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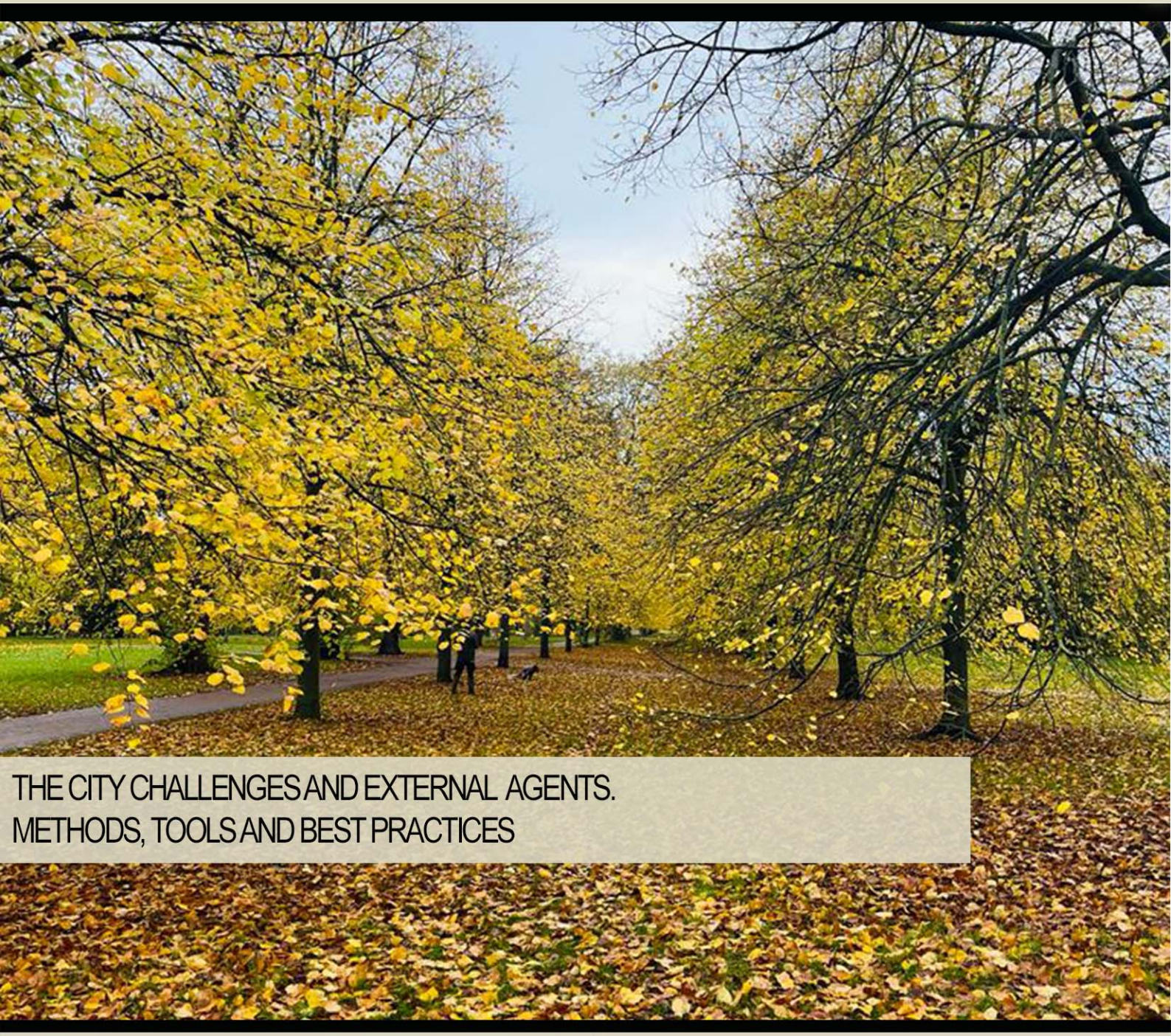

THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES

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The cover image shows a view of Hyde Park in London (United Kingdom) during the autumn season.
The photo was taken by Enrica Papa in November 2023.

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The impact of land taken by logistics in two Italian regions

A proposal for a detection method to inform decision-making processes

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Abstract
In recent years, global e-commerce has grown exponentially due to the evolution of markets and companies' selling strategies. Moreover, COVID-19 has accelerated this trend, increasing the demand for new logistic hubs, responding to the growing request for the online buying/selling of goods/ or services, while generating a remarkable land take process. The national database on LULC and municipal land use plans do not detect logistics, thus limiting the adoption of strategies and policies for contrasting the associated phenomenon of land taken. Photo-interpretation and manual validation techniques, in combination with ancillary geodata, could fill the gap through an in depth classification of selected land use categories for mapping logistic hubs in a simple, accessible and economic way. The method was tested in two northern Italian regions (Lombardy and Friuli-Venezia-Giulia). Results display radical differences between the two contexts, emphasising the heterogeneous impacts generated by logistics on the landscape. Lombardy has a significant concentration of new hubs located in the municipalities surrounding the Milan metropolitan area, whereas, in Friuli-Venezia-Giulia, this type of land take is only a marginal problem when compared to other land use change. Findings confirm the need to define tailor-made land classification methodologies that support the definition of site-specific land take management policies.

Keywords
E-commerce; Logistic hubs; Land use; Lombardy region; Friuli-Venezia-Giulia region.

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1. Introduction: the relation between e-commerce, logistics and land use change

Traditionally, lifestyles of individuals and families, their consumption habits as well as demographic dynamics have influenced urbanisation processes also by increasing the quantity of urban areas (European Commission, 2006, 2012; Jones et al., 2012; Munafò, 2021; Naumann et al., 2019; United Nations, 2015a).

For instance, in Italy, second-home tourism, combined with increased accessibility to remote and peripheral areas, have encouraged the proliferation of new residential estates in coastal and hilly territories with vulnerable ecosystems (Romano et al., 2017). This new urbanisation is often characterised by sprawling and dispersion phenomena, generating a widespread land take process (Romano et al., 2015) and causing a series of environmental, economic and social consequences already well investigated by scientific literature (Artmann et al., 2019; Dinç & Gül, 2021; Dupras et al., 2016; Frumkin, 2002; Siedentop & Fina, 2012). Citizen behaviours, as individual consumers, have unprecedented impacts on the natural environment (Stern, 2000) since changes in citizens' habits and in their purchasing methods have historically led to alterations in land use. An example is the growth of medium-large commercial facilities in peri-urban and suburban areas, with the consequent crisis of small neighborhood commerce and, recently, the growth of the e-commerce market, which has triggered the development of logistic hubs as nodes between the international and local commerce (Calvo-Porral & Lévy-Mangin, 2019). This spatial trend, also called "logistics sprawl, " is now well-established in many cities worldwide (Dablanc, 2014; Dablanc & Ross, 2012). The development of new urbanised areas for logistic hubs largely depends on the increasing demand for goods or services online (e-commerce), with the consequent need for new spaces to store and deliver products. Also, all industries depend on the logistic sector, which significantly impacts economic growth. E-commerce is characterised by the timely delivery of products, which requires a widespread distribution of logistic hubs in peripheral and decentralised areas that can be easily reached by private mobility. Heitz & Beziat (2016) highlighted that most logistic facilities designed for e-commerce are located in suburban areas, moving further from urban centres and sprawling into metropolitan areas, also for the high property prices in urban areas (Dablanc & Ross, 2012). The same authors declared that only with detailed data on logistics activities it is possible to identify different spatial patterns for different policy suggestions (Heitz et al., 2019). Moreover, the global spread of the COVID-19 pandemic has accelerated the expansion of e-commerce, changing the traditional business chain and making e-commerce the preferred channel for buying products during the lockdown restrictions (started in February 2020). In 2020, the purchase of products through the retail model Business-to-Consumer (B2C) - where products move directly from the producer to the end-user - grew by 16% worldwide when compared to 2019. The same index grew by 18% in Europe and the United States and by 16% in China, recording a significant decrease in purchases for services (in Europe -66%, in North America -56% and in Asia - 72%), mostly due to COVID-19 related travel restrictions. Before the COVID-19 pandemic, e-commerce was already in the growth phase in Italy. Nevertheless, during the pandemic, it grew exponentially, recording over 2 million new online consumers and shifting from 27 million pre-COVID-19 to 29 million post-COVID-19 (B2c eCommerce Observatory, 2022). The shipments generated by e-commerce increased by 103% during the lockdown and by 68.5% in the post-lockdown period, demonstrating that the trend is still growing, even after the end of the health emergency. The growth of e-commerce has generated a proliferation of terminals, warehouses and other logistic facilities that allow companies to satisfy the "new consumer", especially in the post-pandemic period (Pokrovskaya et al., 2022). This dynamic has increased the demand for cheaper land to locate new logistic hubs in suburban areas, thus threatening the traditional leisure and shopping network (Calvo-Porral & Lévy-Mangin, 2019). The boom for new logistics corresponded to the crisis of the existing stock of commercial areas, which, in some cases, collapsed in the light of new customer preferences and the logistics and transport sectors are estimated to grow even more in the coming years, to boost e-commerce. In Italy, this trend is also confirmed by the report of the Contract Logistic Observatory "Gino Marchet," (Contract Logistics Observatory "Gino Marchet,"

2020). Similarly, the survey "Impact of Coronavirus on e-commerce in Italy" published by Casaleggio Associati in March 2020, further confirms the need to improve the logistic sector, in which Italian companies are expected to invest 8% (Casaleggio Associati, 2020). Therefore, it can be estimated that in the next few years, in Italy, there will be an increase in the amount of land that will be taken by new logistic hubs and for the development of the related infrastructures necessary to improve connected mobility and accessibility. In the 2022 report of ISPRA (Italian Institute for environmental protection and research) emerges that one of the main causes of land take process is attributed to logistics and large-scale organized distribution.

In the period 2006-2021, less than 3,000 hectares were consumed for logistics (Munafò, 2022), the highest record is reached in the Northwest region of Italy. Between 2021 and 2022, in Italy, an additional amount of 7,076 ha for new urban land has been taken. Logistics and large-scale retail distribution are among the main drivers of increased land consumption in Italy. In absolute terms, the highest land consumption for logistic hubs is in the Northeast, with 1,671 hectares, corresponding to 5.8% of the total land consumption for the period 2006-2012 in the same region. The Northwest follows with 1,540 hectares (6.1%), and the Central region with 940 hectares (4.7%). The contributions of the South and the Islands, while important in terms of hectares, remain marginal (Munafò, 2022). Land take has been blamed for being one of climate change's most severe and important drivers. Soils are commonly considered a non-renewable resource due to their extremely slow formation rate and their resilience when subject to some form of degradation (Ronchi et al., 2019). Land take, and especially soil sealing, is considered an active driver of desertification (Barbero-Sierra et al., 2013), which is the most serious form of land degradation. Soil sealing is a key indicator to measure the sustainable development of the city (Ceci et al., 2023). The European Environmental Agency (EEA) has estimated that, between 2000 and 2018, greenfield has been taken mainly by new industrial and commercial land uses, residential areas and construction sites, including logistic hubs (https://www.eea.europa.eu/data-and-maps/indicators/land-take-3/assessment). According to Dablanc (2014), urban freight logistics is responsible for up to 50 % of air pollutants by transport activities in cities and logistics sprawl leads to an additional increase in mileage and environmental emissions (Dablanc & Rakotonarivo, 2010). For the above reasons, various European documents advocate a reduction in land take. First of all, the current EU Soil strategy for 2030 (European Commission, 2021), the EU Green deal (European Commission, 2019), the EU Biodiversity Strategy for 2030 (European Commission, 2020) and the Roadmap to a Resource Efficient Europe that introduced the target of 'No Net Land take by 2050' (European Commission, 2011a).

This strategy recalls the United Nations Sustainable Development Goal indicator 11.3.1: "Ratio of land consumption rate to population growth rate" used to capture the economic, environmental and social dimensions of land use efficiency (United Nations, 2015b). The lack of a common EU framework for spatial planning and soil, has allowed EU Member States (MS) to act independently by adopting and implementing sectoral policies and strategies for the sustainable management of soils (Ronchi et al., 2019). The issue of environmental sustainability of transportation activities is gaining more and more attention in the last few years. The European Union has promoted specific policies and guidelines for efficient urban logistics, among which are the Communication on the Freight Transport Logistics Action Plan 2007 (Commission of the European Communities, 2007), the White Paper for a competitive and resource efficient transport system (European Commission, 2011b) and the subsequent Communication for resource-efficient urban mobility (European Commission, 2013). In Italy, the EU urban logistic strategies have been implemented in some strategic guidance documents at the national and regional level, through the definition of guidelines and strategies for developing logistics, and port logistics in particular. The lack of national binding regulations has limited the coordination among logistic stakeholders and their inclusion into urban planning for governing, monitoring and managing this process and its related impacts.

From a side perspective, the scientific research and literature has deepened important issue such as the environmental sustainability and the associated measurement of the footprint of freight transportation logistics

using key performance indicators (e.g., missions per km, measurement of noise, and congestion level, as well as mathematical models) (Mariano et al., 2017) or monitoring best practice initiatives for green logistics transitions (e.g., low impact vans, alternative fuels, commercial vehicle sharing, and transit networks for last-mile delivery) (Colicchia et al., 2013; Rosano et al., 2022). On the other side, there is a notable gap in understanding and knowledge the LULC dynamics of logistic land take, which is essential for effectively monitoring this phenomenon and, subsequently, assessing its implications for environmental sustainability. The scarcity of information regarding the extent of land take processes due to logistics hampers the ability to address this issue comprehensively and promote appropriate strategies to govern it. In fact, as highlighted by Heitz et al. (2019), for planning logistics facilities is necessary a good understanding of logistics as an industry sector and their spatial dynamics (e.g. logistics sprawl). So, detailed data on logistics activities allow to identify different spatial patterns for different logistics activities.

Considering these assumptions, the questions raised in this study intend to relate the impact of the surge of e-commerce on the increase of logistic hubs while employing a detection method, to empirically quantify land take. However, this study does not intend to deepen the relation between COVID and land take nor to assess the impacts of land taken by new logistic hubs, which remains a step beyond the basic localization and quantification of this land use change dynamics. Instead, this study focuses on the empirical quantification of the specific category of land taken by logistic hubs.

Logistics facilities usually rely on a broad definition of "logistics" (Heitz et al., 2019) comprising specific buildings, warehouses, which host all activities linked to logistics and freight transportation which includes a plurality of morphologies that cannot be easily detected by automatic classifications. Unfortunately, the automatic detection by remotely-sensed images of land taken by urban areas does not allow a proper quantification of logistic hub, thus requiring manual interpretation.

Mayor gaps in logistic hub detection will be further explained in detail, but they mainly depend on the inherent limits of automatic and supervised classification methods applied to remotely-sensed images.

Therefore, the paper aims to provide a methodology for assessing land taken by logistics as a basic condition to define some policy suggestions for governing this phenomenon with planning instruments (Marquard et al., 2020).

Two study areas were selected to analyse the land take phenomena over a seven-year period (2012 – 2019), in two Italian regions affected by some of the highest land take rates in the country, i.e., Lombardy and Friuli-Venezia-Giulia (FVG), located in north-western and in north-eastern Italy, respectively. The time series selected does not consider the effects of COVID-19 but intends to estimate whether a growth in land taken by logistics was already underway before the pandemic.

The results can be used to set up a method based on geoprocessing integrated by the analysis of remotely sensed data to classify logistic areas as a specific category of land take. In particular, the extension and distribution across the territory of land taken by logistic hubs are studied, including storage and delivery areas of goods and products built in recent years.

This paper is structured as follows: the materials and methods are illustrated in section two; section three presents the main findings; section four discusses possible future applications and section five the conclusions.

2. Materials and Methods

2.1 Case study

Lombardy and FVG are two northern regions of Italy located in the west and the east of the Padan Plain, respectively. Lombardy is bordered on the north by Switzerland, on the south by the Emilia-Romagna region, on the east by Trentino–Alto Adige and Veneto regions, and on the west by the Piedmont region. It has a surface area of 23,844 km^2 and consists of 11 provinces and one Metropolitan City (Milan). Lombardy has the

highest resident population in Italy, with more than 10 million inhabitants (Source: Eurostat, 2019) and a population density of 420 persons/km^2.

As highlighted by Sanesi et al. (2017), Lombardy is a typical example of a European region where human impact has altered the structure and distribution of agricultural and natural areas by reducing them to small patches of land surrounded by cities and a networked infrastructural system. Urban development has taken place heterogeneously, including diverse urban morphologies showing dispersed, fragmented, leapfrog or sprawl patterns (Mazzocchi et al., 2013; Ronchi et al., 2018).

A wide variety of landscape patterns characterises Lombardy: urban (with the metropolitan conurbation that extends from Varese to Brescia passing through Milan and Bergamo); mountainous with the Alps and the Apennines range; lacustrine with various big lakes (e.g., Garda, Iseo, Como and Maggiore); fluvial (with the Po River and its tributaries) and rural, concentrated in the irrigated plains of the Po River valley, mainly producing rice, wheat and corn.

According to the latest official data on land take published by ISPRA in 2021, in the 2012 - 2019 period the urbanisation of the Lombardy region was 4,169 ha (+1%), with urban land covering about 12.1% of the regional administrative area, and a density of 2.76 m2/ha. When compared to the national data (7.1%), the Lombardy region holds the highest urban footprint (12.4%), followed by the Veneto region (11.9%). In 2019, Lombardy reached an absolute record, with over 288,000 ha of its territory artificially covered. The ISPRA national report (2020) also highlighted that "by analysing the degree of urbanisation […] it emerges that in 2019, Lombardy had the largest extension of urban areas (with a high density of artificial surfaces) for over 173,000 ha, equal to almost 20% of the total national urban areas". The most significant increase of land take in absolute terms occurred between 2012 and 2019 and was recorded in the municipalities of Milan (+123 ha), Pozzuolo Martesana (+57 ha) and Ghedi (+56 ha). When considering the rate of change values, the greatest increase occurred in the municipalities of Vizzolo Predabissi and Casirate d'Adda (both with +30%) and Gambarana (+ 26%).

On the contrary, FVG is one of Italy's smallest regions, with a surface area of 7,924 km² and approximately 1.2 million inhabitants, and comprises 4 provinces: Pordenone, Udine, Gorizia and Trieste.

Its landscape is heterogeneous, including coasts, plains, hills, lakes and part of the Eastern Alps. More than 40% of the region is covered by mountainous territory, while hills are approximately 20%, and the rest are floodplains and coastal areas. This heterogeneity has characterised the region's economy, especially concerning its primary production, which ranges from cereal crops (corn and soy) mainly produced in the plains, to the production of wine in the eastern hills.

FVG historically bridged Western and Eastern Europe, as it is located between the Eastern Italian region of Veneto and the Austrian/Slovenian territories. In addition, it is pivotal for developing the Trans-European Transport Network (TEN-T), due to the two high-speed/high-capacity Mediterranean and Baltic Adriatic Corridors, which strengthen the transportation system, which is seen as one of the most important targets for the region's economic development. In more recent years, the regional capital of Trieste has developed the first Italian port for rail traffic (Baccelli & Morino, 2020) and the first oil port in the Mediterranean area (SRM, 2022). For the above-mentioned reasons, the FVG region has the potential to become a key platform for international cargo flows after a further commitment by the Regional and the seaport Authorities and once the Baltic–Adriatic Corridor will be completed (Fabbro, 2015; UNIONTRANSPORTI, 2021)

According to the latest official data published by ISPRA in 2021, between 2012-2019 land take in FVG was equal to 1,214 ha, with a rate of change of about 1.96%. Compared to the national rate in the same period (equal to 1.78), FVG was growing relatively faster than the Italian average. In particular, the province of Udine recorded an increase in urban areas by 703 ha (+2.14%), Gorizia by 88 ha (+1.45%), Trieste by 30 ha (+0.69%) and Pordenone by 393 ha (+2.11%) (Munafò, 2021). Although these absolute numbers are not comparable to the trend of the two decades 1980-2000 (Istituto per l'Ambiente e la Sostenibilità & Centro

Comune di Ricerca, 2000), which showed an increase in daily land take that exceeded 8,000 m^2, this region is still eroding, at a slower rate, a limited and non-renewable resource such as soil, due to the extension of new urban areas, even without a real increase in the number of residents and families (Salata, 2010).

Fig.1 The two Italian regions selected as a case study: Lombardy and Friuli-Venezia-Giulia (FVG)

2.2 Detecting the land taken by new logistic hubs

To gain a precise, quantitative estimation of the importance of logistic hubs on the total extent of land take, it is necessary to rely on an available and suitable Land Use/Land Cover (LULC) database. Nowadays, a great variety of techniques (remote sensing, field survey, cadastres, urban plans) are applied to obtain these data, thus complicating their interpretation, limiting their comparability (Marquard et al., 2020) and often requiring important economic sources. At the European level, conventional LULC classification methods through automatic or semi-automatic techniques applied on remotely-sensed data (e.g., CORINE Land Cover) cannot properly distinguish and separate the commercial, industrial/productive and logistic uses. These LULC typologies are generally merged into a single class under the name "industrial and commercial units" (class 1.2.1 in the CORINE Land Cover nomenclature) which is part of the second-level macro-class 1.2 "Industrial, commercial and transport units". Even though national or sub-national datasets have deepened the thematic or geometric accuracy of the Pan-European dataset, the automatic detection of the logistics hubs from a remotely sensed image has not been developed considering that, from an aerial view, the logistic land use

appears similar to other commercial or productive uses (in terms of ground occupancy, construction's material, permeability, size). This knowledge gap limits the quantification of land taken by logistics and its spatialization while limiting its containment with appropriate policies, strategies, and actions.

Moreover, despite the publishing by many Italian Regions of thematic LULC large-scale maps drawn by mosaicking the different municipal land use zoning plans, the logistic category is not explicitly mentioned among the conventional land use categories, even for the new transformation areas since logistic hubs are labelled as new productive/industrial or commercial uses. Therefore, the recognition of the land taken by logistics is not possible even through land use plans making the need for detecting it even more urgent and necessary as the definition of specific policies and guidelines for efficient urban logistics require detailed knowledge of the phenomenon (e.g., territorial extension, location, intensity). In this study, to overcome these limits, a methodological process was developed to detect logistic land use, by integrating the National Digital Land take Dataset with digital visual photo-interpretation of remotely sensed data and subsequently was tested on the two selected Italian regions.

Firstly, for each region (Lombardy and FVG), LULC maps were downloaded from the national SINANET portal of the Italian Institute for Environmental Protection and Research (ISPRA). These data are two rasters of the National Land Take Map (NLTM), with two temporal thresholds to identify the land take footprint in the selected time interval (2012-2019). The time interval was selected according to the most updated and complete national available LULC data, these thresholds allow us to consider the phenomenon of land take by logistics without the influences generated by COVID-19, verifying whether the increase in logistics areas was present even before the "boost" given by the pandemic.

Since the NLTM rasters referred to two different UTM zones, the files were re-projected and merged with "Mosaic to new Raster" function of ESRI ArcMap 10.8.1, generating a single dataset with Datum WGS84 fused 32 N and 10 m resolution. In the NLTM dataset, the original LULC classification of the two regions was re-classified in a binary legend by assigning code 1 to urbanised areas and code 0 to the remaining classes, including dirt roads and temporary land uses (such as construction sites).

Afterwards, the layers were superimposed using the "Raster combine" function of ESRI ArcMap 10.8.1 to detect the variation between 2012 and 2019. A three-category land take map was obtained where: "0-value" corresponds to non-artificial land, "1-value" is associated with the artificial land and "2-value" is the land take (change from 0 to 1 value). Once identified, the pixels coded with 2-value were extracted and re-classified by photo-interpretation to distinguish the following main LULC classes:

- residential;
- industrial (including agricultural production areas with sealed surfaces, including buildings, feed storage facilities, manure storage facilities);
- commercial;
- infrastructures and transports (including parking lots and related annexed spaces);
- logistics;
- services and facilities.

A preliminary correction of the NLTM has been operated by deleting some geometric features below a certain dimensional threshold (small strips of agricultural or natural areas) improperly classified as land take. Through this process, all those small areas that did not effectively represent land take and some minor interventions for expansions or re-qualifications on the existing industries that changed or diversified their main activity from productive to logistic function were detected. Therefore, this procedure allowed to correct the misclassification and validate our land take analysis. For Lombardy, this process was also refined by an overlay analysis with the LULC class "industrial, artisanal and commercial settlements" (Class 1.2.1.1.1) of DUSAF database (LULC for Agricultural and Forest Soils elaborated by ERSAF - Lombardy Region for the years 2012 and 2018. After the preliminar correction, photo-interpretation was conducted on Google Earth (date of acquisition 4/11/2020)

and, where necessary, integrated by World Imagery dataset of ESRI ArcMap 10.8.1. Finally, the spatial distribution of land take typologies was also investigated to further analyse the phenomenon of land take in both regions (Fig.2).

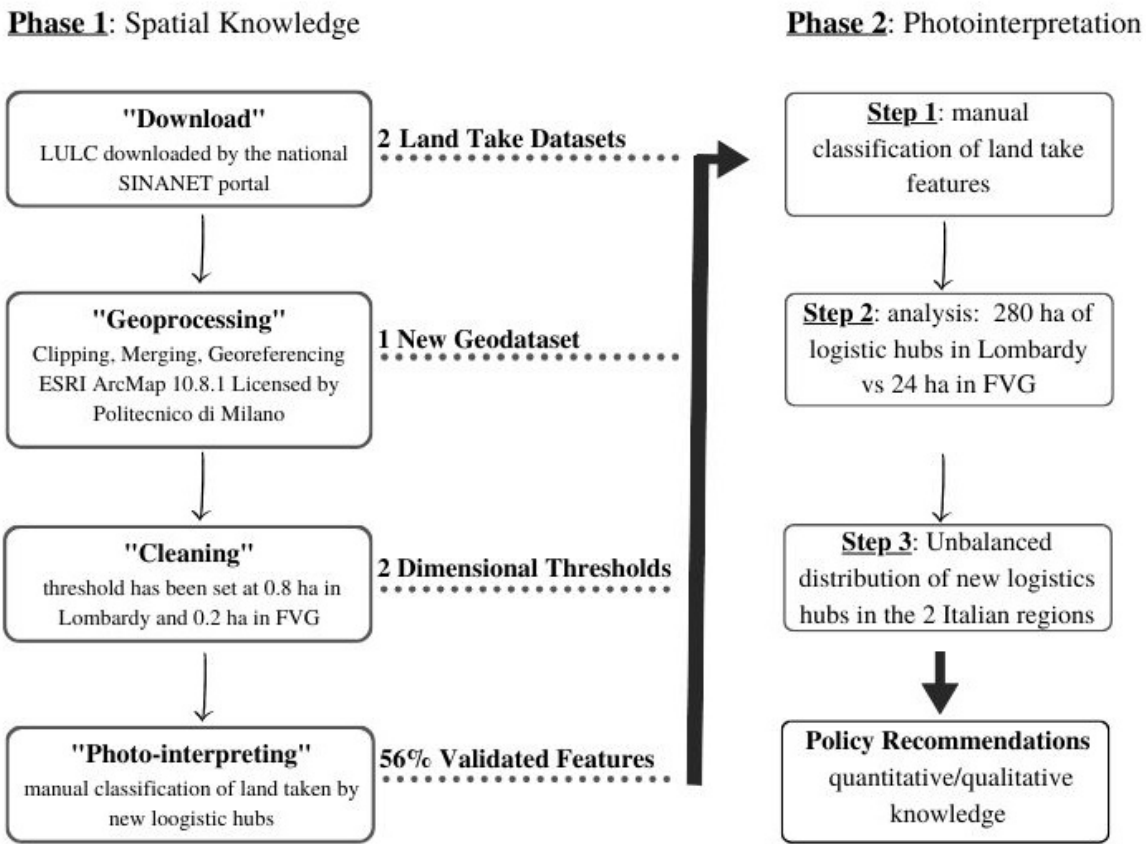

Fig.2 Study approach flowchart

3. Results

3.1 Land taken by logistics in Lombardy

The first result of the photo-interpretation procedure shows that 50% of the land take area is composed of productive, craft, and commercial functions, including warehouses, logistic areas, and productive settlements for agricultural uses. While detailing these functions, three main uses emerged: firstly, the productive/industrial activities have taken about 450 ha, followed by the logistic activities, which occupy about 280 ha and the commercial areas that cover 190 ha. The average size of new logistic hubs is approximately 3.5 ha, 67% of the total is less than 3 ha, while the remaining is over 10 ha.

An additional characteristic of logistic hubs is the accessibility by transport routes, which is a key factor in choosing the location for new areas. In particular, fast and easy accessibility from the road network and the proximity to primary highway axes are considered an asset. Indeed, logistic enterprises mainly rely on the road network and, consequently, the quality, density, and typology of connections are considered essential attributes for economic growth (Yeo et al., 2020).

Most logistic platforms have been developed along some recent highway networks, such as A58 TEEM (the external ring road of Milan), A35 BreBeMi (connecting the cities of Brescia, Bergamo and Milan), A22 Brenner highway (that connects Po valley with Austria and Germany) and A21 (connecting Piedmont region to Veneto region) (Fig. 3). Also secondary roads (new or existing) directly connected to the highway systems have played

a central role in the location of new logistic hubs. For example, provincial road 415 "Paullese", is a junction of TEEM, as well as the western ring road of Caravaggio municipality (in Bergamo province), which strengthens accessibility to the BreBeMi highway by connecting it to the Rivoltana and Padana Superiore.

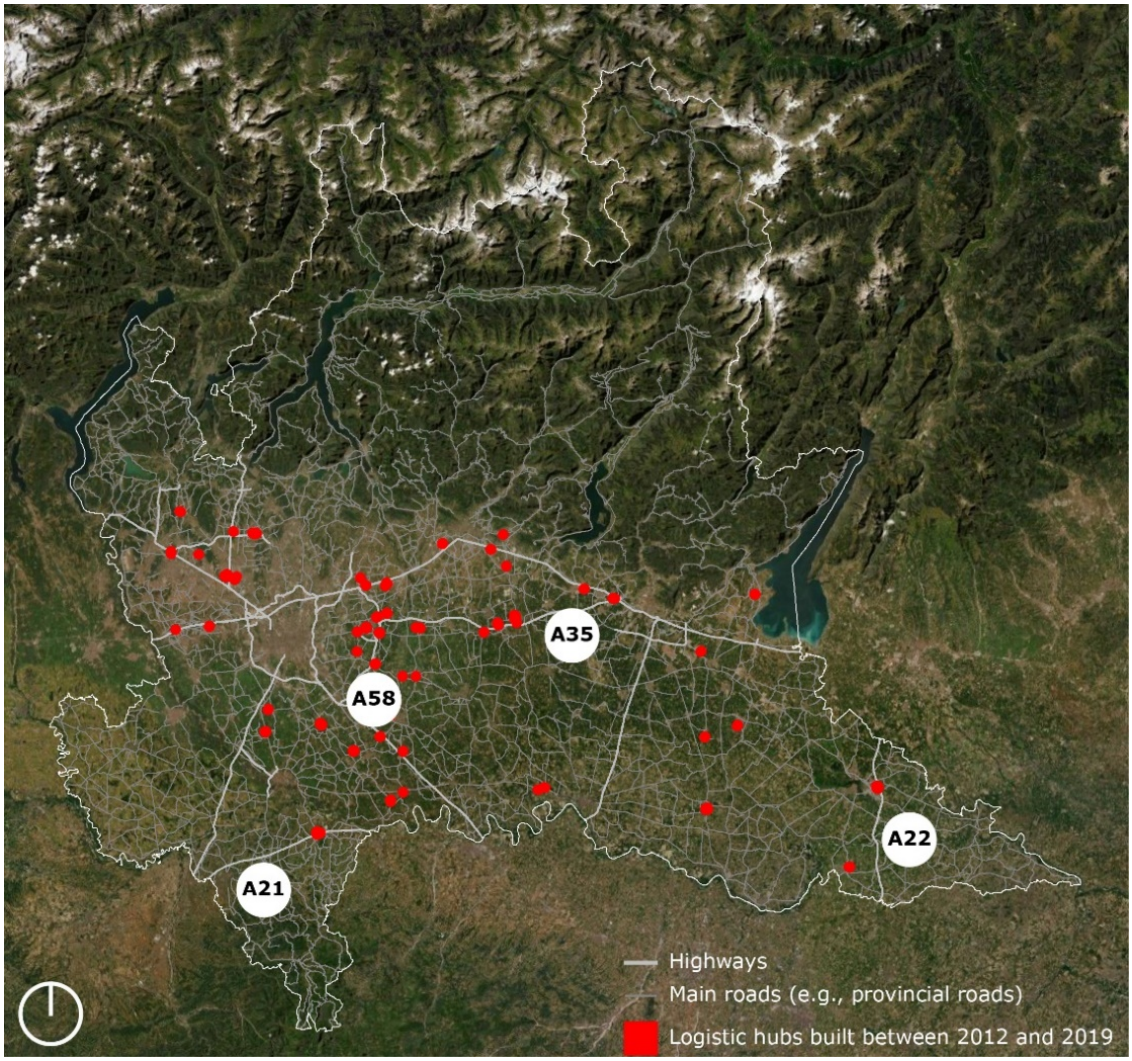

Fig.3 Concentration of logistic hubs built between 2012 and 2019 in relation to the infrastructural system (highways – labelled with "A" followed by a number - and main roads)

A less obvious dynamic concerns the proliferation of new commercial malls and related catering and food services (food chains) that have been developed in the region during the last years. The impact of these recent activities is similar to the new logistic areas because they occupy, on average, large portions of highly accessible land equipped with infrastructures and sealed by impervious surfaces (e.g., buildings, internal viability, and parking lots). Furthermore, detailed observation of new logistic hub's distribution shows that newly developed areas mainly concentrate in small and medium-sized municipalities. In fact, 83% (232 ha) of logistics areas are located in municipalities with less than 10,000 inhabitants (ISTAT, 2021) or in suburban areas. A share of 32% (90 ha) lies in municipalities with less than 5,000 inhabitants, while in medium-large municipalities (with over 10,000 inhabitants), the land taken for the logistic function is relatively contained (less than 40 ha) (Fig.4).

The small number of new logistic hubs in medium-large municipalities also depends on the limited availability of large areas (mostly agricultural), as they have already been subjected to land take in previous years. Moreover, environmental constraints (such as regional parks, Natura 2000 sites) or other restrictions often

protect the remaining peri-urban areas. In small and medium-small municipalities, environmental restrictions are less present and there are still free areas to host logistic hubs.
Additionally, urban rent is a concurrent factor: the price of agricultural land in peri-urban areas is much higher than in less populated and more peripheral locations (Canesi & Marella, 2017). Finally, in densely inhabited municipalities, many new logistic functions have been allocated in the existent stock of the already urbanised land, thus not accounting for new land take. Overall, the logistic hubs in Lombardy have mainly consumed agricultural land: about 70% of the conversion took place on arable areas, 9% of which has occupied permanently irrigated lands.

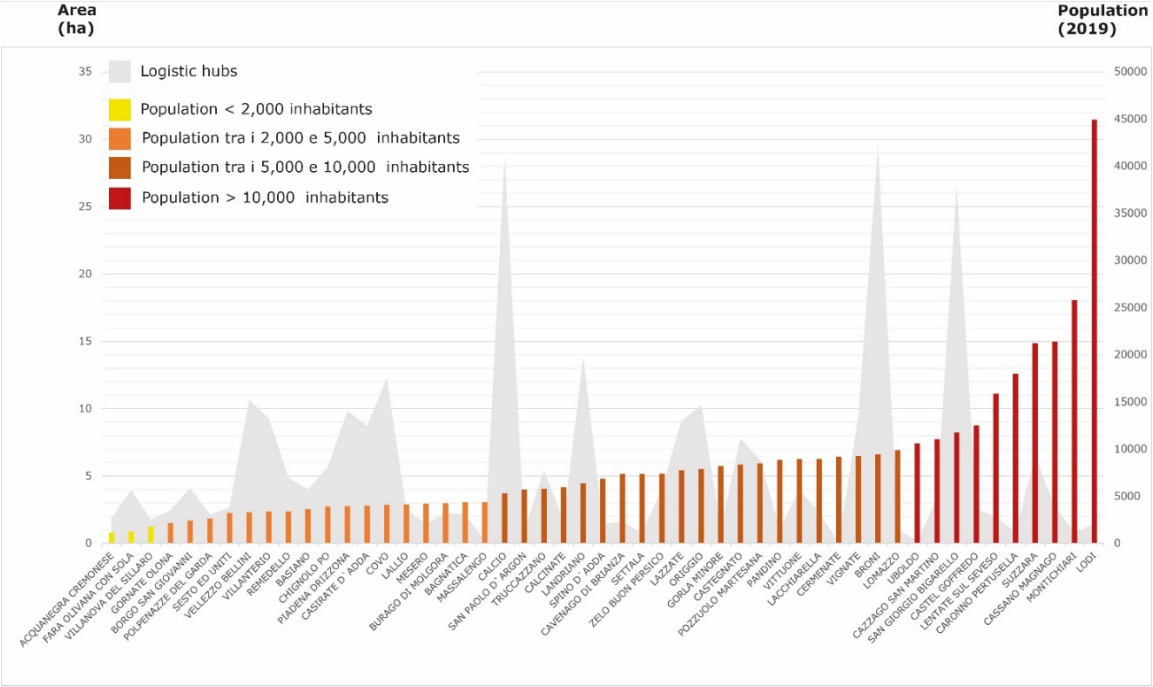

Fig.4 Lombardy municipalities with the highest land take for logistics (2012 – 2019 period): hectares (ha) in relation to the municipal population (2019)

According to the analysis, San Giorgio Bigarello (located in Mantua province), Calcio (Bergamo province), and Broni (Pavia province) are among the municipalities that recorded the most significant increase in land taken for logistic activities. In the municipality of San Giorgio Bigarello, a new logistic site has been created along the A22 highway by transforming an agricultural area of more than 26 ha, with losses of soil and related ES. Additionally, a new hotspot of 28 ha has been detected in the area known as "Quadrangle of logistics", (which includes the municipalities of Calcio, Covo, Cortenuova and Cividate al Piano), where the new logistic hubs have taken over 28 ha of land. Finally, the Broni municipality recorded the highest land take quantity by hosting 29.5 ha of new logistic sites due to the expansion of the existing Business Park along the A21 highway.

3.2 The land taken by logistics in Friuli Venezia Giulia

The photo-interpretation process in FVG had the additional objective of analysing the average dimension of the new land use transformations as a proxy of the morphological characterisation of this process. The manual process of photo-interpretation confirmed 58% of the extracted features (541 ha of land have been verified as land take out of 928 ha). As shown in Fig. 5, the highest share of observed land take (more than 216 ha) concerns the development of new infrastructures (more than 40%). The widening of the A4 highway with the construction of the third lane has strongly affected this process, since it involved an increased occupation of soil by the main highway and the re-development of the major and minor junctions with the local road network.

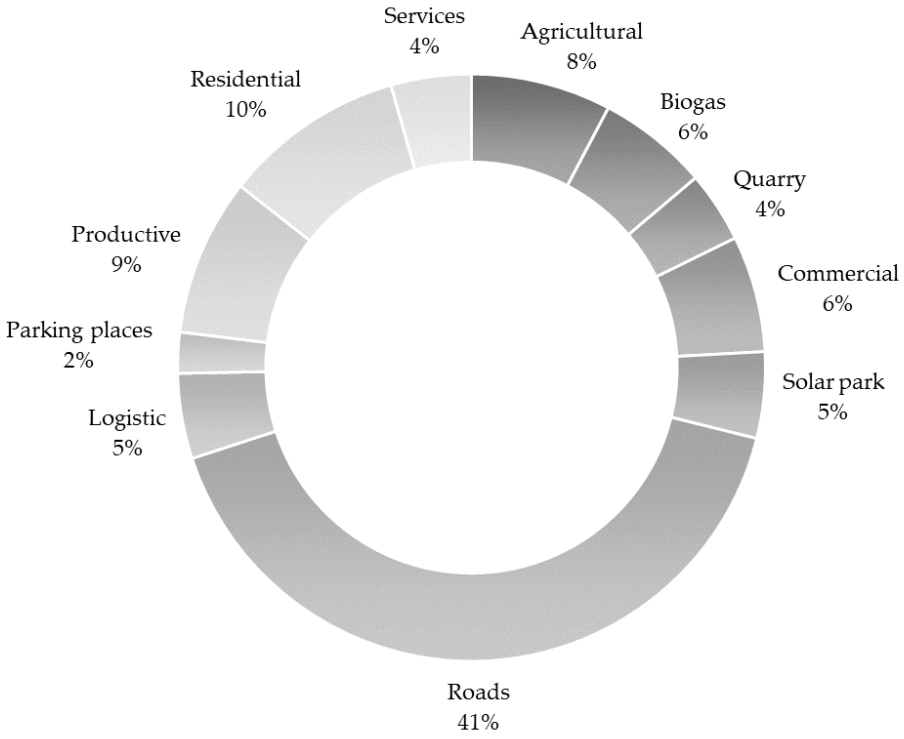

Fig.5 Characterisation of land take in FVG (areas> 2,000 sqm, period 2012 – 2019)

New residential areas represent the second most important class of land take (almost 10%, 52 ha), highlighting how the housing market is still active, albeit oriented towards the construction of energetically sustainable small- and medium-sized allotments (villas, semi-detached and attached houses) (Moudon, 1997), while land taken by new productive sites still occupies 8% (45 ha) of the total. Therefore, the demand for new production lots is still strongly present in FVG and results from the expansion/addition of industrial buildings in partially developed industrial areas that are filling their building capacity.

In addition, 7% (40 ha) of land take is composed of agricultural land consumed for the expansion or addition to existing productive farms, stables and other types of shaded areas for agricultural machinery or animals. Land take in agricultural land has also been characterised by the construction of new biogas plants (6%, 32 ha). This share of land take should be critically evaluated in the light of what this process means: the increasing utilisation of large portions of fertile plain areas for intensive, fast-growing and water-demanding crops that are used to produce energy mainly by the anaerobic digestion process.

Another important share (6%, 33 ha) of land take is composed of new commercial areas, while logistics occupies 4% (24 ha). Other functions (services, infrastructures, quarries, solar parks, and other land uses), have a share that ranges between 1% and 5% (Fig.6). In addition to the previously described expansion of the A4 highway, the land taken by new infrastructures also includes the interchange parking lots and the construction of asphalt or semi-dirt parking lots and squares in industrial areas.

The classified categories of public facilities include water treatment, recycling areas, waste treatment areas, schools, public services, technological parks and hospitals.

From the analysis of the average dimension of the new land use transformations, here intended as a proxy of the morphological characterisation of this process, the features that occupied more than 3 ha were isolated, and the infrastructures (mainly motorways), commercial and logistic areas emerged, in terms of size, among the most impacting land take typologies. There are only two categories of land take that exceed an average extension of 5 ha for each new area of intervention: the first one is solar parks, which should be evaluated by considering that they do not determine a complete sealing process, and the second is logistics.

Fig.6 Concentration of logistic hubs built between 2012 and 2019 in relation to the infrastructural system

The new logistic platforms in FVG occupy an average surface area greater than 5 ha, representing a value exceptionally higher when compared to the production sites (0.7 ha) or the commercial ones (1.3 ha). The new residential areas, which represent 9% of the total land take, have an average size of 0.4 ha, showing that the regional land take for residential, commercial and productive uses is substantially based on small and scattered interventions that are less "visible" when compared to the visual impact of a new logistic hub.
Therefore, even if the total amount of land taken by new residential, productive or commercial areas is much higher than the land taken by logistics, these new expansions are less aesthetically prominent and perceptible because of their relatively contained dimension (morphological size). In contrast, logistics is more visible due to the huge dimension of the new hubs while capturing the attention of citizens and mass media. In addition to the environmental effects of land take (e.g., habitat fragmentation, increased hydrogeological risk, loss of ecosystem services), new logistic hubs seem to generate a visual landscape problem that should be adequately mitigated or compensated to reduce the aesthetic impact. In turn, these changes alter the territory's characteristics with implications on the identity and symbolic value of FVG's landscapes.
As for the distribution of logistics as a function of distance from the main city of Udine (Fig.7), the percentage of land take has been calculated as the amount taken by specific land use functions divided by the surface of

each buffer zone. In Fig.7, the percentage of land take in relation to the buffer area is expressed in the vertical axis while in the horizontal axis, there is the distance in kilometers from the centroid.

Then, each buffer zone's dominant typology of land take was recorded. Moreover, an alternating trend emerges from the study, with a first peak composed of commercial structures at the third kilometer, a second peak (almost 1%) at the sixth kilometer, where consumption is characterised by a prevalence of logistic and commercial surfaces, and a third peak at the thirteenth kilometer where the prevalent consumption concerns agricultural uses and finally a further peak at the twentieth kilometer due to the construction of the third lane of the A4 highway.

The distribution of new functions displayed a noticeable heterogeneity: agricultural consumption for biogas plants seems to characterise the land from the ninth and tenth kilometers away. Similarly, land take for productive activities is characterised by a heterogeneous distribution: from the fifth to the eighteenth kilometer.

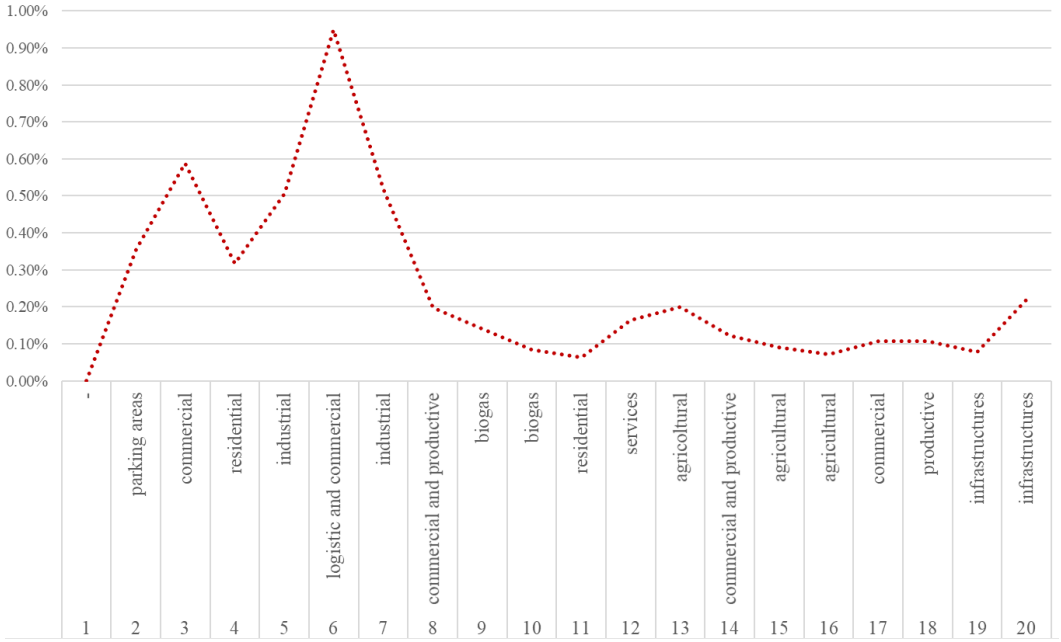

Fig.7 Gradient of the prevalent types of land take from the Udine centroid

4. Discussion

4.1 Policy suggestions

Past experience in this subject matter has clarified that good laws of territorial governance are those that integrate a deep knowledge of past and current land use change dynamics into the political agenda of the regional council, fostering a transparent discussion on what is needed to govern spatial and environmental transformations (Salata et al., 2019). Moreover, the recognition and analysis of the different territorial endowments are crucial factors for the effectiveness of forthcoming recovery policies (Altafini & Cutini, 2021) due to lockdowns and the recession period decurrent of the COVID-19 pandemic (Campagna, 2020). Such a discussion should be grounded on an empirical, technically sound and pragmatic evaluation of the land taken by logistic hubs in different regions. This research highlighted that without proper integration of quantitative/qualitative land take assessment, it is almost impossible to deal with a complex and heterogeneous phenomenon such as logistic hubs. Local Urban Plans and Strategic Environmental Assessment (SEA) procedures should carefully consider the distribution of new logistics to estimate and manage the potential impact of these settlements. The integration at the local level of land suitability indicators should integrate the SEA procedure aiming to define monitoring systems for transforming the quantity and quality of

the land (Fig.8). The monitoring of the recent transformation combined with the information derived from future planning options should be evaluated in the light of land suitability maps rather than landscape and ecosystem biophysical assessments. Feasibility criteria for new logistic hub settlements should be defined by assuming that, whenever possible, no additional agricultural or natural land should be transformed at all (limitation), while in the case of sustainable development, the procedure determines whether the transformation is sufficiently ecologically balanced (mitigation or compensation) (European Commission, 2012). This knowledge should support and integrate future decisions regarding the localisation of logistic hubs while trying to gain maximum efficiency in the selection of sites suitable for transformation. Priority should be given to brownfields, while greenfields could be used only after demonstrating the absence of any reasonable alternative of localisation in the existent stock of already urbanised land. In case a new hub is going to be settled on a greenfield, a preliminary Environmental Impact Assessment (EIA) must accurately estimate the environmental impact and point out the amount and kind of environmental compensation measures the real-estate operator should adopt. Finally, the environmental compensation should be defined and managed by an agreement between the local authority and the contractor. Moreover, the localisation of new hubs should be defined in an inter-municipal planning framework, while considering coordination between municipalities, avoiding an uncontrolled proliferation of new hubs while opting for the concentration in territorial hotspots. Increased dialogue and coordination between administrations can also improve the negotiating capacity with logistic companies (Fig.8).

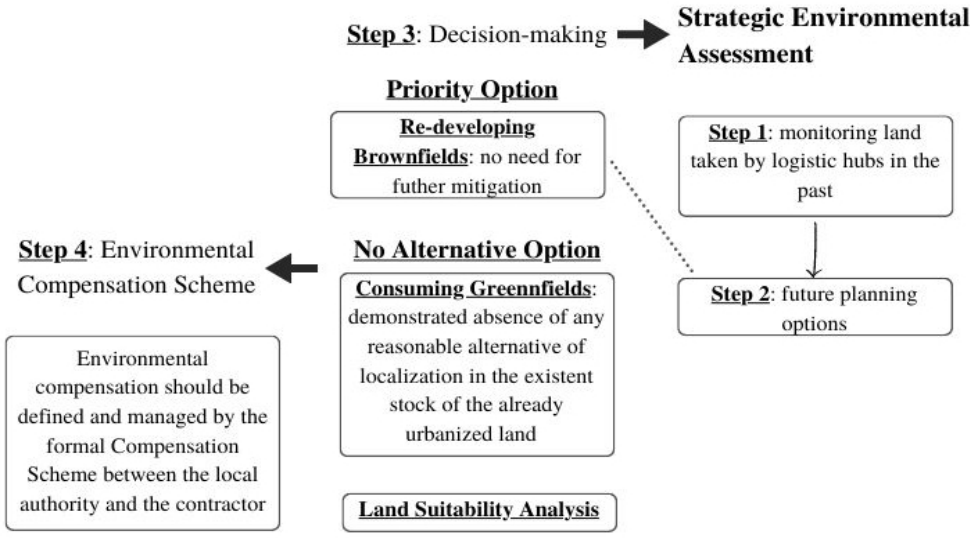

Fig.8 Decision-making flowchart

Concerning the Italian planning system - which entails four tiers corresponding to four levels of government (national, regional, provincial/metropolitan and local) - a national framework planning law should outline the principles and criteria for sustainable logistics localisation while giving all the Regions tools and targets to minimise related impacts and the amount of land taken. Regions should define a planning guideline for setting strategies for minimising the impacts and maximising the benefits of logistics. Regions could also regulate the quantity and localisation of logistic hubs if a national coordination law is set. The metropolitan cities and the local planning authorities should then define their spatial plans for land regulation, according to the regional strategies, trying to minimise the impact of new land transformation and promoting the re-utilisation of brownfields towards the densification, regeneration and re-development of the existing stock of built-up land.

4.2 The local character of Logistic hubs

Results confirm the spatial heterogeneity of the recent land taken by new logistic hubs in Italy. Even if both regions are located in northern Italy, the north-eastern (FVG) and the north-western (Lombardy) areas were subjected to radically different dynamics. Milan is a national hub and makes the area attractive for new logistic hubs even while the real estate market is experiencing a sound crisis. Big firms wanted to allocate their new business in the urban region, even just in the peripheral area, seeking a balance between infrastructural accessibility and economic feasibility.

The higher accessibility due to the most recent extension of the metropolitan highway system (TEEM and BreBeMi), especially on the eastern side, has allowed the development of new logistic settlements that can gain from the competitive benefits of one of the most distributed and widespread highway system in Europe. Besides, the Milan metropolitan area's strategic position represents a node between the east-west and north-south axes. These recent areas, mostly located along the crossroad between Via Emilia and Via Padana Superiore (Romano & Zullo, 2014), the provinces of Lodi, Pavia, Bergamo and Brescia, have been positioned considering the junction between the long-distance and the capillary distribution of goods and services. Indeed, having fast accessibility to A1 or A4 highways means reaching almost all the north Italian locations in two hours. As mentioned above, on the one hand, in FVG there has not yet been a development of logistic hubs like in Lombardy, on the other hand, national and FVG regional policies have been recently settled to strengthen the logistic system of North-East Italy and North Adriatic, where FVG with its Trieste port and the two intermodal railway platforms of Cervignano and Pordenone can play e decisive role (Favaretto, 2008).

In addition, in recent years, the Port Authorities of Trieste and Koper (Slovenia), have signed an agreement – extended to other Port Authorities of the Northern Adriatic – for the revitalisation of infrastructure and traffic, with the ultimate goal of developing an integrated Northern Adriatic polarity within a strategy aimed at offering an alternative to the Northern European ports. With these premises, there is an increased probability that new logistic hubs will be developed in the FVG region, with land taken from agricultural land, especially in the plain.

In this context, in FVG and other regions where logistic hubs are likely to increase, it is essential to rely on a valid method for monitoring these land take dynamics and differentiate their impact from other land use typologies. Over the past several years, there has been a growing discourse within the realms of logistics, regarding the spatial positioning of logistics activities.

This discussion has particularly focused on the intricate dynamics of logistics growth, raising pertinent questions concerning urban policies and their considerations for freight-related matters. This emerging concern underscores a prevailing deficiency in urban planning processes: the seemingly inadequate attention given to the logistics sector. It has come to light that one of the most challenges in orchestrating the development of logistics facilities is the lack of a comprehensive understanding of the spatial distribution of the phenomena. Public decision-makers are faced with a daunting task as they attempt to shape policies and initiatives, hampered by the absence of detailed and precise data.

In essence, the logistics landscape presents a formidable degree of diversity, a facet often underestimated by public policymakers. Consequently, addressing the needs and requirements of logistics facilities has proven to be a multifaceted puzzle, one that necessitates a more informed and nuanced approach to urban planning and policy formulation.

Finally, distinguishing logistics land use from residential, commercial, and productive land use is crucial for understanding the respective contributions of these sectors to the overall increase in land consumption. This understanding, in turn, facilitates the formulation of appropriate policies.

The study reveals that, in spite of the greater visibility of logistics operations and their implications for urban planning, logistics still exerts a comparatively modest impact when contrasted with other land use functions. This dynamic emerges thanks to a detailed analysis of land take functions that can also provide insights on whether certain functions are intricately interdependent.

For instance, the presence of closely connected logistics platforms may be imperative for certain productive facilities. Recognizing and comprehending these intertwined dynamics plays a pivotal role in forecasting potential future developments and crafting proactive strategies to mitigate their associated impacts.

4.3 Limits and potentialities

The manual photo-interpretation of logistic hubs for the two study areas of Lombardy and FVG highlighted some key issues worth discussing. At first, the lack of a real, empirical dimension of the land taken by this specific land use typology is a serious problem that automatic detection methods based on remotely-sensed images and GIS cannot completely solve. Indeed, when the objective is monitoring land uses – defined in the INSPIRE Directive (European Parliament and the Council, 2007) as "land classified according to its current and future planned functional dimension or socio-economic purpose", the functional attributes are hardly inferred with remotely sensed images (aerial or satellite), especially in urban catchments. Hence, the detection of functional urban land use with remotely sensed data in most cases needs to be supported by ancillary data such as plan zoning maps, census data, field observations, etc. The lack of data requires the combination of instruments for detect logistic land use adopting diverse typologies of method that must be scientifically recognized and widely tested and applied. In the study, we firstly adopted land take detection by LULC change analysis plus a second step using a photo-interpretation process to verify the correctness of the results. Both methods are supported by a strong and consolidated scientific literature which has historically used the methods to conduct spatial analyses (among the many: Aldwaik & Pontius, 2012; Estoque & Murayama, 2015; Veldkamp & Verburg, 2004).

The results in the two Italian regions demonstrate that the land taken by logistic hubs can vary significantly according to different contexts. The outcomes cannot be generalized but these dynamics means that the prototyping of automatic detection techniques aimed at distinguishing the logistic hubs from commercial or productive areas, can be achieved only by including an accurate human-controlled detection and by considering the peculiarities of the regional contexts useful to interpret this phenomenon correctly. A possible further development of this research could be the extension of the proposed method to all Italian regions, highlighting the similarities and differences of the phenomenon. Another important issue is the radically different distribution of logistics in the two analysed regions: while in Lombardy, the construction of new logistic hubs shaped the most recent land take process while generating the neologism "logistics sprawl", this is not true for FVG, which, in contrast, experiences a molecular proliferation of residential, industrial, commercial and infrastructural uses, while logistic hubs, from a strictly quantitative analysis, are less relevant. Lastly, the insufficient knowledge and data regarding the land taken by logistic hubs constitute a gap that determines the absence of tailor-made policy instruments to limit logistic settlements' impacts and govern their proliferation. Much further investigation is needed to fully understand these phenomena.

For example, this study limited its investigation in the logistic hub detection among the categories of land take as a preliminary operation that allows further investigation. The impacts of logistic sprawl on ecosystem services, local population or micro-economies (among others) were not addressed even though we consider them a key to fully understanding the phenomena and developing tailor-made policies. The integration of national, regional and local datasets is a key factor in quantifying, understanding and interpreting the phenomenon with its related impacts, especially in Lombardy, where the new expansion of logistic hubs has characterised the recent urbanisation trends. Also, the bureaucratic and legal procedure for transforming the land is much simplified in these suburban locations of the metropolitan region of Milan: the negotiation power between the council of a small municipality and international market operators is disproportionally unbalanced. New multinational corporations can leverage on their economic interest to steer the negotiation with local authorities: they can use an irrelevant part of their capital to acquire land and pay an extra amount of land taxes (known as urbanisation charges - primary and secondary) to obtain construction permits. Market

operators know that maintaining the basic services and public facilities in Italy represents a cost for local authorities, who chronically need to integrate their budget. Thus, logistic real-estate corporations can leverage economic power and easily obtain the necessary authorisation to settle their activities and do their business (Arcidiacono & Salata, 2014). Also, the legal procedure to obtain construction permits is relatively fast, since these typologies of transformation often bypass local planning authorities while receiving "regional" authorisation through programme agreements (Ronchi et al., 2020), being labelled as "public interest" investments. When considering the above circumstances, it appears that without a solid legal framework and strong coordination between regional and local authorities, it is challenging for small municipalities to negotiate the interests of their local communities.

Indeed, these claims for environmental protection or land take limitation, while these aspirations are monetised with long-term agreements that guarantee cash flows for public administrations. Another crucial point is that monitoring spatial dynamics of logistics hubs makes it possible to evaluate the e-commerce market trend, connected to consumer habits and methods of purchasing services and products, which determine, in turn, significant impacts on the soil resource and related ES. Logistics has extremely different effects on Natural Capital compared to industry and commerce. Natural Capital is "the world's stocks of natural assets which include geology, soil, air, water and all living things. It is from Natural Capital that humans derive a wide range of ES which make human life possible" (IPBES, 2019). Therefore, distinguishing an industrial sector from a logistic one is fundamental for estimating the impacts on several ES, as they are two completely different enterprises in terms of occupation, landscape impact, noise, atmospheric emissions and traffic. The methodology developed in this paper allows for detecting the logistic function by differentiating it from the industrial and commercial ones and by providing new knowledge to decision-makers for setting territorial development strategies toward sustainability. Moreover, the results show fundamental differences between the two Italian regions in the average dimension of the new logistic hubs, their localisation, and the amount of new areas allocated to this function. The combination of a quantitative and qualitative analysis highlights these morphological differences, setting the premises for a deeper understanding of developments and for defining appropriate strategies of limitation, mitigation and compensation of the related land take impacts (European Commission, 2012). The results highlight some trends in the localisation of logistic hubs, which should lead to rethinking the current land development models and seeking a better dialogue between market demands and soil and ES conservation targets. New logistics hubs should be planned in areas that allow for minimising environmental impacts, for example, by considering the option of regenerating disused and underused compartments or adopting measures for environmental mitigation and compensation.

5. Conclusions

The phenomenon of land taken by logistic hubs is still scarcely studied and appropriate methods for monitoring the increase and dispersal over the territory of these areas are seldom available and applied. The existing national LULC database as well as the municipal land use plans, do not detect logistic hubs limiting the adoption of strategies and policies for contrasting the associated phenomenon of land taken by this specific land use. Limits are mainly due to the paucity of data and the technological limits that land use classification based on remote-sensed images have on this matter. This paper aims to outline the need to integrate current LULC datasets with the survey of the logistic function while considering past and near future impacts of these transformations due to the growing development of the e-commerce market. The detection and identification of logistic hubs from other land use functions also allow for setting appropriate strategies and actions of limitation, mitigation and compensation of land take that can be integrated into the planning and programming tools (i.e., Urban plans) and in the Strategic Environmental Assessment procedures. This research proposes a methodology that fulfils this lack of knowledge by using a qualitative method – combined with the quantitative one – based on the Official National Land-Take dataset, further re-classified by photo-interpretation with the

support of ancillary data, to better detail the land take classification. The necessity to integrate the current LULC dataset with the logistic function was also noted at the EU level in the development of the Eagle data model (Arnold et al., 2013), conceived for future homogeneous LULC monitoring over the territory of the EU member states, that provides a method to separate the definitions of land uses.

This model, in the Land Use/Function Attributes (LUA) list, provides a specific category labelled as Logistical and Storage Services, defined as "areas used for separate (not linked directly to industries) storage services and logistical services". Therefore, the technologies and methodologies to detect logistic hubs as a separate category exist and need to be employed in the next land use monitoring agenda. In the meantime, in Italy the Eagle model was applied only with a generalised thematic detail level without implementing the detailed categorisation of Logistics (De Fioravante et al., 2021) Hence, the manual method proposed in this paper for this land use re-categorisation, which has been tested in two northern Italian regions, shows the way forward to fill the gap of mapping logistic hubs in a relatively simple, accessible and economic way, also considering the current lack of data or the limited application of method for logistic detection. The results highlight a large variety of differences in the selected case studies (i.e., in terms of the amount of logistic hubs, location choice and dimension), demonstrating the need to develop detailed analyses that consider territorial specificities for supporting policies based on an appropriate knowledge system. Quantitative and qualitative analysis is fundamental to detect not only the intensity of a phenomenon, but also its development, distribution, concentration and character, which is pivotal for regulating and governing the trend with appropriate planning strategies.

We believe that detecting and classifying of logistic hubs in land use analysis can significantly benefit urban planning processes in many ways. Land Use can be optimized by strategically locating logistic hubs in areas with lower land use conflicts, maximizing the utilization of available land, and reducing the need for additional urban sprawl. This promotes more efficient land use and helps protect valuable open spaces.

Also, infrastructure investments can be prioritized to expand transportation networks. This ensures that the urban infrastructure can support the movement of goods and reduces the strain on transportation networks. This goes along the implementation of traffic management measures, and optimization of routes to reduce congestion and improve traffic flow in areas with heavy logistics operations. Logistic sprawl can be promoted also integrating public transportation, cycling lanes, and pedestrian-friendly infrastructure to connect logistics areas with residential and commercial zones, reducing the need for private car usage and improving accessibility.

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Image Sources

Fig.1: Basemap source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Fig.3: Basemap source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Fig.4: Authors elaboration using GeoDemo Istat

Fig.6: Basemap source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

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