglomeration effect of OF, is defined as the influence of the initial presence of OF in the area. Secondly, the influence of spatial heterogeneity, refers to the impact of a territory's features on a farmer's practices. The first component is the agglomeration effect of organic practices. This means that farmers are more likely to adopt organic practices if they are near other organic farmers. These organic farmers, who are initially present in the area, act as ambassadors or technical advisers, thus enabling the practice to spread among their neighbours. Several authors (Bjørkhaug and Blekesaune, 2013; Schmidtner et al., 2012; Coinon, 2022), have tested and measured the influence of neighborhood using different methodologies. For example, Coinon (2022) attempted to approximate each farmer's neighbourhood by identifying the farmers who operate the five closest plots according to the wind direction. Other authors (Bjørkhaug and Blekesaune, 2013; Schmidtner et al., 2012) define neighbours as those within x kilometers of the farm. The various methods used to define the size of farmers' neighbourhoods demonstrate the necessity to take into account the impact of an agglomeration effect.

The literature has also highlighted the existence of local conditions favourable to the development of OF practices. Some authors have studied the influence of spatial heterogeneity on the practice, approaching it through environmental/climatic conditions or the characteristics of the local market. However, the validity of these results is once again context-dependent. While Schmidtner et al. (2012) found that German organic farmers were located far from the city centre, Wollni and Andersson (2014) obtained the opposite result in Honduras over the same period. The same ambiguity of effect persists when we look at the influence of soil quality on the practice of OF. For Gabriel et al. (2009), English organic farmers are located on poor-quality soil. In contrast, Vietnamese organic farmers exploit good-quality land (Lampach et al., 2020).

The literature review cited above does not provide enough information to answer our research question. This is because the analyses are highly dependent on territorial contexts and their generalisation is limited. By carrying out an analysis of the current context in France, extending the analyses of Allaire et al. (2014) and Allaire et al. (2015), we will be able to identify, in Chapter I, the local French conditions that led to the development of OF. To illustrate the heterogeneity between territories, we will focus on the history of the emergence of the OF movement in France. This explains the differential development of OF across french territories. Our analysis will then focus on the actions of public authorities, which have had an impact on development of OF in two ways. Firstly by introducing a global legislative framework. Secondly, by creating public authorities created different conversion dynamics by setting up territorial aid schemes. Finally, we will examine how this spatial heterogeneity affects farmland prices.

In the period following the Second World War, groups of citizens, farmers and doctors formed in various regions to discuss agronomic writings and experiments. They campaigned for the development of a new form of agriculture that would be an alternative to the intensive model, preserving soil quality and enabling natural food production (i.e. without the use of chemicals). The debate on this alternative agriculture focused on two themes. On the one hand, they addressed the practice of agriculture without using chemicals, and on the other hand, they advocated for a change in economic paradigms that would involve shortening distribution channels to promote relationships with consumers. Information on both aspects are gathered in Besson's thesis (Besson, 2007). The main authors of these new agronomic practices are Rudolf Steiner and Albert Howard. In 1924, in eight conferences, Rudolf Steiner founded biodynamic agriculture and theorised his vision of agriculture based on natural methods of soil fertilisation (natural amendment, interaction between crops and livestock), as well as crop cycles aligned with the lunar and planetary calendars. He emphasised the necessity of cosmic energies for plant growth. His writings were particularly well received by some members of the medical community (nutritionists, pharmacists), who were already pointing to a negative link between the use of chemicals and their impact on human health (Leroux, 2015). Albert Howard, for his part, proposed agriculture based on replacing chemicals with natural compost and introducing crop rotations (Howard, 1943). The second pillar of alternative agriculture, promoted in particular by Hans Müller, is the integration of a social dimension into farming. This involves using shorter distribution channels that include the consumer and prioritise social relationships over commercial ones.

In France, three main movements have emerged from the thinking of these authors, each with a territorial influence. The first advocated biodynamics as theorised by Rudolf Steiner: production based on the interactions between man, the earth and cosmic forces. This movement found an echo in Germany (the original birthplace of Steiner's eight conferences) and in eastern France (the first biodynamic farm in Alsace in 1924). The second movement called the 'Lemaire-Boucher method' (after the names of two biologists, Raoul Lemaire and Jean Boucher) suggested replacing chemical products with high-yield organic fertilisers and seeds (such as algae-based fertilisers or natural composting). The Lemaire Company, which sells these products through traditional distribution channels, has found an outlet in particular through the 'GABO' group ('Western Organic Farmers Group'). This group was founded by Raoul Lemaire himself. This conception of alternative agriculture, which is free from chemical inputs, but uses the same distribution channels, was initially introduced in the western France. In response to this market-based approach, the 'Nature et Progrès' association was founded (translated as 'Nature and Progress'). It proposes a new agricultural model that respects nature and advocates for a change in the economic model. The association suggests to break away from the capitalist approach to agriculture by ending competition between farmers. It also promotes fair distribution of profits and direct sales between producers and consumers. This movement aims to make the products of this type of agriculture more accessible, while at the same time increasing the number of producers. The association federates activists working in various professions throughout the distribution channel (producers, processors, distributors and consumers). They want to make natural and social agriculture more accessible to the public. To do this, they organise themselves into organic cooperatives called *Biocoop*[3]. These cooperatives, managed by their members, aim to provide fair compensation to producers (Leroux, 2015). At the same time, the Nature and Progress Association tried to standardise its practices by publishing the first set of specifications in 1972. The aim of these specifications was to provide a regulatory framework for their approach to promoting alternative agriculture, using scientifically verifiable methods. This approach is based on a set of standards that contrast with the esoteric approach of biodynamic agriculture. According to Leroux (2015), in the late '90s and early 2000s, the development of OF was slow. During this period, OF was not well perceived by conventional farmers, who associated it with an activist agricultural practice that gave too much importance to nature. Two

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[3] Today, 6,600 points of sale are counted, representing 22% of the organic store market by 2023

antagonistic visions of agriculture seem to oppose each other: organic and conventional.

To promote the emergence of alternative agriculture, it must be standardised and include incentives for conventional farmers to adopt new practices. Public intervention was therefore essential.

In 1981, the French government promulgated a set of specifications aimed at producing agriculture without using synthetic chemicals. They were based on those of the Nature and Progress Association. In 1988, the term 'organic farming' and its logo were created and protected. At the European level, the specifications for OF were adopted in 1991. OF is the only agricultural practice regulated by European legislation. The legislation has been modified several times[4], ad is currently controlled by European Regulation (EU) 2018/848. The standards define the rules that govern the entire process, from production to processing and retailing.

In addition to regulating the practice, the EU, through the European Common Agricultural Policy (CAP), has offered aid for conversion to OF since 1992. This aid helps farmers compensate for production losses during the conversion period (between two and three years). To receive this parcel-based aid, farmers must agree to apply the specifications of OF on their land for five years. Since 2007, this scheme has been supplemented by another: aid for maintaining OF. This aid allows the farmer to continue receiving support after the five years of the OF conversion contract. Based on these two measures, the French government has drawn up several five-year national plans for the development of OF. These ambitious plans set national production targets, accompanied by measures aimed at players at different levels of the distribution chain. The results are highly contrasted and influenced by the economic situation at the time of their implementation (Wezel and David, 2020).

The first five-year plan, called *Organic farming and food: Towards 2012*, was launched in 2007 by the French Minister for Agriculture. It aimed to increase the number of hectares under OF. At that time, consumption far exceeded national production. In 2006, 50% of the organic products consumed in France were imported. According to Leroux (2015), this strong increase in consumption is due to a series of health crises that have led consumers to reconsider their habits: the mad cow disease crisis in 1986, followed by bird flu in 2004. The measures included in this first plan include aid for converting to and maintaining OF, which is funded by the second pillar

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[4] Abrogated by Regulations (EC) No 834/2007, (EC) No 889/2008 and (EC) No 1235/2008

of the CAP, as well as a tax credit. National aid can be supplemented by regional aid (certification aid, aid for structuring the sector), as well as municipal aid (property tax exemptions). The first plan was a step forward: between 2007 and 2012, the area under OF doubled, rising from 2% to 3.8% of UAA (the initial target was 6%). The two successive plans, launched in 2012 and 2017 respectively, maintained the dynamic of conversion (annual growth rate of certified organic UAA of 14.2%). This dynamic was made possible by maintaining the instruments of the previous plan, adding aid to structure the sectors, and increasing the market opportunities through requirements for a minimum proportion of organic products in public catering (20%).

However, at the end of the last plan's implementation period, the conversion dynamic will stop. Indeed, the year 2021 will see a drop in the amount of land under conversion (-0.9%), followed by an even bigger fall in 2022 (-24.2%). Despite it at the end of 2023, as part of the CAP Strategic Plan requested by the European Union, France set itself the ambitious goal of having 18% of its UAA under OF by 2027 (Ministère de l'Agriculture et de la Souveraineté alimentaire, 2022). This objective may seem impossible to achieve given the current rate of conversion. However, it is in line with the European objectives of the *European Green Deal* (25% of the European Union's UAA to be organic by 2030, European Commission (2020)).

According to Genius et al. (2006), the subsidies granted to farmers has allowed them to reduce the economic pressure and made them less dependent on the income from their production. As a result, they have less incentive to opt for high-yield farming, since they can already earn a certain amount of money. We will therefore examine whether other support schemes offered by national and European public authorities encourage the development of OF. We will see that, depending on the location of the plots farmed, farmers have different opportunities to access subsidies. Thus, we can assume that these territorial subsidies generate differences in the development of OF. In this thesis, two territorial policies will be examined: the payments for Areas facing Natural or specific Constraints (ANC) in Chapter I, and the policy for the protection of Water Catchment Area (WCA) in Chapter II.

In Chapter I, we examine the impact of payments for areas facing natural or specific constraints on the development of OF. This subsidy was created in 1976 and is the largest in terms of amounts financed by the European Agricultural Fund for Rural Development, which is co-financed by national institutions (state and regions) to the extent of 25%. In 2019, 86,226 French farmers were eligible for this subsidy, with beneficiaries receiving an average of 12,235€/year in ANC. This aid aims to maintain farming in areas that are isolated or constrained by natural phenomena (mountains, poor-quality soil), and it helps to maintain economic activity in these regions. The number of French municipalities eligible for ANC will vary depending on the reform of the selection criteria. It could range from 10,429 to 14,210[5].

To deal with the challenge of water pollution from agricultural and industrial sources, the government decided to implement a policy to protect water catchment areas. The goal is to limit potential pollution in areas near sources of water intended for human consumption. Based on a review of different natural experiences of water protection on a local scale (Munich, Lons-Le-Saunier, Lepzig), Sautereau and Benoit (2016) show that the cost of the strategy of preventing water pollution is between 2.5 and 7 times lower than that of the curative treatment of polluted water. The various systems put in place in these towns have made it possible to considerably improve water quality at a lower cost than the treatment required to obtain the same quality. The goal of the WCA policy is to change the farming practices of farms in the catchment area through existing schemes (agri-environmental schemes, regulations). Stakeholders involved in this policy promote OF (Vincent, 2016). The programming law relating to the WCA policy states: ‘In water catchment areas, priority will be given to organic farming areas’ (Article 27 of Law No. 2009-967 of 3 August 2009).

We will study these two territorial subsidies to see how they affect farming practices. The results may differ from one scheme to another. ANC aims to compensate for yield losses due to soil characteristics in defined territories, but there are no other conditions for its award. Under the WCA policy, some of the measures put in place are conditional on the adoption of agri-environmental practices.

Spatial heterogeneity influences not only farmers' practices but also has an impact on population dynamics and land-use planning. People tend to live in areas that maximise their utility. This demand for residential use and other commercial activities can make land markets more competitive, leading to unequal land prices. How do population dynamics affect farming practices ?

Rosen (1974) developed a hedonic pricing method for decomposing the value of goods into the functions of their characteristics. According to Cavailhès and Wavresky (2003), the price of agricultural land is determined by two components. The Ricardian rent corresponds to the share of a land's value that depends on its intrinsic characteristics, which is a function of its yield. The higher the productivity

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[5] From 1 January 2019, in the application of European Regulation 1305/2013 on rural development

of the land, the greater its value. The residential rent refers to the value of residential amenities made possible by the location of the land.

The scientific literature measures the impact of climate (Passel et al., 2017; Bareille and Chakir, 2023), soil, and proximity to cities on the price of land (Cavailhès et al., 2011; Cavailhès and Wavresky, 2003). In these studies, the farming practices carried out on the land are not differentiated; they are assumed to be homogeneous across all farmland. We suggest taking this one step further by distinguishing farming practices in Chapter III. This would allow us to measure the value associated by the market with OF. Theoretically, we can assume that land farmed organically will be sold at a higher price than land farmed conventionally, thanks to two mechanisms. Firstly, the agricultural land market considers the environmental externalities provided by OF, which increases soil productivity (reducing erosion, increasing biomass, and creating water reserves). Secondly, it avoids the cost of converting the land to OF. It allows the buyer to start farming organic food immediately, thus avoiding a two to three years conversion period. Therefore, we can assume, as obtained in the article by Fuller et al. (2021), that organic land will sell for a higher price than land farmed in CF.

Generalising the results of the article Fuller et al. (2021), which were obtained on the US farmland rental market between 2003 and 2011, seems far removed from our context. In Europe, Baldoni et al. (2021) and Kilian et al. (2008) found that CAP subsidies conditional on agri-environmental practices negatively affected the value of land. They argue that the associated valuation of a CAP subsidy on the price of agricultural land depends on the effort required to receive this aid. They find that the impact of coupled production subsidies is greater than that of subsidies conditional on agri-environmental practices. In the case of coupled production subsidies, by purchasing this plot, the farmer will automatically increase the potential amount of his CAP aid. His willingness to pay will be higher. In the case of subsidies conditional on agri-environmental practices, the new landowner will only receive the aid if they continues the farming practices of his previous landowner. This implies that buyers who do not want to farm organically will not value the fact that a plot is farmed organically. Indeed, by not continuing the previous farming practice, they will not recover the CAP aid linked to OF.

Considering the results obtained by these articles, the expected effect of OF on the price of land in a European context is ambiguous. Chapter III will show the value of OF practices on the agricultural land market.

Research questions

Our general research question is as follows: to what extent does spatial heterogeneity influence the dynamics of the development of OF ?

As we saw in this general introduction, the characteristics that create heterogeneity between territories and influence the development of OF are of different kinds. These differences result from the historical construction of organic agriculture in each region. This sector is more or less structured according to the territory, which is reinforced by territorial incentives, such as ANC aid or the WCA policy. Finally, territories are differentiated by natural factors (soil and climate), which can condition different agricultural practices.

The various questions raised in this thesis aim to show that a farmer's location can influence their farming practices. Why are two farmers in different locations not equally likely to farm organically ? The aim is to look at this issue from different perspectives in France between 2015 and 2021. This period was characterised by a strong growth in the number of plots under conversion in OF (15% annual growth), followed by a marked slowdown towards the end of the period[6]. In Chapter I, we analyse the distribution of organic farmers in order to identify the historical influence of the various territorial movements of alternative agriculture and the role of geographical disparities in their dispersion. Our objectives is to identify territorial characteristics that explain the uneven distribution of organic farmers in France. We will see that some variations are due to ANC aid. The location of a farmer's plots may make them eligible for specific aid schemes. These subsidies may influence their farming practices.

To verify the impact of territorial subsidies on organic practices, in Chapter II we will analyse the influence of the policy to protect water catchment areas on farmers' practices. As the areas targeted by this policy were determined at different times (between 2013 and 2021). They also vary greatly in size, from 3 hectares to $7710 km^2$). One of the main issues in this chapter will therefore be constructing the counterfactual group. The control group allows us to measure the changes in agricultural practices (OF and other agri-environmental practices that preserve water quality) attributable to the policy, as well as to identify potential spillover effects, i.e. changes in practices outside the WCA that are attributable to the policy.

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[6] Between 2021 and 2022, there was a 24% decrease in the number of plots undergoing conversion

In Chapter III, we will attempt to measure the value associated with organic practices on the agricultural land market, while controlling for the value associated with the territory. We will use the hedonic pricing method to determine the contribution of each land characteristic to the value of agricultural land. This work aims to determine whether OF practices and the environmental externalities they provide are valued in the price of land. This chapter will also explain how the distance of organic farmers from major cities (as shown in Chapter I) can be explained by the land pressure exerted by residential demand, which drives up the price of land. The methodological challenge in estimating the value of OF on a plot is to neutralise the effect of the territory on the price. The goal is to be able to compare the value of organically farmed land with conventionally farmed land in the same location and with the same natural characteristics. Based on these different lines of research, this thesis will answer the following research questions:

- How are organic farms and farmland distributed among French municipalities? What are the main spatial factors explaining this heterogenous development ?
- Does the delimitation of water catchment areas encourage farmers to change their practices ?
- What is the value associated with the territory in the price of agricultural land? Does organic farming increase the value of land ?

Methodologies

To answer the questions raised by this thesis, we will highlight two important aspects. Firstly, we will discuss the geographic data on farmland used in France between 2015 and 2021. This data is used throughout the thesis and allows for a precise analysis of the evolution of agricultural practices in France. Secondly, we will discuss the econometric methods applied to this data. These methods allow us to measure the effects of territory on agricultural practices.

In order to obtain the most accurate picture possible of localised land parcels in France, the three chapters of this thesis are based on the French land parcel identification system (LPIS), known as Graphic Parcel Register. This system was launched in 2002 following Regulation EC 1593/2000, which required Member States to set up a geolocalised control system for CAP aid. This system is part of the *Integrated*

Administration and Control System[7]. In France, this database is managed by the Single Payment Agency, which also handles various CAP aid payments. Cantelaube and Carles (2014) compared the farmland area data from the annual agricultural statistics produced by the Ministry of Agriculture with the farmland area which were covered by the French LPIS. They found that around 8.5% of French plots were excluded from the LPIS. The main areas that are not represented in the database are vineyards and fruit crops, which show 39.2% and 56.5% of their areas missing, respectively. On the other hand, the database is almost complete for permanent grassland (94.5%) and cereal crops (99.1%). Version 2 of the French LPIS was published in 2015. From now on, precision will be enhanced, with the reference level moving from the islet[8] to the parcel level. This change provides greater precision, particularly regarding the crops grown. In version 1, different crops could be grown on the same islet, but only the most important one was declared. In version 2, we have the associated geometry for each plot, as well as the precise crop among 350 crops that can be grouped into 28 crop groups. Other information has been added to the 2015 version, including catch crops (among 45 crops) and OF practices.

The popularity of this data is growing rapidly. Particular mention should be made of the organic land maps project[9] (called *CartoBio*), launched in November 2022. It is a visualisation tool developed by the French Agency for the development and promotion of OF (Agence Bio) and added to their website. This tool tracks changes in French organic farmland since 2019. The ultimate goal of the platform is to cover 100% of certified organic farms (estimated at 85%) and all land under conversion (information not available in the LPIS). If successful, this would allow certification bodies to update the maps directly by adding new certified plots.

Farming practices are not determined solely by the characteristics of the farmer and their farm. Two identical farms may have different farming practices. The location of a farmer's farm determines access to a network of peers and other benefits that derive from the characteristics of the territory. This interdependence between the practices of farmer i and those of other farmers implies a correlation between ϵ_i

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[7] A set of systems that enable Member States to manage, monitor, and control various CAP interventions. The data from these systems, which can be compared between the various Member States, can be used to conduct ex-post audits on the effectiveness of various multiannual CAP programs

[8] A set of contiguous parcels belonging to the same farmer, delimited by identifiable landmarks (such as farm tracks, roads, rivers, or other parcels)

[9] Available the website: https://www.agencebio.org/cartobio/

and ϵ_j. Consequently, the OLS estimators are biased because the fundamental assumption of independence of the observations is violated (cor(ϵ_i,ϵ_j)$\neq 0$). To overcome this issue, spatial econometric models can be used to integrate these interdependent relationships between observations by creating a neighbourhood matrix (LeSage and Pace, 2009). This matrix of dimensions $n{*}n$, contains information on the relationship between i and j. For each individual i, the interdependent observations j (cor(ϵ_i,ϵ_j)$\neq$ 0), and the independent observations j (cor(ϵ_i,ϵ_j) $= 0$) are identified. This matrix contains all the assumed or observed relationships between the different individuals in the population. These spatial econometrics models then try to identify the variables responsible for this spatial autocorrelation. There are three types of variables: linked to spatial dependence (influence of Y_j on Y_i), linked to spatial heterogeneity (influence of X_j on Y_i) or linked to unobserved neighbourhood variables (influence of $epsilon_j$ on Y_i). Using the *Spatial Autoregressive* models, we can model the influence of spatial dependence on the value of our dependent variable. The literature on the determinants of OF shows that the neighbourhood effect influences its adoption. Schmidtner et al. (2012) and Bjørkhaug and Blekesaune (2013), through their modelling, have shown it Germany and Norway respectively. According to these authors, the higher the concentration of organic farmers in a farmer's neighbourhood is, the greater the probability that the farmer will convert to OF. This thesis aims to demonstrate that the location of the farmer also plays a role in the choice of farming practices. In Chapter I, we will test the influence of spatial heterogeneity, while controlling for spatial dependence, on the distribution of organic land using the *Spatial Durbin Model* (LeSage and Pace, 2009).

However, spatial econometric models have several limitations, which are discussed in particular in Anselin et al. (2008). Two main limitations of these models are important to raise. Firstly, models that study the influence of spatial dependence on cross-sectional data do not identify a causal link between neighbours, but only correlations between them. Indeed, it is possible to detect areas where individuals share the same practice, but the causal relationship is not established. Analysis of Moran's I (Cliff and Ord J, 1981) can be used to detect areas with neighbouring entities with the same characteristics (clustering effect). This measure is only a correlation indicator between close observations. Moreover, according to Anselin (2003), the study of spatial dependence adds an endogeneity problem. Indeed, Y_j can also be influenced by Y_i. In other words, we assume that the neighbour j influences the individual i, but as i is also j's neighbour, it therefore influences the latter. Anselin (2003) calls this phenomenon the *Spatial Multiplier*. Secondly, one of the main components of spatial econometrics models is the construction of the neighbourhood matrix. It must represent all the relationships between individuals, but it is impossible to represent relationships between farmers perfectly at the country level. This representation is therefore only an approximation of reality. To limit this problem, we constructed four neighbourhood matrices in Chapter I, ranging from the most restrictive (only including neighbours that share a border) to the least restrictive (including all neighbours within 20 km).

Due to these limitations, in chapters II and III we consider the effects of spatial heterogeneity without using spatial econometric models.

In Chapter II, we seek to determine the effect of the WCA policy on the development of OF. However, the econometric problem is that the treatment is not exogenous; it is linked to the initial density of organic or conventional farmers in the area[10]. Indeed, since the distribution of organic farmers is not homogeneous across the territory (chapter I), the probability that a farmer will receive the treatment depends on the area where their farm. To neutralise the territorial selection bias, we use spatial RDD methods based on the geographical boundary (Keele and Titiunik, 2015; Lee and Lemieux, 2010). This method compares the effect of a policy between a treated group and a control group located at the border of the treatment zone. Since the WCA are delimited by hydrological studies, the allocation of the treatment (eligibility for the WCA policy) is exogenous to the farmer's decision. Thus, two farmers located on either side of the geographical boundary of the WCA will have the same probability of receiving the treatment (absence of selection bias). This method neutralises the effect of territory on the probability of receiving the treatment and converting to OF. Therefore, the marginal effect of the WCA policy on farming practices will be unbiased.

In Chapter III, to assess the value attributed to organic practices in the price of land, we use matching methods based on geographic distance. We associate a plot of organic farmland sold with the nearest plot of conventional land sold in the same year. This matching method eliminates the endogeneity bias that exists between the characteristics of the farmland and the farming practice. With this method, we match two plots with the same characteristics, and therefore with the same probability of being farmed organically. This matching goes further than propensity score

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[10] In an area with a high concentration of conventional farmers, the use of chemical inputs will be higher, increasing the risk of water pollution

matching. Indeed, by matching two observations that are spatially very close (on average 1.5 km in the study in Chapter III) and sold the same year, we also control for some unobservable characteristics such as the local farmland market.

Contributions

Throughout this thesis, we have made various contributions to the literature. In Chapter I, based on the work of Allaire et al. (2014), we seek to understand the role of territorial heterogeneity, represented by different variables, on the distribution of organic farmers in France. The use of spatial econometric methods and the construction of neighbourhood matrices allow us to explore the relationships that exist between farmers in neighbouring municipalities; and farmers and the features of these municipalities (population, natural environment). We have already seen that the first organic product distribution channels were set up by militants, particularly by organic farmers themselves. The reverse causality between distribution channels and the number of organic farmers is an important econometric problem that is solved in this chapter. This chapter presents several contributions:

1. Manipulating data from the French LPIS makes it possible to study the distribution of plots at the municipal level. The study of the origin of the disparity in OF at the plot level is more relevant than analysis at the farm level. In fact, in the LPIS, 33% of plots are located in a municipality other than that of the head office (Coinon, 2022).

2. The use of the *Spatial Durbin Model* (LeSage and Pace, 2009) allows us to model the relationship between farmers in different municipalities and the way it influences their agricultural practices (spatial dependence). It also models the influence of a farmer's environment on their practice (spatial heterogeneity). This model allowed us to detect new determinants of conversion not mentioned in the literature: soil quality, subsidies, and local regulations.

3. We showed by considering the literature on the determinants of the consumption of organic produce in France (Kesse-Guyot et al. (2013) and Lambotte et al. (2020)) that the potential demand for organic produce influences the number of organic farms. Population characteristics (level of education, type of employment) influence farming practices up to 20 km away. Considering

these characteristics, we have overcome the problem of inverse causality between the number of organic farms and the number of shops selling organic produce.

This study highlights the key role the farmer's environment plays in their choice of practices. Spatial dependence, already identified in the literature, is once again present in the analysis of the location of organic farms in France. The study also shows that there are differences between populations in different regions (level of education, type of employment). These translate into different consumption habits, which influence the practice of local farmers. Finally, this chapter emphasises the importance of considering spatial factors when making decisions about agricultural practices.

In Chapter II, we supplement the results of Chapter I on the role of territorial subsidies in the development of OF. In this chapter, we will focus on the impact of WCA policy (ANC in Chapter I). This policy combines monetary and non-monetary incentives to encourage farmers in the treated area to change their practices. It aims to protect more than 1,000 water reserves. This chapter measures the impact of this policy on the development of agri-environmental practices (permanent cover crops, grassland) and OF, in comparison with the neighbouring untreated area. Two contributions should be highlighted:

1. The creation of a control group to neutralise the endogeneity of the treatment (related to agricultural practices) using the spatial RDD method based on the geographical boundary. This method allows us to observe a spatial spillover of the policy up to 2 km from the WCA.
2. We used the *Staggered DID* method to detect heterogeneity in the effect depending on the treatment start date. We found that the impact of the policy is different between groups treated in 2017 and 2018, compared to other treated areas.

The study found that the targeted farmers changed their cropping practices (increased use of temporary grassland). It also found a slowdown in the development of OF practices in the WCA, with the proportion of organic land being higher in neighbouring areas than in the WCA. This could be due to the timing of the policy and the support provided.

Finally, in Chapter III, we seek to determine the value associated with organic practices in the French farmland market between 2015 and 2021. We use the hedonic price method on farmland sales in France by measuring the value associated with Ricardian rent and residential rent. To control for the endogeneity between agricultural land and organic practices (demonstrated in Chapters I and II), we use matching methods (based on propensity score and geographical distance). These techniques allow us to compare land that is similar in terms of soil characteristics and location, differing only in terms of farming practice. This chapter makes contributions to the literature:

1. The creation of a database, based on the merger of the *Demand for land value* and LPIS databases, comprising 570,000 agricultural lands sold between 2015 and 2021. This database contains information on farming practices at the time of sale (including 7.8% of land farmed organically).
2. The development of a matching method based on geographical distance allows for the comparison of land sold in the same year, which is on average 1.5 km apart. This method neutralises the effect of unobserved characteristics of the area on the price of land.

The 2% lower price can be explained by weak and mispositioned demand. According to the results of Baldoni et al. (2021), only organic farmers are willing to pay a higher amount to acquire land for OF, because they will continue to receive subsidies linked to the practice. However, we show in this chapter that, over the period, organic farmers will have the opportunity to buy conventional land 3.3km away, compared with organic land 8.1km away. This will result in increased land use costs due to higher transportation costs. The combination of these effects explains the price difference in favour of conventionally farmed land. To make organic farmland more attractive and thus increase its value, it would be wise to communicate its advantages (carbon and water storage capacity, increased biomass, less erosion). These advantages can limit yield losses due to future climate events.

This thesis consists of three empirical chapters, presented in the following sections. The first section concerns the chapter entitled '**Spatial factors influencing territorial gaps in organic farming in France**', the second section presents the chapter entitled '**Water policy's influence on local organic farming development**", and the third section details the chapter entitled '**A premium for organic farmland**'. The thesis concludes with a discussion of the limitations and future prospects of the research.

Introduction générale

Contexte et littérature

Comment produire davantage, tout en produisant assez pour nourrir une population toujours plus nombreuse ? En effet, la production agricole doit répondre aux enjeux d'une alimentation durable, définie par l'Organisation des Nations Unies pour l'alimentation et l'agriculture (FAO) comme *"un système alimentaire qui assure la sécurité alimentaire et la nutrition pour tous, sans compromettre les bases économiques, sociales et environnementales de la sécurité alimentaire et de la nutrition pour les générations futures"* (Von Braun et al., 2021). Il faut adapter les pratiques agricoles de manière à ce que la production soit suffisante pour nourrir la population, tout en limitant les pressions exercées sur l'eau, l'air, le sol et la biodiversité. Selon IFOAM Organics International (2019), la promotion de la pratique de l'agriculture biologique (AB) permet d'améliorer les performances des pays sur 8 des 17 objectifs du développement durable. À partir de la littérature scientifique, IFOAM Organics International (2019) rapportent que l'AB répond aux enjeux environnementaux par une amélioration de la qualité de l'eau, et de l'air, ainsi qu'une pression moindre sur la biodiversité marine et terrestre. Sur le plan social, elle améliore les salaires, garantit une consommation responsable et réduit les famines.

Alors que les objectifs européens et nationaux de croissance de l'agriculture biologique, respectivement de 25% de la surface agricole utile (SAU) d'ici à 2030 (European Commission, 2020) et de 18% d'ici à 2027 (Ministère de l'Agriculture et de la Souveraineté alimentaire, 2022) ont été affichés. Le développement de l'OF en France, région analysée dans cette thèse, ralentit. Effectivement, le nombre de terres en conversion a diminué de 0.9% en 2021 et de 24.2% en 2022 (Agence Bio, 2023). Avant de développer les analyses sur ces écarts de développement et comment peut-on les résorber, il est important d'identifier les différences qui existent entre l'AB et l'agriculture conventionnelle (AC), afin de comprendre les enjeux liés à son développement.

La pratique de l'AB se différencie de celle de l'AC par le respect d'un cahier des charges européen encadrant[11]. La production AB est définie par ses principes rigoureux : des produits naturels (sans colorants ni arômes ajoutés), le respect du bien-être animal (accès extérieur, interdiction de certaines méthodes de mutilation animale), l'absence d'utilisation de produits chimiques ou d'organisme génétiquement modifié (interdiction des produits de synthèse et liste stricte de produits naturels autorisés) ainsi que la promotion de pratiques agroécologiques. Les techniques agroécologiques encouragées incluent notamment la diversité des semences, la mise en place de rotation pluriannuelle des cultures permettant des couverts végétaux permanents et l'utilisation de méthodes mécaniques de lutte contre les mauvaises herbes. Ces pratiques différenciées engendrent des écarts de rendement avec l'AC.

Selon Meemken and Qaim (2018), les systèmes en AB qui n'utilisent que des amendements naturels ne fournissent pas assez de phosphore et de nitrate pour la croissance des cultures. Le manque d'apport en produits chimiques limite également leur potentiel de croissance. En outre, l'absence de pesticides fait des cultures biologiques une proie facile pour les ravageurs et les maladies, ce qui peut entraîner une baisse significative du rendement. Les trois principales méta-analyses (Seufert et al., 2012; Ponisio et al., 2015; De Ponti et al., 2012), qui comparent les écarts de rendement entre AB et AC à l'échelle mondiale, montrent qu'un agriculteur biologique obtient des rendements inférieurs de 25% à 9% par rapport à un agriculteur conventionnel cultivant la même culture sur la même surface. Cet écart moyen de rendement connaît des variations en fonction du type de culture. Pour les cultures céréalières, les pertes de rendement sont d'environ 22%, alors que cet écart est seulement de 3% pour les cultures en verger (Seufert et al., 2012). Lorsqu'on observe les différences de rendement non plus seulement au niveau de la culture, mais aussi au niveau de l'exploitation, les auteurs constatent que, pour une exploitation de même superficie, l'écart de rendement total entre l'exploitation AB et AC n'est plus que de 10%. La réduction de l'écart s'explique par une pratique du couvert permanent plus fréquente en bio, ce qui permet un allongement des périodes de récolte ainsi que des productions plus diverses qu'en AC.

L'AB a un rendement plus faible que l'AC, ce qui signifie qu'il faut plus de terres agricoles pour produire la même quantité. Deux autres facteurs expliquent

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[11] Au sein de l'UE, AB est encadrée par le Règlement européen (UE) 2018/848

le besoin accru de terres dans l'AB. D'une part, l'introduction de cultures dites *Culture intermédiaire piège à nitrates* (cultures de légumineuses par exemple) dans les rotations permet d'enrichir le sol en azote, mais ne sert pas directement à la consommation humaine (culture fourragère). D'autre part, en AB, la durée moyenne d'un animal en élevage est plus longue, ce qui nécessite plus de fourrage et de surfaces. Par exemple, selon Treu et al. (2017), la production de produits laitiers AB (beurre et fromage), nécessite une surface de production plus importante de 40% par rapport à une production en AC. Finalement, d'après Muller et al. (2017), si l'AB était la seule pratique agricole dans le monde, il faudrait que la superficie des terres agricoles augmente de 33% pour produire la même quantité de nourriture qu'aujourd'hui.

La comparaison entre les pratiques AB et AC ne doit pas se cantonner à une unique comparaison des écarts de rendement. En effet, les pratiques mises en avant dans le cahier des charges de l'AB permettent de limiter les pressions sur l'environnement, voire d'améliorer son état écologique. L'AB génère une production d'externalités positives plus élevées que l'AC. Ces externalités se distinguent en trois catégories : environnementales, sanitaires et sociales ainsi qu'économique. Elles sont clairement exposées dans le rapport de Sautereau and Benoit (2016), ainsi que la méta-analyse réalisée par Meemken and Qaim (2018).

Même si l'impact de l'AB sur la quantité de sols est négatif (en comparaison à l'AC), son impact positif sur la qualité du sol est bien supérieur. Les pratiques agroenvironnementales de l'AB permettent d'améliorer la structure du sol et la quantité de biomasses. Cela réduit drastiquement les potentiels phénomènes d'eutrophisation[12] et d'érosion (Tuomisto et al., 2012). L'AB contribue également à la fourniture de services écosystémiques essentiels, tels que le stockage du carbone (Gattinger et al., 2012). En ce qui concerne son impact sur la ressource en eau, l'AB se distingue de l'AC par une utilisation moindre et une meilleure rétention(Fleury, 2011), contribuant ainsi à la conservation de la quantité et de la qualité de cette ressource. La meilleure perméabilité du sol permise par la pratique bio renforce la capacité de stockage de l'eau. Ceci contribuant, en période de sécheresse, à la réduction du stress hydrique pour les cultures pouvant aboutir à de meilleurs rendements en AB qu'en AC (Lotter et al., 2003; Gomiero et al., 2011). En ce qui concerne la qualité de l'air, les émissions de CO_2 sont moindres en AB par rapport à

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[12] Processus d'accumulation des nutriments (principalement de l'azote et du phosphore) causé par l'agriculture intensive, qui modifie les équilibres biologiques des milieux aquatiques (mort du poisson, détérioration de la qualité de l'eau).

l'AC (Mondelaers et al., 2009; Tuomisto et al., 2012).En ce qui concerne la biodiversité, les pratiques de l'AB entraînent une augmentation notable de la diversité et de l'abondance des espèces (Bengtsson et al., 2005; Gomiero et al., 2011), qui favorisent notamment la pollinisation (Andersson et al., 2012). Ces résultats s'expliquent par l'absence d'utilisation de pesticides de synthèse, associée à des pratiques agroenvironnementales (infrastructures écologiques, prairies, rotations diversifiées) favorables au retour de la biodiversité (Sautereau and Benoit, 2016).

Cet écart dans la production de services écosystémiques entre AB et AC est très documenté dans la littérature scientifique. Néanmoins, ces aspects non visibles peuvent être méconnus par les agriculteurs eux-mêmes et ainsi non valorisé par ce dernier. Pour le vérifier, nous allons dans cette thèse observer dans le chapitre III si le marché du foncier agricole prend en compte les externalités positives de la pratique AB dans le prix : La valeur d'une terre bio est-elle supérieure à celle une terre conventionnelle ?

Outre ses bénéfices environnementaux, l'AB répond aussi aux enjeux de santé publique. Une alimentation à base de produit AB semble avoir des effets bénéfiques sur la santé, avec des résultats probants révélés par la vaste enquête 'BIO Nutrinet' (Kesse-Guyot et al., 2013). Cette étude, initiée en 2009 avec la participation de plus de 54 000 volontaires. Elle révèle plusieurs avantages pour la santé associés à la consommation de produits issus de l'AB. Parmi les résultats, on note une diminution des risques de cancer (moins fréquents chez les consommateurs réguliers), mais aussi des risques d'obésité (en accord avec l'étude de Bhagavathula et al. (2022) aux États-Unis) et des cas de diabète de types 2 moins fréquents. Selon Barański et al. (2014), ces résultats sont attribuables à des concentrations en pesticides quatre fois moindres dans les produits AB par rapport à ceux de l'AC, à des taux de nitrate moins élevés et à des taux d'antioxydants plus importants. Ces derniers sont associés à une diminution du risque de cancer et de maladie cardiovasculaire. Pour Kesse-Guyot et al. (2013), il peut y avoir des facteurs confondants qui expliquent les différences de niveau de santé entre les consommateurs réguliers de produits issus de l'AB et les autres. En effet, ces deux groupes se différencient par leurs conditions de vie et leurs régimes alimentaires différents. Les consommateurs de produits issus de l'AB ont des régimes alimentaires plus variés, riches en fibres et légumes secs, et avec une plus faible consommation de protéines animales. Ces facteurs pourraient aussi expliquer les différences d'état de santé et d'exposition aux maladies.

L'AB permet de limiter l'impact négatif de l'agriculture sur l'environnement, la biodiversité et la santé humaine. Or, son développement reste marginal au niveau mondial (2% des surfaces mondiales d'après Willer et al. (2024), en 2022) et faible en France (9.2% des surfaces agricoles en 2021). Ainsi, dresser les déterminants de l'adoption déjà révélés dans la littérature et mettre en évidence les lacunes, peut contribuer à l'accélération du développement de l'AB.

Pour comprendre le développement de l'AB, nous aborderons la manière dont la diffusion de l'innovation agricole se répand et comment celle-ci s'intègre dans la trajectoire agronomique de l'agriculteur. Ensuite, nous détaillerons les caractéristiques favorisant la transition des agriculteurs vers la pratique AB mises en évidence dans la littérature.

Padel (2001) reprend la théorie de la diffusion des innovations de Rogers (1983), en l'appliquant à la diffusion de l'AB. Elle considère que l'adoption d'une innovation suit un long processus où certains individus, les pionniers, l'adoptent rapidement et sont progressivement imités par d'autres. D'autres auteurs (Bellon and Lamine, 2009; Sutherland et al., 2012) parachèvent ces travaux en montrant que l'innovation va s'insérer dans des trajectoires agronomiques différentes. Ces trajectoires peuvent être divisées entre deux catégories. La première, dite *input substitution* est basée sur la théorie des changements incrémentaux, et la deuxième, de rupture est nommée *system redisgn*. Dans le premier cas, les agriculteurs progressent graduellement vers la conversion à l'AB. Dans l'autre cas, un événement déclencheur fait en sorte que le changement de pratique est perçu comme indispensable par l'agriculteur. Sutherland et al. (2012), définissent cette trajectoire comme suit : *"The farm manager of the existing 'path dependent' system encounters [...] one or more triggers leading to a 'trigger event' : the realisation that system change is necessary to meet his/her objectives, and/or exploit new opportunities."*. L'évènement déclencheur est différent pour chaque agriculteur. Certains entament la conversion en raison d'une opportunité économique de court terme leur permettant d'augmenter leur résultat économique par des prix plus importants (Merot et al., 2020). D'autres réagissent face à des problèmes de santé (diagnostic de maladie) ou expriment une volonté de limiter leur impact sur l'environnement.

Dans leur article, Schmidtner et al. (2012) définissent une équation qui est dérivée de la fonction d'utilité de l'agriculture. Ils y présentent un calcul selon lequel l'agriculteur se convertira lorsque les gains associés à la pratique AB seront supérieurs au coût lié à la conversion en AB. En d'autres termes, l'agriculteur se convertira quand les gains espérés d'utilité de la pratique AB seront supérieurs à ceux de la pratique actuelle, soit à l'AC. Cette modélisation empirique illustre la théorie des changements incrémentaux. La littérature sur les déterminants de l'adoption de la pratique AB vise à déterminer les caractéristiques et les changements marginaux qui influencent le différentiel entre les pratiques AB et AC afin d'identifier les profils d'agriculteurs les plus enclins à se convertir en AB.

On peut distinguer trois sources qui influencent un agriculteur à se convertir à l'agriculture biologique : lui-même (ses caractéristiques, son exploitation), les politiques publiques et l'environnement local. Certaines caractéristiques de l'agriculteur peuvent l'inciter à passer à l'agriculture biologique. Les profils d'agriculteurs les plus enclins à la conversion sont les jeunes agriculteurs ayant une formation agricole ou générale et qui est sensible aux enjeux environnementaux (Padel, 2001; Genius et al., 2006; Geniaux and Latruffe, 2010). Lapple (2010) a également montré un lien négatif entre la taille de l'exploitation et la probabilité de conversion. Parallèlement, les politiques publiques ont aussi un rôle à jouer dans la décision de l'adoption des pratiques de l'AB, par la mise en oeuvre de réglementation et de dispositifs d'incitation monétaire ou non monétaire. Selon Genius et al. (2006) et Kumbhakar et al. (2009), en Grèce et en Finlande, les subventions reçues par les agriculteurs biologiques ont joué un rôle important dans leur décision de convertir leurs terres. Néanmoins, Geniaux and Latruffe (2010) concluent que les différentes études disponibles ne sont pas généralisables puisque les résultats dépendent du contexte régional et temporel. L'étude d'une caractéristique n'aura pas nécessairement la même influence sur la probabilité d'adoption de l'AB, en fonction de la période et du pays étudié. Par exemple, Gardebroek (2003) obtient qu'aux Pays-Bas, entre 1994-1999, les éleveurs laitiers extensifs exploitants sur de grandes surfaces ont des probabilités plus fortes de conversion, alors que l'effet est négatif pour les producteurs de soja aux États-Unis en 2006 (McBride and Greene, 2009).

La troisième source d'influence est l'environnement local de l'agriculteur, c'est-à-dire l'environnement dans lequel l'agriculteur exerce son activité. Dans cet espace, les interactions sociales, économiques et naturelles peuvent influencer la décision de l'agriculteur de se convertir. L'influence de cet environnement sur la pratique de l'agriculteur dépend de deux composantes. D'abord, l'effet d'agglomération de la pratique de l'AB, qui se définit par l'influence d'une présence initiale d'agriculture bio dans la zone. Ensuite, l'influence de l'hétérogénéité spatiale, c'est-à-dire, l'impact de la typicité d'un territoire sur la pratique d'un agriculteur. La première composante, l'effet d'agglomération de la pratique biologique, se traduit par une probabilité plus importante pour un agriculteur d'adopter la pratique bio s'il se trouve à proximité d'autres agriculteurs bios. Ceux-ci, initialement présents sur le territoire, sont considérés comme des ambassadeurs ou des conseillers techniques de la pratique, permettant sa diffusion auprès de leurs pairs voisins. Plusieurs auteurs (Bjørkhaug and Blekesaune, 2013; Schmidtner et al., 2012; Coinon, 2022), ont testé et mesuré l'influence du voisinage par différentes méthodologies. Par exemple Coinon (2022), a tenté d'approximer le voisinage de chaque agriculteur en identifiant les agriculteurs exploitant les cinq parcelles les plus proches en fonction du sens du vent. D'autres auteurs (Bjørkhaug and Blekesaune, 2013; Schmidtner et al., 2012), définissent les voisins comme ceux se trouvant à moins de x par kilomètres de l'exploitation. Les différentes méthodes utilisées pour définir la taille du voisinage de l'agriculteur démontrent la nécessité de prendre en compte l'impact d'un effet d'agglomération.

La littérature a aussi mis en évidence l'existence de conditions locales favorables au développement de la pratique AB. Des auteurs ont testé l'influence de l'hétérogénéité spatiale sur la pratique, en l'approchant par les conditions environnementales/climatiques ou via les caractéristiques du marché local. Cependant, la validité de ces résultats est encore une fois dépendante du contexte. Alors que Schmidtner et al. (2012) obtiennent que les agriculteurs bio en Allemagne se trouvent éloignés du centre-ville, Wollni and Andersson (2014), trouvent le résultat contraire au Honduras sur la même période. Cette même ambiguïté d'effet persiste lorsqu'on s'intéresse à l'influence de la qualité du sol sur la pratique de l'AB. Pour Gabriel et al. (2009), les agriculteurs bio anglais sont localisés sur des sols de mauvaise qualité tandis que les agriculteurs vietnamiens bio exploitent les terres de bonne qualité (Lampach et al., 2020).

La revue de littérature précédemment citée est insuffisante pour répondre à notre question de recherche du fait de la faible généralisation des analyses, qui sont fortement dépendantes des contextes territoriaux. En menant une analyse sur le contexte actuel en France, en poursuivant les analyses de Allaire et al. (2014) et Allaire et al. (2015), nous pourrons identifier, dans le chapitre I, les conditions locales françaises conduisant au développement du bio. Pour illustrer l'hétérogénéité entre les territoires, nous allons principalement aborder l'histoire de l'émergence du courant de l'agriculture biologique en France, qui fonde le différentiel de développement du bio en fonction des territoires français. Nous ciblerons ensuite l'analyse sur l'action des pouvoirs publics. D'une part, ils introduisent un cadre législatif global pour le développement du bio; d'autre part, ils peuvent créer des différences de dynamiques de conversion par la mise en place de dispositifs d'aide territorialisés. Enfin, nous examinerons comment cette hétérogénéité spatiale se reflète dans les prix des terres agricoles.

À la suite de la Seconde Guerre Mondiale, dans différents territoires, des groupes de citoyens, d'agriculteurs et de médecins se sont formés pour discuter d'écrits et d'expériences agronomiques. Ils militaient pour le développement d'une nouvelle agriculture, une agriculture alternative au modèle intensif, préservant la qualité des sols et permettant une alimentation naturelle, c'est-à-dire sans recours à des produits chimiques. Les débats sur cette agriculture alternative ont porté sur deux thèmes : d'une part, une pratique de l'agriculture sans utilisation de produits chimiques et, d'autre part, un changement de paradigme économique prônant le raccourcissement des circuits de distribution afin de privilégier les relations avec les consommateurs. Ces deux aspects sont documentés la thèse de Besson (2007). Les principaux auteurs qui ont évoqué ces nouvelles pratiques agronomiques sont Rudolf Steiner et Albert Howard. En 1924, lors de huit conférences, Rudolf Steiner a fondé la biodynamie et théorisé sa vision de l'agriculture basée sur des méthodes naturelles de fertilisation du sol (amendement naturel, interaction entre cultures et élevage) et des cycles de cultures accordés sur les calendriers lunaires et planétaires. Il met en avant la nécessité des forces *cosmiques* pour la croissance des plantes. Ces écrits trouvent un écho particulier auprès d'une partie de la communauté médicale (médecins, nutritionnistes, pharmaciens) qui souligne déjà un lien négatif entre l'utilisation des produits chimiques et l'impact sur la santé humaine (Leroux, 2015). Albert Howard, quant à lui, propose une agriculture axée sur le remplacement des produits chimiques par l'enrichissement du sol en compost naturel, en introduisant des rotations dans les cultures (Howard, 1943). Le deuxième pan sur lequel se fonde cette agriculture alternative est l'intégration d'un volet social à l'agriculture, porté notamment par Hans Müller. Cela passe par le recours à des circuits de distribution raccourcis incluant le consommateur et privilégiant les relations sociales aux relations commerciales.

En France, trois courants principaux émergents de la pensée de ces auteurs avec une emprise territoriale. Le premier prône la biodynamie théorisée par Rudolf Steiner, c'est-à-dire une production basée sur les interactions entre l'homme, la terre et les forces cosmiques. Ce courant trouve un écho en Allemagne (berceau initial des huit conférences de Steiner) et dans l'Est de la France (première exploitation suivant la biodynamie en Alsace en 1924). Le deuxième courant, appelé *méthode Lemaire-*

Boucher (du nom de deux biologistes, Raoul Lemaire et Jean Boucher), propose la substitution de produits chimiques par des engrais et semences naturels à haut rendement (par exemple, fertilisants à base d'algues ou compostage naturel). Cependant, ce courant maintient les canaux de distribution traditionnels. La Société Lemaire, qui vend ces solutions, trouve principalement des débouchés via le groupement GABO (Groupe des agriculteurs biologiques de l'ouest). Groupement crée notamment par Raoul Lemaire. Cette conception de l'agriculture alternative, sans usage d'intrants chimiques, mais utilisant les mêmes réseaux de distribution, se développe initialement dans l'ouest de la France. En réaction à ce courant, prônant toujours une agriculture marchande, l'association "Nature et Progrès" voit le jour. Elle propose une agriculture respectueuse de la nature et plaide en faveur d'un changement de modèle économique, avec pour objectifs la fin de la concurrence entre les agriculteurs, une répartition équitable des profits et un retour aux relations directes entre les producteurs et les consommateurs. Ce troisième mouvement souhaite à la fois rendre plus accessibles les produits issus de l'agriculture portée par son modèle tout en augmentant le nombre de producteurs suivant son modèle. L'association fédère des militants exerçant diverses professions tout au long du circuit de distribution (producteurs, transformateurs, distributeurs et consommateurs). Ces adhérents souhaitent que l'agriculture naturelle et sociale soit plus accessible au public. Pour y arriver, ils s'organisent en coopératives biologiques appelées *Biocoop*[13]. Ces coopératives, gérées par leurs membres, ont comme objectif une rémunération juste pour le producteur (Leroux, 2015). Dans un même temps, l'association Nature et Progrès tente de normaliser sa pratique en éditant le premier cahier des charges en 1972. Par ce cahier des charges, Nature et Progrès souhaitent inscrire sa démarche de promotion de l'agriculture alternative dans le cadre d'une réglementation basée sur des méthodes fondées sur des résultats scientifiques et contrôlables. Cette démarche repose sur un ensemble de normes, qui viennent s'opposer à l'approche de la biodynamie reposant sur des concepts ésotériques. Toujours selon Leroux (2015), à la fin des années 90/début 2000, le développement de l'AB s'amorce difficilement. L'AB est mal perçue par les agriculteurs conventionnels qui l'associent à une pratique agricole militante, sacralisant le rôle de la nature. Cette conception très éloignée de leur vision plus marchande de la pratique agricole, créant des antagonismes entre ces agriculteurs.

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[13] Aujourd'hui, 6600 points de vente sont comptabilisés, représentant en 2023 22% du marché des magasins bio.

Pour faire émerger cette agriculture alternative, elle a besoin d'être harmonisée et d'inclure des mécanismes d'incitation pour que les agriculteurs conventionnels puissent envisager l'adoption de nouvelles pratiques agronomiques. L'intervention des institutions apparaît alors indispensable.

En 1981, le cahier des charges promulgué par l'État français vise la production d'une agriculture sans produits chimiques de synthèse. Il est basé sur le cahier des charges de l'association Nature et Progrès. En 1988, le terme *Agriculture biologique* et son logo sont créés et protégés. Au niveau européen, c'est en 1991 que le cahier des charges de l'AB est voté. Unique pratique agricole encadrée par la réglementation européenne. La législation fut plusieurs fois modifiées[14], actuellement le règlement européen (UE) 2018/848 encadre cette pratique. Les normes définissent les règles qui guident l'ensemble du processus, de la production à la transformation et à la distribution.

En parallèle de la réglementation de la pratique, l'UE, via la Politique Agricole Commune européenne (PAC), propose dès 1992 des aides à la conversion en bio (CAB). Ces aides doivent permettre aux agriculteurs de compenser les pertes de production durant la période de conversion (entre 2 et 3 ans). Pour bénéficier de cette aide, l'agriculteur doit s'engager pendant cinq ans à appliquer les cahiers des charges AB sur la parcelle. À compter de 2007, un autre dispositif vient compléter celui-ci : l'aide au maintien en bio (MAB). Cette aide permet à l'agriculteur de continuer à recevoir une aide à échéance des cinq ans du contrat de CAB. Sur la base de ces deux leviers, l'État français élabore différents plans nationaux quinquennaux de développement de l'agriculture biologique. Ces plans ambitieux fixent des objectifs de production nationale accompagnés de mesures destinées aux acteurs à différentes étapes de la chaîne de distribution. Leurs résultats sont très contrastés et influencés par la conjoncture économique au moment de leur mise en œuvre (Wezel and David, 2020). Le premier plan quinquennal *Agriculture et alimentation biologiques : Horizon 2012* pour l'AB fut lancé en 2007 par le ministre de l'Agriculture afin d'augmenter le nombre de conversions en AB. Ce plan intervient dans un contexte où la consommation est largement supérieure à la production nationale. En effet, en 2006, 50% des produits bios consommés en France étaient importés. Cette forte dynamique de consommation s'explique, d'après Leroux (2015), par un enchaînement de scandales sanitaires qui ont obligé les consommateurs à revoir leurs habitudes

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[14] Abrogé par les règlements communautaires n°834/2007 et les règlements (CE) n°889/2008 et (CE) n°1235/2008

de consommations (la crise de la maladie *Encéphalite spongiforme bovine* dite vache folle en 1986, puis la grippe aviaire en 2004). Les dispositifs figurant dans ce premier plan sont des aides CAB et MAB financées par le 2e pilier de la PAC, ainsi qu'un crédit d'impôt. Ces aides nationales peuvent être complétées par des aides régionales (aides à la certification, aide à la structuration de filière) et des aides communales (exonération de taxe foncière). Ce premier plan est une avancée, car sur la période 2007-2012, on observe un doublement des terres en AB, passant de 2 à 3.8% de la SAU (objectif initial 6%). Les deux plans qui succèdent *Ambition bio 2017* (lancé en 2012) et *Ambition bio 2022* (initié en 2017) permettent de maintenir une dynamique de conversion (taux de croissance annuelle des SAU certifiés AB de 14.2%). Cette dynamique est possible grâce au maintien des instruments du précédent plan, à l'ajout d'aides pour structurer les filières, ainsi qu'à l'augmentation des débouchés via des obligations de part minimale de produits bio dans la restauration collective (20%). Cependant, durant la fin de la période d'exécution de ce dernier plan, la dynamique de conversion connaît un coup d'arrêt. En effet, l'année 2021 marque une baisse du nombre de terres en conversion (-0.9%), puis une chute encore plus importante en 2022 (-24.2 %). Pourtant, fin 2023, dans le cadre de la PAC 2023-2027, les États doivent établir un Plan stratégique national pour fixer le cap agricole du quinquennat. La France, se fixe l'objectif toujours aussi ambitieux de 18% de SAU en AB d'ici à 2027 (Ministère de l'Agriculture et de la Souveraineté alimentaire, 2022), déconnecté de la dynamique actuelle des conversions, mais tiré par les objectifs européens du *European Green Deal* (25% des SAU de l'Union Européenne en bio d'ici à 2030, European Commission (2020)).

Selon Genius et al. (2006), les subventions accordées aux agriculteurs permettent de réduire la pression économique qu'ils subissent. Ces dotations leur permettent d'être moins dépendants des revenus générés par leur production. Par conséquent, ils sont moins incités à opter pour une agriculture à haut rendement, puisqu'elles leur permettent déjà d'obtenir un certain niveau de revenu. On va donc se demander si les autres dispositifs d'aide proposés par les pouvoirs publics nationaux et européens permettent aussi un développement du bio. Nous verrons que, selon l'emplacement des parcelles exploitées, les opportunités d'accès aux subventions ne sont pas les mêmes pour les agriculteurs. Ainsi, on peut supposer que ces subventions territorialisées génèrent des différences de développement de la pratique AB. Deux politiques seront étudiées dans cette thèse : l'Indemnité Compensatoire de Handicaps Naturels (ICHN) dans le chapitre I, et la politique de protection des Aires d'Alimentation de

Captage (AAC) dans le chapitre II.

Dans le chapitre 1, nous testons, notamment, l'impact des indemnités compensatoires destinées aux agriculteurs exploitants dans des zones à contraintes naturelles ou spécifiques sur le développement de l'AB. Créée en 1976, cette subvention est l'aide la plus importante en termes de montants financés par le Fond européen agricole pour le développement rural, cofinancée par les organisations nationales (État et régions) à hauteur de 25%. En 2019, les 86 226 agriculteurs français éligibles à cette subvention ont perçu en moyenne 12 235 12,235€/an au titre de l'ICHN. L'objectif de cette aide est de maintenir l'agriculture dans les zones isolées ou contraintes par des phénomènes naturels (montagne, sols de mauvaise qualité). Elle permet de maintenir l'activité économique dans ces régions. Selon les réformes des critères de sélections, le nombre de communes classées en France comme éligibles à l'ICHN fluctue entre 10 429 à 14 210[15].

Pour faire face aux enjeux de pollution de l'eau d'origine agricole et industrielle, l'État décide de mettre en place une politique de protection des aires d'alimentation de captage, soit de limiter les pollutions potentielles dans les zones à proximité des sources d'eau destinées à la consommation humaine. Pour Sautereau and Benoit (2016), à partir d'une revue de différentes expériences naturelle de protection de l'eau à l'échelle locale (Munich, Lons-Le-Saunier, Lepzig, ...), obtiennent que le coût de la stratégie d'évitement des pollutions de l'eau est entre 2.5 et 7 fois moins élevé que celui du traitement curatif des masses d'eau polluées. Les différents dispositifs mis en place dans ces villes ont permis d'améliorer considérablement la qualité de l'eau à un coût moindre que celui d'un traitement nécessaire pour obtenir cette même qualité. L'objectif de la politique d'AAC est de changer les pratiques agricoles des exploitations se situant dans la zone d'alimentation du captage grâce à la mobilisation de dispositifs existants (MAEC, réglementation). Les acteurs de cette politique promeuvent l'agriculture biologique (Vincent, 2016). La loi de programmation relative à la politique d'AAC précise : "sur les périmètres de captage d'eau potable, la priorité sera donnée aux surfaces d'AB" (article 27, loi n° 2009-967 du 3 août 2009).

Par l'étude de ces deux dispositifs territorialisés, nous observerons l'efficacité du changement de pratique agricole. Les résultats peuvent différer selon les dispositifs. L'ICHN a pour objectif de compenser les pertes de rendement dues aux caractéristiques des sols dans des territoires définis, mais n'exige aucune autre condition

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[15] Depuis le 1er janvier 2019, en application du règlement européen sur le développement rural n° 1305/2013.

pour son attribution. Dans la politique d'AAC, une partie des actions mises en place sont conditionnelles à l'adoption de pratiques agroenvironnementales.

L'hétérogénéité spatiale ne se limite pas à influencer la pratique des agriculteurs; elle impacte aussi les dynamiques de population et d'aménagement du territoire. Les individus vont chercher à évoluer dans les territoires qui maximisent leur niveau d'utilité. Cette demande pour usage résidentielle ou pour activités commerciales peut rendre les marchés fonciers plus concurrentiels, ainsi le prix des terres n'est pas le même partout. Comment la dynamique démographique affecte-t-elle les pratiques agricoles ?

La méthode des prix hédoniques développée par Rosen (1974) permet de décomposer la valeur d'un bien en fonction de ses caractéristiques. Selon Cavailhès and Wavresky (2003), deux composantes fixent le prix d'une terre agricole. La rente Ricardienne correspond à la partie de la valeur d'une terre qui dépend de ses caractéristiques intrinsèques et est fonction de la capacité de la terre à produire. Plus une terre sera productive, plus elle aura une valeur importante. La rente résidentielle désigne la valeur des aménités résidentielles permises par la localisation de la terre.

La littérature scientifique mesure l'impact du climat (Passel et al., 2017; Bareille and Chakir, 2023), du sol et de la proximité des villes sur le prix de la terre (Cavailhès et al., 2011; Cavailhès and Wavresky, 2003). Dans ces études, la pratique agricole menée sur la terre n'est pas différenciée, elle est supposée homogène sur toutes les terres agricoles. Pour aller plus loin, nous suggérons, dans le chapitre III, de distinguer les pratiques agricoles pour mesurer la valeur associée par le marché à la pratique de l'AB. Théoriquement, on peut supposer qu'une terre exploitée en AB sera vendue à un prix supérieur à une terre en AC grâce à deux mécanismes. Premièrement, une prise en compte par le marché foncier agricole des externalités environnementales qui renforcent les capacités productives du sol (limitent l'érosion, augmentent la biomasse, créent des réserves d'eau). Deuxièmement, l'évitement des coûts liés à la conversion en bio de la terre permet à l'acquéreur de l'exploiter directement en bio, lui évitant ainsi les deux ou trois ans de conversion. Ainsi, nous pouvons supposer, comme obtenu dans l'article de Fuller et al. (2021), qu'une terre bio sera vendue plus cher qu'une terre exploitée en AC.

La généralisation des résultats de Fuller et al. (2021), qui ont été obtenus sur le marché des terres agricoles en location aux États-Unis entre 2003 et 2011, semble peu pertinente dans notre contexte. En Europe, Baldoni et al. (2021) et Kilian et al. (2008) ont observé que les aides de la PAC conditionnelle aux pratiques agroenvironnementales affectaient négativement la valeur de la terre. Pour eux, la valorisation associée d'une subvention PAC sur le prix de la terre agricole dépend de l'effort à fournir pour recevoir cette aide. Ils obtiennent que l'impact des subventions, dites couplées à la production, ont un effet positif plus important sur la valeur de la terre qu'une subvention conditionnelle aux pratiques agroenvironnementales. Effectivement, dans le cadre des subventions couplées à la production, en achetant cette parcelle l'agriculteur va automatiquement augmenter le montant potentiel de ces aides PAC. Il aura un consentement à payer plus important *ceteris paribus.* Alors que dans le cas des subventions conditionnelles aux pratiques agroenvironnementales, le nouvel exploitant de la terre ne recevra l'aide que s'il poursuit les pratiques agricoles de son prédécesseur. Ces résultats impliquent que les agriculteurs acheteurs ne souhaitant pas exploiter en AB ne vont pas valoriser le fait qu'une terre soit exploitée en AB, car ils ne récupèrent pas les aides PAC liées à la précédente pratique AB.

En considérant les résultats obtenus par ces articles, l'effet attendu de la pratique AB sur le prix de la terre dans un contexte européen est ambigu. Le chapitre III permettra de lever cette ambiguïté en mesurant la valorisation de la pratique AB sur le marché du foncier agricole.

Questions de recherche

Ainsi, notre question de recherche générale est la suivante : dans quelle mesure l'hétérogénéité spatiale influence-t-elle la dynamique du développement de l'AB ?

Comme nous l'avons vu dans cette introduction générale, l'origine des caractéristiques créant l'hétérogénéité entre les territoires et influençant le développement de la pratique bio est de différentes natures. Ces divergences sont le résultat de la construction historique qui a permis de structurer plus ou moins la filière AB. Ces disparités entre territoires sont renforcées par mesures incitatives territorialisées comme les aides ICHN ou la politique d'AAC. Enfin, les territoires se différencient par des facteurs naturels (pédologiques et climatiques), qui peuvent conditionner des pratiques agricoles différentes.

Les différentes questions soulevées dans la thèse visent à montrer que la localisation d'un agriculteur influence sa pratique agricole. Pourquoi deux mêmes agriculteurs exerçant à deux endroits différents n'ont pas la même probabilité de cultiver en AB ? L'objectif est d'aborder cette question sous différents angles au niveau de la France entre 2015 et 2021. Cette période a été caractérisée par un fort développement du nombre de parcelles en conversion (15% de croissance annuelle), suivi d'un net ralentissement sur la fin de période [16]. Dans le chapitre I, nous analyserons la répartition des agriculteurs biologiques pour identifier l'influence historique des différents mouvements territorialisés de l'agriculture alternative, ainsi que le rôle des disparités géographiques sur cette distribution des agriculteurs bio. L'objectif est d'identifier des caractéristiques liées aux territoires expliquant la répartition inégale des agriculteurs bio en France. Dans ce chapitre, nous verrons que certaines variations sont dues au dispositif ICHN. La localisation des parcelles d'un agriculteur peut le rendre éligible à des dispositifs d'aide spécifiques, et ces subventions peuvent influencer ses pratiques agricoles.

Pour vérifier l'impact des subventions territorialisées sur les pratiques bio, nous mènerons, dans le chapitre II, une analyse de l'influence de la politique de protection des aires d'alimentation de captages sur les pratiques des agriculteurs. Comme les zones ciblées dans le cadre de cette politique ont été déterminées à des périodes différentes (entre 2013 et 2021) et qu'elles couvrent des superficies très variées (de 3 ha à $7710 km^2$), l'un des principaux enjeux de ce chapitre sera la construction du groupe contrefactuel. Ce groupe de contrôle permet de mesurer les changements de pratiques agricoles (agriculture biologique et autres pratiques agroenvironnementales préservant la qualité de l'eau) imputables à la politique, ainsi que d'identifier de potentiels effets de débordement, c'est-à-dire des changements de pratiques en dehors de l'AAC, mais imputables à cette politique.

Dans le chapitre III, nous chercherons à mesurer la valeur, sur le marché du foncier agricole, associée à la pratique bio tout en contrôlant pour la valeur associée au territoire. La méthode des prix hédoniques permettra de déterminer la contribution de chaque caractéristique du territoire à la valeur de la terre agricole. Ce travail aura pour finalité de déterminer si la pratique agricole biologique, ainsi que les externalités environnementales qu'elle permet de fournir, est valorisée dans le prix de la terre. Ce chapitre expliquera également comment l'éloignement des agriculteurs biologiques par rapport aux grandes villes (comme cela est montré au chapitre I) s'explique par la pression foncière exercée par la demande résidentielle venant enchérir le prix des terres. L'enjeu méthodologique pour estimer la valorisation de la pratique de l'AB sur une parcelle consiste à neutraliser l'effet du territoire sur le prix. Il s'agira donc de pouvoir comparer la valeur d'une terre exploitée en AB et d'une autre en AC ayant la même localisation et les mêmes caractéristiques naturelles. À partir de ces

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[16] Entre 2021 et 2022, diminution de 24% du nombre de surfaces en conversion

différentes pistes de recherche, cette thèse permettra de répondre aux questions de recherche suivantes :

- Comment les exploitations et les terres agricoles biologiques sont-elles réparties entre les communes françaises ? Quels sont les principaux facteurs spatiaux qui expliquent ce développement hétérogène ?
- La délimitation des aires d'alimentation de captages incite-t-elle les agriculteurs à modifier leurs pratiques ?
- Quelle est la valeur associée au territoire dans le prix de la terre agricole ? L'AB augmente-t-elle la valeur des terres ?

Méthodologies

Pour répondre aux questions soulevées par cette thèse, nous allons présenter deux aspects importants : les données spatialisées des terres agricoles exploitées en France entre 2015 et 2021. Ces données, utilisées dans les trois chapitres de la thèse, nous permettent d'analyser avec précision l'évolution des pratiques agricoles en France. Le deuxième aspect concerne les méthodes économétriques appliquées à ces données. Ces méthodes nous permettent de mesurer l'effet du territoire sur les pratiques agricoles.

Pour avoir la meilleure vision possible du parcellaire localisé en France, les trois chapitres de cette thèse se basent sur le système d'identification des parcelles français, appelé *Registre Parcellaire Graphique* (RPG). Initié en 2002 à la suite du règlement communautaire CE 1593/2000, obligeant les États membres à mettre en place un système de contrôle géolocalisé des aides de la PAC. Ce système fait partie du *Système intégré de gestion et de contrôle*[17]. La gestion de cette base de données en France est gérée par l'Agence des Services et Paiements, qui s'occupe également des différents paiements des aides PAC. Cantelaube and Carles (2014) comparent les données surfaciques issues des statistiques agricoles annuelles produites par le ministère de l'Agriculture et celle couverte par le RPG. Ils obtiennent qu'environ 8.5% des parcelles françaises sont exclues du RPG. Parmi ces surfaces non disponibles

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[17] Ensemble de dispositifs permettant aux États membres de gérer, suivre et contrôler les différentes interventions de la PAC. Les données issues de ces dispositifs, comparables entre les différents États, permettent l'édition d'audits ex-post sur l'efficacité des différentes programmations pluriannuelles de la PAC.

dans la base, on compte principalement les vignes et les cultures fruitières, dont respectivement 39.2% et 56.5% des surfaces sont manquantes. Parallèlement, la base est quasi exhaustive pour les prairies permanentes (exhaustives à 94.5%) et les cultures céréalières (exhaustives à 99.1%). À partir du millésime 2015, la Version.2 du RPG est éditée. Désormais, la précision est renforcée, le niveau de référence passe de l'îlot[18] au niveau de la parcellaire. Ce changement permet une meilleure précision, notamment au niveau des cultures mises en place. En effet, dans la version 1, sur un même îlot, il pouvait y avoir différentes cultures, mais seule la plus importante était déclarée. Avec cette version 2, nous avons pour chaque parcelle la géométrie associée ainsi que la culture précise parmi 350 cultures pouvant être regroupées en 28 groupes de culture. D'autres informations sont désormais prises en compte avec le millésime 2015, notamment les cultures dérobées (parmi 45 cultures) et la pratique agricole biologique.

La popularité de ces données connait une croissance importante. On peut notamment mentionner le projet CartoBio[19] (lancé en novembre 2022), outil de visualisation développé par l'Agence Bio et ajoutée sur leur site internet. Cet outil permet de suivre l'évolution du parcellaire du territoire (depuis 2019), en fonction de la pratique agricole et des cultures. À terme, l'objectif de la plateforme est d'atteindre une exhaustivité du parcellaire AB certifié (actuellement estimé à 85%) ainsi que le parcellaire *en conversion* (information non disponible dans le RPG). Cette exhaustivité permettrait aux organismes certificateurs de mettre à jour directement les cartes en y ajoutant les nouvelles parcelles certifiées.

Les pratiques agricoles ne dépendent pas seulement des caractéristiques de l'agriculteur et de son exploitation. En d'autres termes, deux agriculteurs identiques n'ont pas nécessairement les mêmes pratiques agricoles. Le lieu d'exploitation d'un agriculteur conditionne l'accès à un réseau de pairs, ainsi que d'autres avantages tirés des caractéristiques du territoire. Cette interdépendance entre les pratiques de l'agriculteur i et celles des autres agriculteurs implique une corrélation entre ϵ_i et ϵ_j. Par conséquent, les estimateurs des MCO sont biaisées parce que l'hypothèse fondamentale d'indépendance des observations est violée (cor(ϵ_i,ϵ_j)$\neq$ 0). Dans ce cas, les estimateurs des MCO sont caducs. Pour surmonter ce problème, l'utilisation de méthodes d'économétrie spatiale permet d'intégrer ces relations d'interdépendance

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[18] Ensemble de parcelles contiguës appartenant au même agriculteur, délimité par des repères identifiables (tels que des chemins agricoles, des routes, des rivières ou d'autres parcelles)

[19] Disponible sur le site: https://www.agencebio.org/cartobio/

entre les observations en créant une matrice de voisinage (LeSage and Pace, 2009). Cette matrice de dimensions $n * n$, contient l'information sur la relation entre i et j. Pour chaque individu i, les observations j inter-dépendent (cor(ϵ_i,ϵ_j)$\neq$ 0), et les observations j indépendantes (cor(ϵ_i,ϵ_j) $=$ 0) sont identifiées. Cette matrice contient toutes les relations supposées ou observées entre les différents individus de la population. Ensuite, les modèles d'économétrie spatiale, cherchent à identifier les variables à l'origine de cette autocorrélation spatiale. Ils peuvent être de trois natures : liés à la dépendance spatiale (influence de Y_j sur Y_i), liés à l'hétérogénéité spatiale (influence de X_j sur Y_i) ou liés à des variables inobservées du voisinage (influence de ϵ_j sur Y_i). L'utilisation des modèles *Spatial Auto-Regressive*, permet de modéliser l'influence de la dépendance spatiale dans la valeur de notre variable dépendante. Dans la littérature sur les déterminants de l'adoption de l'AB, Schmidtner et al. (2012) et Bjørkhaug and Blekesaune (2013) ont, par cette modélisation, montré l'influence de l'effet de voisinage dans la pratique bio respectivement en Allemagne et en Norvège. Selon ces auteurs, plus un agriculteur a une concentration élevée d'agriculteurs biologiques dans son voisinage, plus la probabilité qu'il se convertisse au bio sera grande. L'objectif de la thèse est de montrer que la localisation de l'exploitant joue également un rôle dans le choix des pratiques agricoles. Dans le chapitre I, nous testerons l'influence de l'hétérogénéité spatiale, tout en contrôlant pour la dépendance spatiale, sur la distribution de terres bio via la modélisation *Spatial Durbin Model* (LeSage and Pace, 2009).

Néanmoins, les modèles d'économétrie spatiale ont plusieurs limites abordées, en particulier dans Anselin et al. (2008). Deux principales limites aux modèles d'économétries spatiales semblent importantes à soulever. Premièrement, les modèles qui étudient l'influence de la dépendance spatiale sur des données en coupe transversale ne permettent pas d'identifier un lien de causalité entre les voisins, mais seulement des corrélations entre ceux-ci. En effet, on peut détecter des zones dans lesquelles les individus ont une même pratique, mais la relation de causalité n'est pas établie. L'analyse du I de Moran (Cliff and Ord J, 1981) permet de détecter les zones avec des entités voisines ayant les mêmes caractéristiques (effet de concentration). Cependant, cet indice n'est qu'un indicateur de corrélation entre des observations proches. De plus, pour Anselin (2003), l'étude de la dépendance spatiale ajoute un problème d'endogénéité. En effet, Y_j peut aussi être influencé par Y_i. En d'autres termes, nous supposons que le voisin j influence l'individu i, or comme i est aussi le voisin de j, il exerce ainsi une influence sur ce dernier. C'est ce que

Anselin (2003) appelle le *Spatial Multiplier*. Deuxièmement, une des composantes principales des modèles d'économétrie spatiale est la construction de la matrice de voisinage. Elle doit représenter l'ensemble des relations entre les individus; or, il est impossible de représenter parfaitement les relations entre les agriculteurs au niveau d'un pays. Cette représentation ne peut donc être qu'une approximation de la réalité. Pour limiter ce problème, nous avons construit, dans le chapitre I, quatre matrices de voisinage allant de la plus restrictive (limitée seulement aux voisins partageant une frontière) à la moins restrictive (incluant tout le voisinage situé entre 0 et 20 km).

Du fait de ces limites, dans les chapitres 2 et 3, nous prenons en compte les effets liés à l'hétérogénéité spatiale sans utiliser les modèles d'économétries spatiaux.

Dans le chapitre II, nous cherchons à déterminer l'impact de la politique d'AAC sur le développement de l'AB. Le problème économétrique est que le traitement n'est pas exogène : il est lié à la densité d'agriculture bio/conventionnelle initialement présente dans la zone[20]. Effectivement, puisque la distribution des agriculteurs en AB n'est pas homogène sur le territoire (chapitre I), la probabilité qu'un agriculteur reçoive le traitement dépendra de son lieu d'exploitation. Pour neutraliser le biais de sélection lié au territoire, nous utilisons des méthodes de RDD spatiales basées sur la frontière géographique (Keele and Titiunik, 2015; Lee and Lemieux, 2010). Cette méthode compare l'effet d'une politique entre un groupe traité et un groupe de contrôle situé à la frontière de la zone de traitement. En effet, puisque les AAC sont délimitées par des études hydrologiques, l'attribution du traitement (être éligible à la politique d'AAC) est exogène à la décision de l'agriculteur. Ainsi, deux agriculteurs localisés de chaque côté de la frontière géographique de l'AAC auront la même probabilité de recevoir le traitement (absence de biais de sélection). Par cette méthode, l'effet du territoire sur la probabilité de recevoir le traitement et de se convertir à la pratique AB est neutralisé. L'effet marginal de la politique d'AAC sur la pratique agricole sera ainsi non biaisé.

Dans le chapitre III, pour évaluer la valeur attribuée à la pratique biologique dans le prix des terres, nous utilisons des méthodes d'appariement basées sur la distance géographique. Nous associons une parcelle de terre agricole biologique vendue à la parcelle de terre conventionnelle la plus proche vendue la même année. Cette méthode d'appariement élimine le biais d'endogénéité qui existe entre les car-

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[20] Dans une zone fortement concentrée en agriculteurs conventionnels, l'utilisation d'intrants chimiques sera importante, et donc plus le risque de pollution de l'eau sera élevé

actéristiques de la terre agricole et la pratique agricole. Par cette méthode, nous comparons deux parcelles ayant les mêmes caractéristiques, et donc la même probabilité d'être cultivées de manière biologique. Cet appariement va plus loin que l'appariement par score de propension. En effet, en associant deux observations qui sont spatialement très proches (en moyenne 1.5 km dans l'étude du chapitre III) et vendues la même année, nous contrôlons également certaines caractéristiques inobservables, comme le marché local des terres agricoles.

Contributions

Au fil de cette thèse, nous avons apporté diverses contributions à la littérature que nous proposons de résumer ici. Dans le chapitre I, basé sur les travaux de Allaire et al. (2014), nous cherchons à comprendre le rôle de l'hétérogénéité des territoires, approchés par différentes variables, sur la distribution des agriculteurs bio en France. L'utilisation de méthodes d'économétrie spatiale et la construction de matrices de voisinage permettent d'approcher les relations qui existent, d'une part, entre les agriculteurs des communes voisines, et d'autre part, entre les agriculteurs et les composantes de ces communes (population, environnement naturel). Comme nous l'avons déjà abordé, les premiers réseaux de distribution de produits biologiques ont été structurés par des militants, en particulier par les agriculteurs exploitant en AB eux-mêmes. La causalité inverse entre les réseaux de distribution et le nombre d'agriculteurs bio est un problème économétrique important qui est surmonté dans ce chapitre. Ce chapitre présente plusieurs contributions :

1. La manipulation des données du RPG, permet d'étudier la distribution des parcelles au niveau des communes. L'étude de l'origine de la disparité de l'AB au niveau des parcelles est plus pertinente qu'une analyse au niveau des exploitations. En effet, dans le RPG, 33% des parcelles se situent dans une autre commune que celle du siège d'exploitation (Coinon, 2022).

2. L'utilisation de la modélisation *Spatial Durbin Model* (LeSage and Pace, 2009), permet de modéliser les relations qui existent entre les agriculteurs de différentes communes et qui influencent leurs pratiques agricoles (dépendance spatiale) ainsi que l'influence de l'environnement de l'agriculteur sur sa pratique (hétérogénéité spatiale). Ce modèle nous a permis de découvrir de nouveaux déterminants de la conversion, non mentionnés dans la littérature (la qualité

du sol, les subventions et la réglementation locale).

3. En considérant la littérature des déterminants de la consommation de produits bio en France (Kesse-Guyot et al. (2013) et Lambotte et al. (2020)) nous avons montré que la demande potentielle de produits bio, émanant de la commune de l'agriculteur et des communes voisines, influence le nombre de terres bio. Les caractéristiques de la population (niveau de diplôme, type d'emploi) influencent les pratiques agricoles jusqu'à 20 km. En prenant en compte ces caractéristiques, nous avons surmonté le problème de causalité inverse entre les magasins vendant des produits AB et le nombre de surfaces en AB.

Cette étude souligne le rôle primordial de l'environnement de l'agriculteur dans ses choix de pratiques. La dépendance spatiale, déjà identifiée dans la littérature, est une nouvelle fois à l'œuvre lors de l'analyse de la localisation des AB en France. L'étude montre également qu'il existe des différences entre les populations des différentes régions (niveau d'éducation, type d'emploi). Ces différences se traduisent par des habitudes de consommation distinctes, qui influencent les pratiques des agriculteurs locaux. Enfin, ce chapitre renforce la nécessité de prendre en compte l'influence des facteurs spatiaux dans les décisions de pratiques agricoles.

Dans le chapitre II, nous complétons les résultats du chapitre I sur le rôle des subventions territoriales dans le développement de l'AB. Dans ce chapitre, nous nous concentrerons sur l'impact de la politique d'AAC (ICHN dans le chapitre I). Cette politique combine des incitations monétaires et non monétaires pour encourager les agriculteurs de la zone traitée à modifier leurs pratiques, afin d'améliorer la qualité de plus de 1 000 réserves d'eau. Ce chapitre mesure l'impact de cette politique sur l'évolution des pratiques agro-environnementales (cultures permanentes, prairies) et de l'AB, en comparaison avec la zone voisine non traitée. Deux contributions sont à souligner :

1. La création d'un groupe de contrôle permettant de neutraliser l'endogénéité du traitement (liée à la pratique agricole), par la méthode RDD spatiale basée sur la frontière géographique. Cette méthode permet d'observer un débordement spatial de la politique d'AAC jusqu'à 2 km de la zone.

2. Nous avons utilisé la méthode *Staggered DID* pour détecter une hétérogénéité

de l'effet en fonction de la date du début du traitement. Nous constatons un impact différent de la politique entre les groupes traités en 2017 et 2018 par rapport aux autres zones traitées.

L'étude montre des changements de pratiques culturales chez les agriculteurs ciblés (augmentation du nombre de prairies temporaires) et un ralentissement du développement de la pratique AB dans les zones priorisées. On observe que l'augmentation de la part de terres en AB est plus importante dans les zones voisines que dans les AAC. Le timing de la politique et les dispositifs d'aide mis en place pourraient avoir créé des désincitations à la conversion en bio chez ces agriculteurs.

Enfin, dans le chapitre III, nous cherchons à déterminer la valeur associée à la pratique biologique sur le marché des terres agricoles en France entre 2015 et 2021. Pour ce faire, nous utilisons la méthode des prix hédoniques sur les ventes de terres agricoles en France en mesurant la valeur associée à la rente ricardienne et la rente résidentielle. Afin de contrôler pour l'endogénéité entre terre agricole et pratique bio (démontrée dans les chapitres I et II), nous utilisons des méthodes d'appariement (basées sur le score de propension et la distance géographique). Ces méthodes permettent de comparer des terres similaires en termes de caractéristiques pédologiques et de localisation, se différenciant ainsi uniquement par la pratique agricole. Ce chapitre apporte des contributions à la littérature :

1. La création d'une base de données, à partir de la fusion des bases *Demande Valeur Foncière* et RPG, composée de 570 000 terres agricoles vendues sur la période 2015-2021. Cette base contient l'information sur la pratique agricole au moment de la vente (dont 7.8% de terres exploitées en AB).
2. Le développement d'une méthode d'appariement basée sur la distance géographique permet de comparer des terres vendues la même année, qui se situent en moyenne à 1.5 km l'une de l'autre. Cette méthode neutralise l'effet des caractéristiques inobservées du territoire sur le prix de la terre.

Ce prix inférieur de 2% peut s'expliquer par une demande faible et mal positionnée. Selon les résultats de Baldoni et al. (2021), seuls les agriculteurs bio sont prêts à payer un montant plus élevé pour acquérir une terre en AB, car ils continueront de recevoir les subventions liées à la pratique. Or, nous montrons dans ce chapitre que, sur la période, les agriculteurs biologiques auront l'opportunité d'acheter une terre en AC à 3.3 km contre une terre en AB à 8.1 km. Cela entraînera une hausse des coûts d'exploitation de la terre en raison d'un coût de transport plus élevé. Cette combinaison d'effets explique le différentiel de prix en faveur des terres en AC. Pour rendre les terres exploitées en AB plus attractives et ainsi augmenter leur valeur, il serait judicieux de communiquer sur leurs avantages (capacité de stockage du carbone et de l'eau, augmentation de la biomasse, moins d'érosion). Ces atouts pouvant limiter les pertes de rendement causées par les phénomènes climatiques à venir.

Cette thèse est composée de trois chapitres empiriques, présentés dans les sections suivantes. La première section concerne le chapitre intitulé '**Spatial factors influencing territorial gaps in organic farming in France**', la deuxième section présente le chapitre nommé '**Water policy's influence on local organic farming development**', et la troisième section détaille le chapitre '**A premium for organic farmland**'. Cette thèse se termine par une discussion sur les limites et les perspectives de recherches.

Chapter 1

Spatial factors influencing territorial gaps in organic farming in France

This chapter was co-authored with

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Summary of the chapter

Based on the position of organic farmland in France in 2019, the objective of this chapter was to identify local conditions for the development of organic farming. We began by identifying four characteristics that explain the heterogeneous development of organic farming practices in France using a Spatial Durbin Model to control the spatial autocorrelation of organic practices. This study shows that the protected designation of origin label has some ambiguous impacts on practices (i.e., positive for wine labels and not significant for others labels). The proximity of a high demand for organic products, proxy by jobs and level of education of the population, influences organic development. Also, municipalities with low quality land and a high share of forest participate in the development of organic farming.

1.1 Introduction

Organic farming (OF), is defined by the European Commission Regulation No. 834/2007 as farming that does not use chemical pesticides, fertilizers or GMOs (genetically modified organisms), and attempts to preserve the environment and to guarantee the well-being of animals. However, organic agriculture in France is far from being the mainstream practice. In 2018, 9.5% of French farmers were classified as organic farmers and organic land represented about 8.5% of the country's agricultural land (Agence Bio, 2020). These levels of OF in France mean that the supply is far from meeting the demand for organic products since 33.5% of organic products consumed in France are imported (Agence Bio, 2021). In order to reduce these imports and the pollution linked to this trade, the EU is trying to develop organic practices across its territory. Moreover, in its EU Green Deal launched in 2020, the EU announced a transition "towards a healthier and more sustainable food system" (Parliament et al., 2020) characterized by agriculture that preserves biodiversity and the environment. To achieve this, the EU aims to have 25% of UAA (useful agricultural area) in OF by 2030, compared to the current 8%.

The development of organic farming in France is very heterogeneous over the territory. Out of 34,259 municipalities in metropolitan France (excluding overseas territories) with at least one farmer, only 418 (1.2%) are 100% organic, and 52.4% of municipalities do not have any organic farms. This observation forces us to place the analysis at the level of the municipality in order to determine how the heterogeneity of the territories influences the development of OF.

The aim of this article is to understand how organic farmland are distributed among French municipalities by identifying the factors that may explain the heterogeneous development of OF. Until recently, the literature dealing with the determinants of the development of organic agriculture has mainly focused on the individual characteristics of farmers acting on the probability of conversion. The articles of Padel (2001); Genius et al. (2006); Geniaux and Latruffe (2010) report that farmers who are young, who have a high level of education, and who are environmentally sensitive have a higher probability of conversion than other conventional farmer. This article addresses the spatial factors that could explain the gaps in organic development between territories.

Spatial factors are characteristics related to the territory, which can be of natural origin (soil characteristics) or the result of historical human activity in this territory (size of population, number of farmers). These factors can be classified into two categories regarding their influence on organic farming (OF) development: spatial dependence, which pertains to the clustering effect of OF, and spatial heterogeneity, referring to disparities in various characteristics across municipalities, excluding the proportion of OF farmland, which impacts farming practices. Studies by Schmidtner et al. (2012) and Coinon (2022), have demonstrated that the presence of organic farms within a geographic unit influences neighboring farmers to transition to organic methods. This article seeks to investigate whether spatial heterogeneities, such as differences in certain factors among municipalities, shape farming practices. The aim is to identify the local conditions and environments that are favorable to OF, making it possible to formulate public policy recommendations to reinforce these phenomena. Some of these issues have already been raised in the literature. Wollni and Andersson (2014); Lampach et al. (2020), have highlighted the influence of natural environments, in particular soil quality, on the adoption of OF, although the directions of the effect are ambiguous. The influence of these identified factors is tested here to see if they also explain territorial organic development gaps in France.

Additionally, we explore the role of public policies that may create heterogeneity among territories, whether regulatory or through subsidies, on the development of OF. To do so, we will examine the influence of a regulation, Protected Designation of Origin (PDO) areas, and a support mechanism, Payments for Areas Facing Natural or Specific Constraints (ANC), on the dynamics of municipal OF farmland. Finally, we test the influence of the forests and semi-natural elements that are present in the municipality on the development of organic farms. The intention is motivate the transition to OF by the fact that these natural elements are essential to the practice of agriculture and especially to OF.

To consider the influence of the downstream sector, we will first demonstrate that including the number of organic shops may introduce bias into the analysis. This is because the presence of organic shops could be endogenous to the proportion of organic farmers, influenced by the historical development of organic farming in France (Leroux, 2015). Thus, we aim to approximate the local demand of organic consumers. To proxy this demand, we draw on the research by Lambotte et al. (2020) and Kesse-Guyot et al. (2013). In the analysis, we will include the employment and educational characteristics of the population. These individual characteristics are indicative of the likelihood of individuals consuming organic products. By introducing these variables, we expect to observe that the level of potential consumption influences both the agricultural practices within the municipality and those of neighboring municipalities.

To investigate the influence of these spatial characteristics as well as the influence of the organic neighbourhood on the conversion, we proceed with an empirical strategy based on spatial econometric method. After having formed four neighbourhood matrices, we specify a Spatial Durbin Model (LeSage and Pace, 2009) that is robust according to the Lagrange multiplier tests (Anselin, 1988; Anselin et al., 1996) and the common factor test of Burridge (1981).

Finally, the primary contribution of this chapter is to conduct an analysis of France using spatial econometrics methods to explain variations in organic agricultural land across municipalities. These methods make it possible to identify the influence of spatial dependence and spatial heterogeneity. This study complements the previous findings of Allaire et al. (2015), who solely aimed to explain the presence or absence of organic farming, a methodology which has become less relevant as organic agriculture has become less marginal in France (3% of UAA in 2010).

1.2 Spatial factors influencing the development of organic farming: an overview

According to Marshall (1890), then developed by Krugmann (1991), firms tend to agglomerate in a certain geographical area. This agglomeration allows gains of various types. First, it favors the circulation of information and the diffusion of new technologies, helping firms to grow. Second, this agglomeration also tends to guarantee access to a workforce specialized in their fields of activity and in large quantities. Finally, this agglomeration of activities tends to attract upstream and downstream suppliers, therefore reducing transport costs. For Krugmann (1991) the location of the agricultural sector is exogenous. However, according to the article of Daniel (2005), farmers' location choices are endogenously influenced by different local characteristics.

In this section, we will show that some spatial factors of the municipality can influence organic practices by making them easier or more profitable. We look at three categories of factors that differentiate municipalities from each other, which can impact their OF land ratio. These categories are the variables revealed by the new geographical economy (Krugmann, 1991), as well as the differences related to public policies and, finally, the differences in the quality and use of the land.

1.2.1 Agricultural geographical economy

In their studies, Schmidtner et al. (2012); Bjørkhaug and Blekesaune (2013) showed that the agglomeration of organic farms in a given region allows faster development of OF practices than in other regions less concentrated in OF. Indeed, Nyblom et al. (2003) note that conventionnal farmers who have organic farms in their neighbourhood have a higher probability of conversion than an isolated farmers. According to Bjørkhaug and Blekesaune (2013), this effect exists because learning the practices of OF is based more on tacit than formal knowledge. The European specifications governing organic farming (EC Regulation No. 834/2007) set standards on products and production but do not explicitly give the methods for achieving this, as this knowledge can be passed on by other farmers. Thus, the proximity to an organic farmer would increase the probability of accessing his or her tacit knowledge and, therefore, the probability of conversion.

According to Daniel (2005), farmers must be close to consumers and processors since the transport cost of agricultural products is higher than for manufactured products. Indeed, given that agricultural goods most often require specific transport conditions (refrigerated transport, dairy tankers), while being raw materials at the same time, the value per unit transported is fairly low, while the cost of transport is high. For example, dairy farmers require that their products be collected at least twice a day since they are not able to store their output due to its perishable nature. Thus, the location of farmers can be influenced by the proximity of downstream firms.

Concerning the link between urban centers and organic farming, the sign of the causal relationship is ambiguous, depending on the article. According to Schmidtner et al. (2012) who studied OF in Germany, organic farms are moving away from the city centers. However in their study, Wollni and Andersson (2014) found that organic farms are closer to the city (Marcala in Honduras) than conventional farms. This position allows them to be closer to consumers, reducing transport costs. This is because organic farmers are more dependent on consumers than conventional farmers since their products are sold directly to consumers. Moreover, in France, Agence Bio (2016), estimated that in 2015, 41% of organic farmers sold part of their production on the marketplace. We can therefore assume that OF will seek to exploit land close to large towns to reduce the cost of access to consumers.

Regarding the consideration of the proximity of downstream firms concerning the number of organic farmland, according to Leroux (2015), we may suspect reverse causality. Historically, it has been found that organic farmers influence the number of organic shops. Indeed, in the early 1970s, members of the ”Nature et Progrès” association[1], organize themselves to make alternative agricultural products more accessible (called ”organic” from 1981 and protected from 1988). To do this, members from a wide range of professions along the distribution chain (farmers, processors, distributors, consumers) have come together to establish several organic consumer cooperatives known as ”Biocoop”. The members who manage these structures aim to offer local, seasonal produce at a fair price. Today, the Biocoop group has 6,600 stores and will account for 22% of the organic shop market by 2023. In this chapter, we will exclude the number of organic shops as a regressor of the farmland ratio. However, to consider the influence of demand side, we have opted to approximate the potential demand for local organic produce based on population characteristics (type of job and level of education). For Lambotte et al. (2020) and Kesse-Guyot et al. (2013) regular consumers of organic agricultural products are people with a high level of education (Bachelor or Master's degree), holding a managerial position or having a higher intellectual profession and living in cities with more than 200,000 inhabitants are over-represented. Also, Lambotte et al. (2020), found that workers are under-represented among regular consumers of organic products. The results are in line with those of Bermond et al. (2019) who, through a principal component analysis, found that in areas with highly educated populations, the proportion of organic farming is high.

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[1] Created in 1964, this association promotes alternative agriculture based on agri-environmental methods, putting the social dimension at the heart of production (decent wages, short distribution channels). In 1978, this association created the first specifications defining its vision of ”organic” agriculture.

1.2.2 Public policy instruments

To achieve their objectives, the public authorities can make regulation and incentive policies. In France, agricultural policy is mainly played out at the supra-national level by the European Common Agricultural Policy (CAP). Due to its heavy weight (38% of the EU's annual budget), the CAP influences the location of farms in general. For example, according to Daniel (2003), crops supported by market price support mechanisms (dairy, cereals) and other specific aids ("combined aid" for livestock farmers) are less geographically concentrated than other crops. We will look at two land-based public policies and their potential impact on the development of organic farming: Protected Designation of Origin (PDO) areas, and payments for areas facing natural or specific constraints (ANC).

Protected Designation of Origin

This geographical quality label identifies a product "whose quality or characteristics are essentially or exclusively due to a particular geographical environment with its inherent natural and human factors"[2]. In fact, this label is awarded to municipalities located in a specific geographical area, so there are significant differences in the number of PDO per municipality (standard deviation equal to 2.96). These designations can influence the development of OF in a territory. Indeed, to produce under a PDO label, the farmer must comply with the specifications associated with the product. Depending on the regulations, certain standards may reflect European organic regulations, particularly in terms of animal welfare (annual duration of pasture and natural diet). The question then arises as to whether this PDO label serves as a substitute for the OF label, thus negatively impacting the development of the number of organic farmlands, or conversely, whether these two labels are complementary.

For Allaire et al. (2015), the different PDO zones, separated according to the nature of the products (wine, cheese and others), increase the likelihood of the municipality having OF. Wine-growing areas have, however, a greater influence than the other two. Winegrowers are part of a profession that needs a quality label to be able to develop their production. Indeed, according to Avelin and al (2019), 90.3% of the winegrowers marketed their production in 2018. Thanks to the labels, producers can differentiate themselves from the others. This is why, according to Guittard (2020), 96% of the wine-growing areas in France have a label (60% of which are PDO

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[2] Article 5 of Regulation (EU) No 1151/2012

labels). However, concerning cheese production, dairy farmers seek less to differentiate themselves from others because most often (92% of the dairy farmers), they sell their milk production in a long circuit. These farmers will seek to obtain the label that allows them to better value their production. On the one hand, the price of organic milk in France is 40% higher than conventional milk (i.e., 0.461€ per liter in 2019, according to Cazeneuve (2020)). On the other hand, there are differences in the selling price of PDO milk. Indeed, PDO milk from the *Franche Comté* region sells for 0.57€ per liter (24% more than organic milk), whereas PDO milk from the Normandy region sells for 0.4€ per liter (23% less than the price of organic milk). Thus, the effect of dairy PDOs on OF practices may be ambiguous depending on the territory.

These differences in production values will depend on consumers' willingness to pay for both labels. Several articles attempt to measure how much consumers may be willing to pay more for an official sign. Fotopoulos et al. (2003), show that Greek consumers pay both a premium for organic farming and for the PDO label. On the meat market, however, Cubero Dudinskaya et al. (2021) analysis shows that consumers are not prepared to pay for meat with an origin label but are prepared to pay for organic meat. In the cheese market, Corre et al. (2022) analysis found that consumers pay a premium for the PDO label in addition to the organic label for certain types of cheese. Thus, we can assume that the influence of PDO on the development of organic farming depends on the level of substitution between the PDO label and the OF label.

Areas facing natural or specific constraints

Another factor that influences the geographical location of OF is financial support. Indeed, in the study by Latruffe et al. (2013), after 406 interviews with conventional farmers, they found that the main factor that could enable the conversion of these farmers was the financial determinant; an additional subsidy could therefore lead to conversion to OF. As certain subsidies are conditional upon operating land within specific zones, a few part of farmers are eligible. Do these differences in eligibility create disparities in development among these territories?

In this article we focus on payments for areas facing natural or specific constraints (ANC). Created in 1976, this grant is the most important aid in terms of amounts funded by the European Agricultural Fund for Rural Development, co-financed by national organizations (state and regions) to the level of 25%. In 2019, the 86,226 French farmers eligible for this subsidy received an average of 12,235 euros in ANC payments. This aid aims to maintain agriculture in isolated areas or areas constrained by natural phenomena (mountains, poor quality soil). This helps to maintain activity and, therefore, social links in these regions. Since the reform on 1 January 2019[3] , three types of land areas could be eligible, mountain areas, areas facing significant natural constraints, and other areas affected by specific constraints. The areas facing significant natural constraints are areas constrained by biophysical elements [4], allowing for the harmonisation of areas at the EU level. The second category, within the limit of 10% of the surface area of the Member State, is based on criteria specific to each country, which allows adaptation to agricultural and territorial particularities (in France, these criteria include fodder autonomy, extensive livestock farming, share of hedges).

Thus, farmers operating in classified municipalities can claim ANC aid. This classification creates differences in the amount of subsidies received by farmers depending on the area of activity. According to Genius et al. (2006), this additional subsidy received by farmers reduces fiscal pressure. This aid allows them to be less dependent on the income generated by their production. Consequently, they have less incentive to choose high-yield agriculture since this aid already allows them to obtain a decent income. Thus, these farmers may be more inclined to change their practices due to the existence of ANC payments that serve as a guarantee.

1.2.3 Soil quality influence

Finally, territories differ based on their pedological and climatic characteristics. Do these variations influence the distribution of organic farmland? Two articles (Lampach et al., 2020; Wollni and Andersson, 2014) provide a contradictory answer to this question. In their article, Lampach et al. (2020) found that a higher share of organic farmers operate in regions with the best climatic and pedological characteristics for agriculture. They thus conclude that farmers are more likely to convert when soil conditions are most favorable. Whereas, Wollni and Andersson (2014) report that organic farms are most often located in areas where the soil is of poor quality. In-

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[3] By the application of the European regulation on rural development No 1305/2013

[4] Defined in Annex 3 of the EU Regulation No 1305/2013

deed, after studying a population of farmers operating in an area highly subject to erosive hazards, they found a greater share of organic farms in the most constrained areas compared to the rest of the study area. For them, there are two reasons for this result. First, since these areas are characterised by lower yields, the premium price of organic products can help compensate for these yield losses and ensure an income for farmers. Moreover, organic practices can slow down soil erosion by improving soil structure (favouring fodder crops and winter cover to increase organic mass, avoiding deep ploughing). Thus, by the conversion to organic farming, the farmer can improve these yields if they farms on soil subject to erosion(Tuomisto et al., 2012).

The quality of ecosystems surrounding agricultural land is also important. Indeed, according to Power (2010), ecosystem services provided by natural ecosystems, i.e., pollination, biological pest control, maintenance of soil structure, and fertility, are indispensable for agriculture. Indeed, the presence of forests and semi-natural elements [5] has an impact on the quantity and quality of ecosystem services (Bengtsson et al., 2005; Rundlöf and Smith, 2006; Sautereau and Benoit, 2016).

Thus, we can suspect the presence of a link between the presence of forests and semi-natural elements on the conversion to OF. Indeed, the presence of these natural elements improves the supply of ecosystem services, in particular, pest control and soil fertility, thus allowing a substitution for pesticides. As for Latruffe et al. (2013), technical obstacles, mainly disease management and pest control, are the main obstacles to conversion. One can therefore expect to find a higher OF ratio in areas with a high share of forests and semi-natural elements since they are favorable to OF practices.

1.3 Methodology and data

1.3.1 Spatial econometrics procedure

To explain the distribution of organic land in France, we do treat with the spatial autocorrelation of this practice. To do this, we use models that take this phenomenon into account. Here, we will develop a 3-step method for choosing the most appropriate model for our data. To do this, we will first define the neighbourhood of each

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[5] According to Fleury (2011), these are intermediate areas (hedges, moors, wasteland, groves) that are neither cultivated nor forested. The important aspect of these elements is their continuity, and their connection, allowing mobile species to change habitat and find food. Without these elements, the species would disappear in areas of intensive agriculture.

municipality. Then we will test for the presence and origin of spatial autocorrelation. Finally, based on these tests, we will choose the *Spatial Durbin Model*.

First of all, before choosing the optimal spatial model, the neighbourhood matrix must be defined. This matrix, referred to as W, must represent the relationships between the different observations. In our case, $W_{ij} > 0$ if farmers in the municipality have a relationship i with farmers in the municipality j and $W_{ij} = 0$ otherwise. There are two ways of identifying the neighbours of an observation. Firstly, one can characterize all the individuals who share a common border with the observation considered as neighbours. In this case, a matrix of contiguity is formed. The second method to identify the neighbours of an individual is to proceed by the maximum distance. Indeed, after calculating the distances between the different points, a maximum distance is determined from which two observations are not considered as neighbours.

In the articles of Schmidtner et al. (2012); Bjørkhaug and Blekesaune (2013), they specify 15 and 30 km matrices, and 50 km, respectively. In our study, we chose four specializations neighbourhood matrix, one based on the contiguity and three other based on a radius of 10, 15, and 20km. Choosing only the contiguity matrix is too restrictive insofar as farmers in one municipality do not only have relations with farmers in neighbouring municipalities. Taking into account 4 different matrices will allow us to measure the extent of the spillover effects of the different variables taken into account in the model. As for the weight of the relationship between i and j that allows us to judge the intensity of the relationship, we do not have enough information to assign a different weight. In this case, the sum of the weights of the neighbours of each municipality is normalized to 1.

Before estimating our model, it's necessary to first check whether the data show a significant influence of the neighborhood on the organic farmland ratio. If we observe the influence of the neighborhood, we must then determine through which variable the spatial effects transit. To do this, we conduct two categories of tests: the Moran test to detect the presence of spatial autocorrelation, followed by the Lagrange Multiplier test and Common Factor test to determine the nature of this autocorrelation.

Regarding the Moran test of Cliff and Ord J (1981), the results of table 1.1 show that for all four constructed neighbourhood matrices, the hypothesis of absence of spatial autocorrelation in the model is rejected at the 0.1% level. The graph on fig.1.1, is the result of the Moran test for the contiguity matrix. The coefficient of the line, 0.42, shows the correlation between the average share of organic land in the neighbourhood of municipality i and the share of organic land in municipality i. Table 1.1 shows that spatial autocorrelation decreases in intensity with the size of the neighbourhood matrix. In fact, the coefficient is 0.42 when only contiguous neighbours are considered, and 0.25 when all municipalities within a radius of 20km are included in the neighbourhood. This corresponds to a less significant influence of distant neighbours on farming practices in municipality i.

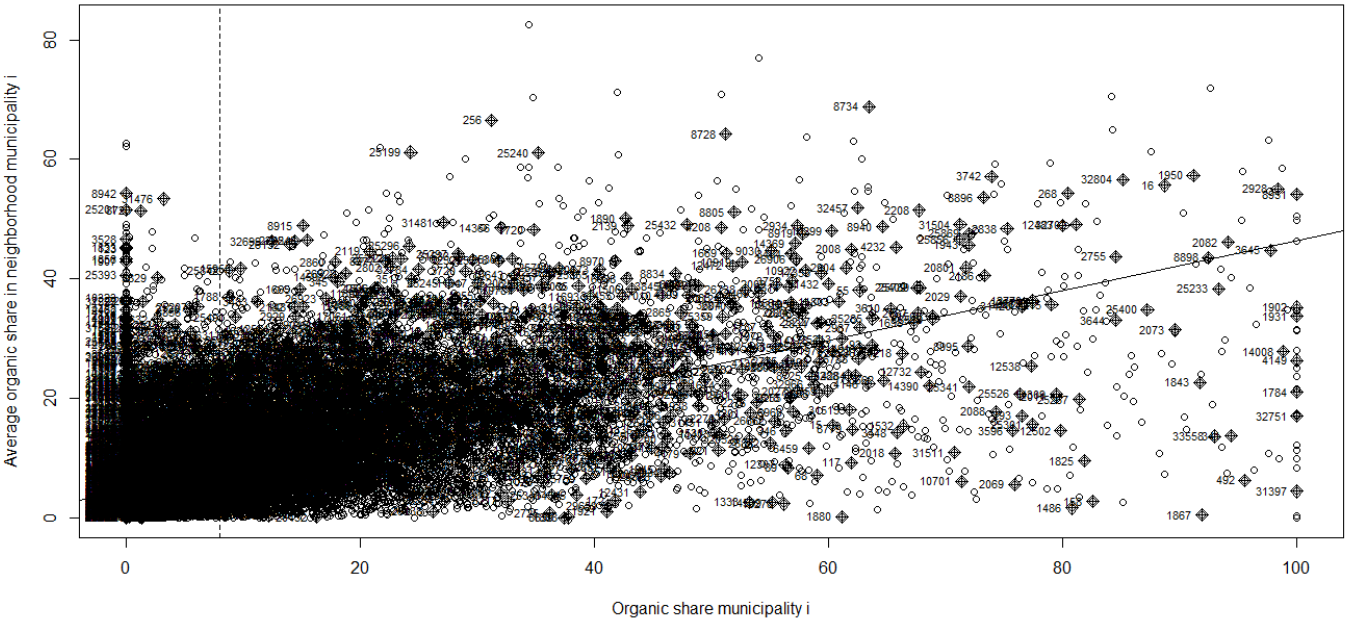

Figure 1.1: Spatial Autocorrelation Organic practice with contiguity neighborhood matrix (Moran's I)

To determine the origin of the autocorrelation, we carried out the four tests of the Lagrange multiplier developed by Anselin (1988) and Anselin et al. (1996). The Lagrange Multiplier Error test makes it possible to conclude under the null hypothesis that the parameter λ (coefficient associated with the influence of neighbourhood error term as in eq.1.2) is equal to 0. The Lagrange Multiplier lag test allows us to conclude under the null hypothesis that the parameter ρ (coefficient associated with the influence of neighbourhood explanatory variables as in eq.1.1) is equal to 0, i.e., absence of spatial dependency. Table 1.1 indicates the presence of the parameters

λ and ρ in the different specifications by the rejection of the H0 hypothesis at the 0.1% level. Finally, to decide which model to choose between a specialization Spatial Durbin Model and a Spatial Error Model in our case, when $\lambda \neq 0$ and $\rho \neq 0$ we perform a test of the common factor hypothesis by the likelihood ratio developed by Burridge (1981). Indeed, for Le Gallo (2002), if $\rho\beta + \theta = 0$, then the expression of the Spatial Durbin Model Eq.1.1 can be reduced in the form of a Spatial Error Model eq.1.2:

$$\begin{aligned} y = \rho W y + X\beta + W X \theta + \varepsilon \\ \varepsilon \sim N(0, \sigma^2 I_n) \end{aligned} \tag{1.1}$$

$$\begin{aligned} y = X\beta + u \\ u = \lambda W u + \varepsilon \end{aligned} \tag{1.2}$$

Thus if the H0 hypothesis is accepted, model Eq.1.1 can be reduced to model Eq.1.2 and, therefore, the model to be estimated is a Spatial Error Model. However, if the null hypothesis is rejected, then model Eq.1.1 can be reduced to a model Eq.1.2 and the model to be estimated is a Spatial Durbin model. Table 1.1, indicates that the null hypothesis of the common factor by the likelihood ratio is rejected (K-1 ddl) for the specifications with a neighbourhood. It appears therefore that the *Spatial Durbin Model* is the most optimal.

Table 1.1: Summary statistics on neighborhood matrices and Diagnostic test for the spatial autocorrelation of the ratio of organic land

	Contiguity	10km	15km	20km
Neigh matrix summary stat				
Average # neighbors	5.86	23.86	52.96	92.52
Max # neighbors	25	29	128	209
Validity test				
Moran test	0.42***	0.33***	0.28***	0.25***
LM lag (H_0:ρ=0)	12939***	22167***	31043***	36673***
LM Err (H_0:λ=0)	12623***	22500***	34860***	47143***
Hausman Test (SDM vs SEM)	263***	120***	52***	38***

Testing the presence and origin of spatial autocorrelation in the ratio of organic land in the municipality, with the four neighbourhood matrices For the validity test part, we have reported the test value. Threshold for rejection of the null hypothesis: $^{***}p < 0.001$,$^{**}p < 0.01$,$^{*}p < 0.05$

Thus, based on the tests previously carried out, the modeling of a *Spatial Durbin Model* that makes it possible to capture the spatial dependence and spatial heterogeneity influence in the data appears to be optimal. This modeling allows us to take account of the explanatory variables of the neighbours and the OF ratio of the neighbours influence y_i. According to LeSage and Pace (2009), the model is written in the matrix form:

$$Y_i = \rho W_{ij} Y_j + X_i \beta + W_{ij} X_j \theta + \varepsilon_i \tag{1.3}$$

Where Y_i is a vector $n{*}1$ referring to the share of organic land in the municipality's total farmland; X_i dimension matrix $n * k$ referring to the explanatory variable associated with all observations, ρ is a scalar indicating the spatial dependence of the model. Then β and θ, are size vectors $k * 1$, respectively the OLS estimator and the coefficient associated with spatial heterogeneity. ε of size $n * n$ is an error vector following a normal law $\varepsilon \sim N(0, \sigma^2 I_n)$. W_{ij} is the weighted neighbourhood matrix for municipality i.

Concerning the estimation of the coefficients, the direct (impact of a change in the municipality i on its own number of organic farmlands) and indirect (spillover effect induced by a change in the neighbourhood on the number of organic farmlands in the municipality i) effects are obtained by simulations of 1000 Markov chain Monte Carlo (MCMC) samples (LeSage, 1997; LeSage and Pace, 2009) based on the distribution of coefficients obtained by the Spatial Durbin Model. This estimation method is used by Lapple and Kelley (2014) because it's more relevant than conventional estimation methods (estimation by the maximum likelihood method) for spatial econometric models.

1.3.2 Data and variable construction

To understand the spatial factors influencing the distribution of organic farmland in France, we built a database of the 34,970 municipalities in metropolitan France. The variable we aim to explain in this study is the proportion of organic agricultural land in the municipality. The first variable of interest represents the share of UAA for organic agriculture in the municipality in 2019. This variable is derived from the processing of the Land Parcel Identification System (LPIS)[6], which is non-anonymized and allows us to determine, at the parcel level, whether it is operated under organic or conventional farming practices. We aggregate this information for each municipality within its geographical boundaries. It's important to note that the LPIS database is not exhaustive, as it includes only farmers receiving support from the Common Agricultural Policy[7].

To test the influence of the determinants identified by geographical economics litterature, we include variables representing demand, population characteristics and the municipality's proximity to major cities. Therefore, we decided to take into account the characteristics of the surrounding populations to approximate which populations are most likely to consume organic products. Based on Lambotte et al. (2020) and Kesse-Guyot et al. (2013), we include the share of the population with high levels of education (*Bachelor Degree* and *Master degree*), as well as the share of the population engaged in two types of professions: *Managers* and *Workers*. Addi-

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[6] Established in France in 2002 as the Land Parcel Identification System enforced by the European Council Regulation No 1593/2000

[7] According to Cantelaube and Carles (2014), the LPIS excluded 8.5% of French plots, mainly vineyards and fruit crops.

tionally, we introduce two variables, *Dist 100* and *Dist 50* representing the distance, in kilometers, from the municipality to cities with populations of 100,000 or more, and between 100,000 and 50,000 inhabitants, respectively. This allows us to determine whether farmers need to be close to towns.

To verify the influence of PDO areas on the distribution of OF, we integrate the number of products that can receive PDO certification per municipality, *# PDO*. This completes the analysis of Allaire et al. (2015), which only took into account the presence of labeled products and not the exact number of PDO. This data allows the construction of four variables, *# Wine& Spirit*, *# Fruit&vegetables*, *# Meat* and *# Dairy product*, referring, respectively, to the number of PDO related to alcohol production (mainly wine), production of certified fruit and vegetables, production and processing of certified meat, and dairy production (mainly cheese).

Then, to test the impact of soil quality on OF practices, we integrate two types of variables. The first refers to soil quality and the other concerns the presence of forest and natural protected areas (NATURA 2000 area). So, to capture the soil quality, we include the variable *Constrained area* constructed by Le Barth et al. (2018)[8].This variable indicates the share of the agricultural area of the municipality that is constrained by at least one criterion defined in Annex 3 of EU Regulation No. 1305/2013. In this annex, the Parliament indicates eight criteria (dryness, shallow rooting depth, poor chemical properties, steep slope, etc.) and 14 thresholds beyond which agricultural land is qualified as a constraint, i.e., its productivity is negatively impacted. In addition, to verify the role of the forest and semi-natural elements, we integrate the *Share_forest* and *Natura2000* variables. The first one refers to the share occupied by the forest and semi-natural elements in the municipality, obtained from the Corinne Land Cover 2018 database, and the second, Natura2000, indicates whether there is a Natura 2000 [9] classified area in the municipality.

Finally, to test the influence of European financial support on the OF ratio, we include the binary variable, *ANC_before_2019* equal to 1 when farmers in the municipality can receive ANC aid. We only take into account the municipalities already eligible before 1 January 2019. Indeed, EU Regulation No. 1305/2013 applies since that date. This regulation is based on the Le Barth et al. (2018) database,

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[8] Database available on the Ministry of Agriculture website : https://agriculture.gouv.fr/

[9] A Natura 2000 area is an area made up of a group of natural land and marine sites. Its objective is to ensure the long-term survival of particularly vulnerable species and habitats with high conservation value in Europe.

allowing the construction of the *Constrained area* variable. To avoid problems of multicollinearity between these two variables, we take into account the municipalities that were eligible for this aid before the introduction of this criteria. Table 1.5 (Appendix 1) shows the origin of each variable as well as the descriptive statistics of the variable.

1.4 Results

1.4.1 Determinants of the municipality's organic farming ratio: SDM analysis

Table 1.2 contains the direct effects of the various specifications of the model with the inclusion of the contiguity neighbourhood (the indirect effect of each specification is reported in appendix 2 table 1.6). These direct effects are equivalent to the 10, 15 and 20km neighbourhood matrices and are therefore not reported in table 1.2. These 5 specifications show us the significant impact of spatial dependence on the share of organic farming, with the same magnitude between specifications ($\rho \cong 0.62$). Appendix 2 table 1.6 shows us the influence of spatial heterogeneity linked to border municipalities on the organic share.

First of all, we can see in specification (2) that the presence of a downstream operator in the organic sector in the neighbouring influences the share of organic land. To go further, we can see that the number of processing companies influences the distribution of organic land. To secure supplies of agricultural raw materials, processing companies can contract with neighbouring farmers, thereby increasing the amount of organic land. However, as shown above, to avoid potential problems of inverse endogeneity between the organic share and the downstream sector, we decided not to opt for this specification but to approximate by the characteristics of the population. Specifications (1-2-4-5) and (3) allow us to judge whether or not it is necessary to separate PDOs according to the type of agricultural sector (wine-growing, market gardening, animal husbandry, dairy). We did not retain Specification (3) since the positive influence of the variable *# PDO* hides part of the information. The other regressions show that not all PDOs have the same effect on the proportion of organic land. While the number of PDO for wine and dairy products (mainly cheese) increases the proportion of organic land, PDO for livestock farming and labels protecting fruit and vegetables do not influence conversion.

Specification (5) tells us that organic farms try to establish themselves away from big cities (more than 100,000 residents, variable *Dist 100*), as was already reported in the article of Schmidtner et al. (2012) on the German context. Finally, to capture the influence of forests and semi-natural elements on the conversion, we specified Regressions (1) and (4). It appears that the share of forest as well as the presence of Natura 2000 areas in the municipality have a positive influence on the OF ratio in the municipality and in the neighbouring municipalities. Indeed, the designation of a Natura 2000 area increases the ratio of organic farmland ratio by 0.41%, and has a cumulative effect on the border municipalities of the area by 1.2%. Finally, based on the AIC and maximum likelihood information criteria, we retain specification (1).

Table 1.3, based on specification (1) of table 1.2, takes the results of the Spatial Durbin Model with MCMC estimation for the fourth neighbourhood matrices. Firstly, we can see the importance of spatial autocorrelation in explaining the distribution of organic land in France (significance of the ρ parameter). Furthermore, by studying the AIC criterion, we note that its value increases with the size of the neighbourhood matrix. This increase tells us that the explanatory power of the model decreases with distance. Thus we can already establish that the influence of the immediate neighbourhood in explaining the proportion of organic farmland is very important, and that this influence decreases with distance.

We can also note that the characteristics of the population influence the share of organic land in the municipality. The most influential characteristic is the share of Master's graduates in the population. The results show a significant spillover effect even in the 20km neighbourhood. In other words, an increase in the share of the population with a Master's degree in the 20 km neighbourhood leads to an increase in the number of organic plots in the municipality studied. Conversely, the proportion of the population with a bachelor's degree in the neighbourhood reduces the number of organic farmland. The results of the table 1.3, also indicate that municipalities with PDO wine labels have a higher share of organic land with a significant spillover effect up to 10km. This result demonstrates that the PDO wine label and the organic farming label are complementary, primarily driven by wine producers' and sellers' pursuit of marketing differentiation to capture the premium price consumers are willing to pay. The other PDO sub-categories do not influence the share of organic farmland.

The presence of a municipality on the ANC list before 2019 (variable

ANC_before_2019), which enabled farmers to receive an additional subsidy, has a positive impact on the municipality's share of organic farmland, increasing it by approximately 1%. There is no spillover effect generated by this variable, which is logical because farmers in municipalities that are not eligible for ANC subsidies will not receive subsidies, so their situation does not change and their probability of converting to organic farming does not change. We can nevertheless note the spatial spillover with the contiguity matrix. Indeed, as a farmer may have agricultural land in several municipalities, they may receive ANC subsidies on part of this land that is in ANC municipalities, and decide to convert all this agricultural land.

Moreover, it appears that areas with significant agricultural constraints exhibit a higher share of organic farmland. This finding suggests that the proportion of organic farmland is greater in regions facing farming challenges compared to other areas. Lastly, the proportion of forests and semi-natural elements in the municipality influences the proportion of organic plots in the municipality as well as in neighbouring municipalities. An increase of the forest or semi-natural element share in a municipality by 1% increases by around 0.02% the share of organic farmland in the municipality. The increase in the proportion of forest in neighbouring municipalities will also have a positive impact on the proportion of organic land in the reference municipality.

Direct Effect	Basline (1)	Org shop (2)	PDO (3)	Natura 2000 (4)	Distance (5)
#UAA	0*	0**	0**	0**	0*
Bachelor Degree	0.57		0.67	0.09	
Master Degree	3.23***		3.37***	3.55***	
Managers	-0.32		-0.37	-0.94	
Workers	-0.195		-0.262	-0.548	
# processor		0.32***			
# supplier		0.02			
Dist 50					0.03
Dist 100					0.11**
PDO					
# PDO			0.11***		
# Wine& Spirit	0.13***	0.12***		0.13***	0.13***
# Fruit&vegetables	0.09	0.04		0.08	0.1
# Meat	0.31	0.21		0.24	0.27
# Dairy product	0.48*	0.46·		0.51*	0.43·
ANC_before_2019	0.94**	1.07**	0.93**	1.11***	0.92**
Constrained surf	1.44***	1.36***	1.48***	1.38***	1.39***
Share forest	2.08***	2.4***	2.08***		2.13***
Natura 2000				0.41*	
ρ	0.62***	0.62***	0.63***	0.63***	0.62***
# Obs	33741	33741	33741	33741	33741
AIC	254780	254710	254840	254900	254790
Log Likelihood	-127361	-127333	-127398	-127423	-127373

The values refer to the direct effect of the variables on the municipality's organic ratio. The indirect effects caused by the adjacent municipality are shown in Appendix 2 in the table 1.6. Estimation of the SDM model obtained from 1000 Markov Chain Monte Carlo simulations. The p-value is represented as a function of these thresholds: $^{***}p < 0.001$,$^{**}p < 0.01$,$^{*}p < 0.05$

Table 1.2: SDM direct effect from contiguity neighborhood

	Contiguity			10km			15km			20km		
Effect	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
#UAA	0*	0	0	0·	-0	-0	0*	0	-0	0	0	0
Bachelor Degree	0.57	-7.72*	-7.16*	0.74	-24.93**	-24.19**	0.90	-32.22*	-31.31·	0.95	-49.72·	-48.77·
Master Degree	3.23***	10.68**	13.90***	2.83***	20.81**	23.64**	2.77***	44.96**	47.72**	2.76***	78.97**	81.73***
Managers	-0.32	-9.46*	-9.78*	0.05	-21.03*	-20.98*	0.64	-42.70*	-42.05*	0.83	-61.36*	-60.53*
Workers	-0.20	-5.47*	-5.67*	0.25	-10.90*	-10.65*	0.49	-7.85	-7.37	0.67	0.91	1.58
PDO												
# Wine& Spirit	0.13***	0.55***	0.68***	0.16***	0.58***	0.74***	0.22***	0.44*	0.67**	0.25***	0.30	0.55·
# Fruit&vegetables	0.09	1.91***	2.00***	0.07	1.59*	1.66*	0.08	1.50	1.59	0.01	1.23	1.24
# Meat	0.31	-1.09·	-0.78*	0.13	-0.94	-0.81·	-0.08	-0.65	-0.73	-0.03	-0.79	-0.82
# Dairy product	0.48*	-1.12***	-0.64***	0.27	-0.88·	-0.60	0.28	-0.88·	-0.60	0.25	-0.79	-0.54
ANC_before_2019	0.94**	1.87***	2.81***	1.47***	1.06	2.53***	1.46***	1.22	2.68**	1.59***	0.92	2.51·
Constrained surf	1.44***	2.24**	3.68***	1.18***	3.55**	4.74**	1.33***	4.20*	5.53**	1.22***	6.68*	7.90**
Share forest	2.08***	6.83***	8.91***	2.73***	4.97***	7.70***	3.07***	3.80·	6.86**	2.97***	4.74	7.71*
ρ		0.62***			0.73***			0.82***			0.87***	
# Obs		33741			33741			33741			33741	
AIC		254780			255930			256630			257200	
Log Likelihood		-127361			-127937			-128287			-128575	

The values refer to the direct, indirect and total effect of the variables on the municipality's organic farmland ratio. Estimation of the SDM model, based on the specification (1) table 1.2, obtained from 1000 Markov Chain Monte Carlo simulations. The neighbourhood matrix used is shown in the first row of the table. The p-value is represented as a function of these thresholds: $^{***}p < 0.001$,$^{**}p < 0.01$,$^{*}p < 0.05$,$^{\cdot}p < 0.1$

Table 1.3: SDM effect decomposition from contiguity, 10, 15 and 20Km neighborhood

1.4.2 Heterogeneity analysis: ratio of organic farmers

To test the sensitivity of our results, we propose testing the same model but changing the dependent variable, i.e. the ratio of organic farmers in a municipality. So, we construct this variable from the number of organic farms in the municipality as of January 1, 2019 (sourced from the French Organic Farming Agency) and the total number of farmers per municipality in 2017 (sourced from the Agricultural Social Security). This calculation allows us to create the variable known as "the municipality's OF ratio"[10], the dependent variable.

First, considering this new dependent variable, according to the diagnostic test table (appendix 3 table 1.7), similar to the previous analysis, it's crucial to account for both spatial dependence and heterogeneity to elucidate the source of spatial autocorrelation. Therefore, performing a SDM is essential to understand the determinants of the share of organic farmers in municipality i.

The comparison of the previous results on the share of organic land (table 1.3) and those here on the number of farmers (table 1.4) are almost identical. In fact, the direction and significance of the coefficients associated with the variables linked to the characteristics of the population, the PDO, and the environmental characteristics (share of forest and share of constrained surface) are identical. However, we note the direct non-significance of the variable *ANC_before_2019* which refers to the municipality eligible to receive ANC aid. This result is not surprising, as farmers can only benefit from this aid if they cultivate farmland in an eligible municipality. So, if a farmer locates his farm in a municipality eligible for ANC but does not farm any land there, they will not be eligible for aid and this will therefore have no impact on his probability of converting to organic farming.

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[10] Corresponding to the number of organic farms in the municipality divided by the number of farmers in the municipality.

	Contiguity			10km			15km			20km		
Effect	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
#UAA	0***	0	0*	0***	0·	0	0***	0	0	0**	0	0
Bachelor Degree	-0.01	-0.1***	-0.1**	0.01	-0.21***	-0.21***	0.01	-0.3**	-0.3*	0.01	-0.46*	-0.45*
Master Degree	0.06***	0.16***	0.21***	0.05***	0.27***	0.32***	0.05***	0.5***	0.54***	0.05***	0.77***	0.82***
Managers	-0.02·	-0.17***	-0.19***	-0.01	-0.3***	-0.31***	-0.01	-0.53***	-0.54***	-0.01	-0.83***	-0.83***
Workers	-0.02*	-0.12***	-0.13***	-0.01	-0.18***	-0.19***	-0.01	-0.2**	-0.2**	-0.01	-0.25*	-0.26*
# Wine& Spirit	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01**	0.01***
# Fruit &Vegetables	0.01*	0.02***	0.04***	0.01*	0.02*	0.03***	0.02**	0.01	0.03***	0.02***	0.01	0.02*
# Meat	0.02*	-0.03**	-0.01***	0	-0.02**	-0.01***	0	-0.02*	-0.02**	0.005	-0.02*	-0.02*
# Dairy product	0	-0.01***	-0.01***	0	-0.01**	-0.01***	0	-0.01*	-0.01**	0	-0.01*	-0.01*
ANC_before_2019	0	0.02**	0.02***	0	0.02*	0.02***	0.01	0.01	0.02*	0.01	0.01	0.01
Constrained surf	0.02**	0	0.02***	0.02**	0.01	0.02**	0.01***	0.01	0.03·	0.01**	0.02	0.03·
Share forest	0.02**	0.08***	0.1***	0.02**	0.08***	0.1***	0.02***	0.07***	0.1***	0.03***	0.06**	0.09***
ρ		0.29***			0.51***			0.65***			0.73***	
# Obs		33741			33741			33741			33741	
AIC		-29665			-30617			-30954			-30993	
Log Likelihood		14859			15335			15504			15523	

The values refer to the direct, indirect and total effect of the variables on the municipality's organic farmers ratio. Estimation of the SDM model, base on the specification (1) table 1.2, obtained from 1000 Markov Chain Monte Carlo simulations. The neighbourhood matrix used is shown in the first row of the table. The p-value is represented as a function of these thresholds: $^{***}p < 0.001$,$^{**}p < 0.01$,$^{*}p < 0.05$,$^{\cdot}p < 0.1$

Table 1.4: SDM effect for a contiguity, 10, 15 and 20Km neighborhood on the share of organic farmers

1.5 Discussion

Based on the findings of this study, we can propose two recommendations to policymakers to enhance the development of OF.

Firstly, it would be beneficial to mandate the inclusion of environmental measures in PDO specifications. This action would facilitate alignment between PDO specifications and European organic standards. Consequently, the transaction costs associated with transitioning to organic farming—such as changes in practices, potential yield reductions, and acquiring new knowledge—for farmers in PDO areas would be reduced. These changes in practice necessary to meet the PDO standards increase the probability of conversion. In this way, a farmer's compliance with PDO specifications could serve as a stepping stone towards a transition to OF.

Second, public policies aimed at increasing and restoring semi-natural elements must be maintained and amplified. These elements allow for a spatial spillover effect of OF development through easier substitution of pesticides and fertilizers. In the already existing "Green Payment" scheme (CAP 2014-2020), it is mandatory that 5% of the farmer's area be classified as an area of ecological interest (AEI), partly corresponding to semi-natural elements. Nevertheless, according to Jereb et al. (2017), 58% of the areas declared as areas of ecological interest are productive areas[11], limiting the production of ecosystem services. Thus, there are two possibilities to improve the system of areas of ecological interest: either(1) by increasing the minimum level of AEI required, knowing that, on average, European farmers in 2016 declared 9.3% of AEI, but leaving the possibility for farmers to have a mixture of productive and non-productive AEI; or (2) by maintaining the threshold at 5%, but counting only non-productive AEI. Under the current CAP (2023-2027), all farmers must meet the "GAEC 8" condition (Good agricultural and environmental conditions, condition number 8), i.e. they must have 4% of their UAA in non-productive AEI (fallow or unproductive elements). An exemption for the year 2024 was adopted on 13 February 2024, allowing farmers to meet this condition with 4% productive AEI.

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[11] Area giving rise to an income from the sale of the crop. For example, farmers decide to grow legumes (lentils, chickpeas, peas) considered as AEI. However, since this land is tilled, the impact on biodiversity is more limited.

1.6 Conclusion

This article builds upon previous studies on the determinants of OF development, focusing specifically on how spatial dependency and heterogeneity influence the expansion of this practice. However, it appears that specific local conditions can influence decisions to convert. This study of organic land ratio of municipalities has made it possible to highlight the important role of the geographical distribution of activities, European agricultural policy and natural environments.

First of all, there is an agglomeration effect of OF in some regions. This study has identified variables that partly explain the origin of this agglomeration effect. We have highlighted the significant spatial spillover effect of the demand for organic products, approximated by the characteristics of the population (qualifications and type of employment), on the local development of the OF.

The spatial heterogeneity of OF is also explained by the differences in subsidies between farmers. Indeed, we found that the OF land ratio was higher in the municipalities listed in the classification as eligible for ANC aid. The impact of PDO areas varies according to the agricultural sector concerned. It appears that the PDO for wine allow for an increase in the organic farmland, whereas the geographical areas concerned by livestock products do not influence conversion. It would seem that, depending on the type of marketing circuit chosen, the PDO and organic labels are substitutes when the farmer chooses a long distribution channel and complementary circuit when the sale is direct to the consumer.

Finally, it appears that organic farming practices are more developed in areas where the agricultural land does not allow high yields. In these areas, organic agriculture practices have two advantages. On the one hand, they make it possible to preserve the quality of the soil, maintaining and even increasing productivity (in the case of drought, according to the Rodale Institute (2011), Lotter et al. (2003)), and on the other, they make it possible to increase the value of the crop produced, thus compensating for the loss of yield due to the poor quality of the soil. In addition, the ecosystem services provided by forests and semi-natural elements seem to increase the development of organic agriculture.

1.7 Appendix

Appendix 1: Summary table of variables

Variable	Definition	Mean	Median	Min	Max	N	Source
Organic ratio	Share of organic land in the municipality	8.01	2.83	0	100	33741	LPIS
	Percentage of the population with						
Bachelor Degree	• Bachelor's degree	16.5%	16%	0	100%	33741	INSEE
Master Degree	• Master's degree	18.5%	17%	0	100%	33741	INSEE
	Percentage of the population with this occupationg:						
Managers	• Managers or Intellectual profession	10.3%	9%	0	100%	33741	INSEE
Workers	• Workers	25.2%	24%	0	100%	33741	INSEE
	Minimum distance (km) between the municipality i and						
Dist 100	• city more 100,000 inhabitants	71	42	0	328	34943	
Dist 50	• city with a population $[50,000; 100,000]$	86.4	48	0	230	34943	
# PDO	Number of PDOs by municipality	1.693	2.96	0	70	33741	INAO
	Number of PDOs related to :						
# Wine& Spirit	• alcohol production	0.88	0	0	70	33741	INAO
# Fruit&vegetables	• certified fruit and vegetables	0.11	0	0	3	33741	INAO
# Meat	• certified meat	0.14	0	0	3	33741	INAO
# Dairy product	• dairy production	0.55	0	0	5	33741	INAO
ANC_before_2019	Municipality classified as areas of natural or other specific constraints	0.41	0	0	1	33741	French Ministry
Constrained surf	Percentage of the municipality's agricultural area subject to natural constraints	39.02%	37.6%	0	100%	33741	GIS Sol
Share_forest	Share of forest and semi natural areas	27%	19.2%	0%	100%	33741	CLC
Natura2000	Presence of a Natura 2000 zone	0.36	0.48	0	1	34970	Natura 2000

Table 1.5: Descriptive statistics of the variables

Appendix 2: SDM indirect from contiguity neighborhood

	indirect (1)	indirect (2)	indirect (3)	indirect (4)	indirect (5)
#UAA	0	0	0	0**	0
Bachelor Degree	-7.722*		-6.756*	-11.607***	
Master Degree	10.679**		11.938***	13.345***	
Managers	-9.455*		-9.758*	-14.891***	
Workers	-5.47*		-6.027*	-8.331***	
# processor		1.229***			
# supplier		-0.409			
Dist 100					-0.042
Dist 50-100					-0.122**
# PDO			0.369***		
# Wine&Spirit	0.547***	0.521***		0.56***	0.558***
# Fruit&Vegetables	1.913***	1.779***		2.576***	2.172***
# Meat	-1.086+	-0.872		-0.935	-0.991
# Dairy product	-1.119***	-1.102***		-1.109***	-1.059***
ANC_before_2019	1.872***	2.189***	1.248**	3.066***	2.295***
Constrained surf	2.235**	1.77*	3.228***	0.268	1.976**
Share forest	6.832***	7.32***	6.996***		7.673***
Natura 2000				1.202**	

The values refer to the indirect effect of adjacent municipalities on the municipality's organic ratio i. The direct effect are shown in the table 1.2. Estimation of the SDM model obtained from 1000 Markov Chain Monte Carlo simulations. The p-value is represented as a function of these thresholds: $^{***}p <$ 0.001,$^{**}p <$ 0.01,$^{*}p <$ 0.05

Table 1.6: SDM indirect from contiguity neighborhood

Appendix 3: Diagnostic test for explain organic farmers ratio

	Contiguity	10km	15km	20km
Moran test	0.19***	0.18***	0.16***	0.15***
LM lag (H_0:ρ=0)	2003***	5083***	8571***	11263***
LM Err (H_0:λ=0)	1822***	4683***	8359***	12030***
Hausman Test	311***	693***	163***	144***

Testing the presence and origin of spatial autocorrelation in the ratio of organic farmers in the municipality, with the four neighbourhood matrices For the validity test part, we have reported the test value. Threshold for rejection of the null hypothesis: $^{***}p < 0.001$,$^{**}p < 0.01$,$^{*}p < 0.05$

Table 1.7: Diagnostic test for the spatial autocorrelation of the ratio of organic farmers

Chapter 2

Water policy's influence on local organic farming development

Summary of the chapter

In France since 2009, a policy to protect Water Catchment Area (WCA) was implemented to preserving and decontaminating these water reserves. To achieve these objectives, farmers in these areas are encouraged to adopt agri-environmental practices, as well as organic farming (OF) practices. This study aims to determine whether WCA policy effectively contributes to the development of organic agriculture in France, as well as other agri-environmental practices (such as the proportion of grassland and permanent cover). This study focuses on the 1215 WCA currently defined in France. Two levels of analysis are used: at the WCA level and at the individual farmer. At the WCA level, by Staggered Difference-in-Difference method (Callaway and Sant'Anna, 2021), indicates that this policy may counter-intuitively slow down the development of OF compared to neighbouring untreated areas. The analysis seems to show that the policy has a spillover effect on the immediate neighbourhood (up to 2 km). This shows that the actions taken are not limited to the strict WCA zone. At the farmer level, over 350,000 French farmers observed over the period 2016–2021, we find the farmers in WCA have a lower probability of converting to OF than their untreated neighbours. The various results indicate that the implementation of the WCA policy has slowed the development of agri-environmental practices through the introduction of incentive instruments, creating windfall effects for treated farmers.

2.1 Introduction

Agriculture in France accounts for 57% of the total water consumption (average between 2010 and 2018), while only contributing to 1.6% of national GDP. In addition to the pressure on water resources, agriculture is a major contributor to water pollution, mainly due to the application of synthetic fertilizers and pesticides, affecting the quality of groundwater (Lerner and Harris, 2009). Indeed, 90% of monitored water sources in France contain at least one pesticide Kristensen et al. (2018). Thus, as a significant consumer and polluter, agriculture plays an important role in the quantity and quality of water.

As a result, according to Feuillet and Michon (2016), between 1997 and 2013, 7 716 water catchments were abandoned in France with pollution being the main reason for abandonment (39% of these water catchments). In these catchments, molecule concentration exceeds the drinking water standards set by the French Ministry of Health (pesticide concentrations $0.10\mu g/L$ and nitrates 50mg/L). The combination of these elements leads to conflicts over the sharing of water between different users. In France, for example, we are seeing farmers seeking to create large water reserves to irrigate their crops to the detriment of natural areas, which can lead to major conflicts such as the *Méga-Bassine de St Solline* controversy[1].

National and European Directives have been put in place to address the challenges of water sharing and pollution. The Water Framework Directive (2000/60/EC) is aimed at sharing water resources, while the Nitrates Directives (1991 and 2010-2016) aim to limit water pollution. One of the policies put in place under the Water Framework Directive and the French Environment Code is the protection of "water catchment areas". The aim is to identify polluted water resources and implement action plans throughout the area around the resource, to improve water quality. The target zone is called the "Water Catchment Area" (WCA), and covers the entire surface area over which every drop of water that falls can reach the water resource. In this area, action will be taken to limit or even eliminate all pollution to preserve and improve the quality of the water so that it remains drinkable. This program has gone through two identification phases. The first was in 2009 with the Grenelle Environment Summit, which set a target of 500 priority WCA. The second was launched

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[1] This conflict arose between environmental activists and a group of 450 farmers who proposed the creation of 16 reservoirs with a total volume of 6 million m^3 of water, intended for agricultural use. The activists criticized the project for potentially monopolizing water resources for agricultural activity and destroying protected areas.

as part of the implementation of the river basin management plan for the period 2016-2021(*Schéma Directeur d'Aménagement et de Gestion de l'Eau* or SDAGE), with a target of adding around 500 WCA. Thus, out of approximately 33,000 water catchments in France, more than 1,000 are designated as protected WCA. In this WCA, a steering committee composed of various stakeholders (project owners, funders, government services, representatives of sectors causing pollution, and environmental associations) must decide on the actions to be implemented in the area to achieve water preservation objectives. The action plan produced by this steering committee is co-constructed by those responsible for pollution and resource users. This co-construction process should lead to greater acceptance of the issues and a willingness to make the effort to change the practices used to replace polluting products. To motivate this change in practices, the committee can implement different types of action (subsidies, training/communication, regulatory tools).

As the agricultural sector is one of the main polluters of these water reserves and a major consumer of this resource, it is interesting to observe its behaviour after the introduction of the WCA policy. It is in the farmers' interest to have access to good quality water to maintain their yields but to do so they must change their practices. Our aim is therefore to observe whether the designation of WCA has led to changes in farming practices. We will measure the changes in farming practices identified in the literature as making it possible to preserve water quality. The farming practices observed will be organic farming (OF), the proportion of grassland (split between permanent and temporary) and changes in permanent cover. These practices, which do not use chemicals and/or improve soil structure, help to limit the impact of agriculture on water quality (Dabney et al., 2001; Blanco-Canqui et al., 2015).

We will adopt two levels of analysis. The first level will be the WCA, which will enable us to observe the impact of the WCA policy on the evolution of agri-environmental practices. Using the Staggered DiD method (Callaway and Sant'Anna, 2021), we will compare the dynamic of agri-environmental practices between treated group (in the WCA) and control group (outside the WCA). We will also test different neighbouring control groups (within a radius of 1 to 10 kilometers) to observe the existence of spatial spillover effects of the policy on neighbouring areas. We will then shift to a second level of analysis, that of individual farmers. Where we will compare the farming practices of farmers affected by the WCA policy with those of other neighbouring farmers who have not been treated (located outside the WCA). The aim is also to measure the heterogeneity of the effect depending on the farmer's involvement in the WCA policy, which will be approached by two indicators: *Weight* and *Commitment*. The *Weight* in the WCA assesses the proportion of a farmer's land within a specific WCA compared to all the land in this WCA. The second indicator, *Commitment*, measures how much this policy impacts the farmer's agricultural practice. Equivalent to the proportion of the farmer's total area located in at least one WCA.

In this chapter, in order to make the treatment random, we will use the spatial regression discontinuity methods (Keele and Titiunik, 2015; Lee and Lemieux, 2010), which proposes to use the geographical boundary of an area to designate the treated individuals and the control individuals. Using this method, we show that farmers on either side of the boundary are similar, and cannot influence their probability of receiving the treatment (elimination of selection bias). In our case, the official delimitation of the WCA will be used as the boundary because, outside this area, farmers cannot benefit from actions linked to the WCA policy. We created 4 control groups based on the proximity of each WCA: 1km from the boundary, between 1 and 2km, between 2 and 5km, and between 5 and 10km. These choices make it possible to test differences in the dynamics of changes in farming practices as a function of distance from the boundary of the WCA, while comparing homogeneous treatment and control groups.

Finally, we conclude with three robustness analyses to check the strength of the effects obtained in the main analysis. The main result tested is that the WCA policy slows down the development of organic farming practices compared with neighbouring regions. These additional analyses also enable us to highlight the mechanisms explaining this result. To do this, we first test the sensitivity of the staggered DID results to change of control group. Next, we will study the influence of AES on agricultural practices, by observing whether or not the contracting of an AES by a farmer in a WCA amplifies their effect. This analysis will enable us to analyse the role of policy instruments in the differences in changes in agricultural practices between WCA. Finally, from a survey based on interviews with 726 organic farmers, we will see that as well as limiting the development of OF. The WCA policy seems to be creating incentives for these farmers to return to conventional farming.

2.2 Overview of water catchment area policy

In this section, we will present the WCA policy and the stakeholders involved. Then, in the second and third sections, we will look at the agricultural practices that need to be encouraged in order to achieve the objectives of preserving water resources. And the resources available to the steering committee to achieve these goals.

2.2.1 Water catchment area protection: from delimitation to action plan

The WCA designates the zone in which any falling water drops may end up in the water reserve. This type of protection zone is added to those already existing in France, namely the *"Immediate Protection Zone"* and the *"Close Protection Zone"*. These two zones are located around the water extraction point. In the *Immediate Protection Zone* (a few meters around the extraction facility), no economic activities are allowed to prevent contamination. In the *Close Protection Zone* (a few hectares around the extraction point), economic activities are regulated. The water catchment area is much larger than these zones because it covers the entire extent of the water resource, and not just the extraction area (ranging from 50 ha to 150,000 ha compared to just a few hectares for the Immediate and Close Protection Zones).The impact of polluting activities in the WCA on water quality is less direct than the impact of activities near the extraction point. So the measures taken by the WCA policy are less restrictive than the regulations applying to the immediate and the close protection zone. The idea behind the WCA policy is to use different incentive measures (regulation, monetary and non-monetary incentive) to encourage changes in farming practices, rather than constrain them.

After the authorities had identified a water reserve to be protected, a hydrogeological study is conducted to delimit the WCA according to the methodology outlined in Vernoux et al. (2014). As shown in figure 2.1, the time between identifying the water reserve to be protected and the official delimitation of this WCA varies greatly from one area to another. Indeed, we observe that every year, over the period 2016-2021, new WCA are delimited.

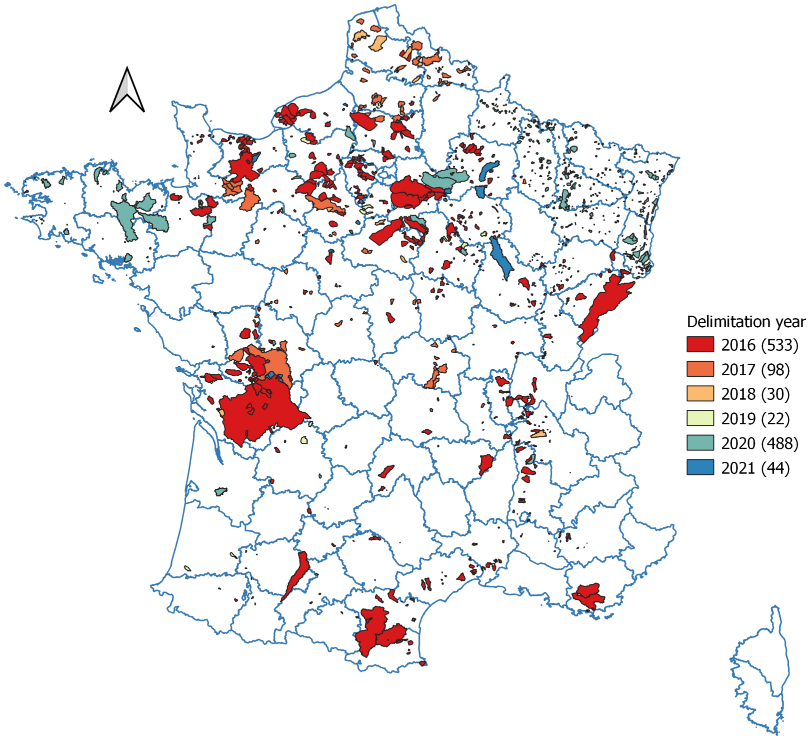

Figure 2.1: Distribution of WCA according to the year of delimitation (source: OiEau)

Once the area has been delimited, a territorial diagnosis is conducted to identify the various pressures on the WCA (agricultural activities, recreational activities, land use planning, etc...) and to assess the water reserve's current state (quality, quantity, and actions already in place). This diagnosis makes it possible to list the environmental and socio-economic issues to which the policy must respond. Based on this diagnosis, the steering committee dedicated to this specific WCA, made up of project owners, funders, government services, representatives of sectors causing pollution, and environmental associations proposes an action plan to achieve the objectives of preserving the water reserve. In this action plan, the steering committee decides which agricultural practices to encourage and how to stimulate change. In the next two subsections, we look at these two aspects to justify our analysis.

2.2.2 Agri-environmental practices for improving water quality

According to the Barrez et al. (2012), farmers' practices in WCA need to evolve towards agri-environmental practices to achieve the objectives of improving water quality in the WCA. These include expanding crop rotations, implementing catch crops, and increasing the area of grassland. These practices effectively minimize erosion, sediment runoff, and nitrate leaching (Dabney et al., 2001; Blanco-Canqui et al., 2015). These methods enhance soil structure and reduce the accumulation of nitrates in the soil, thereby contributing to the preservation of water quality.

In addition to the development of agri-environmental practices, in the law on the implementation of the Grenelle Environmental Summit (law no. 2009-967 of 3 August 2009), article 27 states *"on water catchment areas, priority will be given to OF surfaces"* with a target for the proportion of organic land in the WCA, *"the government will promote production and the structuring of this sector so that the area of agricultural land used for organic farming reaches 6% in 2012 and 20% in 2020"* (article n°31). Indeed, the practices imposed/encouraged[2] by the OF specifications also help to preserve water quality. OF prohibits the use of pesticides and synthetic fertilizers, reducing the risk of pollution by nitrates and pesticides, and by introducing agri-environmental practices, reducing nitrate leaching (Drinkwater et al., 1998).

According to Mondelaers et al. (2009), after a study conducted in 12 countries, it appears that OF, compared to conventional practices, reduces nitrate leaching by 9 to 21 kg/ha. The study by Benoit et al. (2014) found that in large-scale agriculture, even when normalized by production unit, nitrate leaching is lower in OF compared to conventional methods. On a regional level, the case of Munich demonstrates the significant impact of OF on water quality. Since 1992, by providing extra support averaging around 250€ per hectare per year (in addition to CAP aid), the number of organic farmers in the Munich catchment area has increased from 23 in 1993 to 150 in 2010, covering 86% of the agricultural area in the water catchment. This major change in Munich's agricultural landscape has led to a reduction in nitrate levels in water, decreasing from 40 mg/l in 1980 to an average of 10 mg/l in 2010 (Barataud et al., 2013).

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[2] The organic specifications (European regulation (EU) 2018/848) set standards in terms of practices that must be respected; as well as recommendations for production for which compliance is not compulsory.

2.2.3 Monetary or non-monetary incentives in the WCA

In this action plan, the actors mobilize various instruments such as existing regulations, as well as incentives that may be monetary or non-monetary, financed by a multitude of actors (FEADER fund, the State, Water Agency and local authorities). We will first focus on changes in agricultural practices as a function of the intensity with which the farmer is impacted by the WCA policy. Then, we will discuss the various agri-environmental schemes (AES) present in the WCA and their expected effects on agricultural changes.

The studies by Glowacki and von Rueden (2015) and Limbach and Rozan (2023) suggest that when local environmental objectives are identified, the level of environmental effort provided by farmers depends on different factors. Specifically, Limbach and Rozan (2023) finds that farmers considered to be dominant (those farming the most land in a priority area) are more likely to make efforts to protect the environment. This informal status makes farmers more willing to make efforts in favor of the environment. On the contrary, the more farmers there are in a priority zone, the more likely it is that one farmer will adopt free-rider behavior and shift the environmental effort to other farmers. In our context, Durpoix and Barataud (2014), calculates two indicators based on the number of plots a farmer farms in a WCA. The first, called the *Weight* of the farmer in a specific WCA, refers to the surface area of agriculture in the WCA called x divided by the total surface area of this WCA x. This indicator is used to rank farmers in order of importance. It enables us to identify the farmers who need to make the most effort in terms of the environment, if water quality targets are to be met. The second indicator is the farmer's level of *Commitment* to the WCA policy. It represents the proportion of the farmer's land that is located in at least one WCA. Here, we adopt the farmer's viewpoint and examine how this policy impacts them daily. We can hypothesize that their willingness to engage and provide environmental effort depends on their level of commitment. A farmer who owns 1% of their land in a WCA will not be as affected as a farmer who owns 90% of their land within a WCA.

In the European Union countries, since CAP programming 2007-2014, farmers can subscribe to specific agri-environmental schemes called *Agri-Environment-Climate Measures*. More precisely, in areas where biodiversity (mainly *Natura 2000* zones) or water quality are an issue, local authorities can draw up an AES project, known as an *agri-environmental and climate project*. In these environmentally sensitive areas, the authorities have the option of proposing so-called localised AES. These localised AES are contracts under which the farmer commits to respecting an agricultural practice on a surface area (agricultural plot) or linear area (hedges) over a certain period in exchange for an annual payment. For example, a water agency may decide to propose a AES in the WCA x, with a target reduction of $n\%$ in pesticide use by the subscriber farmer. Through these schemes, steering committees can offer farmers in their areas 5-year contracts. Voluntary farmers will then undertake to comply with the conditions of the contract for 5 years, in return for which they will receive a subsidy (the amount of which will vary depending on the measures to be implemented to comply with the conditions). Here, we seek to determine whether the AES put in place explain the changes in agricultural practices in the WCA. In the database, for the year 2020, we have all the plots with AES contracts that were engaged in 2020 or before.

The analysis aims to determine whether the monetary instruments implemented in the WCA have enabled agricultural practices to evolve, with possible spillover effects outside the zone. We will also examine whether the introduction of the AES in the WCA has not created a windfall effect, comforting conventional farmers in their practices and thus not encouraging conventional farmers to switch to OF.

Each action plan is unique, as each steering committee implements different actions depending on its financial resources, the size of the area, and its objectives. Some actions, such as land actions (exchange or purchase of plots) and training/awareness-raising initiatives, have not been included, as obtaining data for these activities can be too difficult.

2.3 Data and methodology

2.3.1 Data construction

We use two databases for our national-level analysis. First, the French *Land Parcel Identification System* (LPIS) from 2016-2021[3]. This non-anonymised geographical database enables us to locate all the agricultural land of farmers receiving aid from the first and/or second pillars of the European Union's Common Agricultural Policy, along with information about their agronomic management (organic or conventional)

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[3] Access through the *Centre d'accès sécurisé aux données*

and contractual agreements with AES (only for the year 2020). Secondly, the WCA database[4] produced by OiEau (French International Water Office), provides us with the official delimitation date and geometric features associated with each WCA. Merging the WCA map with the LPIS, allows us to see which farmers own the farmland in the WCA every year.

To test the hypotheses that being a local dominant influence environmental efforts (Glowacki and von Rueden, 2015; Limbach and Rozan, 2023), we include the variable *Weight*, which corresponds to the proportion of a farmer's agricultural surfaces within the total farmland on a specific WCA. We also include *Commitment*, referring to the proportion of the farmer's farmland in at least one WCA. Here, we hypothesise that the willingness to make the environmental effort of converting to (or remaining in) OF will be positively influenced by these two variables.

We will also test the influence of the WCA policy on the farmer's cropping practices. Thanks to the data contained in the LPIS, we know the main crop for each plot, divided into 28 group codes[5], as well as information on the cultivation of catch crops. Catch crops, grown between two main crops, help to improve soil fertility. We use this information to approximate whether the plot is permanently covered. The first variable we will create is *Share permanent cover*, which refers to the share of area with catch crops. The second variable is *Share grassland*, which can be separated into *Share grassland temporary* and *Share grassland permanent*. This sub-variable is therefore based on categories 17 *permanent grassland* and 18 *temporary grassland*. Finally, we also know from the LPIS data whether the plot is farmed organically or conventionally, enabling us to create the variable *Organic farming*. These different variables are calculated at the level of the WCA, and at the level of the farmer to satisfy our two levels of analysis.

According to Drysdale and Hendricks (2018), the water restrictions imposed on farmers during some periods can leads to changes in their farming practices. To control for this potential effect that could bias our analysis, we integrate the database

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[4] Available on the French International Water Office data website https://www.sandre.eaufrance.fr/

[5] Soft wheat; Grain corn and silage;Barley; Other cereals;Rape seed; Sunflowers; Other oilseeds; Protein crops; Fibre plants; Frost (set-aside areas without production); Rice; Grain legumes; Fodders; Meadows and moors; Permanent grassland; Temporary grasslands; Orchards; Vineyards; Nuts; Olive trees; Other industrial crops; Vegetables or flowers; Sugar cane; Others

Propluvia. This database, produced by the French minister, catalogues all official water restrictions orders imposed in France, along with their associated areas and periods. Based on this information, we include five variables: *'# of water orders'* and a binary variable indicating the type of restriction, ranging from levels 1 to level 4. *Level 1* is a simple communication about water savings. Levels 2 and 3 involve an irrigation ban between 11 a.m. and 6 p.m. and between 9 a.m. and 8 p.m., respectively. The highest level, *Level 4* implies a complete ban on irrigation and the use of localised irrigation systems.

2.3.2 Control group creation: Spatial RDD method to tackle endogenity issue

In the article Barataud et al. (2014), based on an analysis of the first wave of the WCA policy, they show that the WCA policy is guided by three criteria. The first is not surprising: the level of pollution in the water reserve. The second criterion is the strategic nature of the catchment area. If this catchment were abandoned, the population would have difficulty accessing other water resources. The third criterion is political: there must be total coverage of the national territory. This criterion reflects a dual objective: firstly, to avoid negatively stigmatising specific regions, and secondly, to spread the financial burden of the WCA policy actions' throughout the country. These criteria explain the exhaustive distribution of WCA across France (see on the map in figure 2.1). Of the 96 departments in France, 86 have at least one WCA.

So, the eligibility of this policy is not random but also endogenous to agricultural practice. Indeed, the probability of each farmer being eligible for WCA policy depends on his farming practices and those of his neighbours. In particular, we can highlight that we suspect that WCA are areas where the proportion of conventional farms is higher. These areas were selected because they have polluted water reserves, which are mainly of agricultural origin. In 2016, in the WCA delimited between 2017 and 2021, an average of 3% of farmland was farmed organically, compared to an average of 6% in the rest of France. To sum up, eligibility for the WCA policy is not random, as it depends on objective criteria. And as these criteria are partly linked to farming practices. The treatment is therefore endogenous to farming practices.

To eliminate this selection bias, we want to construct a control group allow to compare areas with the same probability of being included in the list of priority

WCA to measure the marginal effect of the policy on farming practices. In order to form control groups and make the treatment exogenous, we chose to compare the treated farmers with their untreated farmer neighbours using the Spatial Regression Discontinuity Design method (Keele and Titiunik, 2015; Lee and Lemieux, 2010). In our case, the allocation of the treatment depends solely on whether or not a farmer farms a plot in a WCA, and, the delimitation of WCA is based on hydrological and hydrogeological studies (Vernoux et al., 2014). Therefore, farmers cannot influence the delimitation of WCA. This means that there is no selection bias between two neighbouring farmers, since neither can decide to participate in the treatment. This approach ensures that the treatment is randomly applied to individuals on both sides of a boundary. By comparing two neighbouring farmers at the boundaries of the WCA, one who has treated by WCA policy and the other who has not, we can observe the difference in their behaviour. This difference will be attributable solely to whether or not they have received the treatment. In essence, if treated and untreated farmers have similar characteristics, any difference in their farming methods can be attributed solely to the location of their land within the WCA.

We established four control groups to test the persistence of the effect, each corresponding to farmers with land located at varying distances from the WCA boundary: within 1 km, between 1 and 2 km, between 2 and 5 km, and between 5 and 10 km (as shown on the map in figure 2.2). The underlying hypothesis is that as the distance from the boundary increases, the disparities between the treatment and control groups will increase.

2.3.3 Econometric methods for two-level analysis

Our approach will produce two different scale analyses, at the WCA level and at the farmer level. The econometric methods used vary according to the issues related to the scales of analysis, and we develop them here.

Changes in farming practices at the WCA level

All WCA are not delimited at the same time for two reasons. Firstly, there were two identification phases (1st identification period from 2009; 2nd period from SDAGE 2016-2021), and within a given zone, the implementation time of the policy varies depending on the size of the zone and the dynamism of the steering committee. Thus, for our 2016-2021 period, new WCA are defined every year. This delimitation date

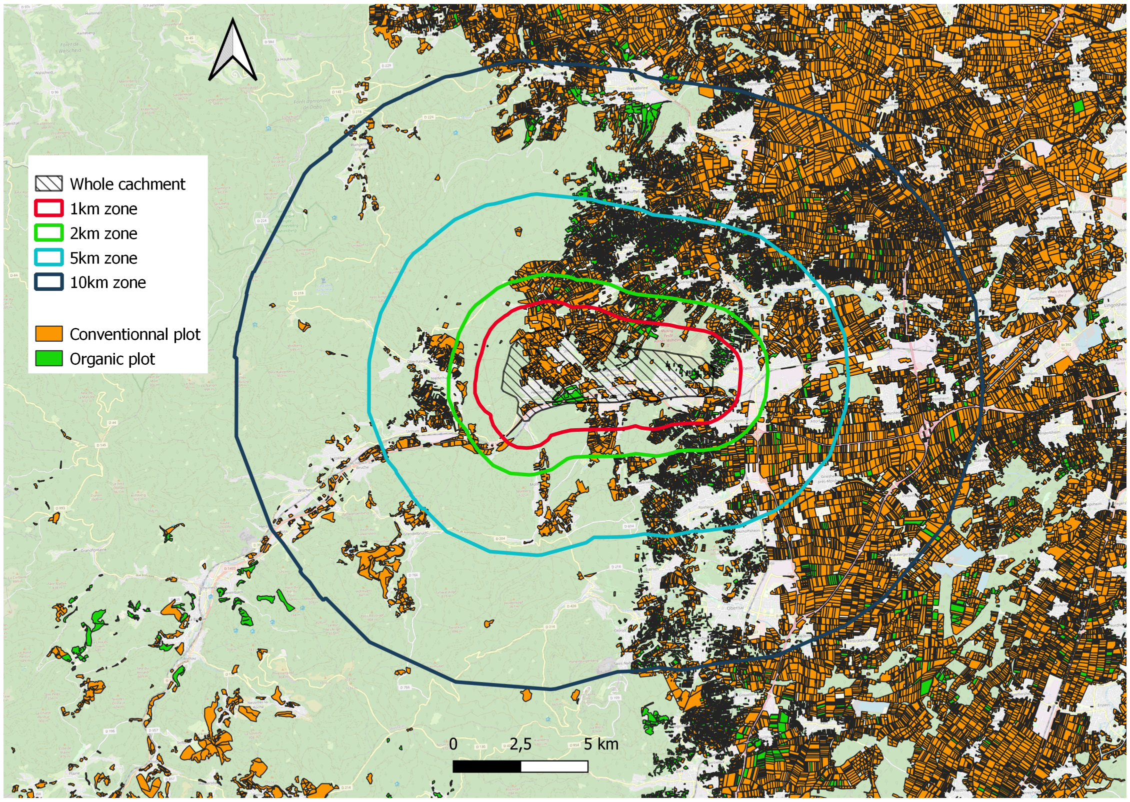

Figure 2.2: Creation of control groups based on distance from the WCA (Source: OiEau and LPIS)

is set by an administrative decree[6]. Table 2.1 illustrates the heterogeneity in the timing of treatment. As the LPIS database starts in 2016, all previous delimitations are attributed to 2016. In our analysis, the "2016" group is excluded because we do not observe the situation before treatment.

Delimitation year	[2009-2016]	2017	2018	2019	2020	2021
# of WCA	533	98	30	22	488	44

Table 2.1: Distribution of WCA by year of year of delimitation

Using the difference-in-differences method to analyse the impact of the WCA policy on agricultural practices leads to biases in these estimates. This approach does not take into account the possibility that the effects of the policy may vary depending on when it is implemented. To consider the different treatment peri-

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[6] The date for each WCA delimitation is available on this website: https://aires-captages.fr/

ods, we use the DiD with Multiple Time Period's method proposed by Callaway and Sant'Anna (2021). In this method, observations treated in the same year are grouped together, and correspond to the year in which the perimeter of the WCA was defined. The authors introduce an estimator called *Group-Time Average treatement effect* (*ATT(g,t)*), which represents the average effect of participating in the treatment for units in group g at period t. If the parallel trend condition is fulfilled (eq.2.2), meaning that the future treated zone and control group exhibit similar dynamics during the pre-treatment period, then eq.2.1 is equal to eq.2.3. Therefore, any differences between the two groups can be attributed to the treatment.

$$ATT(g,t) = E[Y_t(1) - Y_t(0)|G = g] \tag{2.1}$$

$$E[Y_t(0) - Y_{t-1}(0) \,|\, G = g] = E[Y_t(0) - Y_{t-1}(0) \,|\, D = 0] \tag{2.2}$$

$$ATT(g,t) = E[Y_t - Y_{g-1}|G = g] - E[Y_t - Y_{g-1}|D = 0] \tag{2.3}$$

This method enables us to examine the heterogeneity of the treatment effect based on the year of treatment and the duration of exposure to the treatment. We can detect heterogeneous effects according to the time of treatment, as well as the persistence of the effect over time.

Measuring individual agricultural change

We will examine the impact of variations in the intensity of the WCA policy (regarding the *Commitment* and *Weight* indicators) on farming practices, as well as their relationship with the probability that a farmer will convert to organic farming or remain organic in year t. The database will enable us to track farmers over the period 2016-2021, capturing the effect of unobserved variables on their practices. Since the decision variables we are studying do not follow a normal distribution, but a binary distribution (organic or non-organic) or a Poisson distribution (number of hectares of grassland), we use the Generalised Linear Model (GLM), described by the following equation (Baltagi, 2008). This model generates a function $g(\mu_{it})$ that links the mean of the dependent variable to a linear combination.

$$g(\mu_{it}) = \alpha_i + \alpha_t + X_{it}'\beta + \varepsilon_{it} \tag{2.4}$$

With, μ_{it} designate the mean of the distribution, linked to the link function $g(\cdot)$. In the case of the variable follow an logistic distribution $g(\mu_{it})$ is equal to $\log\left(\frac{\mu_{it}}{1-\mu_{it}}\right)$ and with Poisson distribution is equal to $\log(\mu_{it})$. We add two type of regressors, a vector of explanatory variables X_{it} and time specific fixed effects α_t.

Based on this, Croissant and Millo (2019) developed an extension of the GLM model for panel data for account variables and for binomial variables and particularly logit and probit model, matched with the *PGLM* on R package (Croissant, 2021). This package allows modelling of panel models using binomial and Poisson models, with the function estimated by maximising the likelihood associated with the function.

2.4 Results

2.4.1 Distribution between zoning group

Table 2.2 represents the distribution of farmers in the LPIS database, according to their location in relation to a WCA. Note that a farmer is associated with the group closest to the catchment area as soon as he farms at least one parcel in this zone. For example, if a farmer farms one parcel in zone *]0; 1] km* and the rest in zone *+10km*, this farmer is assigned to group *]0; 1] km*. This table shows that the number of farmers impacted by the WCA policy increased significantly from 10.7% of farmers to 17.5% over the period, while the number of farmers decreased by 8%.

First, we will examine the effectiveness of the control group formed using the spatial RDD method. To do this, we will compare the characteristics of the treated and control groups to ensure their homogeneity, and thus demonstrate the elimination of selection bias linked to the treatment. According to the table 2.3, we can compare the means of each group by testing the significance of this difference using the method *Standard Mean Difference* (Austin, 2009; Flury and Riedwyl, 1986). There are significant differences in farm characteristics between the treated and untreated groups, but the control methods based on the WCA border help to limit them. Indeed, farmers with land in WCA are on average larger than the other groups. They are 38 hectares larger than the *+10km* group, but only 10 hectares more than the *1km* group. We also note that the treated farms have less grassland than the rest of the farmers (27% vs. 30% for the *group 1km* and 40% for the *group +10km*). As for the organic share, there is no significant difference among the groups, with a

	2016	2017	2018	2019	2020	2021
Farmer in WCA	10.7%	13.0%	13.5%	13.8%	17.5%	17.5%
]0;1]km	3.0%	3.7%	3.8%	3.9%	5.3%	5.3%
]1;2]km	2.7%	3.3%	3.4%	3.5%	4.6%	4.6%
]2;5]km	7.7%	9.1%	9.3%	9.5%	11.9%	11.9%
]5;10]km	11.5%	13.4%	13.6%	13.8%	16.1%	16.1%
+ 10km	64.4%	57.5%	56.4%	55.5%	44.7%	44.7%
# Total farmers	346189	337584	330415	325557	322213	318342

The value represents the share of farmers operating in each area as a function of distance from a WCA, at period t (in column). A farmer is associated with a group "Farmer in WCA" if he farms at least one of his parcels in a WCA.

Table 2.2: Distribution of farmers by distance from WCA and year

margin of error of 10%. This varies according to the group between 8 and 10% of the zone. To sum up, we can see in the figure 2.6 (on appendix.2) that the *+10km* group appears very different from the treated group. Our group control strategy therefore reduces the selection bias associated with treatment.

Group	WCA	]0;1km]	]1;2km]	]2;5km]	]5;10km]	+10km
Org practice	0.08	0.09	0.1	0.1	0.1	0.09
		(0.02)	(0.05)	(0.06)	(0.07)	(0.01)
#Conv area	102.5	91.33	83.42	80.22	73.59	64.1
		(0.11)	(0.19)	(0.23)	(0.3)	(0.37)
#Area	108.94	98.02	89.86	86.47	79.8	70.07
		(0.11)	(0.19)	(0.23)	(0.31)	(0.38)
#Org area	6.44	6.69	6.45	6.25	6.22	5.97
		(0.01)	(0)	(0.01)	(0.01)	(0.02)
#Perm grass	19.41	22.38	20.93	21.52	22.08	23.58
		(0.08)	(0.04)	(0.06)	(0.07)	(0.11)
#Temp grass	3.75	3.45	3.25	3.5	3.78	5.08
		(0.03)	(0.05)	(0.02)	(0)	(0.12)
#grassland	23.16	25.82	24.18	25.02	25.85	28.66
		(0.07)	(0.03)	(0.05)	(0.07)	(0.13)
#crops different	5.67	5.42	5.2	5.08	4.87	4.38
		(0.09)	(0.17)	(0.21)	(0.29)	(0.47)
#Permanent Cover	9.42	7.83	6.88	6.39	5.37	3.45
		(0.1)	(0.16)	(0.19)	(0.26)	(0.41)
% grassland	0.27	0.3	0.32	0.34	0.38	0.4
		(0.1)	(0.14)	(0.2)	(0.31)	(0.36)
% Permanent Cover	0.07	0.06	0.06	0.05	0.05	0.05
		(0.1)	(0.15)	(0.18)	(0.25)	(0.19)
#water restriction	2.2	2.01	2.14	2.19	2.18	2.16
		(0.05)	(0.02)	(0)	(0.01)	(0.01)
Max lvl water restriction	1.3	1.34	1.4	1.45	1.46	1.43
		(0.02)	(0.05)	(0.08)	(0.08)	(0.07)
#Obs	269939	78327	68794	185023	262698	1152921

The value represented for each group (in columns) is the mean value for each variable (in rows). The value of the standard mean difference between the WCA group and the other control groups is given in brackets.

Table 2.3: Group difference over the period 2016-2021: Mean and standard mean difference between group WCA (summary graph in appendix 2, fig.2.6)

2.4.2 Water catchment level

We analyse the effects of the WCA policy on farming practices across the zone by examining the results of Group-Time average treatement effect by the staggered did in the table 2.4. First, we look at the lines ”2017-2021” which refers to the aggregated Group-Time Average Treatment Effect, i.e. the average impact of treatment, depending on the year of WCA delimitation, in different farming practices. As our LPIS data only covers the period 2016-2021, we must exclude groups that were treated in 2016 and 2021, since we lack information on the share of organic products before treatment (2016) and after treatment (2021).

First we look at the aggregated Group-Time Average Treatment Effect (line 2017-21). It can be seen that the change in organic land in the areas where the WCA policy began in 2017 (Group 2017) and 2018 (Group 2018), i.e. 128 areas (98 in 2017 and 30 in 2018), was lower than in the control areas by around 2%. The WCA delimited in 2019 (Group 2019) and 2020 (Group 2020), showed a similar trend to those of the neighbouring control areas.

We can go even further by looking at the results of the Group-Time Average Treatment Effects (fig.2.3 and coefficients table on 2.4). In the disaggregated results, we can see that for the 2017 and 2018 groups, the OF development trends diverged between the WCA and control zones. The dynamics of OF in control areas were more significant. This gap between WCA and control zone increasing over time. In contrast, for the group treated in 2019 and 2020, the organic share follows the same trend as the control group. We will test the sensitivity of the effect to group changes in the section 2.5.1.

Table 2.4: Group-Time Average Treatement Effect

	Organic farming (%)	Grassland (%)	Perm Grassland (%)	Temp Grassland (%)	Perm cover (%)
Group 2017					
2017	n.s	n.s	n.s	n.s	-0.01$^{\cdot}$
2018	-0.009***	n.s	-0.016***	0.021***	n.s
2019	-0.015***	n.s	-0.015***	0.022***	n.s
2020	-0.023***	n.s	-0.015***	0.021***	n.s
2021	-0.028***	n.s	-0.016***	0.023***	n.s
2017-21	-0.015***	n.s	-0.012***	0.017***	n.s
Group 2018					
2017	n.s	-0.006**	-0.003*	n.s	n.s
2018	-0.009***	n.s	-0.016***	0.025***	-0.02*
2019	- 0.018***	n.s	-0.019***	0.021*	n.s
2020	-0.021***	n.s	-0.022***	n.s	n.s
2021	-0.03***	n.s	-0.018***	n.s	n.s
2017-21	-0.018***	n.s	-0.019***	0.02$^{\cdot}$	n.s
Group 2019					
2017	-0.002$^{\cdot}$	-0.004*	n.s	n.s	n.s
2018	n.s	n.s	-0.014*	0.019***	n.s
2019	n.s	n.s	-0.004	n.s	n.s
2020	n.s	n.s	n.s	n.s	n.s
2021	n.s	n.s	n.s	n.s	n.s
2017-21	n.s	n.s	n.s	n.s	n.s
Group 2020					
2017	-0.005***	n.s	0.003*	-0.005*	n.s
2018	n.s	n.s	-0.01***	0.014***	-0.018**
2019	n.s	n.s	0.003***	-0.003**	n.s
2020	n.s	n.s	n.s	n.s	n.s
2021	n.s	n.s	n.s	n.s	n.s
2017-21	n.s	n.s	n.s	n.s	n.s

Coefficient associated to the Group-Time average treatement on different practices (in column) between the group of WCA delimited in year g and all neighbourhood control group]0; 10]km from WCA, at the time t (in rows). Line 2017-2021 refers to the Aggregate Group - Time effect for the group g. Non-significant differences are reported like this "n.s". The thresholds of the significant difference of the means is represented by : $^{***}p < 0.001$;$^{**}p < 0.01$;$^{*}p < 0.05$; $^{\cdot}p < 0.1$

As regards changes in other practices (proportion of permanent cover and grassland) in the treated areas, the table 2.4 shows that there is no difference with the

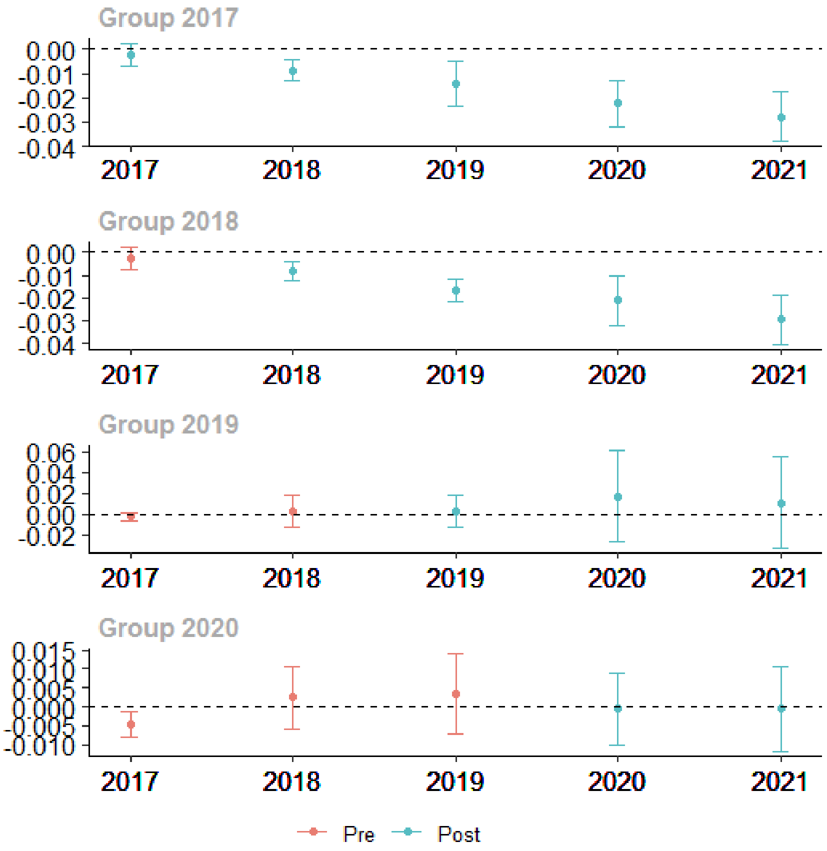

Figure 2.3: Percentage of Organic Farming by year of policy implementation, produced with the *did* package in R (Callaway and Sant'Anna, 2021)

control areas. However, if we disaggregate the grasslands between permanent temporary grasslands (established for more than 7 years), we see a greater growth in temporary grassland in the 2017 and 2018 WCA groups compared to the control groups. At the same time, there is a corresponding decrease of similar magnitude in the share of permanent grassland. Indeed, when considering the aggregated Group-Time Average Treatment Effect (line 2017-2021), there is a 2% smaller difference in permanent grassland between the treated group in 2018 and the untreated group. Conversely, there is a positive difference of 2% in temporary grassland for the treated group in 2018 compared to the untreated areas (similar results for the treated group in 2017).

2.4.3 Farmers level

To confirm the results obtained at the WCA level, we are changing the gradient to observe farmers' behaviour. Over the period from 2016 to 2021, we will study how the treatment affects farming practices. We will use control groups constructed by geographical borders to compare the behaviour of neighbouring farmers.

Table 2.5: Panel GLM with logit distribution on the period 2016-2021: likelihood of organic farming conversion

	Organic Farming Odd ratio
log(Area)	2.63***
log(Area^2)	0.86***
Location (ref=+10km)	
WCA	0.97*
]0;1km]	1.05***
]1;2km]	1.12***
]2;5km]	1.14***
]5;10km]	1.16***
Commitment: % UAA on WCA	0.97$^{\cdot}$
Weight: Max % WCA	5.14***
Water restriction (ref= none)	
Level 1	1.15***
Level 2	0.89***
Level 3	1.16***
Level 4	1.02*
# of water orders	1.01***
(Intercept)	0.02***
Lag water restriction	T
Estimator	Random
#Obs	2017702

Odd ratios, $\exp^{\beta}$ calculated from the coefficients of the Panel GLM model with logit distribution on farming practice (1 = organic farming), obtained using the *pglm* package on R (Croissant, 2021). The p-value is represented according to these thresholds: $^{***}p < 0.001$,$^{**}p < 0.01$,$^{*}p < 0.05$

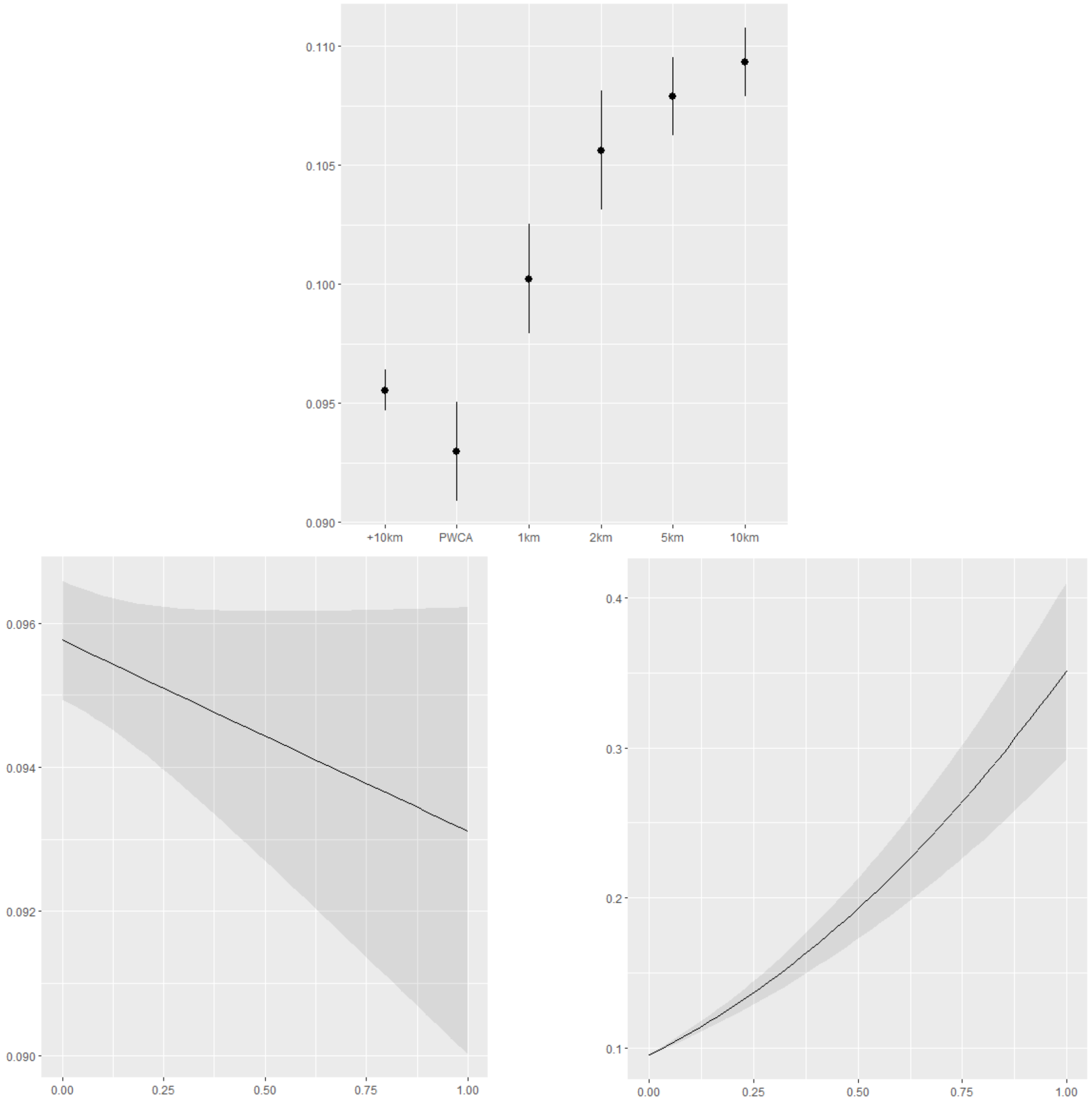

Figure 2.4: Marginal Effects of Group Location (Top) and Commitment (Left) and Weight (Right) on the likelihood of farming organically

Table 2.5 depicts the factors influencing organic practices. The specifications enable us to examine farm-level changes that have influenced the probability of transitioning to organic farming. Odds ratios serve to interpret coefficient results by comparing the probability of the dependent variable being equal to 1 (organic farmer) to the probability of it being equal to 0 (conventional farmer). For the variable *log(Area)*, we find a decreasing positive relationship between the probability of practising organic farming and the size of the farm. It is also worth noting that farmers who are subjected to water restrictions have an increased chance of converting to OF, except in the case of level 2 restrictions. Water restrictions can encourage farmers to rethink their farming practices, especially towards more environmentally friendly methods such as organic farming.

Regarding the influence of a farm location on the likelihood of farming organically, it appears that those who farm land in WCA have a 3% lower probability of farming organically than farmers who farm more than 10 km from the WCA border. However, the other control groups located between]0; 10km] from the border have a significantly higher probability of transitioning to OF than farmers in WCA (graph at the top of fig.2.4).

Regarding the *Weight* variable, we observe a substantial impact, indicating that a farmer occupying all the farmland of a specific WCA is four times more likely to practice organic farming compared to a farmer occupying none of it. However, in the dataset, the average of the *Weight* variable is 1.5% (with a median of 0.2%). Therefore, as illustrated in Fig. 2.4), for low levels of the *Weight* variable, there is no significant difference in the probability of transitioning to organic farming among farmers in WCA. The level of *Commitement* not affect also the probability to convert. Overall, farmers affected by the WCA policy are less likely to farm in OF.

We also observe the evolution of grassland regarding the farmer position. Table 2.6 refers to the GLM regression with Poisson distribution by within estimator with two ways fixed effects. The effect of the farm size indicates that an increase of 1% lead to increase the number of permanent and temporary grasslands by 1 ha, with a marginal decrease with the number of areas. We can also see that, *ceteris paribus*, if the farmer moves from a situation where they is more than 10km from a WCA, to a situation where they is either in a WCA or nearby (up to 10km), his number of grasslands will increase slightly (by 0.1 ha). This increase is mainly characterized by an increase in the number of temporary grasslands. But this increase is not of the same magnitude depending on the zone. Farmers operating within or near WCA (between 0 and 1 km) increase their temporary grassland by approximately 0.6 hectare, compared to 0.3 hectares in zones]2, 10] km, if the farmer was more than 10 km away from a WCA in the previous period.

Table 2.6: Panel GLM with poisson distribution and Two-Way Fixed Effects: *within* estimator

	Grassland	Temp Grassland	Perm Grassland
log(Area)	1.18***	1.4***	1.15***
log(Area^2)	-0.02***	-0.06***	-0.02***
Location (ref=+10km)			
WCA	0.01***	0.05***	0
]0;1km]	0.01***	0.06***	-0.01
]1;2km]	0.01**	0.03***	0
]2;5km]	0.01***	0.03***	0
]5;10km]	0.01***	0.01***	0.01***
Commitment	0	-0.02***	0
Weight	0	0.33	-0.02$^{\cdot}$
Water restr	T	T	T
#N	367915	367915	367915
#Obs	2017702	2017702	2017702

Coefficients estimated by the Panel GLM model with Poisson distribution on number of grassland area (in ha), obtained using the *pglm* package on R (Croissant, 2021). The p-value is represented according to these thresholds: $^{***}p < 0.001$,$^{**}p < 0.01$,$^{*}p < 0.05$

2.5 Robustness analysis

We are conducting three further analyses to verify the effects obtained at WCA and farmer level. First, we will test the sensitivity of the results, obtained by the staggered did, to the change of control groups. Secondly, we will include the AES variable in the analysis at farmer level, to see whether this instrument explains the effects of the WCA policy. Finally, we will test the impact of the WCA policy on the probability of remaining in organic farming, based on a survey of 726 organic farmers.

2.5.1 Sensitivity of Group-Time effect to the control group

We test the robustness of the effects, obtain at WCA level, to changes in the control groups. To do this, we compare the g treated group with only the subgroup of controls linked to the g treated group. In others terms, we exclusively compare the farming practices on a WCA delimit in the year 'g' with those of their neighbours, without considering neighbouring areas of all WCA. For example, in the case of the '2017' group, we compare dynamics of farming practice in the 98 WCA delimit in 2017 with the 98 control zones located within 0 to 10 km. In addition, we examine the heterogeneity of the effect as a function of proximity to the control group, testing each type of control group separately:]0; 1km],]1; 2km],]2; 5km], and]5; 10km]. This analysis aims to highlight heterogeneous effects linked to distance, and spatial spillover effects resulting from the WCA policy.

According to table 2.7, there is no difference in the dynamics of OF between the groups treated in 2017 and 2018 with their closest control groups [0; 1]km,[1; 2]km. Whereas, there is a lower evolution of OF in the WCA compared to the control groups]2;5km] and [5,10km] (around -0.7%).

In Appendix 3, we test the sensitivity of the Group-Time effect to changes in other agro-ecological practices (share of grassland and permanent cover). The results are similar to those obtained in the main analysis for the share of grassland. However, we can see that the effect on the proportion of permanent grassland is heterogeneous depending on the control group chosen. The dynamics of the WCA group delimited in 2017 and 2018 differ significantly from those of the control groups furthest away ([5;10 km]). The dynamic of the WCA is similar to that of the other nearby control groups ([0;2 km]).

In the end, we find that in most cases, changes in farming practices between the WCA group and neighboring areas up to 2 km away follow the same trends. This result allows us to suspect a spillover effect of the policy on land within 2 km of the WCA boundary. There are two possible explanations for this phenomenon. Firstly, some of the land adjacent to the WCA belongs to farmers involved in the WCA policy. Secondly, the actions implemented in the WCA may also benefit farmers adjacent to the WCA.

Table 2.7: Average treatment group-time effect in the share of organic farming: Sensitivity Analysis with Control Group

	Control group				
Organic farming	[0; 1]km	[1; 2]km	[2; 5]km	[5; 10]km	[0; 10]km
Group 2017					
2017	-0.001	0.001	-0.004*	-0.001	0
2018	-0.003	-0.003	-0.005	-0.004**	-0.004*
2019	-0.001	-0.005	-0.007*	-0.005	-0.005
2020	-0.001	-0.006	-0.008$^{\cdot}$	-0.007*	-0.007$^{\cdot}$
2021	-0.001	-0.006	-0.001	-0.008*	-0.007$^{\cdot}$
Group 2018					
2017	0.004	0	0	0	0
2018	-0.013	-0.016	-0.005*	-0.003*	-0.01
2019	-0.016	-0.02	-0.007**	-0.007**	-0.014$^{\cdot}$
2020	-0.018	-0.021	-0.005	-0.005	-0.013
2021	-0.021	-0.019	-0.01*	-0.009*	-0.014$^{\cdot}$
Group 2019					
2017	-0.001	0	-0.001	-0.003	-0.001
2018	-0.002	-0.006	-0.004	-0.001	-0.005
2019	0	-0.004	0.001	0.001	-0.001
2020	0.012	0.01	0.016	0.015	0.013
2021	0.007	0	0.012	0.007	0.006
Group 2020					
2017	-0.005*	-0.006***	-0.003**	-0.004***	-0.004***
2018	0.004	0.003	0.005$^{\cdot}$	0.005$^{\cdot}$	0.004
2019	0.001	0.002	0.002	0.003	0.002
2020	0.001	-0.001	0.001	0	0
2021	0.003	-0.001	0.001	0.001	0

Coefficient associated to the Group-Time average treatement on the share of organic farming between the group of WCA delimited in year g and the neighbourhood of group g at n km from the WCA (in columns), at the time t (in rows). The thresholds of the significant difference of the means is represented by: $^{***}p < 0.001$;$^{**}p < 0.01$;$^{*}p < 0.05$; $^{\cdot}p < 0.1$

2.5.2 Impact of AES on farming practice

To understand the differences in changes in farming practices between WCA, here we will look at the extent to which the possibility of a farmer in a WCA contracting an AES has led to changes in farming practices on his farm.

We will focus on three specific types of AES proposed on the basis of the framework of agri-environmental and climate measures proposed by the "second pillar" of the CAP: *Localised AES Surface*, *Localised AES Linear* and *Herb and Pasture System AES* (HPS AES). The first two are located AES; the farmer can only commit to agricultural land located in the problematic area (WCA, Natura 2000). The variables *Loc AES Surface* and *AES loc linear* indicate whether the farmer has contracted at least one plot or at least 1 metre (hedges) for a localised AES. We do not know what conditions were attached to these contracts. However, since they concern water quality, we can assume that they include a reduction in the use of pesticides and chemical fertilisers, the creation of grassland, and crop diversity. The third type of contract is the *HPS AES*, under which the farmer commits its entire farm to respect the conditions for maintaining these areas already under grass, as well as the non-use of phytosanitary treatments on these grasslands.

Table 2.8, shows that 42.2% of WCA have at least one localised AES surface, while the other two types of AES are less widespread. In the WCA at least one with AES, the average proportion contracted is marginal: 7.5% and 14.5% for Localised AES Surf and HPS AES, respectively.

AES type	Loc Surface	Loc Linear	HPS
% WCA with at least 1 AES	42.2%	10%	13.9%
With at least one AES			
Percentage of farmland in WCA	Mean: 7.5% Median: 3.8%		Mean: 14.5% Median: 6.3%

As localised linear AES is expressed in metres and not in surface area, we cannot calculate the percentage of agricultural land under contract with this type of AES (*Percentage of farmland in WCA*)

Table 2.8: Descriptive Statistics of AES in WCA

Table 2.9: Impact of AES on farming practices, logit and poisson analysis

	Organic Odd ratio	Grassland	Perm Grassland	Temp Grassland
lag(Y)		0.003***	0.003***	0.012***
Localisation (ref=+10km)				
WCA	0.79***	-0.52***	-0.49***	-0.73***
]0;1km]	0.88***	-0.41***	-0.39***	-0.54***
]1;2km]	0.95	-0.39***	-0.37***	-0.52***
]2;5km]	0.95***	-0.36***	-0.35***	-0.43***
]5;10km]	1	-0.26***	-0.26***	-0.28***
Loc AES S	1.37***	0.26***	0.3***	0.08***
Loc AES Lin	1.83***			
HPS AES	0.24***	0.4***	0.5***	-0.5***
WCA * Loc AES S	1.06	-0.05***	-0.1***	0.2***
WCA * Loc AES Lin	1.07			
WCA * HPS AES	2.8***	0.6***	0.6***	0.4***
Control	T	T	T	T
Others AES	T	F	F	F
Obs	330277	328108	328108	328108
Link function g(·)	Logit	Poisson	Poisson	Poisson

Coefficients estimated by the Logit and GLM Poisson models, respectively on agricultural practices (1 = organic farming) and on the number of grassed areas (in ha); over the 2020 period. Odds ratios are reported for the Logit model. The p-value is represented according to these thresholds: $^{***}p < 0.001$,$^{**}p < 0.01$,$^{*}p < 0.05$

Table 2.9 presents the impact of AES on farmers' grassland areas and their likelihood of practising organic farming, for year 2020. This analysis is conducted using logit regression for the organic specification and Poisson regression for the other specifications. Regarding the impact of localised AES surface and linear, the results indicate that the probability of transition to OF for a farmer contracting a localised AES is greater by 37% to 83%. This effect is the same in WCA as in other zones where this type of AES is implemented (e.g. Natura 2000 zones). Regarding the evolution of grassland, it is noted that the number of all types of grassland increases among farmers who contract localised AES surface. The result linked to the interaction variable between being in a WCA and contracting localised AES surface aid is very interesting. It confirms what was found in the main analysis: in WCA, the number of temporary grasslands increase, at the expense of the number of permanent ones.

We also note that when farmers contract HPS AES, their total number of grasslands increases, while the number of temporary grasslands decreases. This result is logical because the purpose of the subsidy is to maintain existing grassland without creating new ones. The table shows that farmers who sign an HPS AES are less likely to become organic than other farmers. This result can be explained by other unobserved characteristics. To contract this type of AES, the farmer must have at least 10 LU (livestock units) of grazing livestock on the farm. In France, only 5.8% of livestock is organic, while 11% of land is organic, meaning that livestock farmers are less likely to convert. This explains this estimate. However, we can see that when a farmer with land in a WCA contracts an HPS AES, their probability of converting to OF increases. This farmer is twice as likely to practise organic farming as one in a WCA who does not contract with an HPS AES. This result should be treated with caution, since this aid is only available in less than 15% of WCA and may be correlated with other unobserved variables related to livestock farming, such as the location of these farms in specific geographical areas. This could explain the impact on the development of organic farming.

2.5.3 Influence of WCA on the maintenance of OF: study in the *Grand-Est* region

Finally, we decided to complete our analysis by focusing on the impact of WCA policy on remaining in OF. To do so, we examined the data collected during a survey conducted by the French Chambers of Agriculture in the 'Grand Est' region between 2021 and 2022. This survey targeted farmers engaged in OF between 2016 and 2019 in Grand Est. More precisely, this survey was conducted from March 2021 to March 2022, with respondents able to answer either online or by telephone. Multiple reminders were sent, resulting in responses from 726 farmers, with a response rate of 59%. The survey consisted of 25 questions exploring the sustainability of organic farms.

Of the respondents, 12.8% expressed a *Very likely* or *Maybe* intention to stop OF practice, and 7.5% expressed a *Very likely* or *Maybe* intention to reduce their agricultural land area. Additionally, 25.9% of respondents cultivate at least one land in WCA.

Table 2.10: Decision to Stop or Reduce Organic Farming Activity - Logit Analysis with Odds Ratio

	Stop (1)	Reduce (2)
Farmer in WCA	2.29	2.75
#Area	1	1
# Employee	1	1.04
Main reason for conversion		
Environmental motivation	0.57	0.54
Health motivation	0.7	0.53
Organic network	0.36	0.32
Distribution Channel (ref: Short channel)		
Short & Long	1.34	0.47
Long	2.27	1.31
Intercept	0.24	0.25
# Obs	617	619
% True Prediction:0	89.6%	91.8%
% True Prediction:1	3.1%	4%

Coefficients estimated by the Logit model, on the decision to *stop* organic farming (1 = stop, 0 = continue in OF), and on the decision to *reduce* the amount of land (1 = reduce, 0 = maintain the same area in the OF). Based on the responses of 726 organic farmers (converted after 2016) located in the *Grand-Est* region from March 2021 to March 2022. Odds ratios are reported. The p-value is represented according to these thresholds: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$; $\cdot p < 0.10$

To assess the impact of being located in a WCA on the likelihood of remaining on OF, we will use a logit model to analyse the intention to either stop or reduce OF. Table 2.10 indicates that farmers who have transitioned to organic farming for environmental reasons (variable *Environmental motivation*) and who maintain contact with other organic farmers (variable *Organic Network*) are more likely to stay in organic farming. The results also show that organic farmers in WCA on the Grand Est region are twice as likely to reduce or stop their organic farming compared to those outside WCA. This confirms that farmers in WCA have access to instruments that may discourage them from practising OF.

2.6 Discussion

The study shows that the WCA policy has slowed the development of OF in the target areas compared to neighbouring areas. The main explanation for this phenomenon is the timing of the policy's implementation, which creates windfall effects for farmers. The study showed that in the treated areas, without the WCA policy, the proportion of organic produce would have been 2% higher (the proportion observed in the control areas). This result can be explained by the fact that the policy was partially implemented between 2016 and 2019, a period of significant growth in organic land in France (17% annual growth in certified organic land). Under this policy, farmers with land in WCA had access to various measures, including AES. This allowed them to receive additional subsidies by changing their farming practices without having to convert to OF, for example by reducing pesticide use and increasing the number of hedgerows. However, neighbouring farmers who are not located in WCA do not have access to these measures. They are therefore more inclined to convert to OF if they are looking for additional subsidies.

Another explanation for the low level of development of agri-environmental practices in WCA may be the low level of knowledge among farmers about the schemes available to them. A relatively small proportion of land under AES contracts in WCA suggests that few farmers are actively engaged in the policy and are not aware of how they can make environmental efforts by adjusting their practices to meet environmental objectives. To confirm these hypotheses, a survey among farmers in WCA should be conducted to assess their level of awareness of WCA policy and measures.

2.7 Conclusion

In this chapter, we have observed the evolution of farming practices in areas targeted by the Water Catchment Area policy. Specifically, we have examined the evolution of practices highlighted in Barrez et al. (2012) such as OF practices, the number of grasslands, and the practice of permanent cover. We have compared these dynamics with those of neighbouring areas to eliminate the policy's selection bias.

The WCA policy has slowed down the dynamic of the OF development. Firstly, at the WCA level, there is a 2% difference in growth rates between WCA delimited from 2017 to 2018 and neighbouring areas. Secondly, when we test each control groups separately (table 2.7), we find that there is no difference in dynamics between the treated and nearby neighbouring areas (up to 2km). This suggests a spatial spillover effect of the policy on nearby neighbouring areas.

Our results at the WCA level are also confirmed at the farmers level. Farmers affected by the policy are about 15 percentage points less likely to farm organically than neighbouring farmers (within a 10-kilometre radius of the WCA). In contradiction with our hypotheses, the two measures of WCA policy intensity on the farmer, measured by the variable *Commitment* and *Weight*, do not affect the probability of transitioning from conventional to organic farming. The negatives impact of the WCA policy are also apparent in a more qualitative approach on the scale of the Grand Est region. A study of 726 organic farmers showed that those farming in WCA had a higher probability of returning to conventional farming.

To explain this result, we suggest that the measures implemented in the AES created windfall effects for farmers. They were not motivated to change their practices completely by going organic. However, farmers in neighbouring areas have followed the national organic development trend from 2016 to 2020.

In terms of the other practices studied, it appears that there are more new grasslands in WCA compared to neighbouring areas. However, the various analyses carried out show that this increase is at the expense of the number of permanent grasslands. The analysis considering AES shows that if a farmer operates in a WCA and contracts an AES, they will increase the number of new grasslands, but decrease the number of older grasslands (more than 7 years old). Therefore, it seems that farmers respect AES by compensating for new grassland by farming old grassland.

2.8 Appendix

Appendix 1: Average Treatement on the treated group effect by year

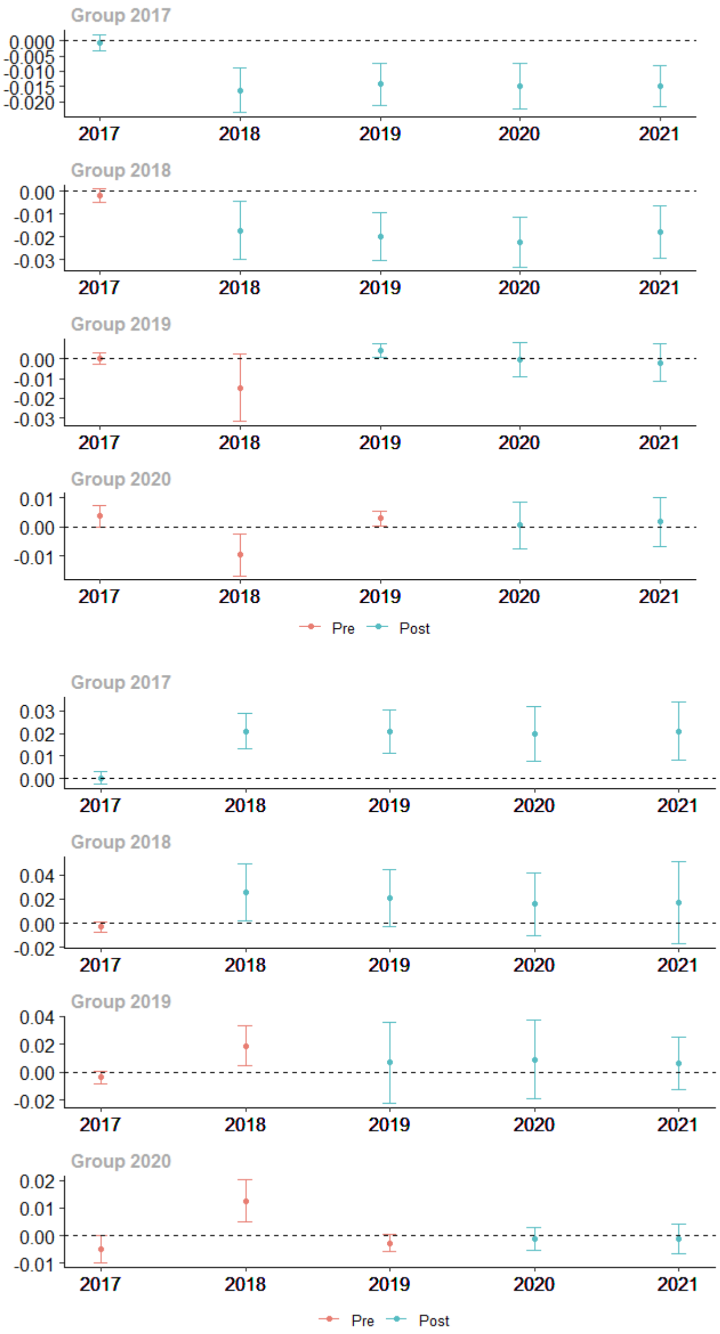

Figure 2.5: Percentage of % permanent grassland (Top) and % temporary grassland (Bottom) by year of policy implementation

Appendix 2: Standard Mean difference graph

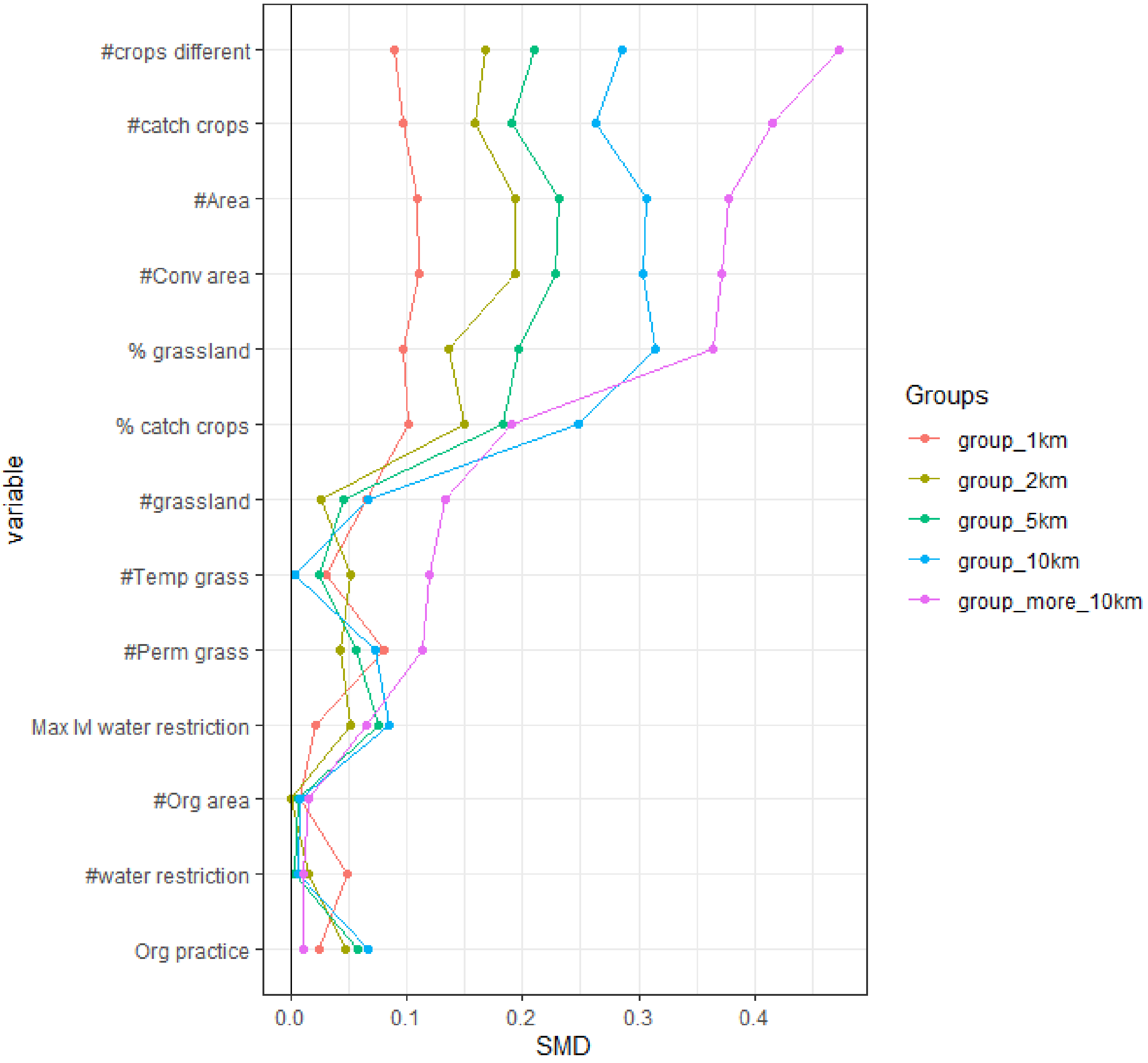

Figure 2.6: Standard mean difference between group WCA and controls groups (coefficients reported in table 2.3)

Appendix 3: Sensitivity of Group-Time effect: Average treatment

	[0; 1]km	[1; 2]km	[2; 5]km	[5; 10]km	[0; 10]km
Group 2017					
2017	0	0	0	0	0
2018	0.003	0.002	0.003	0.003	0.003
2019	0.004	0.003	0.004	0.006*	0.004
2020	0.004	0.002	0.005	0.006	0.003
2021	0.003	0	0.006	0.008·	0.003
Group 2018					
2017	0.001	-0.003	-0.005	-0.006**	-0.004
2018	0.001	0.004	0.005	0.006	0.004
2019	-0.004	-0.001	0.001	0	0
2020	-0.007	-0.006	-0.003	-0.004	-0.004
2021	-0.004	0	0.003	0.004	0.001
Group 2019					
2017	-0.002	-0.006	-0.004	-0.005*	-0.005·
2018	0.002	0	0.001	0	0
2019	0.003	0.003	0.007	0.007	0.005
2020	-0.002	-0.005	0.003	0.005	-0.001
2021	-0.009	-0.009	0	0.001	-0.005
Group 2020					
2017	-0.004·	-0.003	-0.001·	0	-0.002
2018	0.002	0.001	0.002	0.001	0.001
2019	0	0.001	0.002	0.002·	0.002
2020	0.001	-0.001	0	0	0
2021	0.002	0.001	0.003	0.002	0.002

Coefficient associated to the Group-Time average treatement in the share of grassland between the group of WCA delimited in year g and the neighbourhood of group g at n km from the WCA (in columns), at the time t (in rows). The thresholds of the significant difference of the means is represented by: $^{***}p < 0.001$;$^{**}p < 0.01$;$^{*}p < 0.05$; $\cdot p < 0.1$

Table 2.11: Average treatment group-time effect in the share of grassland: Sensitivity Analysis with Control Group

	[0; 1]km	[1; 2]km	[2; 5]km	[5; 10]km	[0; 10]km
Group 2017					
2017	0.001	0.001	0	0	0.001
2018	-0.007	-0.004	-0.015	-0.018***	-0.01*
2019	-0.006	-0.003	-0.014	-0.016***	-0.009*
2020	-0.004	-0.003	-0.013	-0.016**	-0.008*
2021	-0.004	-0.004	-0.013	-0.015**	-0.008*
Group 2018					
2017	0.002	0	-0.001	-0.002	0
2018	-0.015	-0.023*	-0.01	-0.012	-0.017*
2019	-0.017*	-0.023*	-0.014*	-0.016*	-0.018**
2020	-0.017$^{\cdot}$	-0.024*	-0.014$^{\cdot}$	-0.016*	-0.019**
2021	-0.015	-0.022*	-0.011	-0.012	-0.016*
Group 2019					
2017	0.001	0	0	0.001	0
2018	-0.014	-0.018	-0.018	-0.02	-0.018
2019	0	0.001	0.002	0.003$^{\cdot}$	0.001
2020	-0.006$^{\cdot}$	-0.005	-0.004$^{\cdot}$	-0.003	-0.004
2021	-0.008$^{\cdot}$	-0.008$^{\cdot}$	-0.006$^{\cdot}$	-0.005	-0.007$^{\cdot}$
Group 2020					
2017	0.001	0.002	0.004	0.005**	0.003
2018	-0.009*	-0.019***	-0.009*	-0.011**	-0.014***
2019	0.002$^{\cdot}$	0.003**	0.003$^{\cdot}$	0.004***	0.003***
2020	0.002	0.001	0.002	0.002	0.002
2021	0.003	0.003	0.004	0.004	0.004

Coefficient associated to the Group-Time average treatement in the share of permanent grassland between the group of WCA delimited in year g and the neighbourhood of group g at n km from the WCA (in columns), at the time t (in rows). The thresholds of the significant difference of the means is represented by: $^{***}p < 0.001$;$^{**}p < 0.01$;$^{*}p < 0.05$; $^{\cdot}p < 0.1$

Table 2.12: Average treatment group-time effect in the share of permanent grassland: Sensitivity Analysis with Control Group

	[0; 1]km	[1; 2]km	[2; 5]km	[5; 10]km	[0; 10]km
Group 2017					
2017	0.001	0.002	0.002	0.001	0.002
2018	0.028**	0.039***	0.022**	0.023***	0.03***
2019	0.027**	0.035**	0.023**	0.025***	0.029***
2020	0.025**	0.032**	0.022**	0.024***	0.027***
2021	0.026**	0.032**	0.024**	0.026***	0.028***
Group 2018					
2017	-0.003	-0.004	-0.004	-0.004*	-0.004
2018	0.02	0.03*	0.015	0.018	0.023*
2019	0.017	0.025*	0.014	0.016	0.02·
2020	0.014	0.02	0.011	0.012	0.016
2021	0.014	0.022	0.013	0.015	0.018
Group 2019					
2017	-0.002	-0.004	-0.004	-0.005*	-0.004
2018	0.024	0.039·	0.019	0.021	0.029*
2019	0.001	0	0.004	0.004	0.002
2020	0	-0.004	0.006	0.007	0.001
2021	-0.005	-0.004	0.006	0.006	0.001
Group 2020					
2017	-0.005*	-0.003	-0.004*	-0.005*	-0.004*
2018	0.01**	0.022***	0.012**	0.013***	0.017***
2019	-0.003·	-0.004**	-0.001·	-0.001	-0.003*
2020	-0.001	-0.003·	-0.002	-0.002	-0.003
2021	-0.002	-0.003	-0.002	-0.003	-0.003

Coefficient associated to the Group-Time average treatement in the share of temporary grassland between the group of WCA delimited in year g and the neighbourhood of group g at n km from the WCA (in columns), at the time t (in rows). The thresholds of the significant difference of the means is represented by: $^{***}p < 0.001$;$^{**}p < 0.01$;$^{*}p < 0.05$; $\cdot p < 0.1$

Table 2.13: Average treatment group-time effect in the share of temporary grassland: Sensitivity Analysis with Control Group

	[0; 1]km	[1; 2]km	[2; 5]km	[5; 10]km	[0; 10]km
Group 2017					
2017	-0.007	-0.015$^{\cdot}$	-0.009	-0.01$^{\cdot}$	-0.012*
2018	-0.046***	-0.07***	-0.028***	-0.026**	-0.049***
2019	-0.042***	-0.07***	-0.026***	-0.023**	-0.048***
2020	-0.04***	-0.066***	-0.023***	-0.021*	-0.045***
2021	-0.037**	-0.064***	-0.022**	-0.019$^{\cdot}$	-0.043***
Group 2018					
2017	0.005	0.009	0.012	0.013	0.011
2018	-0.037*	-0.056**	-0.035*	-0.037**	-0.045***
2019	-0.037$^{\cdot}$	-0.057**	-0.029$^{\cdot}$	-0.029*	-0.043**
2020	-0.035$^{\cdot}$	-0.066**	-0.033$^{\cdot}$	-0.03*	-0.049**
2021	-0.025	-0.045$^{\cdot}$	-0.018	-0.016	-0.032$^{\cdot}$
Group 2019					
2017	-0.007	-0.008	-0.001	-0.003	-0.004
2018	-0.022	-0.038$^{\cdot}$	-0.009	-0.002	-0.024$^{\cdot}$
2019	0.001	-0.003	-0.003	-0.001	-0.003
2020	0.009	0.008	0.003	0.001	0.006
2021	0.007	0.007	0.003	0.002	0.005
Group 2020					
2017	0.002	-0.005	-0.004	-0.003	-0.004
2018	-0.002	-0.004	0.007	0.006	0.001
2019	-0.004	-0.005	-0.01	-0.009	-0.007
2020	0.002	0.005	0.01	0.009	0.008
2021	-0.002	0.001	0.002	-0.001	0.001

Coefficient associated to the Group-Time average treatement in the share of permanent cover between the group of WCA delimited in year g and the neighbourhood of group g at n km from the WCA (in columns), at the time t (in rows). The thresholds of the significant difference of the means is represented by: $^{***}p < 0.001$;$^{**}p < 0.01$;$^{*}p < 0.05$; $^{\cdot}p < 0.1$

Table 2.14: Average treatment group-time effect in the share of permanent cover Sensitivity Analysis with Control Group

Chapter 3

A premium for organic farmland

Summary of the chapter

The European ”Green Deal” set a target of 25% organically farmed land by 2030 (only 8.5% by 2022). To achieve this objective, we are looking for other sources of income generated by the conversion to organic farming. In this chapter we test the existence of a ”premium” for organic farmland. In this study, we compare the sales prices of 569,162 farmlands sold between 2015 and 2021 in France (44,302 of which are organic). The hedonic price method, which controls for Ricardian and residential rent, shows that organic land sells for less than conventional land. To control for endogeneity between soil characteristics and farming practices, we perform two types of matching (based on propensity score and geographical distance minimisation). The results show that organic land sells for even lower prices at slightly lower prices (-2.4%) than the same conventional land. This can be explained by a spatial mismatch between the supply and demand of organic land. Over the period 2015-2021, an organic farmer seeking for farmland could find a conventional opportunity at a distance about 3.3km from his farm and 8.1km for an organic opportunity (a difference of 4.8km).

3.1 Introduction

Organic farming has experienced significant growth in France since the 2010s, coinciding with an increase in demand for organic products. There are two ways to expand organic supply. One is by converting conventional land into organic farming, and the other is by acquiring existing organic land. While the conversion of agricultural land to organic farming usually takes two to three years[1], in the former case, if the farm meets organic standards, it can immediately begin producing organically. Therefore, it is reasonable to expect that land immediately suitable for organic production will have a higher market value. Given the scarcity of this type of land, which currently accounts for only 10% of the national total of agricultural land, limited availability in the face of sustained demand should lead to an increase in prices.

Organic farming (OF) responds to the demographic challenge of feeding 9 billion people by 2050 while respecting the environment (Muller et al., 2017). More specifically, according to Barbieri et al. (2021), natural nitrogen makes it possible for OF to occupy 60% of the world's arable land. However, land use will have to increase due to lower yields in OF (between 8 and 25%). Thus, according to Muller et al. (2017), without changes in diet or a reduction in food waste, the occupation of agricultural land will have to increase by at least 33%. According to Helga et al. (2021), only 1.5% of the world's surface area was farmed organically in 2019. The European Green Deal sets a target of 25% of land farmed organically by 2030, compared to 8.5% in 2020. For Latruffe et al. (2013), the main obstacle to conversion is financial. Therefore, it is worth investigating whether concerns about income loss are justified.

To convince farmers who are hesitant to convert for economic reasons, it is essential to find other potential sources of income heterogeneity linked to the conversion to OF. Here we will focus on the agricultural land market in France, to answer the question: Does organic farming increase the value of land ? To do so, we observe differences in land sale prices depending on farming practices.

We hypothesise that there is a premium for the price of organic farmland. Firstly, it is possible to farm organic land directly and avoid the conversion period. Secondly, the acquisition of organic land enables farmers to farm land of better environmental quality than conventional land. High-quality land for organic farming is primarily

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[1] The length of the conversion process depends on the crop (art.17 of Council Regulation (EC) No 834/2007 of 28 June 2007)

due to the absence of pesticides or chemical fertilisers and the increased use of agri-environmental practices (permanent cover,crops diversity, fertilization with compost and green manure).

According to Tuck et al. (2014) and Underwood et al. (2011), land farmed with organic methods has 30% more biodiversity than conventional farms. This is due to the fact that organic land has a richer environmental landscape (hedges and other semi-natural elements) that is conducive to the development of habitats for various species. Additionally, according to Geiger et al. (2010), intensive pesticide and fungicide use on conventional farms reduce biodiversity. The obligation of permanent soil cover in OF makes it possible to improve carbon storage (Gattinger et al., 2012) but also reduces soil erosion (Reganold et al., 1987). Lastly, Sautereau and Benoit (2016) and Lotter et al. (2003), have evidenced organic land's higher water storage capacity, allowing for better yields during drought periods. Thus, organic land's agronomic qualities are intrinsically superior It is interesting to see whether organic land sells for higher prices. In other words, do agricultural land buyers value its environmental assets ? Additionally, for an organic farmer or someone seeking to convert, it is preferable to buy land that is already certified organic, rather than converting the land to organic, because they can immediately begin production under the organic farming label. Therefore, we can assume that some farmers are willing to pay more for organic land because it saves them years of conversion. This chapter aims to determine whether there is a premium for organic farmland on the French agricultural land market.

According to the French Ministry of Agriculture (2022), in 2020, 51% of French farms were owned by at least one farmer aged over 55. This indicates that in the next few years, there will be many retirements, which will in turn increase farmland availability. If there is a premium for organic farmland, farmers will have an interest in converting their land before selling to make a more significant capital gain and thus leave with a greater starting capital for retirement. This rent is often forgotten in profitability calculations.

In this study, we will focus on the case of French agriculture, the EU country that faces the greatest challenges regarding OF. The EU is the world's largest agricultural power, with an estimated production of 418 billion € in 2019 (Eurostat, 2020). This achievement is largely due to France, the leading contributor at 18%. However, among the top four European agricultural producers, France has the lowest organic land ratio (7.5% in 2018, compared to 15.5% for Italy and around 10% for Germany and Spain). This also means that France has the greatest potential for conversion. Another interesting fact is that France is the EU-15 country with the lowest average price for agricultural land. Indeed, in 2019, agricultural land sold at an average price of 6000€, while it was 69,600 € in the Netherlands (Eurostat, 2021). According to Ballet (2021), in 30 years, 7.7% of agricultural land has been artificialised. The decreased availability of land, combined with a growing population and demand for environmentally friendly agricultural products, will increase competition over land. This should in turn lead to higher land prices. Studying the French agricultural land market will allow us to assess the availability of organic and conventional land and their respective prices.

According to Rosen (1974), the price of a property can be broken down into a set of influencing factors; this is the hedonic pricing method. In the case of agricultural land, we separate the factors considered in the Ricardian theory of agricultural rent and those from the residential rent theory. The first refers to Ricardo's theory (Ricardo, 1817), which states that the value of land equals its productivity. The second refers to the value of agricultural land on the day it is sold for residential use (Cavailhès and Wavresky, 2003). The hedonic price method shows that the geographical location of agricultural land influences its price, especially in cases of proximity to urban centres. Other articles have demonstrated that providing recreational services on agricultural lands, such as hunting, increases their value (Henderson and Moore, 2006). Baldoni et al. (2021) and Kilian et al. (2008) show that Common Agricultural Policy funding affects land prices. The effect of this funding on prices depends on the applicable requirements for eligibility. Indeed, coupled aid tends to drive up the price of land. The acquisition of land allows for increased production, leading to an increase in coupled aid for production. Conversely, according to these authors, support linked to agri-environmental measures will have a smaller impact on land capitalisation than CAP coupled and decoupled support. Firstly, the new owner will not automatically receive aid unless they continue with the same agronomic practices. Secondly, agri-environmental schemes are mostly available in areas where the soil or soil characteristics are poor or strongly limit agricultural practices. As such, the availability of agri-environmental subsidies on a plot of land may mean agronomic constraints for the future acquirer, prompting them to reduce their purchase offer. Despite this, the relationship between the improvement of the ecological state of the land, enabled by the OF, and its sale price has been under-researched. The difference in the respective market values of organic and conventional farmland is only addressed in Fuller et al. (2021). This study found that in the United States between 2003 and 2011, organic farmland rental prices exceeded those of conventional land by 26%. In their chapter, this premium seems unjustified because the organic label does not improve the economic situation of farmers. It is based on the willingness of farmers to pay in order to avoid a three-year conversion period.

We will test whether there is a premium for organic farmland by using an original database of 569,162 plot sales (including 44,302 organic plots) made in France between 2015 and 2021. To isolate the marginal effect of organic practice on the price of land, we will control for other determinants already found in the literature (Ricardian rent and residential rent). First, an OLS regression on the entire database allows us to observe the influence of Ricardian rent and residential rent on land prices. Secondly, to eliminate the endogeneity issue between farming practices and land type, we perform two types of matching. The first method uses propensity score matching (PSM) to study the characteristics of the land that seem to influence organic farming. After calculating this propensity score for each parcel sold, we match organic land with conventional land that has the closest propensity score. In other words, we match land with the same probability of being farmed organically. The second method is called distance-based matching; it matches based on minimising the geographic distance criterion between two plots. In other words, we will compare the price of organic plots with the price of the nearest conventional plots sold in the same year. Once we have matched the organic and conventional lands that exhibit the same characteristics (PSM) or is closest and sold in the same year (distance-based matching), we compare their sale prices to assess the effect of organic practices on the selling price.

3.2 Determinants of agricultural land prices

According to Cavailhès and Wavresky (2003), the price of agricultural land corresponds to the capitalisation of future rents. These rents may be of two types: agricultural (income from cultivated land) and residential, which refers to the value of the plot if it were sold for residential use. According to Levesque (2007), this residential rent is 10 to 50 times higher than the sale price for agricultural use in France. There are two possibilities. If the farmer expects that his land can never be converted to residential use (for example, it is too far away from a town), then the price will depend only on future agricultural rents. However, if a conversion to residential use is anticipated, the sale price will depend on the productive and geographical characteristics of the land.

3.2.1 Ricardian rent

First, we must examine the determinants of Ricardian rent. In particular, we will consider how soil and weather conditions affect yields. For Ricardo (1817), the value of a piece of land depends on its ability to produce. Several factors influence productivity and thus land value: weather, soil properties, both physical (slope, altitude, erosion) and chemical (nitrogen and carbon content, etc.), and the type of farming practised on the land (mechanical work, chemical fertilisers).

Currently, in response to environmental issues, the impact of weather conditions on agricultural production is a subject of significant research. In particular, Mendelsohn et al. (1994) first studied the impact of global warming on agricultural production. They found that increased temperatures would result in changes to crops. Indeed, at a given temperature, yields vary depending on the type of crop that is cultivated. Plants that prefer temperate climates are replaced by plants with higher yields during warmer periods[2]. According to this author, the increase in temperature encourages farmers to change their crops to maximise yields. However, the new crop is less profitable in absolute terms than the previous one, which explains the negative relationship between temperature and income.

An analysis of European farms, that models different scenarios[3], found that farms in southern Europe will suffer more from global warming. The global temperature increase will benefit the northern European regions, boosting their production. Conversely, the southern regions, which are already warmer, will see their production decline. As the relationship between agricultural production and temperature is reversed, northern countries converge toward maximum production, while southern countries experience the opposite trend. The seasonal effects of rising temperatures must also be considered, as warming in spring and autumn has a positive effect on agricultural production (extending the harvest period). Warming is detrimental to production in winter and summer: in winter, it increases the risk of disease and pest outbreaks, while relatively cool summers reduce the likelihood of drought. Accord-

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[2] In the article by Mendelsohn et al. (1994), they give the example of wheat, which is replaced by maize and then by pasture as the temperature increases

[3] The article simulates three climate scenarios for the year 2100 based on the IPCC (2000) report.

ing to IPCC (2000), precipitation should increase, allowing for a marginal increase in production due to reduced drought periods. However, increased rainfall during spring and autumn can slow plant growth, especially when sunlight is scarce. Recent work by Bareille and Chakir (2023), shows that on the agricultural land market between 1996 and 2019, increased summer temperatures contributed to an increase in sales prices.

Soil composition also affects yield. The productivity of the soil is mainly a result of its sand and clay content. Sandy soils have lower yields: their high permeability makes water retention difficult and increases the loss of organic matter. These soils are relatively more acidic than others, with a pH of about 5.5 (Usowicz and Lipiec, 2017; Rusinamhodzi et al., 2011). High-clay soils are more permeable and can hold more water and nutrients. Based on the index of clay and sand content in soils, Panagos et al. (2012) proposed a European database of soil productivity (10 km grid). The European Soil Data Centre (Panagos et al., 2012) has also published a database of slopes (10 km grid). The physical properties of the soil affect its productivity. Slope is associated with critical erosion phenomena. The slope increases water erosion, which can be further aggravated by extensive mechanical work, such as deep ploughing, or the use of tractors. Several authors (Kiflu and Beyene, 2013; Gregorich, 1998), have found that these factors cause differences in nutrient and carbon concentrations between the high and low parts of the slope. Deficiencies in chemical elements can result in lower yields.

The type of farming can also affect yields. Indeed, OF prohibits the use of chemical inputs. Differences in yields between the two types of agriculture have been found to average between 20% (Seufert et al., 2012) and 9% (Ponisio et al., 2015). These meta-analyses show that the results vary at the crop level. Indeed, while orchard crops experience a low yield decrease, cereal yields decrease by more than 20%. Therefore, it is essential to control the type of crop grown on the farmland.

3.2.2 Residential rent

The value of the residential rent corresponds to the anticipated value of the land upon conversion to residential use. According to Cavailhès et al. (2011), the sale price, P of agricultural land is equal to:

$$P = \underbrace{\frac{R_A}{i}(1 - e^{-it^*})}_{\text{Ricardian rent}} + \underbrace{\Big(\frac{R_0 - \delta x}{i} + \frac{g}{t^2})e^{-it^*}}_{\text{Residential rent}} \tag{3.1}$$

Where R_A denotes the agricultural rent, R_0 denotes the residential rent in the Central Business District (CBD), x the distance of the land from the CBD multiplied by δ the unit transport cost, g the population growth rate, i the discount rate and t^* the date of conversion to residential use. If we break down the second part of the equation, we can see that residential rent depends on three parameters: population growth rate, distance to the central business district and date of conversion to residential use.

First, an increase in the expected demographic growth of the area where the land is located leads to an increase in future demand. This increase in demand leads to a rise in residential rent on the day the conversion is possible. Therefore, as the population growth of dynamic cities is higher than that of isolated municipalities, a negative relationship between residential rent and distance from the CBD can be observed. The second factor influencing land value is the distance from the CBD boundary. When a city is dynamic, with significant population growth, urban planners may decide to expand it by pushing the residential boundaries further out. If agricultural land is located on the edge of a dynamic city, the probability that the planning authorities will make it buildable is high.

3.3 Methodology and data for land valuation

In this section, we develop two aspects before leading the econometric analysis on the value associated with organic farming on farmland prices. First, we will highlight the matching methods used to control for the endogeneity bias between farming practices and farmland types. Once our groups have been formed, we can estimate the influence of organic practices on the price of agricultural land. Secondly, we will present the database that allows us to answer our research question.

3.3.1 Matching method to tackle the endogeneity problem

According to a study by Allaire et al. (2015) and our chapter I, organic farmers are very unevenly distributed across country. In the French departments of *Var* and *Bouches du Rhône*, over 40% of the UAA was farmed organically by 2022, while in *Pas-de-Calais*, *Somme* and *Val d'Oise*, less than 2% was farmed organically (Agence Bio, 2023). The existence of a concentration of organic farmers positively influences the development of. In addition, the authors found that areas with low to moderate slopes (foothills and medium-altitude mountains) have higher concentrations of. Another study by Schmidtner et al. (2012) conducted in Germany found that organic farmers are concentrated in areas with lower soil quality and less favourable climatic conditions. This is based on the soil climate index provided by the German Federal Office for Building and Regional Planning in 2002. Furthermore, they are often located in areas with higher rainfall. The decision to convert to OF is therefore influenced by geographical and climatic factors that are out of an individual's control. Farming practices can be explained by the characteristics of the land, so a hedonic analysis that incorporates both farming practices and soil characteristics may bias the results. To overcome this problem, we use two different matching methods to compare an organic plot with the same conventional soil. We will thus compare two plots with the same probability of being used for OF.

The first matching method we use is propensity score matching. This two-stage method, developed by (Rosenbaum and Rubin, 1983), matches two observations with the same probability of being farmed organically. In the first stage, a logistic regression model is used to estimate the probability that a plot of farmland will be farmed organically. From the regression coefficients, we can define propensity scores corresponding to the probability that plot i will be farmed organically, given its set of characteristics $X = x_i$. Thus, the propensity score can be expressed as $p(X) \equiv Pr(P = 1|X = x_i)$.

In the second step, we associate two observations with the same probability of being farmed organically. However, in reality, they have two different farming practices: one is organic and the other conventional. As $p(x)$ is continuous, the probability of two observations having the same propensity score is therefore zero. Therefore, it is necessary to apply a matching method based on $p(x)$, specifically the matching algorithm. To do this, we use the *Nearest Neighbor Matching* method (Stuart, 2010). This involves minimising the distance between propensity scores in the treated group and the control group. Each treated observation is matched with the observation of having the nearest propensity score. To compare different specifications of the matching algorithm, we introduce a *caliper*, a predetermined maximum allowable distance that can separate a treated individual from an untreated individual.

For the second matching method, we proposed a new method, called *Distance-based matching*. Using this method, we propose to match the organic land sold with the nearest conventional farmland sold in the same year. The goal is to compare two observations in the same local agricultural land market: two plots of farmland facing the same potential buyers. This method allows us to control for the spatial heterogeneity of buyers' financing capacity on the agricultural land market.This is very important because the variability of land prices between areas in France is very significant. For example, on the market for unbuilt land and grassland, the median price per hectare of farmland in the *Boûches du Rhône* was 15,100 euros in 2022, while it was only 2400 euros in the *Jura*[4] (SAFER, 2023). This method allows us to compare the prices of two plots that differ only in their practices. It also allows us to control for several unobserved variables. We can associate land in the same natural and urban environments. Later, we will see that thanks to the large amount of data in the database, we can associate two farmlands, on average 1.5 km apart.

Once we have matched our organic plots, eliminating the endogeneity problem, we can measure the impact of the organic practice on the selling price using the hedonic price method. To do this, we regress the price of the plot according to the agricultural practice as well as to control for the Ricardian and the residual rent, as follows:

$$Y_i = \beta_0 + \beta_1 Organic_i + \beta_2 Ricardian_i + \beta_3 Residential_i + \epsilon_i \tag{3.2}$$

This OLS model allows us to establish whether there is an added value associated with OF practice and to observe the determining variables in land sale prices. Here Ricardian rent is captured here using the following variables: seasonal average temperature and total seasonal rainfall (during the year of sale and the average over the 5 years before the sale), land properties (size, slope and composition) and dominant crops. The municipality centrality index (Hilal et al., 2020) approximates residential rent, along with demographic growth and the median income of local residents.

3.3.2 Database of sold farmland and its characteristics

To tackle this chapter's main question, it was necessary to create an original database. In France, the type of farming (Organic or conventional farming) performed on the

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[4] Interactive maps of the French agricultural market are available at: https://www.le-prix-des-terres.fr/carte/

land at the time of the sale is not specified. This database was built from two existing databases, *Demand for land value* (DVF+) and the *Land Parcel Identification System* (LPIS). We then add the characteristics of these parcels sold to control the impact of Ricardian and residential rent.

The first database, *DVF+*, lists all land transactions (sale of houses, buildings or agricultural plots) made in France over the period 2014-2022 (excluding the 4 French departments Moselle, Bas-Rhin, Haut-Rhin and Mayotte). It is produced by the French General Direction of Public Finances and includes sale price (excluding notary fees), the surface and transaction date for each transaction. The data was linked to the land register made available by CEREMA. Here we use April 2023 version of DVF+ open data[5], (a non-anonymous version of this database is available upon request). In our database extract, we only keep mutations[6] involving agricultural land. As a mutation can concern several agricultural plots, and we only have the total price of the mutation, we give the average price per hectare for each piece of land sold within the same mutation. Precisely, using a geopositioned file for each plot, we disaggregate the different plots sold in the same mutation, and we assign the price to the hectare. Since it is impossible to distinguish the prices of each individual plot in the mutation, each plot is assigned the total price of the mutation divided by the total number of hectares sold in the mutation. To sum up, for example, if a farmer sells 15 different plots representing a total area of 100 ha for 100,000€. We have 1 observation, for an amount of 100,000€ for 15 plots sold. We have the spatial geometry of each plot but not the marginal price of each plot. As we only have the price for all the plots sold (at the mutation level), we assign a value of 10,000€/ha (Total price of the mutation divided by the number of hectares changing ownership) to each plot sold. From this database, we also have the variable *Land categories*, which refers to the types of farming activities performed on each mutation. This variable is divided into four sub-categories: 'Vineyard', 'Orchards', 'Grassland and Arable Land', and 'Mixed'. The last sub-category indicates that in the different parcels sold in the mutation, several categories of land are mixed, such as grassland and orchards.

The second database, the LPIS, contains annual listings of all agricultural land units receiving CAP aid. It is produced by the French Single Payment Agency, which also handles various CAP aid payments. It provides the GPS position of each field

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[5] Available on the website: https://datafoncier.cerema.fr/

[6] A mutation refers to all property that changes ownership in the same transaction.

as well as their size and crop. Since 2015, it also indicates the type of agriculture practiced on each parcel (Organic or conventional farming).

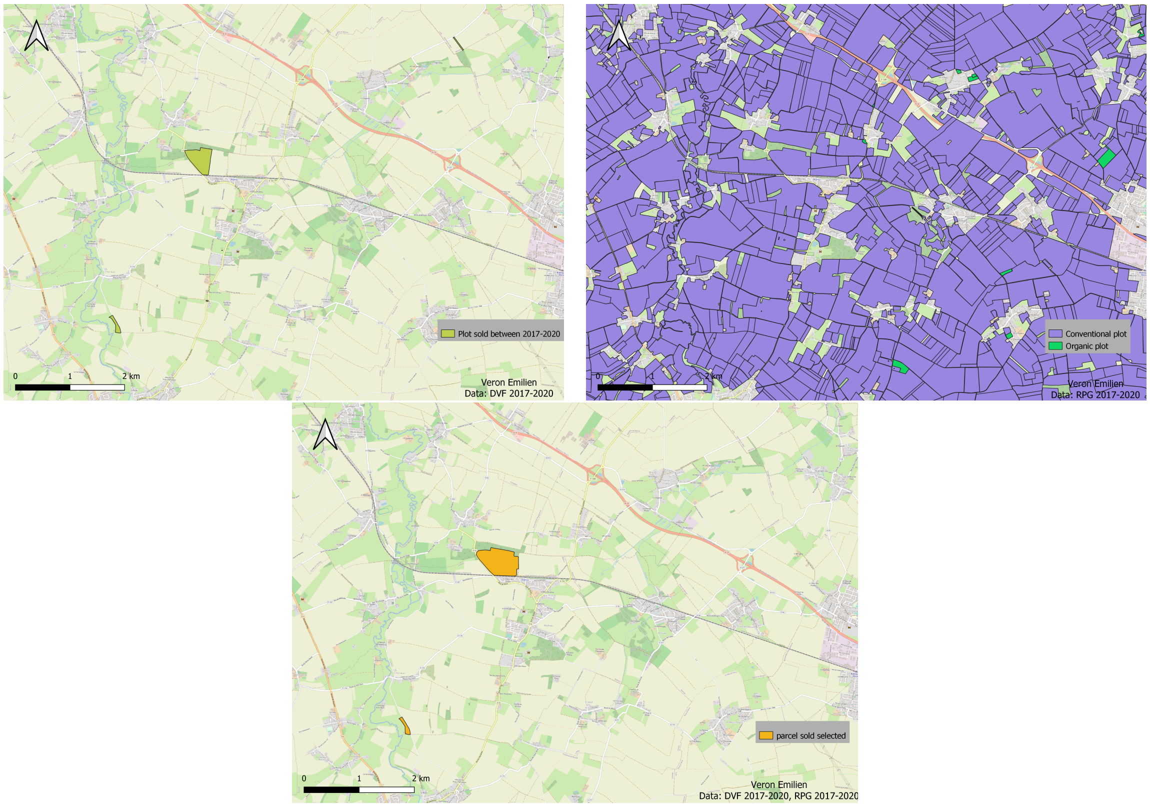

Figure 3.1: Land database construction with DVF database (Top-left), LPIS database (Top-Right), and merging data (Bottom)

To create this database, we extract from the *Demand for land value* database all sales of agricultural land without buildings for each year (fig.3.1 top-left). We also we extract files from the *LPIS* database, one file per year over our period (2015-2021) (fig.3.1 top-right). This second database allows us to geolocate the organic and conventional land farmed each year. Eventually, we then merge the two geofiles of the same year, and kept only the merged parcels (fig.3.1 bottom). In our fictional example[7] (fig 3.1), from the three land sales, we obtain two observations, i.e. we know the selling price per hectare of these two conventional lands. Then we apply the clean data methodology adopted by the SAFER[8] removing sales involving areas

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[7] In Fig 3.1, The agricultural practice on the plots is randomly assigned.

[8] The *Société d'aménagement foncier et d'établissement rural* is an organisation that is tasked with ensuring the proper functioning of the agricultural land market and preserving agricultural

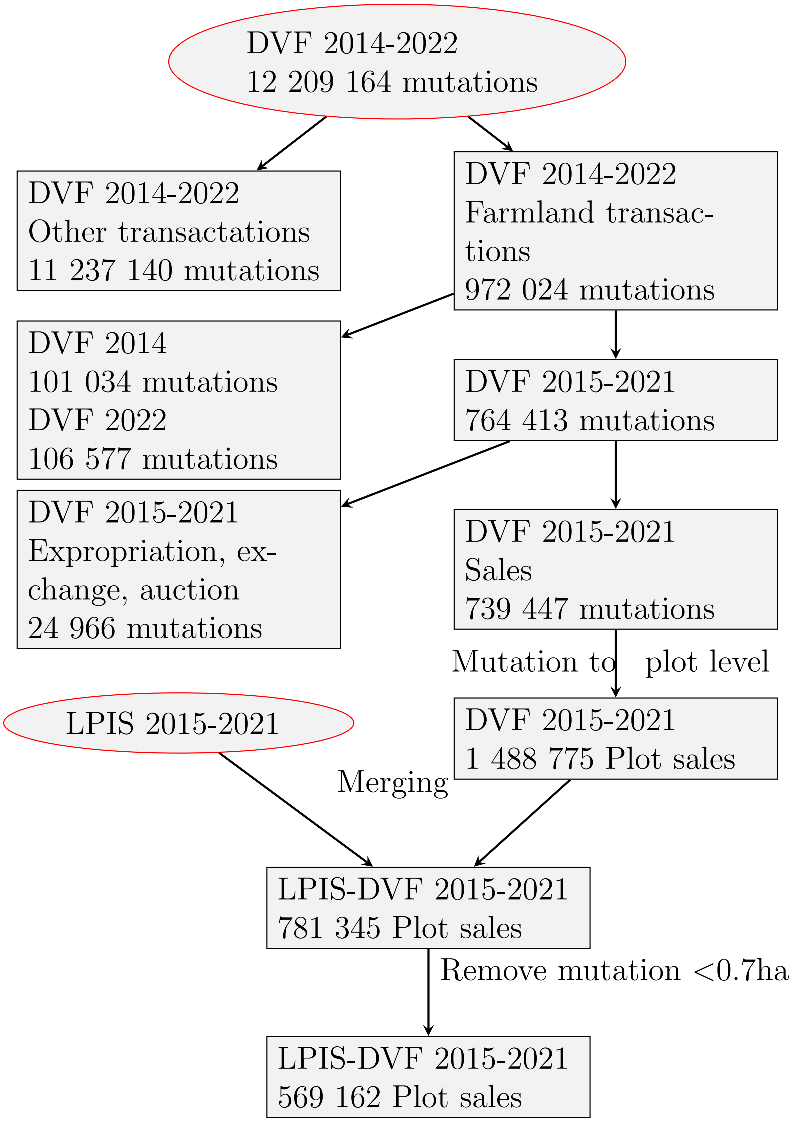

Figure 3.2: Database construction diagram

of less than 0.7 hectares. The different stages of cleaning and merging with the LPIS database are summarized in Figure 3.2.

This gives us a total of 569162 observations (524860 sales of conventional plots and 44320 sales of organic plots) between 2015 and 2021. Table 3.1 shows that, over the period, the number of transactions increases at an average rate of 5.8%. This rate appears to be overestimated, given the large number of transactions in 2021, due in part to catch-up from 2020, probably as a result of the Covid-2019 restrictions. According to agricultural practice, the table 3.1 shows a consistent increase in the

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areas. It published an annual report, which includes the average prices of agricultural land at the sub-departmental level.

number of organic land sales over the period. Indeed, the average growth rate for organic sales was 23.3%. This effect is explained by a growing increase in organic land conversions over the same period in France.

Table 3.1: Distribution of parcels sold by practice and year of sale

	2015	2016	2017	2018	2019	2020	2021	2015-2021
Conventional sales	95.2%	94.1%	93.3%	92.4%	91.5%	90.4%	89.7%	92.8%
Organic sales	4.8%	5.9%	6.7%	7.6%	8.5%	9.6%	10.3%	7.2%
Total sales	71188	75349	78396	83319	87867	78572	94471	569162

To perform a hedonic analysis, we therefore added information on sold plots to our database. This information can be divided into two categories, affecting respectively the Ricardian rent and the residential rent.

First, the climate variables (precipitation and temperature) come from the JRC-MARS meteorological Database project (Toreti, 2014). This project interpolates data from weather stations in the European Union and neighbouring countries, on a 25x25km spatial grid, every day since 1979. For this chapter, we extracted daily temperature averages and the total precipitation over the period 2010-2021. We then seasonalized these data, as the influence of climate data on agricultural production varies according to the season (Mendelsohn et al., 1994; Passel et al., 2017). The average temperature per season and the total precipitation per season in the year of sale are used as indicators, as well as the averages of these two climate variables over the last 5 years.

Soil variables (soil composition and slope) are taken from the European Soil Database v2 Raster Library 1kmx1km, produced by the European Soil Data Centre (Panagos et al., 2012). We have extracted the layers *Texture* and *Slope*[9]. The *texture* variable corresponds to the soil type based on two components, clay and sand, ranked from 1 to 5, where 5 corresponds to a very fine soil texture with a clay composition greater than 60%. The *slope* variable refers to the average slope level by 1x1km grid,

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[9] In the European Soil Database v2 Raster Library, *Texture* corresponds to the layer *TEXT-SRF-DOM*, and *Slope* refers to *SLOPE-DOM* layer

classified from 1 (level: between 0 and 8%) to 4 (steep: greater than 25%). All the variables are more describe on Appendix 1 table ??.

Finally, information on the main crop grown[10] on the declared plot was retrieved from the LPIS, with 329 different crops listed. For our analysis, we use the grouping proposed by the data-producing organization into 28 crop groups (see on IGN (2017)). In order to characterize the land use on the parcel, we also take into account the variable *libtypbien* (already used to single out transactions involving sales of agricultural land), which distinguishes four categories of farmland. The fourth category *Mixed agricultural land* indicates that different types of land were sold in the same mutation.

For residential rent, we use the database resulting from research by Hilal et al. (2020), who proposed a new classification of French municipalities according to their services and facilities, compared with those of neighboring municipalities, in order to observe population dynamics. The result is a composite indicator ranging from level 0 (non-central municipality) to level 4 (major center of amenities and services), taking into account demographic data (population, standard of living, employment rate) and available services[11] (hospitals, schools, stores, etc.). For our study, to approximate the residential rent of the parcel sold, i.e. the rent for the amneties[12] perceived for the location of this parcel, we take into account the centrality index, the demographic growth between 2006 and 2016, as well as the median income of the municipality in 2016. As the demand for residential land increases with population and income, we can assume that the more expensive the land, *ceteris paribus*, in areas with strong demographic growth and in central municipalities.

3.4 Results

We will use the original database containing 569 162 sales of agricultural plots in France between 2015 and 2021 to study how organic practices affect land prices. Firstly, we perform a hedonic regression based on OLS estimators using all the data. Secondly, to eliminate the endogeneity bias between farming practices and land characteristics, we create three new sub-groups using PSM and distance-based matching.

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[10] Crop present on the plot on June 1st

[11] From the INSEE permanent equipment database:https://www.insee.fr/fr/metadonnees/source/serie/s1161

[12] an amenity is a tangible or intangible aspect that improves the quality of life or attractiveness of a specific location

Based on these sub-groups, we run a new regression on a hedonic model to measure the impact of organic practices on farmland prices.

3.4.1 Hedonic analysis on all farmland data

The specification on the table 3.2 shows the results obtained by the OLS regression of the log price per hectare of land sold as a function of the land characteristics relating to Ricardian rent (agricultural practice, slope, climatic and soil characteristics) and relating to the geographical positioning of the plot, which makes it possible to approximate the residential rent (central municipality index).

Based on these specifications, it appears, over the period 2015-2021, that organic farming on land has a negative impact on its price. In fact, according to the specifications, organic land sells for 2.4% less than conventional land. This price difference between the two farming practices varies from +3% to -10% depending on the year. Concerning the Ricardian rent, soils with a fine composition (high clay content), allowing better water storage and nutrients sell 13% more than coarse soils (high sand content). Farmland in flat areas sells for more than sloping land (from -4% to -12% depending on the slope). The influence of seasonal rainfall shows that a 1% increase in summer increases the price by 0.14% respectively. Land with the hottest summers is also seeing a drop in price, for fear of drought.The results validate the importance of Ricardian rent in land prices. Therefore, the determinants of soil productivity influence an important part of the price of land.

Spatial dynamics around farmland also influence land prices. We observe that land prices evolve positively with the level of centrality of the municipality in which the land sold is located. In fact, according to Hilal et al. (2020), a high level for a commune is synonymous with attractiveness, as these communes attract jobs, services and facilities. Indeed, these two elements increase the residential demand in the area and increase the probability of agricultural land being sold for residential use. As a result, the residential value of these plots is greater than if they were located in lower-level municipalities. This is why the price difference between land in a level 0 (Non-center municipality) municipality and a level 4 municipality (Main center) is +63%.

Table 3.2: Farmland price decomposition, OLS regression

	2015-2021		
	log(price/ha)		price/ha
	(1)	(2)	(3)
Organic	-0.024**	0.027*	2953
Year *Org (ref: 2015)			
2016		-0.055**	
2017		-0.06***	
2018		-0.10***	
2019		-0.07***	
2020		0	
2021		-0.06***	
Area	-0.002***	-0.002***	-144***
Land Categories (ref: grassland and arable land)			
Orchard	0.18***	0.18***	2109
Vineyard	0.73***	0.73***	17189***
Mix	-0.47***	-0.47***	-4452
Texture (ref: Coarse)			
Medium	0.06***	0.06***	310
Medium Fine	0.12***	0.12***	3812***
Fine	0.13***	0.13***	3839**
Very Fine	-0.1	-0.1	475
Slope (ref: Level)			
Sloping	-0.12***	-0.12***	-654
Moderately steep	-0.04***	-0.04***	-166
Mean Temperature (mean 5 years)			
Summer	-0.05***	-0.05***	2104
Winter	-0.08***	-0.08***	-1959
Autumn	0.19***	0.19***	4048
Spring	-0.06***	-0.06***	-2869
Sum Rainfall(/100ml) (mean 5 years)			
Summer	0.14***	0.13***	7937*
Winter	-0.13***	-0.13***	-10197***
Autumn	0.13***	0.13***	508
Spring	-0.11***	-0.11***	514
Centrality municipality (ref: level 0)			
Local center (level 1)	0.08***	0.08***	3771***
Intermediary center (level 2)	0.18***	0.18***	8946***
Structuring center (level 3)	0.38***	0.38***	167974***
Main center (level 4)	0.63***	0.63***	35064***
Year (ref: 2017)			
2016	0	0	-162
2017	0.08***	0.08***	3517*
2018	0.12***	0.12***	5436**
2019	0.17***	0.17***	8984***
2020	0.21***	0.21***	5384**
2021	0.24***	0.24***	6479**
(Intercept)	6.26***	6.27***	195
Dept	TRUE	TRUE	TRUE
Crops Gr	TRUE	TRUE	TRUE
Precipitation&Temperature t	TRUE	TRUE	TRUE
Adj R^2	0.36	0.36	0.003
Num.obs.	556134	556134	556134

The p-value is represented according to these thresholds: $^{***}p < 0.001$,$^{**}p < 0.01$,$^{*}p < 0.05$

3.4.2 Hedonic analysis on matching data

In this second part of the analysis, we use the matching method based on propensity score and geographical distance to overcome the endogeneity problems raised earlier between the organic farming practice variable and the other variables. The purpose of this method is to verify the robustness of the results found in the table 3.2, which is the negative influence of organic farming on land sale prices. To achieve this, we will compare the sales prices pairwise for land parcels with an equal probability of being cultivated. We will carry out two different matching operations. The first matching will be done by minimising the Propensity Score derived from the probability of being treated in organic farming with respect to the observable characteristics. The second matching will be done by minimising the geographical distance to the plots sold in the same year. In this way, each treated observation will be matched with the closest conventional plot geographically sold in the same year.

For the first matching based on the propensity score derived from the logistic regression results, as provided in table 3.3. The results from the table confirm that soil characteristics influence the adoption of organic farming. Specifically, sloping lands are more likely to be cultivated using organic practices. On the other hand, contrary to Schmidtner et al. (2012) findings, land with less rainfall is more likely to be organic. From the propensity score of each observation, we applied a matching algorithms. The algorithm employed Nearest Neighbor Matching with replacement and included a caliper set at 0.005.

The second matching method is based solely on minimising the geographical distance crossed with the year of sale. The 44,302 organic lands sales are matched with the 44,302 closest conventional land sales. We perform another matching in which we add the land category criterion in addition to the year criterion. More precisely, with these two criteria combined, we match an organic vineyard sold in year t with a closer conventional vineyard sold in the same year t. The same applies to orchards, grassland/arable land and mixed categories. As indicated in table 3.4, the average distance between two matched observations are repectively 1.5 km and 1.96km. Due to this relatively low average proximity, we can hypothesize that this matching approach also controls for unobserved characteristics in our data, such as local land market dynamics (financial capacity of farmers in the area, land demand). We also see, on the table 3.5, all the 44,302 organic plot sell are match, with around

	Logit (Organic=1)
Year (ref: 2015)	
2016	0.07***
2017	0.18***
2018	0.25***
2019	0.33***
2020	0.39***
2021	0.45***
Texture (ref: Coarse)	
Medium	-0.07***
Medium Fine	-0.07**
Fine	-0.04**
Very Fine	-0.2
Slope (ref: Level)	
Sloping	0.03***
Moderately steep	0.06***
Mean Temperature (mean 5 years)	
Summer	0.06*
Winter	-0.07*
Autumn	0.18***
Spring	0.06*
Sum Rainfall(/100ml) (mean 5 years)	
Summer	0
Winter	-0.16***
Autumn	-0.06*
Spring	-0.15***
Centrality municipality level (ref: non-center municipality)	
Local center (level 1)	0
Intermediary center (level 2)	-0.02*
Structuring center (level 3)	0
Main center (level 4)	-0.07·
Land Categories (ref: grassland and arable land)	
Orchard	0.3***
Vineyard	0.14***
Mix	0.05
(Intercept)	-2.26***
Departement	TRUE
Precipitation&Temperature t	TRUE
Obs	556134

The coefficients associated with the logit regression explain farming practices as a function of soil characteristics and location. The p-value is represented according to these thresholds: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$; $^{\cdot}p < 0.1$

Table 3.3: Propensity score regression: impact of plot characteristic on organic farming practice

half the number of conventional plot. This means that, on average, one selected conventional plot has been matched with 2 organic plots.

	Mean	Median	Sd	Nb.obs
Match Distance: Year	1.5	1.13	1.51	88604
Match Distance: Year + Land Categories	1.96	1.24	4.1	88604

Table 3.4: Descriptive statistics on Distance-based matching performance (in km)

Now that we have created our three sub-groups via the matching methods, which are respectively the sub-group based on propensity score from table 3.3 with the Match Nearest algorithm with replacement by a 0.005 caliper; and the other two from distance-based matching with the addition of the year criterion and the same land categories. These matching methods make it possible to homogenise the groups, and to neutralise the effect of unobserved characteristics linked to soil type (sub-group *PSM*) or linked to location (sub-group *Distance-based matching*). We again perform a hedonic price analysis using OLS estimators varying according to the different subgroups, with a baseline model based on the entire database. The results from table 3.5 show the coefficients associated with the Organic variable. To obtain these results we add the same control variable like the regression as specification (1) and (3) of table 3.2. This table shows that, for 4 samples, organically farmed land sells for between 1.4% and 3.2% less than conventional land. These results reinforce the previous ones, showing that even if we control for the endogeneity of the variable *Organic*, the sign and magnitude of the coefficient remain the same.

Table 3.5: Effect of organic practice on price, sub-group sensitivity analysis

Sub-group:	All data (before match)	PSM	Distance-based matching Year	Distance-based matching Yr&Land Cat
Price/ha	2953	-20	1075	851
log(Price/ha)	-0.024**	-0.014*	-0.029***	-0.032***
# Organic land	43283	42583	44302	44302
# Conventional land	556134	30699	21945	21861

Coefficient associated with the variable *Organic* on the price per ha and the log price per ha in the hedonic regression based on the OLS estimators and the different subgroups, with control variables (same as in specification (1) and (3) table 3.2). The subgroup "PSM" contains the observations retained after the matching based on propensity score from table 3.3 with the Match Nearest algorithm with replacement by a 0.005 caliper. The p-value is represented according to these thresholds: $^{***}p < 0.001$,$^{**}p < 0.01$,$^{*}p < 0.05$

To test the robustness of our effect, we observe whether the impact of organic practices on land prices differs depending on the type of farming activity. We carried out a hedonic analysis based on the *Distance-based matching yr&Land Cat* data. We analysed four different categories : "Vineyard", "Orchards", "Grassland and Arable land", and "Mix". The results of the table 3.6 show that organic vineyards are sold 6% more per hectare (or 10,000€) than conventional vineyards. This shows that organic vineyards are highly sought-after and valued. At the same time, orchards and other organic grassland and arable land are sold for between 5 and 11% less than conventional land.

	Vineyard	Orchards	Grassland &Arable land	Mix
Price/ha	10427·	-4472*	-874***	-23
log(Price/ha)	0.063**	-0.116*	-0.057***	-0.22·
Distance (mean in km)	2.5	10.6	1.6	31.8
# Organic land	5323	826	38050	103
# Conventional land	2676	427	18713	45

Coefficient associated with the variable *Organic* on the price per ha and the log price per ha in the hedonic regression based on the OLS estimators and the different subgroups, with control variables (same as in specification (1) and (3) table 3.2). Based on a database from *Distance-based matching yr&Land Cat*, divided into subgroups based on land categories. The p-value is represented according to these thresholds:$^{***}p < 0.001$,$^{**}p < 0.01$,$^{*}p < 0.05$,$^{\cdot}p < 0.1$

Table 3.6: Effect of organic practice on price, by land categories sub-group

3.5 Discussion on the lack of an organic farming premium: potential mechanisms

The results showed that organic land is sold at a lower price than conventional land (with variations from one year to the next). We did not anticipate this result because we had identified two channels justifying the extra premium: avoiding the loss of 2/3 years of converting the land to OF and accessing land with better environmental externalities (better carbon and water storage, reduced erosion). If the land buyer does not value these aspects, his willingness to pay for organic land will be null. Therefore, it is important to investigate the demand aspects. Specifically, we want to discuss the types of potential buyers and the future projects they envisage for this land.

The first added value of buying an organic plot is the opportunity to farm the plot directly organically. However, if a conventional farmer wishes to remain a conventional farmer, they will not value this aspect. Therefore, only farmers who want to continue farming organically on this land will value this characteristic. This limits the potential demand for organic land. As OF practice is marginal, there is a problem of under-availability. Indeed, there is relatively less organic land for sale than conventional land. Only 11.7% of the agricultural land was farmed organically in 2020. Moreover, these lands are exploited by five years younger farmers on average (45 years old against 49.7 in conventional farming according to the 2010 French agricultural census). The leading cause of land sales is retirement, which explains why organic land for sale is scarce. This low number of offers suggests a mismatch between buyers and sellers on the organic farmland market. Indeed, as the OF is marginal, the probability for an organic farmer to find a nearby organic field for sale is lower than for finding a conventional plot.

Minimum distance	Mean Org sales	Mean conv sales	Diff t-test
Sales_{2015}	10.6	3.4	7.2***
Sales_{2016}	9.6	3.4	6.2***
Sales_{2017}	8.4	3.3	5.1***
Sales_{2018}	7.8	3.3	4.5***
Sales_{2019}	7.1	3.2	3.9***
Sales_{2020}	7	3.3	3.7***
Sales_{2021}	6.3	3.2	3.1***
$\text{Sales}_{2015-21}$	8.1	3.3	4.8***

$Sales_{2015}$ refers to the database contain all farmland sell in 2015. An organic farmer looking for land to buy in 2015 will find the nearest organic land 10.6km away, and conventional land 3.4km away. The p-value associated to the difference between *Mean Org sales* and *Mean conv sales* represented according to these thresholds:$^{***}p < 0.001$

Table 3.7: Minimum distance to an organic farm and farmland for sale (in km)

To measure the extent of the low organic supply, we calculated the minimum distance between an organic farm and an organic land for sale and between an organic farm and a conventional land for sale. We did this from the database of land sales used in this chapter, in which we include the geographical location of all organic farmers notified to the French Organic Agency[13](51,110 farmers). Table 3.7, shows that the hypothesis is well tested. Indeed, on average, if an organic farm wishes to acquire land, the closest land will be conventional land. Indeed, there is a 4.8km difference between buying conventional and organic land for an organic farmer. Over the period 2015-2021, conventional land for sale was, on average, 3.3km away from organic farms compared to 8.1km for organic land for sale. Even though the distance for an organic farmer looking to buy organic land is reduced, from a minimum of 10.6km in 2015 to 6.3km in 2021, due to the increased supply of organic land for sale, buying organic land remains less accessible. This new result shows that an organic farmer who buys organic land will suffer higher operating costs than if they had bought conventional land. This additional cost is due to the higher transportation costs associated with the 4.8km difference on average between buying organic and conventional land. This additional transportation cost reduces the organic farmer's willingness to pay for organic land.

The second asset of organic farmland, the provision of ecosystem services beneficial to agriculture, may not be taken into account by the farmer buyer for various reasons. Firstly, if the farmer buys the land to resell it for residential use in the short term, the latter will not value the agronomic properties of the land. The buyer will be interested only in the residential amenities provided by the location.

In the other case, the buyer wants to use the land for agricultural use. They may not be aware of the environmental benefits of organic farming. Although the benefits of organic practices in terms of the production of ecosystem services are known to the scientific community, they may be less well known to farmers. In addition, carbon or water storage services, for example, are not visible features when buying land. Buyers are therefore not prepared to pay more for features that they do not know about or observe.

We can also assume heterogeneity in the provision of agricultural production ecosystem services depending on the length of time the land has been converted. For example, land that has been following organic practices for two years will have a lower ecological status than land that has been converted for ten years. We therefore need to complete our analysis by testing the heterogeneity of the price attributed to organic practices as a function of the length of time the land has been converted.

Finally, a more in-depth study based on the past and future history of the farm-

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[13] Available on the following website:https://annuaire.agencebio.org/

land would enable us to verify the various hypotheses put forward. The history of the land would allow us to observe the effect of the length of conversion to organic farming on the selling price. This analysis would make it possible to approach the value associated with the level of provision of ecosystem services beneficial to agricultural production. This database would also make it possible to track the agronomic trajectory of the land after it has been sold. It would be used to understand the purchaser's project and to observe whether the land was acquired for its assets linked to agricultural practice, or for its geographical characteristics.

3.6 Conclusion

In conclusion, this new database provides information on the sale prices of agricultural land with farming practices between 2015 and 2021. Using two different matching methods (PSM and distance based matching) allows us to control for the endogeneity problem linked to the characteristics of the plot and practices. By comparing two plots that are less than 2km apart, we can control for unobserved variables and identify the marginal effect of organic practices on prices. We found that organic land sells at a lower price than conventional land. The value of organic practices on the land price varies depending on the crop. Indeed, organic vineyards are sold for 6% more per hectare than conventional vineyards. For orchards and arable land, however, organic land is sold for less than conventional land. Winegrowers are willing to pay more for agricultural land that is already organic because it allows them to produce high-value-added products.

The lower price of organic land (averaging 2% per hectare) does not mean that the market ignores the environmental impact of organic farming. Indeed, when we look at the demand for farmland, we see that the transportation costs associated with buying organic land are higher (4.8km more than conventional land for sale). This makes organic land less attractive.

In addition, it is important to note that the land price is mainly explained by Ricardian rent. Our analysis shows that weather conditions vary from region to region, affecting soil productivity and explaining part of the difference in land prices. However, the soil's physical characteristics (composition or slope) also influence its productivity and thus its value on the land market.

As we finally discussed, our analysis focuses on the supply side of the land. We have left out the demand side on the hedonic regression. However, as we have just shown, the relatively small supply of organic land compared to conventional land leads to a geographic mismatch problem. Organic farms looking for land find it easier to get access to conventional land than to organic land. It is important to study demand for land to understand the effect of organic practices on prices. The value of organic farming depends on how long the land has been converted and the buyer's plans for using the land.

3.7 Appendix

Appendix 1: Descriptive statistics of variables

Table 3.8: Descriptive statistics of the continue variables

Variable	Definition	Nb. Obs	Min	Max	Mean	Source
Area	Size of the plot sold (in hectares)	459430	0.7	489	8.41	DVF+
Av temperature$_t$	Average temperature each season Mean season temperature during years of sales, 25km Grid					European Joint Research Center
Summer		569162	9.8	25.6	19.3	
Winter		569162	-5.1	11.2	5.6	
Autumn		569162	0.6	16.2	10.8	
Spring		569162	3.6	18.5	13.4	
Av temperature over 5y	Average temperature each season Mean over 5 years before sales 25km Grid					European Joint Research Center
Summer		569162	9.4	25.1	19	
Winter		569162	-6.1	11.1	5.4	
Autumn		569162	-0.08	16.5	10.2	
Spring		569162	2.5	17.6	13.1	
Av precipitation$_t$	Average precipitation each season/100ml Sum season temperature during years of sales, 25km Grid					European Joint Research Center
Summer		569162	0.15	3.28	1.98	
Winter		569162	0.71	5.1	1.64	
Autumn		569162	0.6	3.74	1.36	
Spring		569162	0.75	4.5	1.76	
Av precipitation over 5y	Average precipitation each season/100ml Mean over 5 years before sales, 25km Grid					European Joint Research Center
Summer		569162	0.4	3.5	1.6	
Winter		569162	1.1	4.4	1.85	
Autumn		569162	1.28	5.24	2.21	
Spring		569162	0.9	3.72	1.94	
Artificialisation growth	Share of the municipality's surface area that has changed from natural to urbanized betwenn 2009-2019	459424	0	21.96	0.5	French Government
Population Growth	Population growth rate of the municipality during 2006 and 2016 (%)	569144	60	200	6.4	INSEE
Median income	Median income in the municipality in 2016 (%)	547963	10932	48288	20128	INSEE

Table 3.9: Descriptive statistics of the discrete variables

Variable	Definition/Source	Value	Nb.obs	%
Organic	Type of farming soil at the time of sale	0 = Conventional practice	420854	91.6
	/DVF and LPIS	1= Organic practice	38576	8.4
Texture	Dominant surface textural class 10km grid	**Coarse** (18% < clay and > 65% sand)	72612	12.8
	/European Soil Data Center	**Medium** (18% < clay < 35% and >=15% sand, or 18% < clay and 15% < sand < 65%)	273585	48.6
		Medium Fine (< 35% clay and < 15% sand)	156108	27.7
		Fine (35% < clay < 60%)	60585	10.8
		Very fine (clay > 60%)	37	0.001
Slope	Dominant slope class 10km grid	**Level** (ranging from 0 to 8%)	414963	73.8
	/European Soil Data Center	**Sloping** (ranging from 8 to 15%)	118838	21.1
		Moderately steep (ranging from 15 to 25%)	28285	5.0
Centrality level	Centrality munipality Index	**Non-center municipality (level 0)**	312473	54.9
	bases on Hilal et al. (2020)	**Local center (level 1)**	169559	29.8
		Intermediary center (level 2)	72925	12.8
		Structuring center (level 3)	12158	2.1
		Main center (level 4)	2030	0.3

General conclusion

The aim of this thesis was to expand the existing literature on the influence of territorial differences on the development of. We used an empirical approach supplemented by the use of spatial indicators to identify various types of territorial heterogeneity (natural, historical, political), as well as their effects on farmers and their agronomic trajectories.

This thesis addresses three research questions:

- How are organic farms and farmland distributed among French municipalities? What are the main spatial factors explaining this heterogeneous development?
- Does the delimitation of water catchment areas (WCA) encourage farmers to change their practices ?
- Does organic farming increase the value of land ?

To respond to the first question, we must first underline, as Allaire et al. (2014) have shown, that plots are distributed very unevenly across the territory, with significant agglomeration effects. The *Spatial Durbin Model* approach can help us better understand the factors contributing to this disparity. We note that organic farms are often located far from large towns, in densely wooded areas and on soils less suitable for farming. However, organic farmers operate in areas that are far from major cities but close to populations likely to consume organic produce. These areas have a high proportion of university graduates and a low proportion of working-class people. Regarding the influence of public policies, *area facing natural constraints* subsidies have a positive effect on the number of lands in OF. In terms of PDO policy, the results depend on the type of product labelled. The OF label and the wine PDO label are complementary, while the other PDO labels have no impact on the development of OF. Finally, the neighbourhood matrices show that border neighbourhoods have a predominant influence, as well as an influence on potential demand for OF products up to 20 km away.

The answer to the second question is more nuanced. The impact of the WCA policy on farming practices varies according to when it was implemented, the comparison group and the farming practice observed. We have demonstrated that this policy has had no impact on the dynamics of OF in the areas treated from 2019 onwards, or that it has been negatively compared with neighbouring areas treated in 2017 and 2018. The comparison of the treated groups with their respective neighbourhoods reveals two other results. Firstly, in neighbouring areas located less than 2 km from the WCA, no differences in practice were observed. This could indicate a potential treatment beyond the zone. Secondly, in more distant areas (between 2 and 10 km from the WCA), the development of OF is much greater than in the WCA. These results are consistent with those obtained from the qualitative survey of the organic farmers located in the *Grand Est* region. This survey showed that a significant proportion of organic farmers operating in a WCA wanted to stop farming organically.

The chapter III answers the third question by showing that organically farmed land is sold for about 2% less than conventionally farmed land. This result can be explained by a more marginal market for organic land, resulting in more difficult access to this land (further away from potential buyers). Nevertheless, this lower value shows that the positive externalities of OF are not considered on the agricultural land market. This chapter supports the recommendation of Crowder and Reganold (2015): *"Financial instruments are needed to give monetary value to the externalities that arise from agricultural practices"*. Furthermore, the results of Chapter III show that there is heterogeneity in the value attributed to organic practices on the farmland market, depending on the crop. Organic vineyards sell for 6% more per hectare than conventional vineyards. For orchards and arable land, however, organic land sells for less than conventional land. This result echoes Chapter I, which shows that PDO and organic labels for wine production are complementary. Wine growers are willing to pay more for agricultural land that is already organic, because it allows them to develop high-value-added production.

Limits and future extensions

In Chapter I, it is possible to identify a limitation and a potential extension based on the current state of the OF market. The analysis developed in this chapter is based on cross-sectional data from 2019, which does not allow us to measure the dynamics of change in OF in the municipalities. Data from the French LPIS from 2015 onward could allow us to go further and tackle this issue. However, since most of the variables are invariant in the short term (number of PDO, forest cover, soil characteristics), our results are not affected.

It would also be beneficial for the analysis to include an extension: the observation of reversion dynamic (switching from organic to conventional farming) in France. Given the current state of OF, it would be interesting to locate these reversions and understand their determinants. The model developed in Chapter I could test the influence of territorial heterogeneity on the probability to quit OF. This analysis would require the consideration of the individual characteristics of the farmer and his farm. We can formulate the following hypothesis at this stage: the more a farmer maintains relationships with organic farmers' networks, the lower their probability of switching is. We also assume that the specialisation of a farm is an important factor in deciding whether to return to conventional farming. For example, organic dairy farms experienced oversupply in 2022. In May 2022, the price for organic milk was lower than the one for conventional milk, which led to a reclassification of some of the production from organic to conventional. This event could have prompted farmers to make drastic decisions and switch back to conventional farming.

The analysis presented in Chapter II could be expanded along two axes to address its current limitations. We have limited access to the actions carried out in each WCA, which focuses only on agri-environmental schemes. This limits our ability to formulate comprehensive public policy recommendations. To overcome this, we must collect all administrative documents at the level of each WCA. Then, using automatic natural language processing (NLP) methods, we can identify all the actions implemented as part of the policy. Identifying the latter makes it possible to realize an exhaustive coverage of the actions carried out in each WCA. This will allow us to understand the heterogeneity of agricultural practices between WCA and to measure the effectiveness of each type of instrument.

The other way in which this chapter could be developed is by assessing the impact of changes in agricultural practices on water quality on WCA. To do this, we intend to supplement our current database with water quality data and aquatic biodiversity inventories provided by the French Biodiversity Office. The goal of this analysis is to examine how these agronomic changes affect the environment, particularly water quality. This project would enrich our Chapter II by providing a multidimensional analysis of the impacts of the WCA policy.

In Chapter III, we have identified a limitation and possible extensions. The method uses proxies for soil characteristics from the *European Soil Database v2 Raster* (Panagos et al., 2012). This database is used to characterize a plot by slope level and average granularity of the soil. By this approximation, the marginal effect of OF on price is biased by soil quality. In our database, if two adjacent plots are cultivated organically and conventionally respectively, our method assigns them the same soil characteristics. However, in reality, soil quality varies greatly from one plot to another, so these two contiguous plots will not have the same observed quality. As mentioned in Chapter I, it is more likely that the conventional farmer will farm the better land. Therefore, the 2% difference in sales between organic and conventional land is not only due to the difference in practices, but also to unobserved differences in soil quality.

A way to develop this chapter would be to enhance the database by adding longitudinal tracking for each plot. Using the spatialised French LPIS data, it would be possible to track plots even after a change in ownership. This plot tracking could allow us to perform an analysis of the heterogeneity of land prices depending on how long they have been farmed organically. In other words, we could determine whether the value attributed to the practice of OF is constant or whether it varies according to the duration of conversion. Two methods of analysis could be envisaged. The first would be to use the same method as that employed in the third chapter, based on hedonic price analysis with spatial matching. A second method would be to estimate the effect of conversion time solely through Ricardian analysis on repeated sales (Bareille and Chakir, 2023). With this second method, after selecting only land sold twice over the period, we calculate the difference in selling price for each parcel. By neutralizing the effects of unobserved variables (plot fixed effect), this method would make it possible to obtain the marginal effect of the farming practice change of the plot between the two sales.

Future research

The land market: a tool to mobilise for the development of more sustainable agriculture

In Chapter II of this thesis, we studied the farmland market, focusing on sale prices. However, it would also be interesting to collect the identities of buyers in order to predict agronomic trajectories. According to the 2020 agricultural census, only 20% of UAA is farmed directly (compared with 50% in 1946, and 25% in 2010). Consequently, in 80% of cases, the information contained in the French LPIS only gives information about the farmer who farms the land. We cannot identify the owner, who can then influence farming practices on this land.

Léger-Bosch (2015) identifies among the acquirers of agricultural land new forms of land ownership by public and associative actors. Through various legal forms (local authorities, associations), these actors seek, through the acquisition of land, to preserve agricultural activity and to prevent the development of urbanisation. They make their land available to new farmers with sustainable farming projects in the form of farm tenancies through rural leases with environmental conditions. Such leases include specific clauses designed to encourage or impose agri-environmental practices (planting hedges, reducing the use of chemicals, etc.). These initiatives are still marginal, but they address important issues. They limit the concentration of farmland, encourage the establishment of new farms, and accelerate the development of sustainable farming practices. Specifically, two questions arise:

- What motivates savers to participate in these new forms of land ownership ?
- What are the most effective financial mechanisms ?

These new forms of land ownership can be financed by individual private savings. It is important to consider the motivations of those who invest financially or voluntarily in these structures. The *'Dis-Bio'* INRAe metaprogramme should make it possible to understand the determinants of participation and the amount of the contribution to a system of land ownership. The goal of the experiment is to offer the participants various financing instruments and ask them how much they would like to make a donation or to invest in different land ownership projects. Two of the three financial instruments are those offered by Association 'Terre de Liens': donations and savings with tax benefits (66% and 25% tax deductions, respectively). The third option available to participants in the experiment is to take out a subscription to buy part of the produce from the farmer. This third system allows farmers to secure the sale of part of their production. This experiment will allow us to identify the most effective financing instruments and determine individual motivations for participation (altruism or optimising savings). The results will be used to push forward public policies based on the willingness to pay obtained during the experiment.

Adapting agricultural practices to climate change

From 1982 to 2023, 99.2% of French municipalities experienced at least one natural disaster, with 8% suffering more than fifteen (Antoni and Joassard, 2024). In recent years, there has been a rise in the number of droughts caused by climate change (Lee et al., 2023). These phenomena can lead to restrictions on the use of water. As we saw in Chapter II, these restrictions influence farmers' practices. We can now look at the temporal aspect of these changes. Are the adaptations made by farmers temporary or permanent ? Does exposure to a natural disaster make them aware of their role in climate issues (trigger) ? More broadly:

- To what extent do extreme natural events encourage farmers to change their practices ?

We would like to observe how the probability of adopting sustainable practices (organic farming, new crops, agroforestry, etc.) varies according to the frequency of exposure to extreme weather events. It is assumed that the effect will vary depending on the type of farmer, as well as the frequency and intensity of weather events. Firstly, according to Osborne and Evans (2019), not all farmers attach the same importance to climate change when making agronomic decisions. They define four types of farmers, ranging from the analyst to the disengaged. Analysts are farmers who carefully study weather forecasts by cross-referencing them with other scientific data and their knowledge of the area in order to make decisions about their farming practices. They also define the profile of farmers as 'disengaged': those who do not take weather data into account in their decisions and who base their decisions solely on market values or commodity prices. Therefore, facing the same natural phenomenon, farmers do not choose the same practices. Secondly, for a given farmer type, we expect a decreasing positive relationship between the probability of changing practices and the frequency of extreme events. This is because the first disasters may encourage farmers to change their practices. However, if these disasters are repeated, they could develop a fatalistic attitude[14] towards climate change, leading them not to change their practices.

To carry out this analysis, we will use the European LPIS data, whose availability differs from country to country. This will enable us to observe changes in European agricultural practices, which we will combine with meteorological data. Event study or DiD modelling will make it possible to isolate the marginal effect of a climatic phenomenon on exposed farmer compared with non-exposed farmer. The project could also be extended to examine the role of CAP subsidies in limiting these changes. This project will contribute to the literature on the adoption of adaptation and mitigation strategies in the face of climate change.

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[14] Osborne and Evans (2019) define this behaviour as that of certain farmers who are resigned to climate change and are unaware of long-term adaptation methods for dealing with the consequences of natural change

Conclusion générale

Dans cette thèse, nous avons cherché à compléter la littérature sur l'influence des divergences territoriales sur le développement de l'AB. Nous avons utilisé une approche empirique complétée par l'usage d'indicateurs spatiaux pour identifier des hétérogénéités territoriales de différentes natures (naturelles, historiques, politiques). Nous avons également observé leurs effets sur les agriculteurs et leurs trajectoires agronomiques.

Nous avons mené cette réflexion via trois questions de recherche :

- Comment les exploitations et les terres agricoles biologiques sont-elles réparties entre les communes françaises ? Quels sont les principaux facteurs spatiaux qui expliquent ce développement hétérogène ?
- La délimitation des aires d'alimentation de captage incite-t-elle les agriculteurs à modifier leurs pratiques ?
- Quelle est la valeur associée au territoire dans le prix de la terre agricole ? L'AB augmente-t-elle la valeur des terres ?

À la première question, il convient d'abord de répondre, comme l'avait montré Allaire et al. (2014), que les parcelles en AB sont réparties de manière très disparate sur le territoire, avec des effets d'agglomération importants. L'approche par modélisation *Spatial Durbin Model*, permet de comprendre les caractéristiques qui renforcent ces divergences. Nous observons que les exploitations en AB sont généralement situées loin des grandes villes, dans des zones densément boisées et sur des sols moins adaptés à la pratique agricole. Cependant, les agriculteurs en AB exploitent dans des zones éloignées des grandes villes, mais proches des populations susceptibles de consommer des produits biologiques. Ces zones sont caractérisées par une forte densité de population ayant atteint un niveau d'études universitaire et faiblement ouvrière.

Concernant l'influence des politiques publiques, les subventions ICHN influencent positivement le nombre de terres en AB. En ce qui concerne la politique des AOP, les résultats dépendent du type de produit labellisé. Le label AB et le label AOP viticole sont complémentaires, tandis que les autres labels AOP n'ont aucune incidence sur le développement de l'AB. Enfin, les matrices de voisinage retenues permettent d'observer l'influence prédominante du voisinage frontalier et une influence de la demande potentielle de produits AB jusqu'à 20 km.

La réponse à la deuxième question est plus nuancée. L'impact de la politique AAC sur les pratiques agricoles varie en fonction du moment de son implantation, du groupe de comparaison et de la pratique agricole observée. Nous avons montré que cette politique n'a eu aucun effet sur la dynamique de l'AB dans les zones traitées à partir de 2019, ou qu'elle a été négative par rapport aux zones voisines traitées en 2017 et 2018. La comparaison des groupes traités avec leur voisinage permet d'identifier deux autres résultats. Premièrement, dans les zones voisines situées à moins de 2 km de l'AAC, aucune différence de pratique n'est observée. Cela pourrait indiquer un potentiel traitement au-delà de la zone. Deuxièmement, dans les zones plus éloignées (entre 2 et 10 km de l'AAC), on observe un développement de l'AB bien supérieur à celui des AAC. Ces résultats sont cohérents avec ceux de l'enquête qualitative menée auprès des agriculteurs en AB dans la région *Grand Est*, montrent que dans les AAC, une part importante d'agriculteur exploitant en AB ont la volonté d'arrêter la pratique AB.

Le chapitre III nous permet de répondre clairement à la troisième question puisqu'il observe que les terres exploitées en AB sont vendues environ 2% moins chères que des terres exploitées en AC. Ce résultat s'explique par un marché des terres biologiques plus marginal, se traduisant par un accès plus difficile à ces terres (plus éloignées des acheteurs potentiels). Néanmoins, cette valeur inférieure montre que les externalités positives de l'AB par rapport à l'AC ne sont pas prises en compte sur le marché du foncier agricole. Ce chapitre appuie la recommandation de Crowder and Reganold (2015) *"Financial instruments are needed to give monetary value to the externalities that arise from agricultural practices"*. En outre, les résultats du chapitre III montrent qu'il existe une hétérogénéité de la valeur accordé à la pratique bio en fonction de la culture. On observe que les vignes AB sont vendues 6% plus chères à l'hectare que des vignes en AC, alors que pour les vergers et les terres arables, les terres AB sont vendues moins cher que les terres en AC. Ce résultat fait écho au chapitre I qui révèle que les AOP et l'AB dans la viticulture sont complémentaires. Les vignerons sont prêts à payer plus pour une terre agricole déjà en bio. Cette dernière leur offrant la possibilité de développer une production à valeur ajoutée plus importante.

Limites et extensions futures

Dans le chapitre I, il est possible de soulever une limite et une extension possibles au vu de la conjoncture du marché de l'AB. L'analyse développée dans ce chapitre est basée sur des données en coupe transversale pour l'année 2019, ce qui ne permet pas de mesurer la dynamique d'évolution de l'AB dans les communes. L'utilisation des données du RPG à partir du millésime de 2015 pourrait pallier ce manque. Toutefois, comme la majorité des variables sont invariantes à court terme (le nombre d'AOP, la part de forêt, les caractéristiques pédologiques), nos résultats ne sont pas remis en cause.

L'analyse pourrait aussi bénéficier d'une extension : l'observation des déconversions de la pratique AB (passage de l'agriculture biologique à l'agriculture conventionnelle) en France. Étant donné la conjoncture en AB, il serait intéressant de localiser ces déconversions et d'en comprendre les déterminants. Le modèle développé au chapitre I pourrait tester l'influence de l'hétérogénéité territoriale sur la probabilité de quitter l'AB. Une telle analyse demanderait d'inclure les caractéristiques individuelles de l'agriculteur et de son exploitation. On peut à ce stade formuler les hypothèses suivantes : plus un agriculteur entretient des relations avec des pairs agriculteurs en AB, plus sa probabilité de déconversion est faible. De plus, nous supposons que l'orientation technico-économique de l'exploitation joue un rôle important dans la décision de retour vers l'AC. Par exemple, les éleveurs laitiers AB ont connu en 2022 une période d'excédent de production. En mai 2022, le prix du lait biologique était inférieur à celui du lait conventionnel, ce qui a conduit à un déclassement d'une partie de la production AB en AC. Cet évènement a pu entraîner des décisions radicales de retour à l'AC pour les éleveurs affectés.

L'analyse présentée dans le chapitre II pourrait être approfondie en suivant deux axes afin de pallier les limites actuelles de ce chapitre. Notre accès limité aux actions menées dans chaque AAC, qui se concentrent uniquement sur les MAEC, nous empêche de formuler des recommandations de politiques publiques complètes. Pour y remédier, il est essentiel de recueillir l'ensemble des documents administratifs au niveau de chaque AAC. Ensuite, en utilisant des méthodes de traitement automatique du langage naturel (NLP), nous pourrons identifier toutes les actions mises en place dans le cadre de la politique. Une fois cette étape franchie, la couverture exhaustive des actions par AAC nous permettra de comprendre l'hétérogénéité des pratiques agricoles entre les AAC. Cela nous permettra également de mesurer l'efficacité de chaque type d'instrument.

Le deuxième axe d'approfondissement de ce chapitre consiste à évaluer l'impact des changements de pratiques agricoles sur la qualité de l'eau dans les zones affectées par la politique des AAC. Pour cela, nous envisageons de compléter notre base de données actuelle avec des relevés de qualité d'eau et des inventaires de la biodiversité aquatique fournis par l'Office français de la biodiversité. Cette analyse vise à examiner comment ces changements agronomiques influencent l'environnement, en particulier la qualité de l'eau. Ce projet enrichirait notre chapitre II en offrant une analyse multidimensionnelle des impacts de la politique des AAC.

Pour ce qui est du chapitre III, nous avons identifié une limite et des extensions possibles. En raison de l'absence d'indicateurs de qualité du sol au niveau de la parcelle, la méthode intègre des proxies pour les caractéristiques du sol à partir de la base de données *European Soil Database v2 Raster* (Panagos et al., 2012). Cette base permet de caractériser une parcelle par le niveau de pente et la granularité moyenne. Par cette approximation, l'effet marginal de la pratique AB sur le prix est biaisé par la qualité du sol. En effet, dans notre base de données, si deux parcelles contiguës sont exploitées respectivement en AB et en AC, notre méthode leur attribue les mêmes caractéristiques pédologiques. Or, comme en réalité, la variabilité de la qualité du sol est très importante (variant d'une parcelle à l'autre), ces deux parcelles contiguës n'auront pas les mêmes qualités observées. Comme mentionné dans le chapitre 1, il est plus probable que ce soit l'agriculteur en AC qui exploite la meilleure terre. Par conséquent, l'écart de vente de 2% entre les terres AB et AC n'est pas uniquement dû à la différence de pratiques, mais aussi à des différences de qualité du sol non observées.

Une voie d'approfondissement de ce chapitre serait d'enrichir la base de donnée avec le suivi longitudinal de chaque parcelle. Grâce aux données spatialisées du RPG, il serait possible de suivre une parcelle même après un changement d'exploitant. L'un des intérêts de ce suivi parcellaire serait de pouvoir mener une analyse d'hétérogénéité des prix du foncier en fonction de la durée de conversion en AB de la terre. Deux méthodes d'analyse pourraient être envisagées. La première consiste à utiliser la même méthode que celle employée dans le troisième chapitre, basée sur l'analyse des prix hédoniques avec matching spatial. Une deuxième méthode serait l'estimation de l'effet de la durée de conversion se ferait uniquement via l'analyse ricardienne sur les ventes répétées (Bareille and Chakir, 2023). Par cette deuxième méthode, après avoir sélectionné uniquement les terres vendues deux fois sur la période, il s'agit de calculer la différence de prix de vente pour chaque parcelle. En neutralisant les effets des variables non observées (effet fixe parcelles), cette méthode permettrait d'obtenir l'effet marginal du changement agronomique de la parcelle entre les deux ventes. En d'autres termes, nous pourrions déterminer si la valeur attribuée à la pratique de l'agriculture biologique est constante ou si elle varie en fonction de la durée de conversion.

Recherches futures

Le marché foncier, un instrument à mobiliser pour développer une agriculture plus durable

Dans le chapitre 3 de cette thèse, nous avons étudié le marché du foncier agricole en nous concentrant sur les prix de vente. Cependant, il serait aussi intéressant d'identité les acheteurs pour comprendre la trajectoire agronomique prévue. Selon le recensement agricole de 2020, seulement 20% des SAU sont exploitées en faire-valoir direct (contre 50% en 1946, et 25% en 2010). Par conséquent, dans 80% des cas, puisque les informations contenues dans le RPG donnent uniquement des informations sur l'exploitant de la terre, nous ne pouvons pas identifier les propriétaires. Or, le rôle de ce dernier est important dans les pratiques agricoles qui sont exercées sur ces terres.

Léger-Bosch (2015) identifie parmi les acquéreurs de terres agricoles, de nouvelles formes de propriété foncière portées par des acteurs publics et associatifs. À travers diverses formes juridiques (collectivités, associations), ces acteurs cherchent, par l'acquisition de terres, à préserver l'activité agricole face à l'urbanisation et à encourager son exploitation par des pratiques agroenvironnementales. Ils mettent leur terre à la disposition de nouveau installant portant des projets d'agriculture durable sous le statut de fermage par des baux ruraux à clauses environnementales. Ce type de bail intègre des clauses spécifiques visant à encourager ou à imposer des pratiques agroenvironnementales (implantation de haies, réduction de l'utilisation de produits chimiques, etc.). Ces initiatives sont encore marginales, mais elles répondent à des enjeux importants. Elles limitent la concentration des terres agricoles, favorisent l'installation de nouvelles exploitations et accélèrent le développement des pratiques agricoles durables. Plus précisément, deux questions méritent d'être soulevées :

- Quelles sont les motivations des épargnants à participer à ces initiatives de portage foncier agricole ?
- Quels sont les dispositifs financiers les plus efficaces ?

Ces nouvelles formes de portage peuvent être financées par l'épargne individuelle privée. Il est pertinent de s'intéresser aux motivations des particuliers qui investissent financièrement ou bénévolement dans ces structures. Le métaprogramme INRAe "Dis-Bio" devrait permettre de comprendre les déterminants de la participation et du montant de la contribution à un système de portage foncier agricole. L'objectif de l'expérience est de proposer aux participants différents instruments de financement et de leur demander le montant qu'ils souhaitent investir ou donner dans différents projets de portage foncier agricole. Deux des trois dispositifs financiers, sont ceux proposés par l'Association Terre de Liens: le don et l'épargne solidaire avec avantages fiscaux (respectivement 66% et 25% de déduction fiscale). Le troisième est la possibilité, pour le sujet, de souscrire à un abonnement l'engageant à acheter une partie de la production à l'agriculteur. Ce système est basé sur celui des *AMAP* (Association pour le maintien d'une agriculture paysanne). Ce troisième dispositif permet à l'agriculteur de sécuriser la vente d'une partie de sa production. Cette expérience permettra d'identifier les instruments de financement les plus efficaces et de déterminer les motivations individuelles pour participer (altruisme ou optimisation de leur épargne). Les résultats auront vocation à proposer des politiques publiques basées sur les consentements à payer obtenus durant l'expérience.

Adaptation des pratiques agricoles face au changement climatique

Entre 1982 et 2023, 99.2% des communes françaises ont connu au moins une reconnaissance de catastrophe naturelle, dont 8% qui en ont subi plus de 15 (Antoni and Joassard, 2024). On note que les dernières années ont été marquées par une augmentation du nombre de sécheresses, causée par le changement climatique (Lee et al., 2023). Ces phénomènes peuvent entraîner des restrictions sur l'utilisation de l'eau. Nous avons vu dans le chapitre II que ces restrictions influencent les pratiques des agriculteurs. On peut maintenant se questionner sur la temporalité de ces changements. Les adaptations mises en place par les agriculteurs sont-elles temporaires ou permanentes ? L'exposition à la catastrophe naturelle fait-elle prendre conscience à l'agriculteur de son rôle dans les enjeux climatiques (élément déclencheur) ? Plus généralement :

- Dans quelle mesure l'exposition des agriculteurs aux phénomènes naturels extrêmes les incite-t-elle à modifier leurs pratiques ?

Nous souhaitons observer comment la probabilité d'adopter des pratiques durables (AB, nouvelles cultures, agroforesterie, etc...) varie en fonction de la fréquence d'exposition à des phénomènes extrêmes. À cette question, on suppose que l'effet variera selon le type d'agriculteur, ainsi que la fréquence et l'intensité des épisodes météorologiques. Premièrement, selon Osborne and Evans (2019), les agriculteurs n'accordent pas tous la même importance au changement climatique dans leurs décisions agronomiques. Ils ont défini quatre types d'agriculteurs allant de l'analyste au désengagé. Les auteurs définissent les *analystes*, comme des agriculteurs qui étudient minutieusement les prévisions météorologiques en les croisant avec d'autres données scientifiques et leur connaissance fine du territoire pour prendre des décisions sur leurs pratiques agricoles. À l'opposé, ils définissent le profil d'agriculteurs *désengagés*: ceux qui ne tiennent pas compte des données météorologiques dans leurs décisions et qui se basent uniquement sur les valeurs du marché ou les prix des matières premières. Ainsi, face à des phénomènes naturels donnés, les agriculteurs n'adoptent pas les mêmes choix de pratiques. Deuxièmement, pour un profil d'agriculteurs donné, nous nous attendons à obtenir une relation positive décroissante entre la probabilité de changement de pratique et la fréquence des événements extrêmes. En effet, les premières catastrophes pourraient inciter l'agriculteur à changer ses pratiques. Toutefois, si celles-ci se répètent, il est possible qu'il développe un comportement fataliste[15] face au changement climatique, le poussant à ne pas modifier ses pratiques.

Pour réaliser cette analyse, nous utiliserons les données européennes du RPG, dont la disponibilité diffère d'un pays à l'autre. Cela nous permettra d'observer les

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[15] Osborne and Evans (2019) définissent ce comportement comme étant celui de certains agriculteurs résignés face au changement climatique et ignorant des méthodes d'adaptation à long terme face aux conséquences du changement naturel

changements dans les pratiques agricoles européennes, que nous combinerons avec les données météorologiques. Les modélisations Event study ou DiD nous permettraient d'isoler l'effet marginal d'un phénomène climatique sur une agriculture exposée par rapport à un agriculteur non exposé. Ce projet pouvant être aussi étendu aux rôles des aides PAC dans la limitation de ces changements. Ce projet enrichirait la littérature sur l'adoption des stratégies d'adaptation et d'atténuation face au changement climatique.

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Incentives and spatial heterogeneity on organic farming development

RÉSUMÉ

Cette thèse étudie le rôle de l'hétérogénéité des territoires dans le développement de l'agriculture biologique (AB) en France. Le chapitre 1 identifie des facteurs spatiaux permettant de comprendre l'inégale répartition des terres en AB. Le chapitre 2, par l'étude de la politique d'Aire d'Alimentation de Captage, permet d'observer les dynamiques locales des pratiques agro-environnementales. Le chapitre 3 mesure la valeur accordée à la pratique AB sur le marché foncier agricole entre 2015 et 2021.

Mots clefs: Agriculture biologique, Foncier agricole, Economie géographique, Registre parcellaire graphique

RESUME

This thesis examines the role of spatial heterogeneity in the development of organic farming (OF) in France. Chapter 1 identifies the spatial factors that explain the uneven distribution of land under OF. Chapter 2, through the study of the Protect Water Catchments Area policy, allows for observing local dynamics of agro-environmental practices. Chapter 3 measures the value of OF practices on the farmland market between 2015 and 2021.

Keywords: Organic farming, Farmland market, Geographical economics, Land Parcel Identication System