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URBAN MARGINAL RUDERAL AREAS AS HOTSPOTS FOR ILLEGAL WASTE DUMPING

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Abstract: Illegal dumping is a persistent environmental issue in urban areas, yet the spatial factors driving the location of dump sites remain poorly understood. The study introduces the concept of the urban marginal ruderal area—a space characterised by proximity to marginal roads, adjacency to buildings of varying land-use classes, and ruderal vegetation indicative of advanced plant succession. These accessible yet seemingly disorganised areas are particularly susceptible to illegal waste disposal. Data on dump sites in Łódź, Poland, were collected through field surveys, Volunteered Geographic Information (VGI), and UAV (drone) surveys. Using a predictive model, we produced a map identifying hotspots of potential waste accumulation within the city. The results confirm that such zones are widespread throughout the target research area. However, preliminary findings suggest that the precise location of dumps within these zones may be governed not solely by geographical factors but also by social ones, warranting further investigation. Accordingly, a dedicated section of this work addresses the susceptibility of urban spaces to littering by supplementing the geospatial modelling with a discussion of possible sociological interpretations of the phenomenon under study.

Keywords: illegal dumping, ruderal vegetation, waste management, geospatial analysis, Łódź

Słowa kluczowe: dzikie wysypisko, roślinność ruderalna, gospodarka odpadami, analiza geoprzestrzenna, Łódź

Introduction

Geographical space is not a homogeneous structure. Rather, it encompasses the Earth's surface in its full physical complexity, capturing the character and diversity of the natural environment (Dziewoński 1967; Chojnicki 1999). It is not only a measurable structure, comprising the natural elements of the Earth's shell, but also the permanent development of this shell resulting from human activity (Liszewski 1995). Simultaneously, as a whole, it is full of more or less similar things – spatially coherent entities (Jiang and Zheng 2019).

We are aware that its components vary in structure, composition, coverage, and the social and natural roles we attribute to them. Geographical space can be seen as a living structure (Alexander 2002) full of mutual relationships, as well as a subject of

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cognition, a measurement instrument used in geographical research, and a resource that affects social activities in complex ways (Lisowski 2014; Włodarczyk 2014). Contemporary geographical and sociological theories provide frameworks for understanding this relationship, arguing that a space is not an isolated entity but part of an interconnected whole—the goodness of a place depends on its surroundings and on the larger forms that contain it, thereby creating a recursive definition of spatial quality.

Interestingly, human activity itself can imbue or constitute a space with meaning (Löw 2016). A place can be valued or defined by comparing its physical features with the phenomena that occur within its boundaries. It is clearly visible in urban areas where some human activities leave temporary traces, while others permanently alter how a space is understood and experienced. The accumulation of these human interactions gradually inscribes social significance onto physical structure. This raises the question of whether certain places are more susceptible to particular activities occurring or roles being acquired, and how this connects to the users of the place. Such considerations are relevant when examining spaces open to diverse plant, animal, and human populations.

Shared urban spaces operate as social realms where multiple—sometimes conflicting—uses and interpretations coexist. In these conditions, the concept resembles the notion of an arena in relation to social worlds, as introduced by Strauss (1978). Although shared spaces encompass a range of urban environments, significant attention must be paid to specific areas within them that lack clear ownership or oversight. These transitional no-man's-land zones serve as connective tissue between urban districts, each weaving through neighbourhoods and binding together different sections of the city. Their ambiguous status makes them compelling subjects for examining how humans interact with and shape geographical space. The absence of defined stewardship creates a vacuum where collective responsibility dissolves.

Waste dumping represents one such interaction. It remains an open question whether the absence of defined ownership drives shared spaces to become dumping grounds, where household waste and construction debris accumulate precisely because no entity claims responsibility for their protection or maintenance. Analysing such a phenomenon could reveal how perceptions directly shape the character and condition of urban connective zones, transforming potentially valuable public assets into degraded landscapes that mirror the social disconnect between residents and the supposedly shared territory. Kacperczyk and Żulicki (2022) previously identified distinct positioning strategies among various stakeholders regarding unauthorised dumping through a situational analysis conducted in Łódź, Poland, revealing how different entities frame their roles and responsibilities in relation to this persistent urban problem.

Illegal rubbish dumping has long been a concerning issue (Du *et al.* 2021), particularly regarding its environmental (Critto *et al.* 2003) and public health risks (Triassi *et al.* 2015). The social sciences have investigated the societal implications of illegal rubbish dumping, conceptualising it as a sign of public disorder that predicts crime (Massa *et al.* 2025), or as a factor in economic property devaluation (Eshet *et al.* 2007). Moreover, many attempts have been made to model the spatial patterns of illegal dumping sites (Karimi *et al.* 2022; Syafrudin *et al.* 2023; Matos *et al.* 2012), combining this approach with social variables (Meidiana *et al.* 2025; Ngalo and Thondhlana 2023; Guyot *et al.* 2025). Nevertheless, interpretative sociological inquiries have remained rare (Kacperczyk and Żulicki 2022; Hohl *et al.* 2023; Holmes and Perczel 2024). Despite the interest in the issue of illegal rubbish dumping, there is a lack of studies that have employed both geospatial modelling and interpretative sociological perspectives. This paper is intended to fill this gap.

To tackle the research problem of illegal dumping occurrence in the urban setting, the study introduces the working definition of the *urban marginal ruderal area*—a space characterised by proximity to marginal roads, adjacency to buildings of varying land-use classes, and ruderal vegetation indicative of advanced plant succession. The study aims to examine the problem of illegal dumping through the lens of the *urban marginal ruderal areas* concept and to juxtapose geospatial analysis of this type of space with sociological readings and interpretations. It argues that such spaces — accessible yet seemingly disorganised are particularly susceptible to illegal waste disposal.

During the study, the phenomenon is approached from dual perspectives: geographical and sociological. In the first analytical section of the

article, we present the study on the susceptibility of urban spaces to fly-tipping. In the second, we deploy the sociological imagination (Mills 1959) to discuss the geospatial data and interpret the research results, exploring possible sociological insights into the studied phenomenon. The multidisciplinary approach, although complicated and often giving rise to terminological tensions, allows for a richer treatment of the topic. On the one hand, marginal areas are understood as an existing segment of geographical space—a substrate upon which various types of relationships emerge—and, on the other hand, as a place that gains significance through the roles ascribed to it by humans.

Methods and Materials

Illegal Dumping Data Collection

Data regarding the locations and features of illegal dump sites were collected using Epicollect5 (Aanensen *et al.* 2014). We adopted a participatory, citizen science approach (Goodchild 2007) to aquire Volunteered Geographic Information (VGI). Epicollect5 is a geo-questionnaire platform that enables the collection of GPS coordinates, photographs, and other data through free mobile applications for Android and iOS, as well as a web interface (Aanensen *et al.* 2014). The platform also provides an open-access data visualisation web service, which we have used since the first record was collected. Epicollect5 was developed by the Centre for Genomic Pathogen Surveillance at the Oxford University Big Data Institute. It is non-commercial software that has been applied in diverse projects, including public health research in sub-Saharan Africa (Aanensen *et al.* 2014), mapping access to drug outlets in Vietnam (Beardsley *et al.* 2023), and investigating street tree communities in India (Anujan *et al.* 2024).

The first, pilot phase of the illegal dump site mapping lasted six months, from 1 March to 31 August 2022. This phase was originally intended to "build the map for citizens and with citizens through participatory smartphone research" (Kacperczyk and Żulicki 2022, p.177). We invited residents of Łódź via local media, our university's social media channels, and the project webpage to map dumping sites in the city. During the pilot, 56 volunteers created 208 VGI records. A total of 454 photographs were submitted, as volunteers could upload up to four photos per record. A summary of the first phase of data collection is available in our earlier work (Kacperczyk and Żulicki 2022).

A citizen science approach was used to obtain a subjective depiction of illegal dumping spots as perceived by city inhabitants. Citizen science is understood as networks of citizens who conduct scientific observations (Goodchild 2007). This approach allowed us to explore how volunteers conceptualised an illegal rubbish dump and what they considered valid for submitting via Epicollect5. Thus, a bias in the resulting dataset is unavoidable and treated as an advantage. Volunteers contribute VGI data as "eyes and ears of the city," and each record "is in fact the coincidence of two events: the issue itself and the decision of a resident or passer-by to report it" (O'Brien *et al.* 2015, 113). Citizen science has been successfully employed in similar studies concerning spatial patterns of illegal dumping sites (Guyot *et al.* 2025), as well as a broader spectrum of incivilities in the city (O'Brien *et al.* 2015).

After the pilot phase, we kept the data collection platform available for volunteers and other stakeholders without further promotion from our side. Thus, a total of 414 locations, along with additional photographs, were submitted by 31 December 2025, constituting the final dataset of locations and features of illegal dump sites for this paper. Figure 1 shows all collected spots.

Orthomosaics

Photogrammetric data, in the form of orthomosaics, were collected over areas affected by illegal waste dumping and used to visualise problematic areas and assess the condition and composition of the waste. An orthomosaic is a current image of the terrain with metric features, used to perform spatial analyses in a study. It is created by capturing remote sensing imagery over the study area. Each point in the surveyed area is photographed from above, both vertically and perpendicularly. To achieve this effect, dozens of images of the surveyed area were taken and combined into a single composite image. The process of achieving the visual effect of a cartometric orthophotomap begins with aggregating files from a single photogrammetric run. Next, a photogrammetric product creation program establishes the data-collection path required to initiate

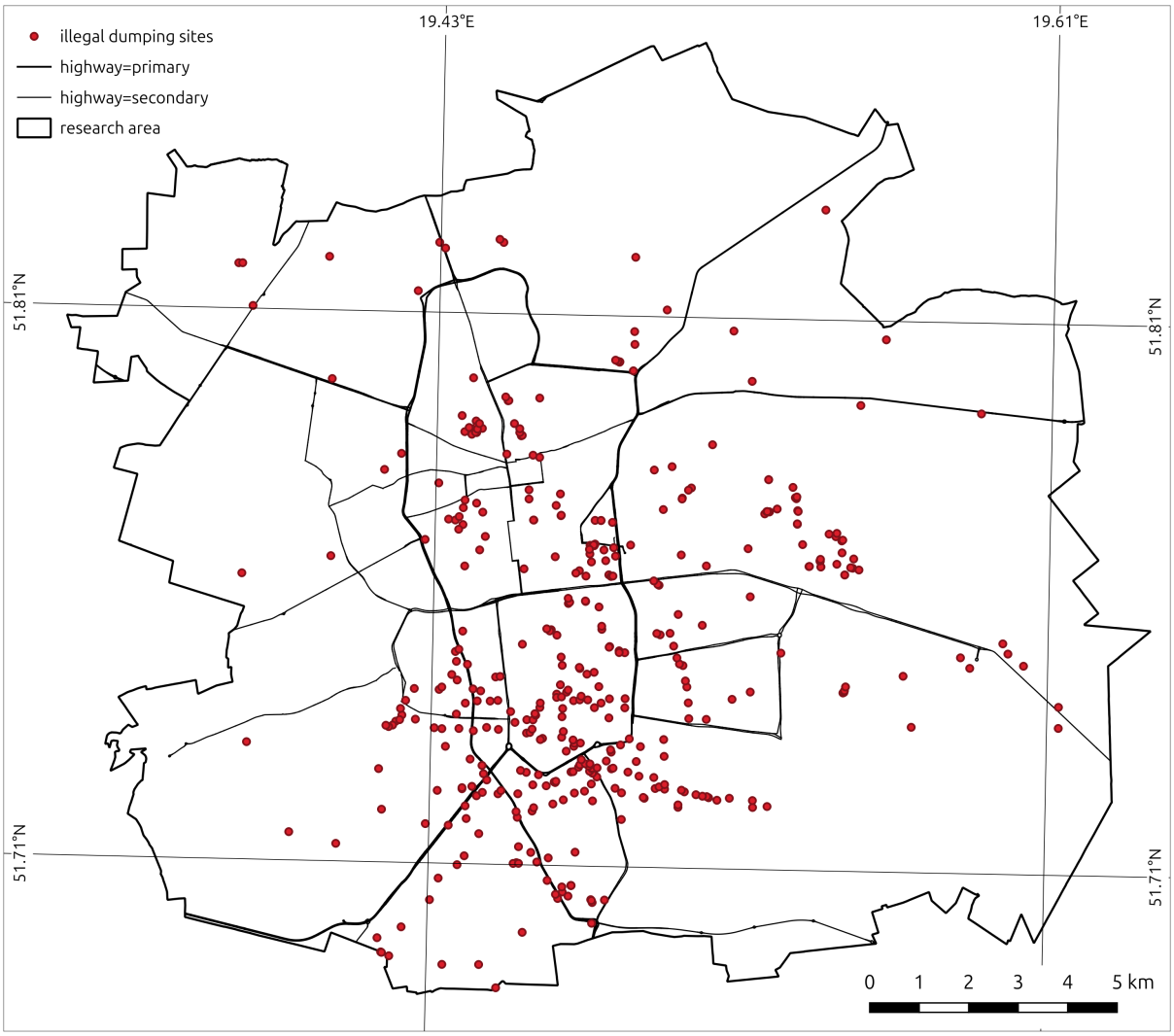

Fig. 1. Illegal dumping sites identified during the research (state for 2025), Łódź, Poland (background layers: OpenStreetMap)

the process. As a result of image processing, a GeoTiff file is created. This file not only visualises the surveyed area but also provides the cartographic characteristics of the spatial reference system, enabling further work in spatial analysis programs (GIS). Orthomosaics are used in geodetic surveys, construction, spatial planning, and environmental protection.

In our study on aerial identification, an orthomosaic is an excellent data source for showing the spatial distribution of illegal dumping, allowing us to determine the spatial characteristics of the study area, its size, and the concentration of objects of interest. The selection of survey sites was performed using location data available in Epicollect5. The study focused on illegal dumps that had formed in areas with low road or pedestrian traffic, lower population density, and minimal vegetation cover. In urban areas, drone surveys were conducted primarily in undeveloped land between residential neighbourhoods or on their outskirts—remote locations whose spatial characteristics, as stated in the hypothesis, are conducive to the formation of illegal dumping sites. Areas around airports and military bases were excluded from the aerial surveys for safety and regulatory reasons. Sites selected for orthomosaic processing were areas where shrubs or trees did not significantly obscure the dumped waste.

After inspecting each illegal dumping site, unmanned aerial vehicle (UAV) flights were conducted at altitudes of 60m to 80m within a 100m radius of the delineated illegal dumping centroid, capturing RGB images of 3cm ground sampling distance (GSD). The camera was positioned at nadir during flight. Metadata describing flight parameters, such as the time of capture and geolocation, were also collected during the flight, which

are crucial for subsequent data processing. Imagery was captured using an enterprise-tier drone, a DJI Mavic 3E, equipped with a non-cartographic camera. The field survey was conducted on dry, sunny days.

Fig. 2. Orthomosaic captured on Lodowa St., Łódź, Poland [51.741, 19.523] (*photo by: Maciej Kossowski* 2025)

Case Studies Spatial Data Encoding

Grounding the analysis in concrete geographical contexts required defining case scenario areas that reflect the diverse settings in which illegal dumping typically occurs. The process of creating and visualising spatial features for the selected illegal dumping areas was multi-faceted.

The first phase involved constructing the spatial context by retrieving relevant data from OpenStreetMap (2025) (OSM). Each provided orthophomosaic area served as an entry point to delineating the analytical area of interest (AOI). To standardise the AOIs across various urban spaces, we set their scope to a circle with a radius of 100m, with the origin at the centre of mass of the corresponding non-empty aerial image. The chosen radius was sufficient to cover all selected illegal dumping areas and provided adequate information regarding their neighbourhood. The AOI was then used to automatically query OSM for specified geometric features, including linear and polygonal features such as pedestrian routes, roads, railways, built-up areas, vegetation, parking lots, earthworks, crops, allotment gardens, cemeteries, industrial areas, and water bodies. The utilised query engine was provided by HeiGITs' open-source project Ohsome API (2025) and its accompanying integration called Ohsome-py (2025). The data synchronisation utility was coded in Python (2025). Table 1 denotes each OSM query predicate used to collect data regarding the corresponding spatial feature type. The acquired data were processed as Geopandas (2025) data frames and persisted as a geospatial dataset (geopackage; gpkg). OSM was used exclusively to acquire feature geometry, whereas attributes were created in advance as placeholders, left empty for subsequent manual interpretation.

The next step was to identify all OSM feature properties relevant to the research. For each AOI, this process was carried out by a human annotator who had access to additional openly available data sources such as Google Maps Street View (2025), OpenStreetMap (2025), Mapillary (2025), and data from the Polish National Geodesy and Cartography Agency (GUGiK), along with the possibility of visiting the selected area during a field study to gather additional information. During the interpretation process, the annotator had the opportunity to refine geometries retrieved from OSM and to introduce additional features. The result was a fine-grained spatial context dataset available for each case study area.

Given a set of spatial context layers and orthomosaics, the annotator prepared the illegal dumping feature layer. The annotation framework targeted four distinct object categories: (1) individual or small waste patches (typically $<1m^2$), (2) larger waste clusters and accumulation zones, (3) potential terrain barriers such as walls, fences, or vegetation boundaries that may influence dumping patterns, and (4) various types of light sources that could indicate monitoring or accessibility. These categories were selected based on their relevance to understanding both the spatial distribution of illegal dumping and the environmental factors that enable or deter such activities.

Table 1
OpenStreetMap feature acquisition predicates. More information can be found at the OSM map features wiki (2025).

code	description	properties	ohosme-py filter
pedestrian_route	paths for pedestrians and cyclists	condition	highway=cycleway or cycleway=* or sidewalk=* or highway=path or highway=footway or footway=*
roads	vehicular road network	condition, surface type	highway=motorway or highway=motorway_link or highway=trunk or highway=trunk_link or highway=primary or highway=secondary or highway=tertiary or highway=residential
railway	rail infrastructure	-	railway=*
built_up	buildings and structures	type, number of floors, construction year, roof surface type, condition, material	building=*
vegetation	green and vegetated areas	type, condition	landuse=forest or landuse=meadow or landuse=grass or natural=grassland or natural=scrub or natural=heath or leisure=park or landuse=flowerbed or landuse=orchard or landuse=plant_nursery
parking	open-air parking areas	-	(amenity=parking or amenity=motorcycle_parking) and (not (building=parking or building=garage or building=garages))
earthworks	artificial landforms and embankments	-	embankment=yes or man_made=embankment or man_made=dyke or (water=moat and intermittent=yes) or defensive_works=moat
crops	agricultural cultivation areas	-	landuse=vineyard or landuse=farmland
allotment_gardens	community garden plots	-	landuse=allotments
cemetary	burial grounds	-	landuse=cemetery or amenity=grave_yard
water	water bodies	-	((water=* or natural=water) and (not (water=wastewater or water=moat))) or place=sea or natural=coastline or natural=bay
industrial_area	industrial land use zones	-	landuse=industrial

Detectability criteria constrained the annotation. Objects had to be clearly identifiable in the provided UAV imagery at the available spatial resolution, with sufficient spectral contrast or geometric distinction from the surrounding environment. Ambiguous or partially obscured features were flagged for secondary review to maintain dataset consistency.

This hybrid approach balanced processing efficiency with annotation accuracy, as automated methods captured prominent features while human annotators refined boundaries, resolved misclassifications, and identified subtle or contextually complex instances. The combined dataset was then processed and visualised individually for each AOI using QGIS, allowing for spatial verification, quality control, and preliminary pattern analysis across different sites before final dataset compilation.

Spatial Data Analysis

The training dataset comprised 414 georeferenced samples representing confirmed illegal dumping sites (positive class) acquired from Epicollect5. To generate unlabelled samples (potential negative class), buffer rings with inner and outer radii of 100m and 200m, respectively, were constructed around each positive sample. Unlabelled locations were randomly oversampled by a factor of 5 from the overlapping ring geometries, yielding 2483 samples (414 positive and 2069 unlabelled). This spatial sampling approach increased the likelihood of including nearby areas without waste presence without losing geographical proximity to actual dumping sites, which is fundamental for capturing similar environmental characteristics.

Seven land-use feature categories were selected from OSM: (1) marginal roads: residential, service, unclassified roads, paths, and tracks; (2) low green areas: grasslands, meadows, scrublands, allotments, and gardens; (3) high green areas: forests, tree rows, orchards, and parks; (4) buildings: non-apartment structures and parking facilities; (5) isolated areas: quarries, landfills, bare rock, industrial zones, construction sites, and abandoned areas; (6) dead-end roads: private or restricted-access service roads and tracks; (7) vacant lots: brownfield sites, greenfield sites, and disused/abandoned properties. Categories were represented by their corresponding OSM predicates

(tag filters). Each tag filter was used in an OSM spatial query and extracted as geometry (shapes) with an extent equal to the buffered convex hull of all sample locations forming the feature. Feature values for 2483 locations were computed as the minimum Euclidean distance between the illegal dumping site location and the geometry of each collected OSM filter. The final feature set was then decomposed by analysing correlations between OSM predicates. Predicates (OSM tag filters) with high positive Pearson correlation coefficients were grouped, forming a 24-column feature vector (Table 2).

Given the absence of confirmed negative samples, a Positive-Unlabelled (PU) learning technique was adopted using the spy technique. The positive samples were randomly partitioned into a *training subset* (85%) and a *spy* subset (15%). The spy samples were intentionally mislabelled as negatives and combined with the unlabelled samples. A Random Forest classifier was then trained on this combined dataset to learn preliminary decision boundaries. The trained classifier's predicted probabilities were evaluated on the spy samples. A threshold was set at the 1st percentile of spy sample scores, corresponding to the lowest probability scores among known positives. Unlabelled samples scoring beneath this limit were designated as reliable negatives, as their characteristics strongly differed from the positive class distribution. The final dataset comprised 612 samples (414 positives and 198 reliable negatives)

Using the positive samples and the identified reliable negatives, the Recursive Feature Elimination (RFE) (2026) technique was applied to a Random Forest Classifier (2026). Feature importance was evaluated using model accuracy as the optimisation metric (Guyon *et al.* 2002). RFE iteratively removed the least important features, selecting the optimal feature subset that maximised classification performance, leaving exactly half of the feature set for further processing.

We conducted an exhaustive grid search with cross-validation to discover optimal Decision Tree Classifier (2026) hyperparameters. The search resulted in the following estimator attributes: criterion=gini, max_depth=6, min_samples_leaf=5, min_samples_split=2, and ccp_alpha=0.01. Model performance was measured using two metrics: accuracy and the F1-score. Accuracy served as the primary metric for model selection. The estimator was persisted using the SKOPS (2026) library and utilised to infer the probability of an illegal site occurrence across the entire research area of Łódź, at a resolution of 10 (approximately 15 047.5 m^2) H3Geo (2026) grid cells.

Results

Classification

A decision tree classifier was trained to predict the occurrence of illegal dumping sites using distance-based features derived from OSM. The model achieved an average accuracy of 82.98% and 87.55% F1-score during 5-fold cross-validation. The decision tree paths have been visualised in Figure 3. The plot shows that proximity to residential roads is the primary discriminating feature at the root node.

The left branch, closer to residential roads, contains sequential splits on scrub, building, and forest proximity, yielding several positive-dominated leaves. The largest capture sites are near scrublands and buildings. The right branch, farther from residential roads, splits immediately into tertiary roads, producing a positive leaf for sites near trees and tracks. Scrub, tracks, paths, built-up areas, and parks further stratify the remaining samples. Notable positive leaf areas include those near greenfield areas. The dominant negative leaf captures locations along paths that are distant from parks — areas lacking both accessibility and vacancy characteristics.

The model confirms that illegal dumping concentrates in transitional zones that combine vehicular access (residential, paths, tertiary roads, tracks) with land vacancy indicators (scrub, greenfield). Remote locations that lack this infrastructure–vacancy intersection are reliably classified as negative.

The model leverages strong neighbourhood-related spatial patterns inherent in the data. By employing a positive-unlabelled learning approach combined with a rich OSM-derived feature vector, we constructed a geospatial representation that captures similarity between areas with confirmed illegal dumping sites and candidate locations.

Table 2

OpenStreetMap feature vector, description source: OSM map features wiki (2025).

label	**description**	**RFE selected**	**ohosme-py filter**
abandoned	features that have been abandoned by their owner, but which are still visible in the landscape and useful for navigation		abandoned=yes
allotments	allotment gardens with multiple land parcels assigned to individuals or families for gardening		landuse=allotments
building	used to describe many different sorts of buildings, including houses, factories and ruined buildings	*	(building=* and building!=apartments)
commercial	commercial zone, predominantly offices or services		amenity=parking or landuse=commercial
construction	an area being built on		landuse=construction
forest	forest or woodland, sometimes considered to be restricted to managed woodlands or tree plantations		landuse=forest
grass	smaller area of grass, usually mown and managed		landuse=grass or landuse=meadow
grassland	area where the vegetation is dominated by grasses and other herbaceous (non-woody) plants		natural=grassland
greenfield	undeveloped land scheduled to turn into a construction site	*	landuse=brownfield or landuse=greenfield or landuse=landfill or landuse=quarry
highway_path	generic path used by pedestrians, small vehicles, for animal riding or livestock walking	*	highway=path
highway_primary	major highway linking large towns. In cities, a major arterial road		highway=primary
highway_residential	road in a residential area	*	highway=residential
highway_secondary	highway linking large towns. In cities, an arterial road of lesser importance		highway=secondary
highway_service	provides access to a building, service station, beach, campsite, industrial estate, business park, etc.	*	highway=service
highway_tertiary	road linking small settlements, or the local centres of a large town or city	*	highway=tertiary
highway_track	minor land-access road like a farm or forest track	*	highway=track
highway_unclassified	public access road, non-residential		highway=unclassified
industrial	area with predominantly workshops, factories or warehouses	*	landuse=industrial
orchard	used to mark intentional planting of trees or shrubs maintained for food production		landuse=orchard
park	park, usually in an urban (municipal) setting, created for recreation and relaxation	*	leisure=park
railway	area of land dedicated to train operation or support		landuse=railway
scrub	uncultivated land covered with shrubs, bushes or stunted trees	*	natural=scrub
tree	single trees or places where flowers and other plants are grown	*	leisure=garden or natural=tree_row or natural=tree
wood	tree-covered area		natural=wood

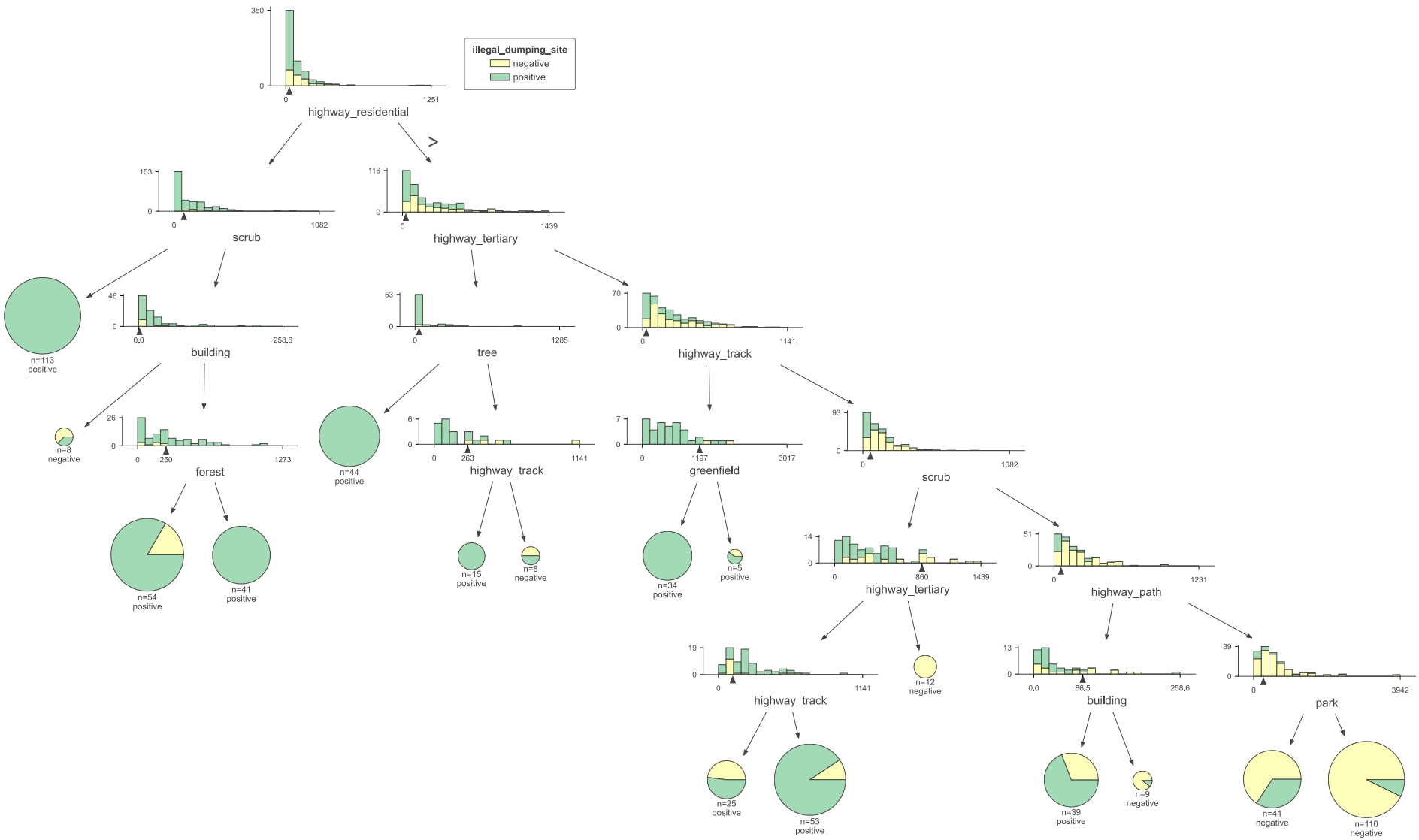

Fig. 3. Result decision tree model - illegal dumping site as the positive class

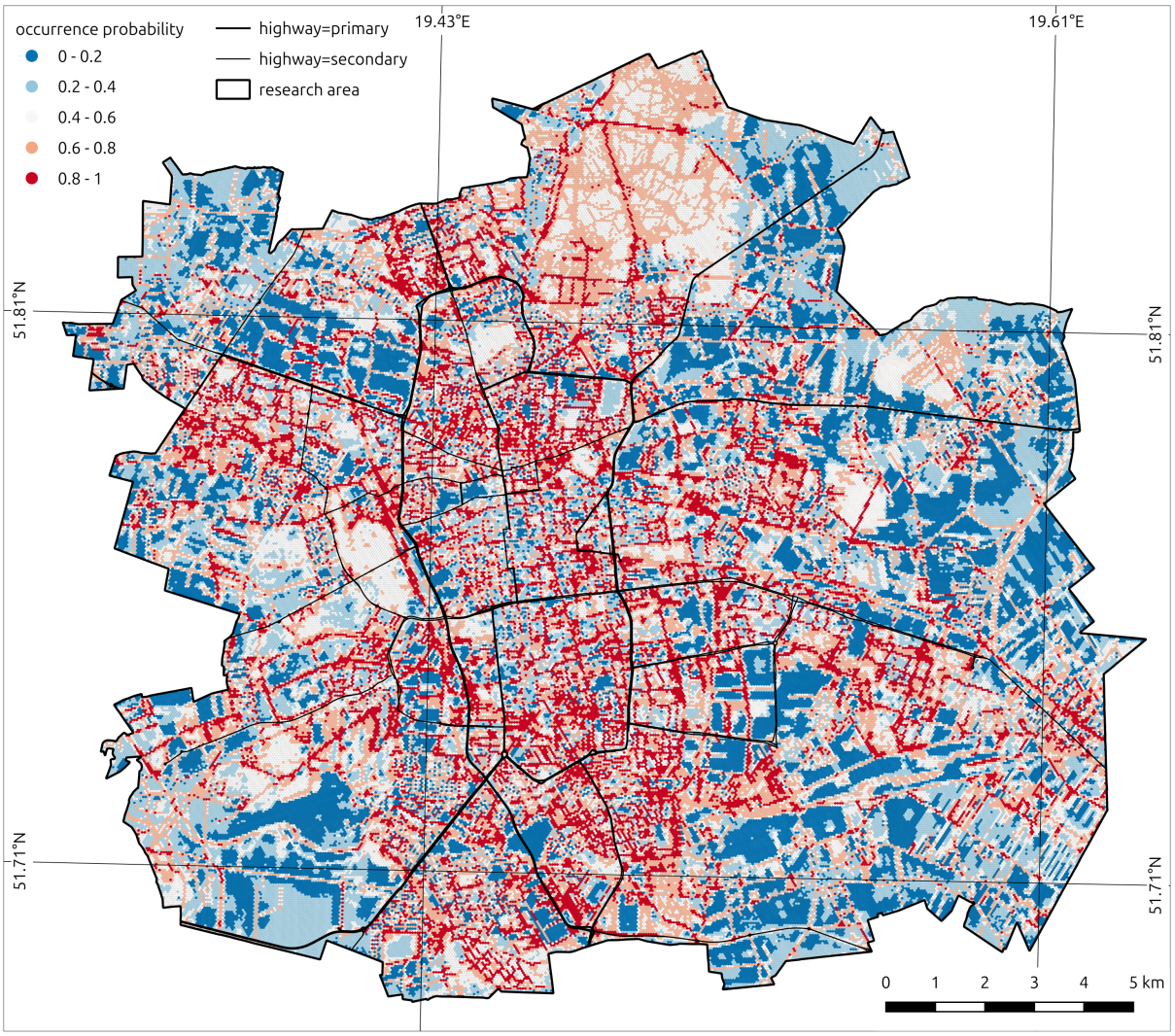

Fig. 4. Area susceptibility expressed as illegal dumping site occurrence probability heatmap, Łódź, Poland (0 - low probability; 1 - high probability)

The model demonstrates notable stability, consistently assigning existing dumping sites to the positive class with high probability ($\overline{x}_{proba} = 0.80$, $\sigma_{proba} = 0.17$). This consistency yields a significant practical outcome: the classifier can reliably identify high-risk areas that share structural characteristics with known sites.

Beyond predictive performance, the decision tree architecture provides an inherent explainability layer that is valuable for both detection and mitigation efforts. Assessing area susceptibility is straightforward—relevant feature values are computed for a given location and passed through the trained classifier. Figure 4 presents a visualisation of this procedure applied across the entire study area of Łódź.

Furthermore, the model's interpretable structure suggests actionable intervention strategies. Consider an area identified as high-risk due to its proximity to residential roads and scrubland—a configuration the decision tree associates with illegal dumping. A targeted land-use intervention, such as converting the ruderal vegetation into a managed green space (e.g., a recreational lawn, playground, or community garden), could shift the location's feature profile toward a lower-risk classification. Such transformations address the underlying vacancy signal that attracts illegal disposal while simultaneously enhancing neighbourhood amenity value.

Discussion

The spatial analysis presented in the previous section demonstrates that illegal dumping sites cluster in specific urban configurations. These are tran-

sitional zones that combine vehicular and pedestrian accessibility with features indicating land vacancy. However, the model's explanatory power, while substantial, leaves room for factors beyond pure spatial determinism. To understand the full complexity of illegal dumping as a socio-spatial phenomenon, we propose a five-layer interpretive framework that combines sociological and geographical reasoning to explain the illegal rubbish dumping in the city.

Layer I: Creation of a Marginal Ruderal Area

The consequences of illegal dumping permeate the geographical space. As urban spaces develop, they inevitably produce land fragments that escape the logic of planned development. Such areas emerge at boundaries between various land-use categories, e.g., where residential zones stitch to industrial sites, are shaped by transportation corridors, or are divided to an extent that prevents subsequent splits. Human activity in these places is limited, allowing for increased ruderal plant succession. In other words, the marginal ruderal zone comprises more than vegetation; it is a particular configuration of geographical space characterised by intersecting spatial conditions but also a visible prolonged neglect (Figures 5 to 8).

The question is whether the illegal dumping sites can be called spaces that break the wholeness of the urban structure postulated by Alexander (2002), i.e., places where the complex relationship between a location and its surroundings has degraded. Unlike the coherent urban fabric, where each element reinforces its neighbours, marginal ruderal areas exist as spatial anomalies. They are accessible yet peripheral, visible yet overlooked, technically owned yet practically abandoned.

The results show that, importantly, marginal ruderal areas are not random occurrences but systematic products of urban development patterns. In Łódź, a post-industrial city marked by economic transition and demographic decline (Nowakowska *et al.* 2025; Brzeziński 2023; Liszewski and Young 1997), these spaces proliferate. Former factory grounds, abandoned railway sidings, and depopulated residential peripheries create an extensive network of potential dumping locations. The city's spatial structure thus contains the seeds of its waste management challenges.

Layer II: Growth of an Illegal Dumping Site

From a physical geography perspective, the problem we are examining—illegally dumped waste—is a form of sediment deposition on the ground surface. It constitutes material that aggregates in certain locations due to specific features of the terrain, water conditions, vegetation, or specific relationships between objects. Due to their topography, certain locations possess the potential to "catch dirt," retaining it in a further location. Grass, or Poaceae (Latin: *Poaceae, Gramineae*), is an excellent example of undergrowth that captures and retains all debris and litter. Therefore, it possesses the agency to accumulate deposited material. A simple plastic wrap or a lightweight plastic bag fluttering in the breeze easily catches on the twigs of small shrubs or trees, which in this space begin to act as "rakes" or, analogously to nose hairs, halt the flow of carried matter. Humans play a key role in the phenomenon under study, as they are the primary agents and the primary drivers of illegal dumping. Therefore, without addressing human behaviour and their relationship with the things they create, use, and discard, it is impossible to understand the essence of the phenomenon.

Nevertheless, human agency alone does not fully describe what happens in the space of an illegal dump site, because from the moment the waste touches the ground, a series of physicochemical processes begins that determine the matter's fate and the place where it was deposited. Humans discard, and nature "does its thing": plants grow, cover rubbish, and at this stage, they also "do something".

The agency of non-human beings also plays a significant role in what we observe. The plants and animals that live in a given area create a living habitat that absorbs the debris left behind and transforms it as it grows. Therefore, it is impossible to isolate human agency as the key to understanding this problem when trying to understand the phenomenon of illegal dumping. The aforementioned mechanical, physicochemical, biological, and environmental phenomena also constitute part of the assemblage we are examining.

The frame of reference for this system (assemblage) is the city, which, similarly to geographical space (Alexander 2002), is a living structure: a system within which countless relationships occur among diverse elements and actors.

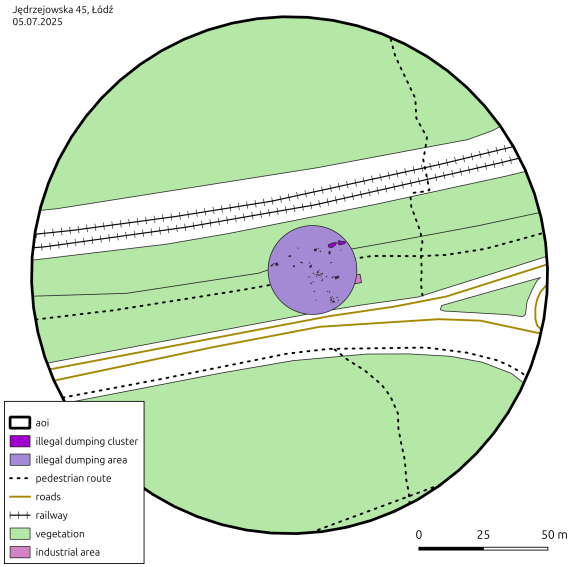

Fig. 5. Case A - Jędrzejowska 45

Fig. 6. Case B - Lodowa 91

Fig. 7. Case C - Wełniana 3

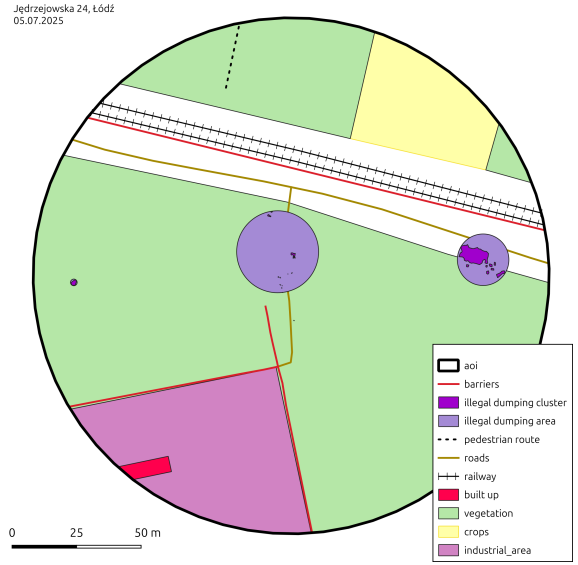

Fig. 8. Case D - Jędrzejowska 24

In the simplest terms, these elements and actors can be divided into two subsystems: the urban and the social. The urban subsystem includes all material components of the city, both human-made and natural, which together form its spatial structure. The social subsystem, in turn, comprises all individuals who utilise the city, with its residents forming the primary group (Wallis 1977). The two systems remain in constant interaction, influencing each other. Human activity may assign meaning to space or shape it, but space also determines human behaviour (Lefebvre 1991; Jałowiecki 2010; Löw 2016; Sudjic 2017). Nevertheless, in the city, it is the human being who plays the key role in shaping it. Space *is both a value and has a certain value; it is therefore appropriated collectively and individually, both in real terms – often legally sanctioned – and symbolically* (Jałowiecki 1991). In this context, the development of an illegal dumping site may proceed in stages.

Urban space is created by residents within the limits of the possibilities available to them (Sudjic 2017), but the first step towards the emergence of an illegal dumpsite is when a fragment of space is abandoned or when social control over it weakens. For example, when a company relocates its operations elsewhere, its former premises remain unused. For the legal owner, this space loses its prior utility. Unused and deprived of social control, the area becomes appropriated by nature – ruderal vegetation, such as scrub. For some time, this fragment of the city remains under the dominion of nature, until the attributes of this space (vegetation, lack of surveillance, care and social control) contribute to its rediscovery, symbolic appropriation (Jałowiecki 2010), and constitute a space with a new meaning (Löw 2016).

If buildings are present on the site, the space might be first appropriated (not in the legal sense) by "scrap hunters". For this group, every element of the saleable material in the space has a significant value. They also leave new traces of use (e.g., a hole in the fence, removed sections of fencing), which function as an *invitation* for new categories of users who also find value in the space, such as individuals seeking a place to consume alcohol illegally. These new users leave additional traces (e.g., empty bottles and beer cans). According to the theories discussed more broadly in the next sections, rubbish attracts more rubbish (Wilson and Kelling 1982), making such spaces ideal locations for further waste dumping. This encourages other actors to dispose of their rubbish there, including renovation and tyre repair companies. Dumping waste becomes a practice of giving space new meaning (Löw 2016) and transforming it into a new entity – an illegal dumpsite.

This activity is part of a specific mechanism that takes place in the social subsystem, consisting of a permanent game within the space among individual and group actors (Castells 1982; Jałowiecki 2007; Sagan 2007; Kociuba 2013). In this case, we are dealing with an attempt at the symbolic appropriation of space. The steward of the space is not its legal owner, but rather the one who defines that fragment of the city through its mode of use – in this case, by dumping waste.

Layer III: Transforming to a Space of Shamelessness

The results provide strong evidence that the margins of most second-class roads with ruderal vegetation, such as scrub, are hotspots for illegal rubbish dumping in the city. We interpret these results through the concept of non-places (Augé 1995) and certain aspects of the revised broken windows theory (Wilson and Kelling 1982).

Highways and airports are examples of non-places, conceptualised as anonymous, transitional spaces built for utility rather than for celebrating human relations, history, or identity (Augé 1995). Marginal ruderal areas also constitute a space for transfer between various zones of the city, being part of the urban tissue that serves to (dis)connect them; yet, in a way that is not obvious, they enable movement beyond the designated arteries of main roads and official infrastructure. Roads of the second and lower classes share such non-place features, but, unlike highways, they lack the institutional protections provided by public and private stakeholders. These protections materialise as indicators of care, such as a maintained road surface, orderly roadside vegetation, and restricted access. Thus, we argue that marginal roadside ruderal areas are hotspots for illegal rubbish dumping because they are non-places suffering from weak care. That implies the absence of institutional efforts by place owners, as well as a lack of individual care enacted by users. Individuals who dump their rubbish or litter may not care about such transitional, quickly passed-by places that have little meaning for their

relationships, history, or identity. A marginal ruderal zone is thus characterised by visible, prolonged neglect, as a consequence of weak care.

Material indicators of weak care in the city, such as ruderal vegetation and the accumulation of rubbish in the streets, were often framed as physical disorder that signals a lack of social control (Massa *et al.* 2025; Sampson and Raudenbush 1999; Müller 2015; Guyot *et al.* 2025). According to the broken windows theory (Wilson and Kelling 1982), a lack of social control in the neighbourhood becomes evident in physical and social disorder. Besides rubbish accumulation and ruderal plants, authors list graffiti, vandalism, and abandoned and damaged buildings or cars as physical disorder indicators. Meanwhile, gatherings of teenagers on street corners, public intoxication, fighting, sleeping on the sidewalks, prostitution, homeless people, and the concentration of panhandlers indicate social disorder (Wilson and Kelling 1982; Massa *et al.* 2025; Sampson and Raudenbush 1999). These *incivilities* (Sampson and Raudenbush 1999, 604; Guyot *et al.* 2025, 1; O'Brien *et al.* 2015, 133; Massa *et al.* 2025, 2894), understood as evidence of disorder, thus of a weak social control, lead to an accelerating spiral of further disorder and more severe crime incidents in the neighbourhood (Wilson and Kelling 1982; Massa *et al.* 2025).

Despite limited empirical support for the theory in the original publication (Wilson and Kelling 1982), and mixed results in numerous attempts to test it in the field (Müller 2015; Massa *et al.* 2025), the *broken windows* became a well-known and recurring concept in sociology and criminology (Sampson and Raudenbush 1999; Guyot *et al.* 2025). The phrase "rubbish attracts rubbish" was even used in journalistic coverage of our pilot project (Szybka 2023), which exemplifies how a common-sense version of broken windows theory is commonly reproduced through the idea that disorder reinforces disorder as a sign of a weak control. Nevertheless, we find the aforementioned focus on social control insufficient for interpreting marginal roadside ruderal areas as hotspots for illegal rubbish dumping.

Social control is understood as the capacity to realise the common goals of a social unit, and living in a safe environment is believed to be an example of a widespread, consensual goal (Sampson and Raudenbush 1999). However, the common function for a non-place is to facilitate flows and transit (Augé 1995). We argue that as long as second and lower-class road surfaces are acceptably maintained for quick passage, the roadsides may receive very little, if any, social control toward a common goal because the common goal of utility is realised through the ability to pass through the marginal spaces.

With that notion in mind, we shift our interpretation from social control to care. We argue that care for a place precedes social control under the place; control is a consequence of care. "We believe that the typification of "non-places" is related to the prior definition of a given space as heterogeneous, non-urban, uncontrollable, and taken over by ruderal vegetation or decay processes" (Brzeziński *et al.* 2025, 21). Originally, visible indicators of disorder were presented as proof that "no one cares" (Wilson and Kelling 1982, 3), meaning that community control over a place is poor; thus, the act of creating even more disorder, such as breaking more windows, costs the perpetrator nothing. Following this causality, illegal rubbish dumpsites themselves were described as an "open sign of no-man's land, where anything can be done without consequences" (Massa *et al.* 2025, 2912). Nevertheless, there is little agreement regarding empirical evidence for causal relations among disorder, social control, and crime (Lanfear *et al.* 2020). The proposed interpretive shift towards visible indicators of care is helpful for interpreting our empirical results, because reframing marginal ruderal areas as non-places of weak care allows us to point to utility, and not other meanings, as a common goal for such places. Thus, both formal and informal control over a place originates in defining a place as something to be cared for. With that interpretation, marginal ruderal areas are hotspots for illegal rubbish dumping because they receive weak care from the owners, users, and perpetrators.

Our shift towards care allows for a more explicit acknowledgement of various stakeholders in the arena (Strauss 1978), and of their conflicting interests. The logic of control presupposes a dual division between those who control and those who are controlled. According to the broken windows theory, if the control level is lowered, some of the controlled begin to misbehave and commit various forms of incivility (Wilson and Kelling 1982). Conversely, the logic of care presupposes the cooperation of stakeholders who may disagree, fight, and force conflicting agendas, interests, and goals,

while being collectively concerned with an issue, place, or other boundary object (Star and Griesemer 1989).

Moreover, the concepts of control and care are useful for discussing the affective dimension of illegal rubbish dumping. While many efforts have been made regarding the role of fear, especially by authors employing the broken windows theory (Lanfear *et al.* 2020; Massa *et al.* 2025), others have focused on shame as an affect related to disorder in the city (Baydar and Güngör 2021). Shame is defined as "caused by the feeling of being pinned down by another subject's gaze and [shame] involves the inadequacy of the self in acceding to an ideal" (641). According to this definition, perpetrators who dump their rubbish illegally could, or should, feel shame as they act wrongly. Indeed, making perpetrators subjects of a "pinning-down gaze" via photo traps, video surveillance, or lighting is considered an effective tool for preventing illegal dumping (Agency 1998). Being watched by an examining gaze has long been understood as a means of disciplining and punishing (Foucault 1979).

The impression of being under the gaze is also induced through posters placed on bin lorries and waste bins, which may elicit fear, shame, and a sense of being monitored among potential perpetrators of illegal dumping of rubbish, referred to in the UK as fly-tipping, as shown in Figure 9.

Remaining in plain sight and being visible while dumping waste discourages this activity. At the same time, concealing this behaviour indicates a high level of internalisation of the no-fly-tipping norm, as well as shame associated with rule-breaking behaviour. Additional reinforcement comes from the financial penalties (fines ranging from PLN 500 to PLN 5000[1]) and awareness of the legal consequences.

Concurring with the notion of the arena (Strauss 1978), the question of who defines the ideal that perpetrators and other stakeholders should accede to arises: specifically, *who*, *how*, and *for what purpose* determines who should be ashamed or what constitutes the common goals of a social unit. Critical scholars have pointed out that the source of shame for institutional owners is a lack of policies of care for the economically underprivileged segments of the city's population, rather than "a lack in a presumed order that serves the interests of the economically privileged" (Baydar and Güngör 2021, 647).

Fig. 9. Close-up of illegal dumping prevention poster in Bath, England (*photo by: Anna Kacperczyk 2023*)

Thus, we hypothesise that those who define common goals of a social unit, and who decide who should be ashamed, are primarily the privileged and powerful stakeholders rather than those whose concentration signifies a social disorder: homeless people, prostitutes, or teenagers. A detailed discussion of the aforementioned problem of definitional power is beyond the scope of this paper; therefore, we conclude this stage of the discussion by arguing that marginal ruderal areas are hotspots for illegal rubbish dumping because they are spaces of shamelessness, and this shamelessness pertains to all stakeholders who collectively fail to care for these spaces.

Simultaneously, our conceptualisations of "care" and "shame" are largely laden with the perspectives of privileged, powerful stakeholders who can impose their definitions. Even the useful lens of non-places (Augé 1995) as anonymous and predominantly utilitarian zones is inflected by the perspective of the privileged, for whom such utility was designed.

1. Polluting or littering in public is punished by a fine according to the Polish Code of Petty Offences, Art. 145. Dz.U.2022.0.2151

Layer IV: Forming a Place of Disorder

In the sociological approach proposed by Martina Löw, "space is viewed as a relational arrangement of living beings and social goods constituted by two processes: spacing and the operation of synthesis" (Löw 2016). Spacing is an active, dynamic process of constituting space by placing objects, people, social goods, and symbols, and associating them in specific ways. In this fundamental mechanism, relational space is created not by itself, but through active social actions and material placement. The material substrate and *building blocks* of this process could also be earth, rock, minerals, inanimate objects, and living beings (Löw 2016). The operation of synthesis is "required for the constitution of space, that is, goods and people are amalgamated to spaces by way of processes of perception, imagination, and memory" (Löw 2016).

Löw's proposal is a relational one: in contrast to absolutist or dualistic approaches, which assume that "both space and bodies exist, relativist traditions are of the view that space results from the structure of the relative positions of bodies" (Löw 2016). For us, it is important that the "constitution of space contributes to the systematic production of places" (Löw 2016). Therefore, the same physical place is something different for the different entities that enter it. For social scientists, an illegal dump is a space for research, something intriguing, cognitively appealing, and a complex and fascinating subject of study that scholars can explore and discuss from a scientific perspective. For someone who throws waste away, an illegal dump can be a place to leave their rubbish, a convenient spot to feel the relief of getting rid of the burden of unwanted items. For a resident walking their dog, who encounters an illegal dump, it is a space of disappointment. They expected a beautiful forest or a green area, but instead saw disorder and something that shouldn't be there: *things out of place* (Reno 2014). The presence of abandoned rubbish will be an element of the degraded space, a trace of waste that deprives the spot of its aesthetic value. For a homeless person, items left in urban green spaces (blankets, sleeping bags, cardboard boxes) are valuable survival tools, allowing them to create their own ad hoc arrangement of temporary living space. It is not "clutter," but rather a storage area for goods, although a resident of a nearby apartment building might see it differently.

Therefore, there is no such thing as objective space. We are dealing with a variety of spaces produced by different entities, not with a single, uniformly perceived space. We are constantly dealing with space that is seen, used, and produced by someone. And the same principle applies to places of disorder.

What is defined as disorder always refers to some definition or idea of order. In Polish law, spatial order is defined as "such a shaping of space that creates a harmonious whole and takes into account in orderly relationships all functional, socio-economic, environmental, cultural, compositional and aesthetic conditions and requirements". Such a broad definition may be helpful in the field of spatial planning and management, but it is poorly applicable to a resident's everyday life. Nevertheless, it is possible to indicate specific features that act as signals of spatial disorder: a lack of harmony between elements, structures, and infrastructures left to their own devices, landscape scattered with redundant objects, pyramidal waste tips, disused industrial constructions, collapsing buildings, ruins and rubble, broken equipment, objects that do not work or fulfil no aesthetic function, and dilapidated, broken things, characterised by various degrees of decay (DeSilvey 2020).

Layer V: Becoming a Subject of Action

Illegal dumping, as a specific type of event, is of interest to many social entities (Kacperczyk and Żulicki 2022). It is also the object of work (both mechanical and symbolic) by entities involved in the arena surrounding this problem. There are two contradictory forces at work in this phenomenon: the activities of entities that illegally dump waste in unauthorised locations, and those that remove it, organise activities for this purpose, or point out the need for such removal. It is difficult to estimate the size and relative proportions of these two mutually exclusive groups of people and activities. However, the persistence of the illegal dumping phenomenon indicates that these forces are balancing each other out. On the one hand, we have the perpetrators — people illegally disposing of waste — usually individuals, sometimes two or three people, and less often organised groups, such as demolition contractors and car tyre shops (Agency 1998). On the other hand, there are officials of local government, the city guard or police, municipal sanitation com-

pany employees, city activists, or simply residents participating in clean-up events. The first group operates more randomly and unpredictably, while the second, out of necessity, follows their traces — cleaning up what has been left in the field, with much less ability to predict where the work will take place next. The first group is poorly structured and not formal, making their activities more difficult to track. The second is deeply embedded in administrative and local government structures, which, in turn, can hinder the flexibility and effectiveness of their actions. Observers, often described as *moral entrepreneurs* (Howard 1963), also appear in the field of action, publicly demanding a ban on littering and siding with the cleaning forces against the litterers (Brzeziński *et al.* 2025).

On the social side, we have two types of activities that involve human interference in geophysical space: adding new, environmentally problematic material elements or removing them from a given area. Beyond this specific physical work, there is also a discursive one being done all the time in the broader arena of the dispute over illegal dumping – concerning how the problem should be addressed, which divisions of competence should be applied, and which policies should be implemented to mitigate it. Arena as *a field of action and interaction between a potentially infinite wide variety of collective entities* (Clarke 1991) is a "battlefield" between various entities that maintain their particular vision of action and a definition of the situation (Strauss 1978, 1982b, 1982a, 1993). The discourse revolves around numerous individual and collective actors (residents, city authorities), as well as institutional ones (services), and two critical non-human actors: rubbish and urban nature.

Remedial actions are always entangled with numerous administrative, legal, and organisational constraints and depend on the technical capabilities and financial resources of the entity taking action. We assume that fly-tippers are also subject to similar restrictions and operate within their own technical and economic capabilities and according to their own patterns of rationality. From our point of view, the most intriguing elements are the reasons for abandoning waste in a given location, which remain the most unpredictable factors of the phenomenon under study and, at the same time, trigger and determine the entire dysfunctional cycle of illegal waste deposition.

Conclusions

We examine the phenomenon of illegal dumping from two perspectives: geographical and sociological. The latter attempts to describe the human contribution to its creation and maintenance, situating it within a specific geographical space where it materialises as abandoned waste and assumes a tangible, physical, and sensory character. Waste has a material nature, and this materiality becomes problematic because the deposited matter is subject to biochemical changes under atmospheric conditions and interacts unpredictably with the environment. Thus, illegal dumps are not merely an aesthetic issue (Kacperczyk 2021).

We investigate these events and places meticulously using VGI data, UAV flights, OSM, and observations of illegal dump locations, their appearance, and arrangement relative to other objects, to identify spatial patterns that particularly predispose them to littering. Our analyses show that it is mainly a space of ruderal vegetation, perceived as feral or uncivilised, which people associate with a no-man's-land, neglected and left to itself, where it is easy and safe to deposit unwanted material: waste, excrement, and urine.

The modelling results, in the form of a vulnerability map, show how much of the urban landscape is susceptible to perpetrators' decisions. The spatial relationship between unauthorised dumps and ruderal spaces reveals much about the structure of cities and the status of wild green spaces there (Lorimer 2015). Left untouched, where spontaneous natural vegetation is allowed to flourish (at least temporarily), ruderal spaces constitute extremely valuable parts of cities. They serve as a *connective tissue* that mediates between areas that remain entirely under human control. They also provide a basis for creating corridors and pockets of wildlife within cities. Creating and maintaining such spaces is often achieved not through additional actions or financial expenditures, but precisely through the abandonment of any investment, the cessation of human activity in a given area, and, by doing so, the elimination of anthropopressure. Leaving them untouched by human intervention and returning these places to natural habitats strengthens cities' resilience in the face of biodiversity loss and climate change.

Future Work

The geography of nature conservation is moving toward integrating and nurturing urban islands of wilderness. The future lies in treating them as fully protected areas, since wildlife is recognised as residing at the very heart of urbanity. This new perception of the city as inevitably permeated by the wild and the uncontrolled, connecting relationally and networked with that which lies beyond the city's topography, reflects the new language of ecology and nature conservation, which speaks of "green infrastructure, ecological corridors, or ecological networks" that "enable 'connectivity', 'permeability', and 'fluidity' at the landscape scale" (Lorimer 2015).

The problem is that these very areas – which introduce elements of chaos and wilderness into the city, which can be sanctuaries for birds, insects, and small wildlife (Baydar and Güngör 2021) – are ruthlessly exploited by humans as rubbish dumps. Furthermore, any intervention to "save" these places involves transforming, reshaping, and commodifying them, thereby stripping them of their most valuable qualities: their chaotic, untamed, feral features.

Therefore, we pose the following questions for future investigation: what does it mean for a city to have ruderal spaces? And how should they be treated? Do we want to control them (sell them, develop them with infrastructure) or leave them alone to remain wild and fulfill their natural functions within the city? Are we capable of creating or maintaining these wilderness areas in our cities? Or do we strive to eliminate, control, trim, or neglect them, abandoning ruderal areas to the mercy of fly-tippers?

Conflict of Interest

The authors reported no potential conflicts of interest.

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Data availability

Illegal dumping location data are available on Epicollect5.

Use of AI disclosure

During the preparation of this work, the authors used Anthropic Claude Opus-4.5 and Grammarly to improve the readability and language of the manuscript. After using these tools, the authors carefully reviewed and edited the content as needed and take full responsibility for the final version of the article.

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Author contributions

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Kamil Brzeziński: Writing – original draft
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