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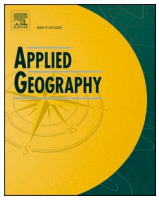

Spatial proximity in 'local' Alternative Food Networks: a case study of AMAP in France

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ABSTRACT

This paper explores the emerging paradigm of alternative food networks (AFN), with a focus on AMAP (Association pour le Maintien de l'Agriculture Paysanne) in France as a case study. Delving into the multifaceted concept of spatial proximity within such networks, this paper explores three hypotheses drawn from literature on the spatiality of AFN, analyzing both 'local' distances variability and the characteristics of agricultural and urban contexts where such local-based AFN take place. Methodologically, the study leverages an original, manually compiled database at a national scale encompassing AMAP producers and distribution points. Specific analytical protocols are developed combining traditional geographical approaches with machine learning techniques. Key findings reveal the influence of both population density and agricultural land availability on the distances between producers and selling locations. Moreover, the study discerns that the nature of products and their processing levels significantly shapes 'local' distances. Additionally, the paper offers insights into distinctive features of the morphological landscape associated with AMAP producers. These findings may serve as a catalyst for future inquiries into the spatial dynamics and potential spatial configurations of alternative food networks.

1. Introduction

In the last few decades, with the increasing awareness of the environmental and health implications of food choices, alternative marketing models emerged (Aprile & Punzo, 2022). Drawing significant attention internationally (Brunori, 2007; Maye, 2013; Whatmore et al., 2003), alternative food networks (AFN) are defined as the practices that emerged in the 1990s against the standardization, globalization and unethical nature of the industrial food system and the consequent academic body of work (Edwards, 2016). Among various initiatives, some promote a higher level of 'proximity' between places and actors of production and consumption (Poulot, 2014). Hence, multiple studies within the scientific community delve into the notion of food proximity and explore its wide semantic range (Deprez, 2017; Jones et al., 2004; Tregear, 2007). Proximity is a multifaceted concept, encompassing socioeconomic dimensions such as shared values, relational connections, intermediary count or economic benefit distribution (Eriksen, 2013; Praly, 2014). However, its primary criterion is geographical, indicating spatial closeness between places of production and consumption (Martinez et al., 2010) and often related to the notion of 'local'.

In France, AMAP (Association pour le Maintien de l'Agriculture Paysanne) are an example of such AFN based on proximities. AMAP aim to bridge consumers with food producers, facilitating access to fresh, seasonal produce while ensuring producers a stable income. They are structured through contractual agreements between consumers and producers, and materialized by a regular distribution of fresh, locally grown products (Guiraud, 2019). Through this direct partnership, AMAP promote sustainable agriculture, responsible consumption, and community solidarity (Miramap p.1, 2014). AMAP prioritize local production to facilitate direct interactions between producers and consumers, thereby reducing relational distances associated with intermediaries. For this reason, they provide an ideal case study to explore the notion of proximity, focusing on its spatial dimensions. Still, there is a lack of consensus in the scientific community regarding the definition and measurement of spatial proximity in AFN and the meaning of local food remains vaguely defined (Bingham, 2022; Kneafsey et al., 2013), alongside a scarcity of large-scale empirical studies. When examining spatial proximity, two prevalent approaches are employed: proximity as a threshold, often an arbitrary absolute distance utilized to define a 'local' geographical area; conversely, other studies regard proximity as the outcome of a spatial process (Consalès et al., 2022), thus considering it as a combination of place-specific

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attributes. Within the latter framework, researchers explore a range of attributes that might explain the spatial variability of the proximity, such as the nature of production (Bingham, 2022; Carroll & Fahy, 2015; Ostrom, 2006) or the population density of the served urban area (Baysse-Lainé, 2021; Kneafsey et al., 2013). Additionally, some studies analyze the morphological features associated with rural landscapes oriented towards 'local' food networks (Mouléry et al., 2022). Building upon these insights, this study aims to conduct an in-depth investigation into spatial proximity, examining its characteristics and variability in relation to their local contextual factors through three hypotheses. The aim of this study is to conduct a national-level empirical analysis of AMAP spatial distribution in France, utilizing innovative spatial analysis protocols to explore spatial proximity in alternative food networks and contribute to the scientific debate on the notion of 'local' (Gatrell et al., 2011).

This paper is organized as follows. Section 1 describes the emergence of 'proximity'-based AFN, the diverse comprehension of this term (both from academic and non-academic domains), and finally presents the three main hypotheses guiding this paper's research goals. Section 2 frames our study area and the collected database. Section 3 empirically tests the work hypotheses over a national-scale database. Section 4 discusses the main results of this work, and finally, a conclusive section underlies limits and future perspectives.

2. Contextualization

2.1. Emergence of proximity-based alternative food networks

The contemporary agrifood system relies on increasing yields and competitive pricing to ensure food security, focusing on spatial specialization (Poulot, 2014), intensification and productivism (Allaire & Daviron, 2017; Devienne, 2018; Temple et al., 2018), and international food trade (Hairy & Perraud, 1988). European trade policy evolves alongside, and international agri-food imports and exports increased by +€64.2 billion and +€83.6 billion respectively between 2013 and 2023 (Eurostat, 2024). These productivist and liberal dynamics primarily benefit the largest farms: increasing productivity allows reducing the unit selling prices, thereby enhancing competitiveness in the global market (Lange et al., 2013; Van den Ban, 2002). In France, large farms (generating over 250k€ annually) now represent 40% of French agricultural areas (Agreste, 2021). These dynamics are strengthened by changes in the Common Agricultural Policy (CAP), which favors large farms by allocating per-hectare direct payments (Pe'er & Lakner, 2020).

In contrast to this dominant globalized model, alternative approaches based on 'proximity' emerge (Renting et al., 2003). As early as the 1960s, alternative food networks (AFN) known as *teikei* (提携) appear in Japan amid concerns over the heavy use of chemical fertilizers (Lagane, 2011). *Teikei* involve collective purchasing of chemical-free food directly from producers, with a charter ensuring a direct relationship to consumers. In the United States, *Community* Supported *Agriculture* (CSAs) emerged in the 1980s as an AFN, ensuring a fair remuneration for producers. CSAs rapidly expanded, generating up to $226 million in sales by 2015 (Morgan et al., 2018). In France, AMAP (*Associations pour le Maintien de l'Agriculture Paysanne*) appeared in the early 2000s. Similarly to CSA, these organizations rely on regular meetings between producers and consumers, with an additional requirement for producers' spatial proximity (Miramap p.1, 2014).

Born out of concerns over the sustainability of the contemporary food system, AFN are often seen as beneficial to the environment (Mundler & Rumpus, 2012), enhancing social participation and cohesion (Dimitri et al., 2016), and raising interest in food quality (Paül & McKenzie, 2013). Such considerations regarding AFN's social and environmental benefits have been widely discussed in the scientific literature (Lulovicova & Bouissou, 2023; García-Martín, 2021; Michel-Villareal et al., 2019). Public institutions have also shown interest in AFN, launching local sustainable food policy initiatives such as the Milan Urban Food Policy Pact (Milan Urban Food Policy Pact, 2015) and the Glasgow Food and Climate Declaration (Glasgow Declaration, 2021). In France, legislation is evolving to develop these proximity-based alternatives: created in 2014 b y the French Ministry of Agriculture, Food Territorial Projects (*Projets alimentaires territoriaux*) aim to bridge the gap between local production and food demand, to develop the consumption of a sustainable and 'local' food (Chambre d'agriculture, 2024). However, what encompasses the 'local' and 'proximity' terms is yet to be discussed.

The notion of 'proximity' entails multifaceted dimensions and scopes including spatial, relational, institutional, and cultural aspects (Bingham, 2022; Eriksen, 2013). Two main research directions explore 'proximities'. On one side, commercial proximity qualifies the consumer's closeness to groceries commercialization places (Deprez, 2017), stimulating investigations about equity of its spatial accessibility (Charreire et al., 2010; Lytle & Sokol, 2017; Merchez et al., 2020; Vonthron, 2021). On the other hand, proximity refers to the spatial relationship between production and consumption stakeholders, characterized by the number of intermediaries, the product quality information, or the share of benefits among stakeholders (Praly, 2014). In both cases, spatial proximity qualifies the geographical connections between the places where food is produced and consumed (Hasanzade et al., 2022). Generally speaking, most AFN aim to re-spatialize food systems (Marsden et al., 2000; Renting et al., 2003), and involve short distances between producers and consumers as local constructions (Paül & McKenzie, 2013). In France, AMAP are defined as 'a collective formed by all the members and producers engaged in a local, solidarity-based partnership, contractualized without commercial intermediaries, with a spirit of sustainability' (Miramap, p.1 2014). Although this definition does not explicitly specify any limits regarding the geographical extent of what should be considered local, it still encompasses, among other criteria, the geographical 'local' aspect of the food network. What is spatially considered 'local' is however subjected to an ongoing debate (Bingham, 2022; Kneafsey et al., 2013).

2.2. The spatiality of proximity-based AFN

Two approaches are commonly used to conceptualize spatial proximity: as a *threshold*, often arbitrarily defined; or, *as the result of a spatial process*, discussing local food systems through their sources to distribution flows (Kremer & DeLiberty, 2011). Thresholds are either defined as administrative boundaries or arbitrary distances, delimiting a given perimeter around a chosen center feature. Most thresholds characterize production-to-retail locations distances, including eventual processing steps. For instance, local perimeter is set at 400 miles from the retail location in the United States (Food Conservation and Energy Act, 2008); and Canada delineates the province perimeter and up to 50 km from its border (Enthoven & Van den Broeck, 2021). The EU Joint Research Centre (2013) suggests a 20–100 km maximum radius between production, processing and retail locations (Kneafsey et al., 2013). In France, governmental institutions such as ADEME (2017) set a limit from 30 to 100 km between production and consuming locations, while others suggest a 50–100 km range (Callois, 2022). Aside from institutional and scientific perspectives, movements such as locavorism debate a 160–250 km boundary for 'local' production (Poulot, 2012). Concrete initiatives such as numeric commercialization platforms for local food set a maximum distance between the production and pickup locations, for instance 250 km for *'La ruche qui dit oui'* (Stephens, 2021).

Authors often favor a place-dependent characterization of the local perimeter, depending on the case study context (Kneafsey et al., 2013). 'Local' spatial scale is often described as resulting from the relationships between actors (Nost, 2014), or as an ethical distance (Loudiyi et al., 2022). The local scale thus becomes an endogenous process to be studied (Consalès et al., 2022), embedded in its locality (Kremer & DeLiberty, 2011), and thus varying with the food network type or the supporting

organization. Many authors rely on the concept of 'foodshed,' which encompasses various understandings. On one hand, foodshed refers to the spatial identification and tracing of food flows in terms of imports and exports (Schreiber et al., 2021), which bridges the concept of food self-sufficiency (Bingham, 2022; Zasada et al., 2017). For instance, Zasada et al. (2017) compares the potential agricultural supply and food demand within four European metropolitan administrative areas, to assess their level of self-sufficiency. On the other hand, foodshed is defined as the agricultural capacity required to meet a specific territory's food demands (Schreiber et al., 2021). For instance, Darrot (2014) explores the spatial distance required to supply the Rennes metropolis with food. Here, what is considered 'local' depends on the agricultural capacity of the territory's surroundings.

In this perspective, general hypotheses emerge in the scientific literature to characterize the local scale variability. According to literature exploring the production-retail distances variability, this geographical perimeter would depend on the product type (Carroll & Fahy, 2015) or the associated transportation costs (Bingham, 2022). Certain variables such as population density would also affect how agriculture penetrates the territory of a metropolis (Corsi et al., p. 35–36, 2015). According to certain authors, the dimensions of cities might impact geographical proximity (Guiraud, 2019; Kneafsey et al., 2013), making the local perimeter dependent on demographic variations (Baysse-Lainé, 2021).

Another research direction explores the spatial contexts of such AFN. In the United States, most CSA are located near major metropolitan areas (U.S. Department of Agriculture, 2012). Brinkley (2018) analyzes AFN in Baltimore County using graphs, and demonstrates that such AFN exhibit 'small worlds' architectures, with the most connected nodes located within peri-urban areas. Indeed, peri-urban areas are commonly outlined as favorable locations for the emergence of AFN (Low, S.A. et al., 2015; Paül & McKenzie, 2013; Cicia et al., 2011). Such peri-urban areas are qualified as 'contested' spaces, subjected to both housing development dynamics for urban expansion, and demands for agricultural activities (Brinkley, 2018). Thus, shortening the physical and relational distances between producers and consumers represents a key strategy to support and maintain peri-urban agriculture (Wästfelt & Zhang, 2016). In Southern France, Guiraud (2019) characterizes the integration of producers and AMAP pick-up points into the urban fabric, identifying three groups of networks: 'urban' AMAP, with a pick-up point located within an urban area, close to consumers but far from the producers; 'peri-urban' AMAP, with a peri-urban pick-up point, closer to producers and farther from consumers; and 'agri-urban' AMAP, where the producers are very close to the city, thus shortening the distances both to the pick-up points and to consumers. Thus, the spatial contexts of AFN and, in particular, their embeddedness within the urban fabric, are widely studied in the literature and have been shown to be determinant characteristics of such alternative networks.

Moreover, the scientific literature describes how the agricultural plot system morphology, such as size, fragmentation, and diversity, might play a role in their integration to the global productivist agricultural model (Latruffe & Piet, 2014; Looga, Jürgenson, Sikk, Matveev, & Massikamäe, 2018; Ntshangase et al., 2018). When it comes to alternative commercialization models, smaller farms located within the peri-urban fringe have been identified as particularly conducive to undertaking CSA proposals (Cicia et al., 2011). However, few authors have yet focused on the morphological specificities of agriculture associated with AFN, such as Mouléry et al. (2022) analyzing the morphology of agricultural plots oriented towards 'local' beef commercialization.

Overall, the spatiality of local-oriented AFN has been studied from various research fields proposing diverse methodological approaches (Enthoven, 2021; Gatrell et al., 2011). Many authors analyze the food miles variability using qualitative methods, favoring a territorial-embedded approach to assess what factors influence what is considered 'local' (Baysse-Lainé, 2021; Carroll & Fahy, 2015; Kremer & DeLiberty, 2011; Ostrom, 2006). Few quantitative geography papers have explored food miles variability on a broader scale (Bingham, 2022). Instead, quantitative approaches often focus on the morphological analysis of agricultural plots, shedding light on their adaptability to the dominant productivist agricultural model (Latruffe & Piet, 2014; Looga, Jürgenson, Sikk, Matveev, & Massikamäe, 2018; Ntshangase et al., 2018), as opposed to alternative models such as short food chains-oriented agriculture (Mouléry et al., 2022). Moreover, many studies identified peri-urban areas as common locations for such networks to develop (Wästfelt & Zhang, 2016; Guiraud, 2019; Brinkley, 2018; Low, S.A. et al., 2015; Paül & McKenzie, 2013; Cicia et al., 2011), underlining the importance of considering AFN spatial contexts.

2.3. Research hypothesis and objectives

This study examines various interpretations of geographical proximity, without seeking comprehensive conclusions regarding its implications. It employs empirical investigation at a national level using a database of AMAP in France. Therefore, the following sections constantly refer to this specific form of proximity-based AFN.

Three main research hypotheses exploring the spatiality of AFN guide this paper's structure.

At first, the paper focuses on the factors that influence the spatial variability of distances between producers and retail locations. This variability seems to be linked to population density, as suggested in previous research works (Guiraud, 2019; Kneafsey et al., 2013), and further outlined from semi-structured interviews conducted in two French metropolitan areas by Baysse-Lainé (2021). In other words, AFN located within large metropolitan areas displaying high population densities would exhibit longer 'local' distances. Thus, our primary objective is to investigate whether **the spatial distance between production and consumption areas within local food networks varies according to the population density of the serviced city (H1)**.

The second hypothesis explores distance variability based on product typologies, drawing on previous research highlighting the importance of product types in defining 'local' distances (Carroll & Fahy, 2015; Ostrom, 2006). Expanding on this, our second hypothesis is stated as follows: **distances between production and consumption areas within proximity-based food chains vary according to food characteristics (H2).**

While the first two hypotheses concentrate on proximity as the distance between retail outlets and their producers, the third hypothesis focuses on local characteristics surrounding the latter. When considering proximity-oriented producers, some authors argue that certain rural landscapes properties such as a rural-urban fringe localization (the proximity of agriculture to urban consumers) are particularly conducive to the development of direct sales (Brinkley, 2018; Paül & McKenzie, 2013). Moreover, rural plot morphology could hinder the development and integration to the productivist and intensive dominant agricultural model (Latruffe & Piet, 2014; Looga, Jürgenson, Sikk, Matveev, & Massikamäe, 2018; Ntshangase et al., 2018), thus providing opportunities for alternative production formats (Cicia et al., 2011; Mouléry et al., 2022). Our last hypothesis thus aims to investigate whether **specific morphological and land-use features characterize the local rural landscape surrounding producers involved in local AFN (H3)**.

3. Material and methods

3.1. AMAP in metropolitan France

As delineated in preceding sections, this study aims to explore spatial proximity within the context of French alternative food networks, with a particular focus on AMAP. Two reasons underlie the choice of focusing on this specific format. From a thematic perspective, this choice allows analyzing spatial proximity. AMAP are associations where consumers commit to supporting local producers by purchasing regular buckets of fresh produce through a contract (Géoconfluences, 2023). Typically,

these contracts ensure transparency about the farming methods, often organic, and involve upfront payments to secure income for producers (Guiraud, 2019). In practice, weekly or bi-monthly distribution of products allows producers and consumers to meet and exchange directly, sometimes including on-farm visits for consumers. It is to be acknowledged that the sales locations in AMAP are actually pick-up points, as the commercial transaction occurs beforehand in the form of a contractual agreement. Thus, the term 'pick-up point' will be used in the following sections to refer to locations where consumers and producers meet to exchange products. AMAP operate under a charter defining principles such as agroecological practices, popular education, solidarity-based relationships, and direct participation in local economies (Miramap, 2014). By facilitating direct ties between producers and consumers, AMAP minimize organizational, social, and economic distances. This allows us to focus solely on spatial proximity, its characteristics and variability.

From a methodological perspective, studying spatial proximity in the case of AMAP at a large scale would require very specific geographical data. Such study must indeed rely on precise geographical databases identifying both farms associated with AFN described by their spatial extent and the associated pick-up points. Common databases used in rural studies such as the French General Agricultural Census (RGA) only allow to identify producers joining AFN without a precise geographical information about their extent and with no information about their selling points. Land Parcel Identification System (LPIS) is a census conducted for all European farms benefitting from the CAP fundings. While providing spatial data on agricultural plots, LPIS does not bring information on their associated food network. Official databases such as the US Community Flow Survey (U.S. Department of Transportation, 2020) provide such information but are not AFN specific and do not characterize the type of food network involved. None of the databases presented above meet the required criteria, thus a key challenge of this study is to create a comprehensive database of these local-based AFN phenomena. AMAP websites provide comprehensive information on both producers and pick-up locations, including their network relationships and the product type commercialized, and guarantee their participation in local-based AFN. Each AMAP can have multiple associated producers, and each producer can supply multiple AMAP, creating a network database linking production and marketing locations.

The decentralized nature of AMAP information, scattered across various websites created by the organizations or AMAP themselves, underscores the self-organized character of these local food networks, highlighting regional disparities in their organizational structures across France. Although data collection thus implies a multi-sourced data collection, structuration and aggregation, these websites serve as valuable sources of data that can be used to analyze AFN, supporting the use of AMAP as a case study.

In summary, AMAP are a well-suited case study for analyzing local AFN, as their core principles imply a-spatial proximities. Furthermore, the accessibility of geographical data through various websites, allows a comprehensive national-scale overview of the phenomenon of local-based AFN including both production and selling points.

3.2. Data collection and caveat

The creation of a spatialized network database linking AMAP in metropolitan France with their supplying farms involved a combination of semi-automatic and manual data collection methods, implemented between March and June 2023 (Appendix 1). The database consists of two tables: the first contains the nodes of the network representing both pick-up points and producers along with their addresses. The second table contains the links between pick-up points and their supplying producers, detailing the network connections between them and characterizing the types of products traded.

The raw collected database underwent a first preprocessing phase. First, the geocoding of production and pick-up locations was implemented and used to enhance the link database with their corresponding distances. Second, a reorganization of product type information was required due to considerable heterogeneity in detail and semantic consistency from the websites. Product types with less than 3 observations, were removed due to their extremely low representation. Furthermore, producers located at very large distances from the selling points were also removed: despite the emphasis on geographical proximity, some producers are located beyond the national borders (i.e. Greek olive oil, southern European oranges, Mexican coffee, Thai rice). These products prioritize regional production specificity over spatial proximity, often carrying organic or 'fair trade' labels, and are the subject of research focusing on sustainability and labels in alternative food networks (Teufer & Waiguny, 2023; Michel-Villarreal et al., 2019). Such AFN align with the 'international CSA' niche initiatives (Rommel, 2019), based on relational proximity and promoting fair compensation for producers and food sustainability (Weber et al., 2021). However, these producers should be rather considered as 'spatial exceptions' when applying the French definition of AMAP, as they do not aim to meet the spatial proximity criteria. Given the specific focus on the spatial aspects of 'local' AFN within the French case study and the limited number of such examples (only 1.2% of the producers-pick up points relations), these observations are excluded from our database for the subsequent analysis.

The collected dataset may present some limitations. First, webpages updates may not always occur on a regular basis, resulting in potential incompleteness or outdatedness of the collected data. Some AMAP websites list only regularly associated producers, while others include all producers regardless of the frequency of provisions. A second aspect involves the lack of detailed information about certain product origins. For example, processed products often mention the address of the food processing factory rather than its original production location; especially for composite products (such as bakeries or breweries), which represent less than 12% of our observations (links database). While we acknowledge the bias mentioned above, AMAP websites thus remain valuable sources of data, providing insights into the origins and destinations of products.

3.3. Exploratory data analysis

Before delving into a more comprehensive study, an exploratory data analysis of the collected database was conducted. The database includes 2100 AMAP pick-up points spread across 1546 municipalities of metropolitan France (4.4% of all municipalities). According to INSEE's functional urban areas classifications (INSEE, 2021), 42% of AMAP pick-up points are located within central cities or first suburb municipalities, 49% in second suburb municipalities and 8.7% of are situated outside the influence of a major city. The cartogram of AMAP pick-up points' spatial distribution according to INSEE urban types (Fig. 1a) suggests that AMAP are predominantly an urban phenomenon, mostly located within primary urban centers and municipalities of primary urban centers. Such observations suggest that AMAP represent an alternative food distribution model tailored to the food supply strategies of urban areas. The cartogram of producers supplying AMAP distribution (Fig. 1b), categorized by the same INSEE urban types, indicates that these producers are located close to urban areas, primarily within suburban municipalities of secondary urban centers. Rural areas beyond urban influence are minimally involved in the AMAP phenomenon, both in terms of AMAP producers and pick-up points.

Analyzing the distances between AMAP and their associated producers on one hand, and producers to their associated AMAP on the other, provides further insight into their network configuration. The dataset linking AMAP pick-up points and producers shows a very diverse organizational structure, ranging from 1 to 35 associated producers with an average of 4.3 producers (median: 3). On the other hand, producers provide from 1 to 35 AMAP pick-up points with an average of 1.8

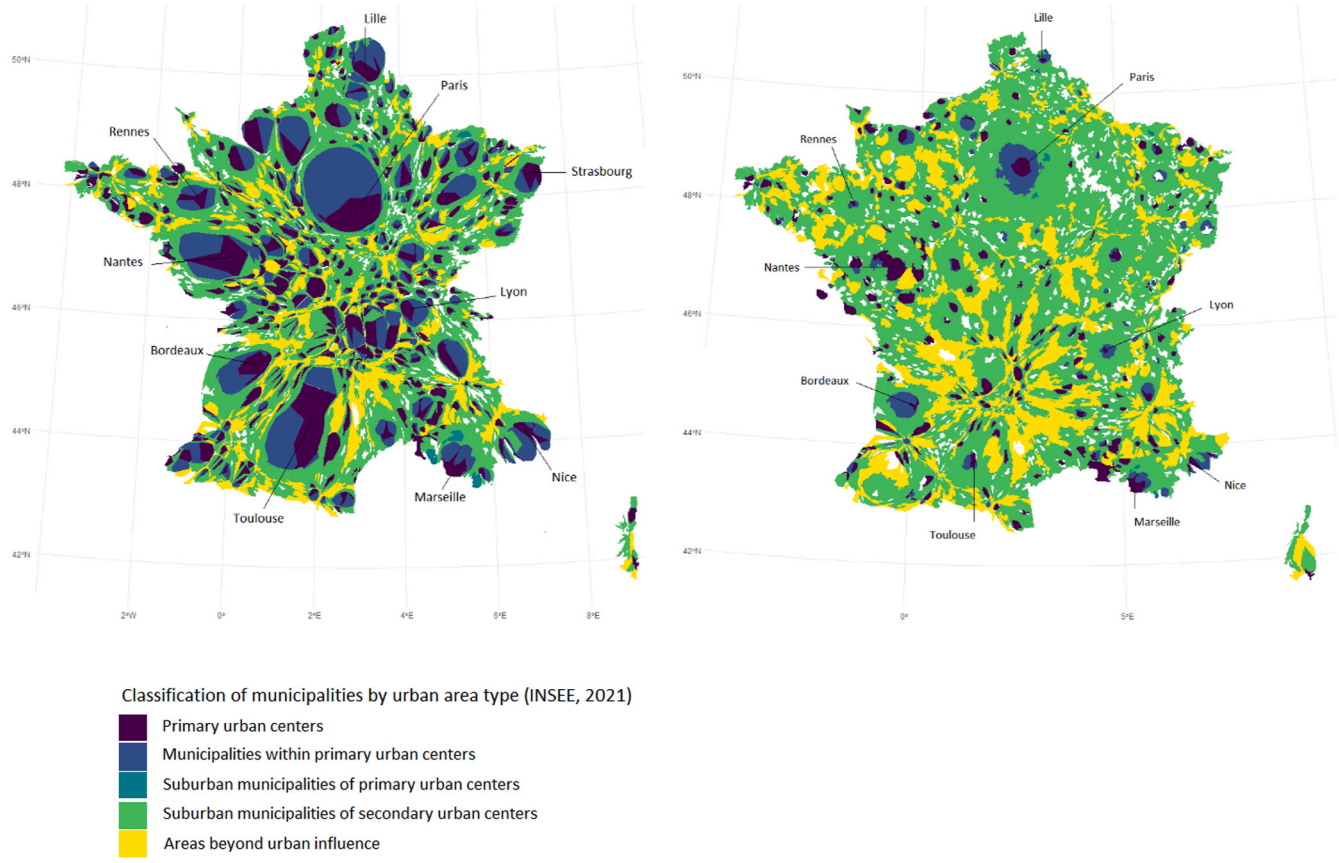

Fig. 1. Cartograms of French urban areas, scaled by the number of (left) AMAP pick-up points (2,100), and (right) AMAP-affiliated producers (5,200). Colors correspond to INSEE urban areas typologies (INSEE, 2021).

(median: 1). 869 AMAP (41% of them) are only provided by one producer, 34.6% of which (14.2% of the total) participate in on-farm sales. The overall network is mostly constituted of simple relationships, suggestive of self-organized systems qualified as 'small worlds' (Brinkley, 2018). When focusing on distances, the average extent between each producer-AMAP pair is 44.1 km, with a median value of 19.1 km (Table 1) (45.6 and 20 km, respectively, when excluding on-farm sales). The average distance from each AMAP to its associated producers is 36 km (median: 18.4 km). This decrease of average/median distance implies that larger AMAP, associated with more producers, tend to acquire their products from more distant sources. Although positive, the statistical correlation between the number of associated producers and the mean distances traveled is however not significant. Very few producers engage with multiple AMAP (31.6% of them): they typically collaborate with one to two AMAP, with an average of 1.8 (median: 1). The average distance from each producer to its associated AMAP pick-up points is 44 km (median: 18.1 km).

AMAP offer a wide variety of items, with vegetables being the most prevalent (found in 65% of AMAP), followed by bread (36%), cheese (29%), poultry, eggs, and fruits (between 21 and 26%). Additionally, honey, beef, and dairy products are available in 18–21% of AMAP. Certain AMAP also offer less common products, such as walnuts or chestnuts (2%), which may either be locally produced or specific to certain French regions (e.g., Ardèche walnuts or Corsican citrus). Fig. 2 shows the distribution of distances between AMAP and producers for each product type. It appears that most raw plant-based products ('^' symbol in Fig. 2) display shorter distances, as well as the animal derived products (such as honey, eggs or cheese; '¤' symbol). Animal-based ('o' symbol) and processed products (such as flours, beer, bread, etc.; '*' symbol) are associated with larger distances. These observations support the hypothesis in existing literature regarding the variability of distances based on product types (Carroll & Fahy, 2015; Ostrom, 2006). Exceptions are however made for certain products, such as beer, bread or bakery products. Bread being a multi-processed product, one could expect its distribution being associated with larger distances. The location of these products refers to their processing location (bakeries, mills and breweries) rather than the production location (manually checked for a subset of producers). In the scientific literature, recent studies advocate for a global approach of local AFN, involving all steps from farming to retail (Bingham, 2022). Taking these factors into account, it is important to acknowledge possible limitations in our outcomes when dealing with processed products.

Table 1
Summary table comparing mean and median distances of AMAP producers measured using both Euclidean distance and street-network time and distances.

Median/mean distances:	Euclidean distances (km)	Road distances (km)	Time distances (minutes)
For all pairs AMAP-producer	19.1/44.1	26.4/57.8	29.9/49.7
By AMAP	18.4/36	24.8/47.7	27.5/41.5
By producer	18.1/44	24.8/58.4	28/49.6

4. Results

In this section, the analysis is structured into three distinct parts, each dedicated to testing one of the three previously stated hypotheses. Specific spatial modeling methods and datasets are employed, tailored to each hypothesis. The aim is to investigate three aspects of spatial proximity: the distance between producers and pick-up points (sections 3.1 and 3.2) and the contextual characteristics of farms (section 3.3). Our aim is to offer comprehensive insights into the various dimensions

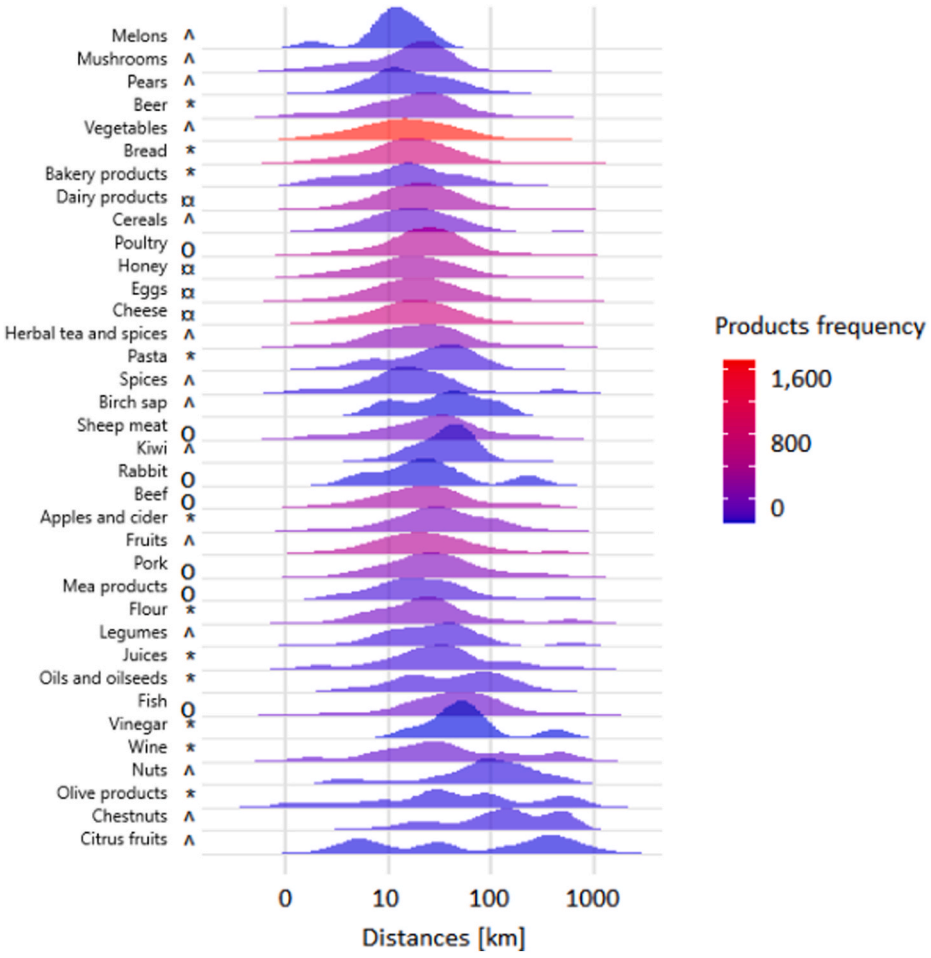

Fig. 2. Ridgeline plot of the distances distributions (km) by product, measured as (Euclidean) distances between producer and pick-up point locations.

of spatial proximity associated with the specific case of AMAP food networks in France.

4.1. *Exploring variability in distances: population density as a key factor?*

This first section examines our first hypothesis regarding the factors influencing the variability of distances between farms and pick-up points within local food circuits, assessing whether the spatial distances between production and consumption areas vary according to the population density of the city supplied (H1). We first tested the hypothesis questioning the relationship between distances and population densities. A series of bivariate analyses examine the linear relation between the logarithm of population density and size on one hand, and on the other hand distances between producers and (i) cities' barycenters, (ii) all AMAP locations, and (iii) AMAP (with more than one associated producer) locations. The outcomes consistently reveal a positive trend with a correlation coefficient ranging between 0.32 and 0.45. However, the significance value (R-squared) of these correlations is weak, ranging between 0.11 and 0.29 (Table 2). The residual dispersion indicates heteroskedasticity, with cities of lower population densities exhibiting higher variability of distances, and denser cities displaying lower variability around higher distance values. This could imply the presence of underlying factors, particularly for smaller cities, that are not accounted for in the proposed relationship.

Although this first hypothesis is partially supported by our AMAP data, the result is not particularly satisfactory, suggesting that the distribution of AMAP producers cannot be solely attributed to urban population size or density. Instead, the spatial distribution of AMAP producers is influenced by the availability of agricultural lands surrounding urban areas, defining the potential areas for their localization. Thus, we suggest that average distances of AMAP producers to the pick-up points are influenced by a function of both population density and the distribution of agricultural lands around urban areas. Therefore, the relationship can be rewrite as in the following formula:

$$Mean\ (AMAP.to.producer\ dist.) = \alpha(pop.density) + \beta(agricultural\ land\ distribution)$$

While AMAP-to-producers distances and population density are straightforward measures (Formula 1), a specific protocol to measure the distribution of agricultural land surrounding urban areas is required. Inspired by Lemoy and Caruso (2018) we implemented a radial analysis, here applied to the agricultural landscape. At first, we defined

Table 2
Correlations and determination coefficient values of the (log/log) linear relations between population (measured as size and density) and distance of producers from cities' barycenter and AMAP.

(Log-Log) Linear relations between:	Distance producers to cities' barycenter (median/mean)	Distance producers to AMAP (median/mean)	Distance producers to AMAP (≥ 2 paysans) (median/mean)
Population density	$R^2 = 0.15/0.16$ correlation = 0.38/0.40	$R^2 = 0.20/0.16$ correlation = 0.45/0.32	$R^2 = 0.29/0.25$ correlation = 0.54/0.50
Population size	$R^2 = 0.12/0.13$ correlation = 0.34/0.36	$R^2 = 0.11/0.08$ correlation = 0.32/0.21	$R^2 = 0.13/0.12$ correlation = 0.45/0.41

concentric rings of 250 m width, from the city hall up to 70 km. Then, within each ring we measured the share of agricultural land (over the total mainland) from Corine Land Cover (CLC 2018), to build cumulative curves of the agricultural surfaces around each city within the 70 km span. Finally, logistic functions were fitted over these cumulative curves (Fig. 3a). The resulting logistic function describes the probability distribution of agricultural land use as a function of the distance from the city center to the periphery. These probability functions can be summarized by two parameters describing the key properties of the cumulative distribution of agricultural land uses: the midpoint *X0* and the rate of growth *k*. The former indicates the threshold position where the logistic curve transitions from its initial growth phase to its saturation phase, while the latter describes the speed of the transition. The midpoint *X0* is here used in Formula 1 as a proxy variable describing the agricultural land distribution.

As literature interested in the variation of local distances along with population density mostly relies on metropolitan case studies (Baysse-Lainé, 2021; Corsi et al., 2015), we test this relationship for the ten largest French metropolises: Paris, Lyon, Marseille, Lille, Toulouse, Bordeaux, Nice, Nantes, Strasbourg, Rennes. This decision is reinforced by the previously highlighted heteroskedasticity observed in the relationship between population density and AMAP-to-producers distance. For the 10 largest metropolitan areas case studies, the estimated parameters for Formula 1 are respectively $\alpha = 3.28$ (p-value: 0.051) and $\beta = 3.13$ (p-value: 0.042), with an R-squared of 0.69[1] (adjusted R-squared: 0.6). The regression equation suggests that both population density and the agricultural land distribution (*X0*) significantly influence the mean distance of AMAP producers. The coefficient α indicates that for every unit increase in population density, the mean distance of AMAP producers is expected to increase by 3.28 km, holding all other variables constant. Similarly, the coefficient β implies that an increase in the agricultural land distribution (*X0*) by one unit is associated with an increase in the mean distance of AMAP producers by 3.13 km, under the assumption of constant factors. However, while the regression equation captures the relationship between variables, it does not establish a causal relationship between them; moreover, the assumption of linearity could hide nonlinear relationships between variables.

Beyond these methodological limitations, we have shown that in the case of metropolitan areas, the size of the city and agricultural availability can influence the variability of local distances. Such a relationship cannot be significantly established for small and medium cities. In this sense, it can be assumed that the metropolitan urban structure involves peri-urban spaces large enough to catalyze the presence of AFN. To deepen our analysis, we further analyzed this specific rural-urban fringe. In this regard, we propose to explore the relationships between AMAP agriculture and conventional agriculture at the rural-urban interface. Therefore, we examined the distribution of AMAP producers relative to urban agricultural landscapes to highlight local behaviors and nuanced variations across the 10 metropolitan regions. The same protocol implemented previously to construct cumulative curves of agricultural surfaces is replicated here to AMAP producers, displaying the proportion of AMAP producers at a specified radius over the total number of AMAP producers (Fig. 3b). By comparing the cumulative distributions of AMAP producers and overall agricultural surfaces, we can discern whether they demonstrate similar patterns or diverge at particular distances from the city center. The ratio of the two parameters *k* and *X0* for AMAP producers and overall agricultural availability describe their relative spatial distribution patterns. A ratio of k greater than 1 indicates faster expansion of AMAP producers compared to overall agriculture, with increasing distance from the city center, and vice versa. Similarly, a ratio of *X0* smaller/larger than 1 suggests that AMAP producers extend closer/farther to the city center compared to overall agriculture (Table 3).

When observing the AMAP producers' distribution (Fig. 3b), Paris, Marseille, Bordeaux, Toulouse show higher dispersion with the distance from the city center (lower *k*) with larger distances (higher *X0*) of AMAP producers concentrations, reaching only 50% of them after 45–50 km. Conversely, Lille and Rennes are characterized by a higher concentration of AMAP producers, closely located to the city center (higher values of *k* and smaller *X0* of about 20 km). Other cities (Nice, Nantes, Lyon and Strasbourg) are characterized by an intermediary behavior between the two previous groups with an *X0* value of about 30 km. When observing the distribution of the overall agricultural areas (Fig. 3a), different outcomes are outlined: Strasbourg, Paris, and Marseille display a steeper curve, indicating a high concentration (higher *k* values) at a given distance (*X0* varying between 50 and 70 km). The other cities can also be sorted into two groups: the first encompasses Nice, Toulouse, Nantes and Lyon with a higher concentration of agricultural land (intermediary *k* values) at closer distances (*X0* of 55–60 km); and the second includes Lille, Bordeaux and Rennes with a higher dispersion (lower *k* values) at higher distances (*X0* of 60–80 km).

The ratios between the cumulative distributions for each city (Fig. 3c) reveal two main patterns. In Marseille and Paris, the curves display very high ratios near the city center, decreasing steadily with distance, suggesting a prevalence of AMAP-oriented producers in proximity to the city center. This higher ratio at smaller radii in Marseille and Paris might stem from agricultural land scarcity close to the metropolitan center, due to natural parks and extensive built-up areas respectively. Other cities exhibit bell-shaped curves indicating the relative probability of finding AMAP producers at various distances from the city center. Bordeaux and Toulouse show lower relative distribution values, with a small peak at 30–40 km, while other cities have higher concentrations closer to the city center (25–35 km), with Rennes and Lille showing the highest peak at shorter distances (20–25 km). Strasbourg stands out with a bell-shaped curve, showing high relative values at short distances as for Rennes and Lille, but also high values at lower radii as for Paris and Marseille. Border cities (Nice, Lille, Strasbourg) display peaks at shorter distances due to the AMAP distribution's anisotropy, as overall agriculture curves extend beyond the border, whereas AMAP are primarily located within France.

4.2. Exploring variability in distances: product category

The second hypothesis investigates how product typology influences the variability of distances between AMAP and producers, as suggested by scientific literature (Carroll & Fahy, 2015; Ostrom, 2006). As previously presented in Section 2.3 (Fig. 2), product types display various distributions of their AMAP-to-producer distances. Our objective here is to investigate how different products are associated with distinct spatial distributions, ultimately leading to the identification of primary groups of products defined by their shared proximity profiles. We initially conducted a bivariate Kolmogorov-Smirnov test on the distance distributions of our 36 product types. Kolmogorov-Smirnov coefficients (KS) are specific to observation pairs (one-on-one product types) and quantify the distribution similarity within each pair. Such a resulting matrix allows an understanding of the product types' distributions similarities; many KS statistics lack significance due to the sparse frequency of occurrences within the database. The resulting coefficients are then utilized as a similarity matrix for hierarchical ascendant clustering (HCA). This approach allows for the identification of groups of product types (dendrogram in Fig. 4) based on the similarity of their spatial distance distributions.

In parallel, we developed a five-fold classification of products based on their origin and processing level, including categories for raw and plant-based products, processed food, animal-origin products, animal-derived products, and multi-composite products.

The HCA dendrogram and expert-based classification combined (Fig. 4) reveal associations between food types and distance

[1] The R-squared reaches a value of 0.83 (adjusted R-squared 0.75) if including *k* as a third independent variable in Formula 1.

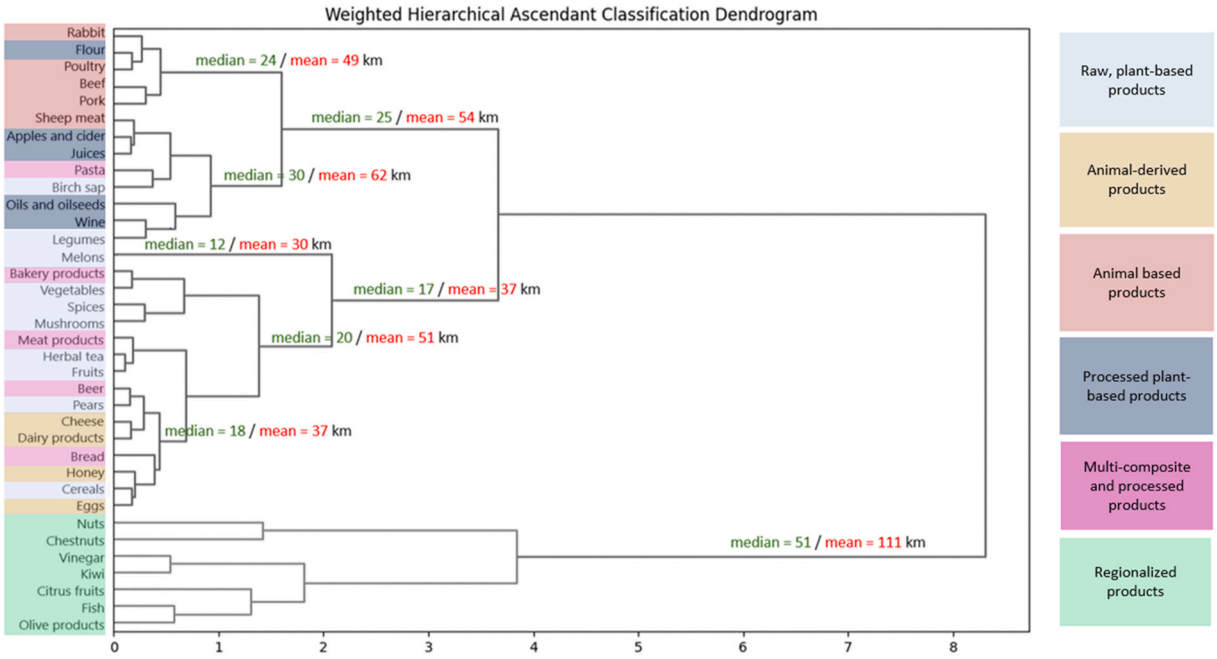

Fig. 3. Cities' logistic functions for the cumulative distribution of (a) agricultural land uses - from CLC (upper left) and (b) AMAP producers (upper right). (c) Ratio of AMAP producers and overall agriculture sigmoid functions for each city (bottom). Logistic functions are rescaled on the x-axis based on the city's population size to make their curves comparable (Lemoy & Caruso, 2018).

Table 3
Parameters of the fitted logistic functions of cumulative curves for both AMAP producers number (from our dataset) and overall agriculture land use surfaces (from CLC) and their ratios. When excluding multi-composite products, the corresponding x0 values (*) increase by a coefficient ranging from 1,17 (Paris) to 1,82 (Nantes) while k values do not change. The framed column highlights the values of X0 used in Formula 1.

	Logistic fit for cumulative AMAP producers distribution			Logistic fit for cumulative agricultural areas			Comparison	
City	k	x0	R2	k	x0	R2	k ratio	X0 ratio
Paris	0.07	44.1*	0.99	0.08	63.44	1	0.89	0.69
Lyon	0.13	27.2*	0.99	0.06	59.8	1	2.16	0.45
Marseille	0.07	38.7*	0.97	0.07	70.5	1	1	0.54
Lille	0.13	16.47*	0.96	0.05	59.9	1	2.6	0.27
Toulouse	0.09	40.35*	1	0.06	56.31	1	1.5	0.72
Bordeaux	0.07	38.69*	0.98	0.05	65.92	1	1.4	0.58
Nice	0.11	29.4*	0.99	0.07	53.7	1	1.57	0.55
Nantes	0.11	27.96*	0.99	0.06	57.07	1	1.83	0.49
Strasbourg	0.12*	24.77*	0.97	0.09	52.67	1	1.33	0.47
Rennes	0.17	19.34*	0.98	0.05	76.38	1	3.4	0.25

distributions. The raw plant-based category (light blue) and animal-derived products (yellow) have the shortest observed distances, merging into a common category with average and mean values of 17 and 37 km respectively. The animal-based category (red), including poultry, beef, and pork, converges in a group with higher median and average distances of 24 and 49 km respectively. The processed plant-based category (dark blue), comprising products such as cider, juices, and oils, is characterized by an intermediate median and average distances of 30 and 62 km respectively. While there is convergence between product type classification and distance-based clustering for previous groups, divergence is observed for other products. Indeed, multi-composite products are distributed in different branches of the dendrogram. Their scattering might be explained by the declared production locations, either relative to one of the composite ingredients, or associated with the processing facility. Finally, a specific group of products (in green) exhibits exceptional distances, with the highest median and average values of 51 and 111 km respectively. This group of mixed product types shares a common factor: regional specificity of production, such as chestnuts from Ardèche and Corsican citrus fruits. From this diagram, we observe that the medians and averages of regionalized products (green) exceed the median and average of all other products. The main two branches of the hierarchical clustering show a threshold at an average distance of around 50–60 km, which could suggest a possible spatial limit for local food production.

Cross-referencing distance-based clustering results with expert product categorization reveals varying distances between production and pick-up locations based on product type and processing level. Consistent with prior research (Bingham, 2022), we observe longer distances for manufactured crops versus table crops, with a gradient extending from raw or minimally processed items to animal-derived and then animal-origin products. Additionally, a diverse group of products exhibits the greatest distances, emphasizing the presence of region-specific offerings within AMAP, showcasing traditional products from distinct areas.

4.3. Morphological and land use characteristics of AMAP-oriented agricultural spaces

Our last hypothesis explores the characteristics of AMAP-oriented agricultural spaces, building on literature suggesting that certain rural

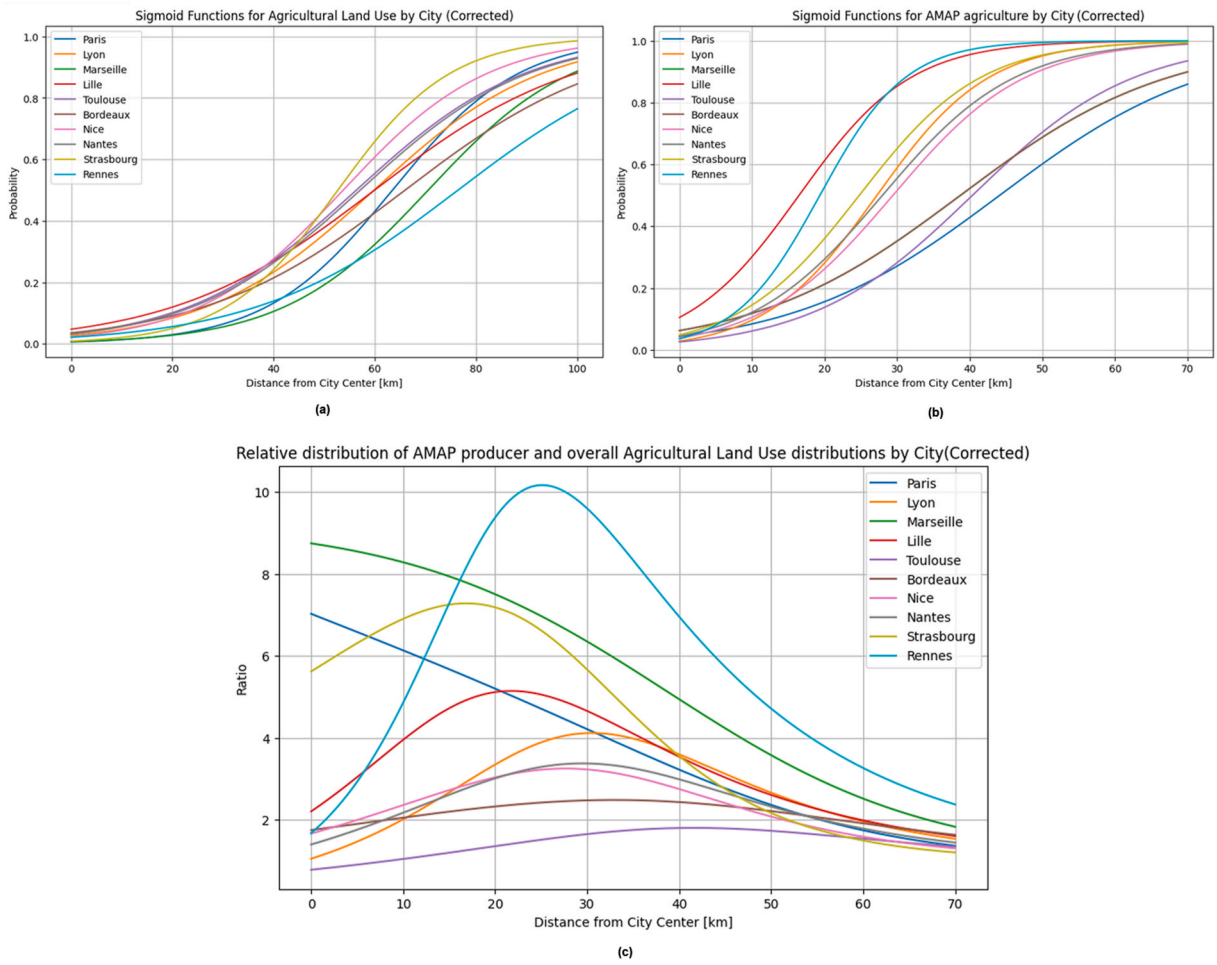

Fig. 4. Hierarchical Agglomerative Clustering of product typologies based on Kolmogorov-Smirnov test results.

landscapes may provide the necessary conditions for farming practices to diverge from the productivist and intensive dominant agricultural model (Latruffe & Piet, 2014; Looga, Jürgenson, Sikk, Matveev, & Massikamäe, 2018; Ntshangase et al., 2018). The objective is to determine whether AMAP producer locations identified in our database are associated with distinct rural landscape characteristics when compared to the overall agricultural landscape. To address this question, this work relies on a quantitative characterization of the local context surrounding points of interests (Araldi et Fusco, 2019; Serra et al., 2018), AMAP producers in this case, considering various morphological and land use descriptors in their local surrounding areas.

To characterize the landscape morphological contexts of the 5200 producers, we begin by delineating circular areas at three radii corresponding to local, meso, and macro-scale landscapes (600, 1200 and 2400 m respectively) centered on each AMAP producer point. Several indicators were computed for the rural environments within these areas, utilizing two open-access vector datasets. Firstly, the French LPIS (Graphic Parcel Register, RPG) encompasses the agricultural holdings benefiting from the Common Agricultural Policy, spatially detailing their agricultural plots. Secondly, we used the CLC land cover database providing five main categories of land use (agricultural, artificial, natural, wetland and water occupation). The selected morphological indicators encompass two primary aspects of the agricultural landscape structure: the geometry (from RPG) and land use (from CLC) of agricultural regions. From the former we obtained morphological indicators of the rural plot system, based on literature, namely roughness, connectivity, and number of plots (Mouléry et al., 2022), and supplemented by additional indicators such as areas, perimeters, compaction, elongation, fragmentation, and convexity of the plots. From the latter, land use indicators were implemented as shares of different land use types within the buffer's perimeters.

Following the acquisition of local-based multiscale descriptors, we deviate from traditional approaches implementing unsupervised clustering methods (Araldi et Fusco, 2019; Serra et al., 2018). Instead, we adopt a classification strategy to delineate indicators associated with AMAP producers' locations. To achieve this, we gather identical context-based indicators across 27,000 randomly dispersed points throughout all agricultural surfaces (within CLC agricultural land polygons). Leveraging machine learning models in conjunction with contextual analysis methods, we discern the indicators that distinguish between the AMAP-producers and random populations. We evaluate and compare Random Forests, XGBoost, and the Logit model for classification, employing training and testing subsets to ensure statistically robust model selection. Additionally, to address potential imbalances in the dataset, we implement resampling techniques. Random Forests achieved the highest performance, with an accuracy of 0.991 and an F1 score of 0.831. The SHapley Additive exPlanation (SHAP) method (Lundberg & Lee, 2017) was subsequently utilized to analyze the importance values of each feature for local predictions and interpret the effects of rural environment descriptors on the target variable.

The SHAP analysis reveals distinct environmental characteristics associated with AMAP-oriented production points (Fig. 5). Firstly, the share of agricultural surfaces is underrepresented within the surrounding area (600m) and characterized by smaller parcels dimensions (low median areas within 2,400m). These results suggest that AMAP producers might be located in closer proximity to urban areas. Secondly,

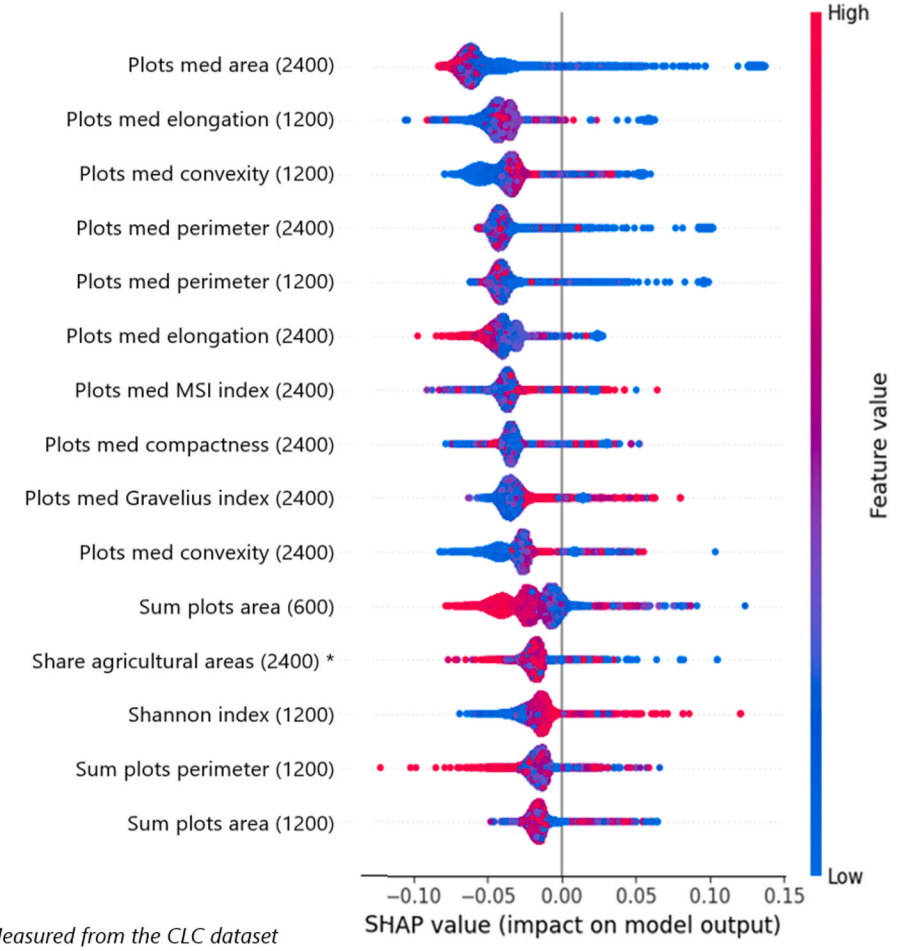

Fig. 5. SHAP approach applied to Random forest classification model for proximity/random production points.

AMAP-oriented producers are situated within agricultural contexts characterized by greater diversity in terms of product types (higher Shannon index within 1200m).

Moreover, as literature previously suggested (Mouléry et al., 2022), AMAP-oriented agricultural areas display a particular environmental morphology. Our results corroborate that these environments are characterized by smaller plots (Cicia et al., 2011), with lower values for the median plot surfaces and perimeters at a 2400 m radius. Finally, AMAP-oriented agriculture is associated with specific plot shape (high Gravelius and MSI indices), which was previously identified in literature as an influencing factor for agricultural productivity (Latruffe & Piet, 2014). Thus, plots whose morphological characteristics are not fitted for the intensive and productivist dominant model would likely be associated with alternative forms of commercialization.

In conclusion our results suggest that production areas supplying AMAP are associated to specific land use and morphological specificities characterized by smaller, fragmented parcels, with a higher diversity of production types, located within mixed land use context. These findings support existing literature suggesting a specific signature for plots serving AFN; and suggest that local-based AFN are alternative economic outlets for farms whose size and morphology are less adapted to the conventional productivist model.

5. Discussion

5.1. Discussion and further work hypotheses

Two perspectives are adopted in this paper to analyze alternative food networks: the first concerns the variability of so-called 'local' distances between production and distribution locations; the second characterizes the spatial contexts of agricultural areas oriented towards AFN commercialization.

To begin, the exploratory analysis of our database indicates average AMAP-producer distances of about 44 km, a result that falls within the range of institutionally defined thresholds (ADEME, 2017; EU Joint Research Centre, 2013; Conservation and Energy Act, 2008), respectively 30–100 km, 20–100 km, and 400 miles. Such observation also aligns with the existing literature (Callois, 2022; Poulot, 2012; Stephens, 2021), mentioning 50–100 km, 250 km, and 160–250 km, respectively.

As shown in our empirical findings, the observed average AMAP-producer distances might vary according to the type of product and the urban system within which they are located. When considering the role of product types, our results highlight four cohesive groups of food categories described by specific AMAP-producers distances distributions: raw plant-based, animal-derived, animal-based, and processed plant-based products categories, are listed from shortest to longest distances, aligning with prior research identifying spatial profiles according to food types (Bingham, 2022). Our research being led at a national level, such results suggest coherent spatial distances of certain food types to city centers. Contextualizing these results with the agricultural dynamics may suggest a spatial organization of agricultural types in the city's vicinity. Following a phase of agricultural spatial sectorization (Poulot, 2014) and development of international trading (Hairy & Perraud, 1988) in the 20th century, the emergence of AFN can be seen as indicative of a relocalization process for food exchanges. This process appears to align with Von Thunen's economic model, with agricultural distances to the city center depending on product specialization and production techniques (Dickinson, 1969). In this sense, Wästfelt and

Zhang (2016) show that in the case of direct sales, distance to the city plays a role in terms of transportation costs since consumers also bear these transportation costs. Such a model requires to be further developed and discussed according to the contemporary context of metropolitan peri urbanization. Furthermore, the strong representation of certain products (vegetables, cheese, etc.) in AMAP offerings, suggest that some types of production might be distributed very homogeneously across space, justifying their consistent proximity to cities, while rarer crop types would rather be dispersed or clustered into specific areas, as described by Poulot (2014). Furthermore, it is noted that these groups of products with cohesive distributions have median spatial distances of 12–30 km and average distances of 30–62 km. For comparison, the median and average distances of the *spatial exceptions group* presented in section 3.2 reach 51 and 111 km, respectively. Here, an average threshold of 50–60 km can therefore be identified as pertinent to distinguish what constitutes a local distance and what does not. This observation also confirms that the relational proximity sought by AFN does not always imply strong spatial proximity (Baysse-Lainé, 2021; Weber et al., 2021).

Moreover, the urban system as a second factor influencing AMAP-producer distance variability has been explored: our results indicate a weak positive correlation between the population density of the city supplied and the distances between AFN pick-up points and their associated producers. While our results align with the hypotheses on distance variabilities stated in the literature, based on empirical case studies of large cities (Baysse-Lainé, 2021; Corsi et al., 2015; Guiraud, 2019; Kneafsey et al., 2013), the high residual dispersion of distances within lower population density areas suggests the presence of underlying factors in smaller cities. This result supports the idea of a variable perception of 'local' distances according to urban or rural contexts, considering their surrounding agricultural availability, as suggested in Carroll and Fahy (2015). In this perspective, we stress the necessity of new studies on the spatiality of AFN in the context of small and medium-sized cities. Beyond population density, our results show that agricultural land distribution around metropolitan areas represents a significant factor in explaining AMAP-producer distance variability. Its integration in the general regression model contributes significantly to the explanation of the variability of local distances for larger cities (Corsi et al., 2015).

The second group of insights emerging from this work focuses on the AFN spatiality. Two sections of this work contributed to this analysis. First, section 3.1 focuses on the distribution of AMAP-oriented agricultural land around urban areas through a radial analysis (Lemoy & Caruso, 2018). Second, section 3.3 characterizes the local contexts surrounding points of interests (Serra et al., 2018), AMAP producers in this case, considering various morphological and land use descriptors.

Focusing on the ten largest French metropolitan areas, the first protocol identifies peaks (see section 3.1), representing the distances from the main city center where the presence of AMAP-oriented agriculture is denser relative to the surrounding agricultural availability. These peaks span from 15 to 45 km around the city center, which means that conventional agriculture prevalence slowly increases beyond this range. Such observations show that AMAP-oriented agriculture is primarily located within a limited perimeter, below a certain threshold that can be set after 50 km from the city center, considering that the curves generally follow a Gaussian distribution. These results further validate our earlier conclusions regarding the presence of a threshold between 50 and 60 km, which defines the boundary for what should be considered local.

The protocol presented in section 3.3 shows that AMAP-oriented agriculture tends to be excluded from large agricultural spaces. This observation supports the peri-urban nature of proximity-oriented agriculture, as widely described in the literature (Brinkley, 2018; Cicia et al., 2011; Low et al., 2015; Paül & McKenzie, 2013). Moreover, two aspects of our results suggest a relationship between agricultural practices and commercialization strategies. First, the hybrid land use and high production diversity observed suggest that AMAP-associated agriculture is not located in the same land-use context as the dominant agricultural model, characterized by segmented and specialized agricultural areas (Poulot, 2014). Second, certain morphological features of agricultural plots tend to be associated with an AFN presence: AFN-oriented farms tend to display smaller plots (Cicia et al., 2011), and more complex shapes with higher rugosity (Mouléry et al., 2022). Such characteristics were previously shown to be associated with lower agricultural productivity (Latruffe & Piet, 2014; Looga, Jürgenson, Sikk, Matveev, & Massikamäe, 2018; Ntshangase et al., 2018). Thus, farms with alternative farming practices could more consistently engage with AFN, in line with literature highlighting the importance of AFN as commercial outputs for small and medium-scale farms (Yacamán Ochoa et al., 2019; Galt et al., 2011). In this perspective, a future research avenue could be dedicated to assessing the agricultural spaces potential for local food development, by identifying the agricultural spaces matching such characteristics.

Given the evidence and results gathered so far, we might reasonably assume that the notion of 'local' in the specific case of AMAP in the French national context, seems to vary between 15 and 65 km. These conclusions might have implications on public policies. The variability of local distances clearly exceeds administrative boundaries. Analyzing such AFN and their local distances, as proposed in this article, thus enables a reflection on the optimal scales for deploying public policies aimed at developing these food chains. French Food Territorial Projects are mostly administered by municipalities (Lulovicova & Bouissou, 2023), and initiatives such as Milan Urban Food Policy Pact (2015) are launched at a city level. European foodshed studies still essentially rely on metropolitan administrative areas (Darrot, 2014; Mouléry et al., 2022; Zasada et al., 2017). However, in a USA case study, Bingham (2022) shows that food self-sufficiency drops when assessed at a county-level as compared to a state-level. Moreover, previous research work has shown that AMAP among all AFN types maintain high social proximity scores (Benedetti et al., 2023), suggesting that ambitions to maintain strong social ties throughout the supply chain can be met, even at a scale beyond the municipal level. Confronting the results of the present paper with existing public policies might help identify the most conducive spatial dimensions for their effective deployment. Finally, our results confirmed that the rural-urban fringe is conducive to AFN development. Increasing public policy focus on these peri-urban areas could help preserve agricultural spaces that are more likely to be oriented towards AFN. In this context, the French Climate and Resilience Law (2021) sets a goal of Net Zero Artificialization (ZAN) by 2050, which could contribute to maintaining agricultural spaces in the immediate periphery of cities. Such insights could also enrich urban planning and land use literature, which frequently addresses infilling dynamics.

5.2. Limitations and improvement perspectives

This study explores various perspectives on the spatial scope and characteristics of 'local food' by exploring literature hypotheses on the spatiality of alternative food networks. Few limitations are worth acknowledging in order to identify opportunities for further research.

The first limitation concerns the multiplicity of commercialization strategies. On one hand, the same producer might commercialize through both alternative and conventional food networks. In this sense, the French General agricultural census indicates that 23% of farms generate part of their revenue by selling through short supply chains (Agreste, 2021). On the other hand, producers who choose short supply chains often opt for diverse networks simultaneously, either being local markets, producer shops, direct farm sales, or AMAP (Chaffotte & Chiffoleau, 2007). In this sense, Brinkley's (2018) work shows that these alternative marketing chains are often more resilient than conventional networks due to their 'small-world' architecture and the farms' diversified commercialization strategies. Broadly understanding the

complexity of such networks would require including AFN in all their forms. However, while our study aims to globally analyze the spatiality of alternative food networks, no public database currently exists at a national scale describing multimodal AFN types. This emphasizes that many of these alternative networks are 'bottom-up' initiatives and do not stem from a centralized dynamic that would facilitate data collection. Our choice to focus on AMAP is precisely motivated by the need to access available data at a country level. A second limitation concerns the manual data collection process. Although the public access to the website data could allow for the replication of the same method in the future, data collection is highly time-consuming and not easily replicable. Moreover, the multisource and bottom-up nature of this information give rise to potential issues regarding the uniformity and completeness of the dataset (as discussed in section 2.2).

Additional considerations concern the accuracy of the official datasets utilized in this study, resulting in possible biases in our results (RPG, CLC). Sources of bias might concern the detection of small agricultural plots both in CLC and RPG: the former, relying on satellite image vectorization, limits the detection of smaller objects. The latter only includes agricultural plots eligible for European financial compensation, often excluding smaller agricultural plots. The exclusion of small plots might influence our results regarding AFN/AMAP contexts, which have been demonstrated to be particularly related to fragmented and smaller plot systems.

Further empirical study could be undertaken to refine the methodological protocol implemented. A specific research avenue could explore different methods of measuring distances (such as road distances or travel time), incorporating logistic constraints in the analysis of AFN. Additionally, the urban systems in which AFN take place present another specific aspect: the prevalent monocentric cities approach does not always accurately reflect the network-based system of AMAP, where producers could specifically locate in multicenter metropolitan areas serving different centers. Specific models and analytical approaches should also be proposed in relation to city size/density. Finally, further machine learning developments could also enhance the model precision by incorporating additional morphological and sociodemographic descriptors, as well as adopting a more multilevel approach to account for the diverse contexts where AMAP networks take place.

6. Conclusion

Drawing from an original database on AMAP in metropolitan France, this study delves into multiple hypotheses from existing literature to examine the concept of spatial proximity within AFN. This work addresses two primary objectives: examining the variability of so-called 'local' distances between production and distribution sites, and characterizing the spatial contexts of agricultural areas oriented towards AFN. The hypotheses exploration leads to the following key findings.

The analysis revealed distinct patterns in the distances between AMAP producers and city centers based on product categories. Aligning with previous research, the findings described how the product type and its processing level are associated with specific distances, highlighting coherent distance distributions for certain product types.

Correlations between the AMAP-producers distances and the population density of the city supplied were shown to be particularly weak for small towns, but significantly stronger for metropolitan areas, especially when including agricultural land availability as an additional regression parameter for the latter. Such results emphasize the need for further research to explore the spatial dynamics of AFN in smaller and medium-sized cities.

Moreover, the study assessed the distribution of AMAP-oriented agricultural land around the ten largest French urban areas. The results reveal that AMAP agriculture is prevalent within a range of 15–45 km from city centers, compared to the available agricultural land. This observation highlights that local-oriented agriculture is primarily focused within a limited perimeter around the city center, aligning with existing literature that highlights the significance of rural-urban fringes in the AFN development. This idea is also supported by the results on the spatial contexts of AMAP-oriented agriculture, underlining that such agriculture tends to be excluded from large agricultural areas, and exhibit characteristics that contrast with dominant agricultural dynamics, such as smaller plots with complex shapes and higher crop diversity.

Overall, by coupling three analyses of the same collected dataset, this study findings identify a reasonable spatial variability of local distances for the French AMAP, approximately ranging between 15 and 65 km from the production site to the AMAP pick-up point. While the results suggest that the spatial variability of local distances extends well beyond municipal administrative boundaries, often chosen as perimeters for developing food relocalization policies, this paper also confirms the importance of the rural-urban fringe in conducting AFN development. In this sense, analyzing AFN and their 'local' distances offers valuable insights into the optimal scales for deploying public policies, and emphasizes the importance of preserving peri-urban agricultural areas, which appear particularly suited for AFN development.

CRediT authorship contribution statement

Juliette Benedetti: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Investigation, Formal analysis, Data curation, Conceptualization. **Alessandro Araldi:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1

List of AMAP websites the collected data has been retrieved from.

National AMAP census:

- http://www.reseau-amap.org/recherche-amap.php
- https://www.avenir-bio.fr/

Regional AMAP census:

- SUD: http://www.lesamapdeprovence.org/
- Hauts de france: https://www.amap-hdf.org/
- Ile de France: https://amap-idf.org/
- Pays basque: https://www.inter-amap-pays-basque.org/
- Basse normandie: http://www.amap-bn.fr/
- Haute normandie: http://reseau-amap-hn.com/amap?search=#searching
- Lorraine: http://loramap.org/
- Loire: http://www.amapdelaloire.fr/lereseauloire/infosetcontactsdesamapdelaloire/
- Midi-Pyrénées: https://amapreseau-mp.org/liste-amap-midi-pyrenees

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