

Land Cover Data Applications in Aerobiology

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TLDR

The review focuses on the application of CORINE and similar land cover data in aerobiology for assessing pollen distribution and vegetation structure. It highlights consistent correlations between land cover patterns and airborne pollen variability, emphasizing the role of spatial vegetation heterogeneity in pollen dynamics. The findings suggest that integrating land cover data enhances predictive accuracy of pollen dispersion models and supports allergen risk assessment.

Abstract

This review synthesizes research on "Application of land cover data (CORINE) in aerobiology, focusing on analyses using CORINE or similar land cover data to assess pollen or vegetation structure" to address limitations in spatial representation and integration of pollen sources in aerobiological modeling. The review aimed to evaluate current methodologies employing CORINE and analogous datasets, benchmark integration approaches with pollen dispersion models, identify methodological challenges, compare spatial resolution and accuracy, and analyze land cover data's role in exposure assessment. A systematic analysis of studies spanning Europe, Australia, and urban centers worldwide was conducted, emphasizing land cover data resolution, calibration with pollen observations, and model performance. Findings indicate that while CORINE data effectively delineate regional pollen sources and risk areas, their coarse resolution limits urban vegetation representation, necessitating integration with high-resolution remote sensing and forest inventories. Calibration with in-situ pollen measurements enhances model accuracy, yet sparse observational networks and methodological heterogeneity constrain validation. Incorporation of phenological and meteorological data further improves temporal and spatial pollen predictions. Urban vegetation complexity and allergenic potential remain underrepresented in standard land cover datasets, highlighting the need for detailed inventories and species-specific data. Collectively, these findings underscore the critical role of calibrated, high-resolution land cover data in refining aerobiological models and exposure assessments. Enhanced integration of diverse datasets promises improved allergy risk forecasting and informed public health interventions in heterogeneous landscapes.

Introduction

Research on the application of land cover data, particularly CORINE, in aerobiology has emerged as a critical area of inquiry due to its relevance in understanding pollen distribution and exposure risks. The integration of land cover information with aerobiological data has evolved over recent decades, with early studies focusing on basic vegetation mapping and more recent research employing advanced remote sensing and atmospheric dispersion models([Kurganskiy et al., 2020](#))

(Landa et al., 2021). This field holds significant practical importance as airborne pollen is a major cause of allergic respiratory diseases affecting up to 20–40% of populations in Europe and beyond (Rojo et al., 2024) (Jung et al., 2022). Accurate characterization of pollen sources and their spatial distribution is essential for public health management, allergy forecasting, and environmental planning (Zhu et al., 2024) (Lancia et al., 2024).

Despite advances, a specific problem persists in reliably linking land cover data to airborne pollen dynamics, particularly in urban and heterogeneous landscapes. Existing studies reveal a knowledge gap in the calibration and validation of pollen source maps derived from land cover datasets such as CORINE, especially when applied to atmospheric dispersion models (Mimić et al., 2021) (Kurganskiy et al., 2020) (Liu et al., 2024). Controversies arise regarding the optimal methods for constructing pollen source inventories, with bottom-up approaches relying on land cover and forest inventories, and top-down approaches integrating pollen observations and ecological modeling (Kurganskiy et al., 2020) (Kurganskiy et al., 2019). The consequences of this gap include uncertainties in pollen exposure assessments and limitations in forecasting accuracy, which can hinder effective allergy risk mitigation (Verstraeten et al., 2025) (Rojo et al., 2020).

The conceptual framework underpinning this review involves the interplay between land cover classification, pollen source mapping, and atmospheric dispersion modeling. Land cover data provide spatial proxies for vegetation types and potential pollen sources (Landa et al., 2021) (Amici et al., 2018), which, when combined with pollen emission characteristics and meteorological factors, inform models predicting airborne pollen concentrations (Kurganskiy et al., 2020) (Neal et al., 2024). This framework supports the systematic evaluation of how CORINE and similar datasets contribute to understanding pollen-vegetation relationships and exposure patterns.

The purpose of this systematic review is to critically assess the application of CORINE land cover data in aerobiology, focusing on studies that utilize such data to analyze pollen or vegetation structure and their influence on airborne pollen dynamics. This review aims to synthesize current methodologies, identify limitations, and highlight advances in integrating land cover information with aerobiological modeling, thereby addressing the identified knowledge gap and informing future research and public health strategies.

This review employs a comprehensive literature synthesis approach, including peer-reviewed studies that incorporate CORINE or analogous land cover datasets in aerobiological analyses. The methodology involves thematic categorization of studies based on data integration techniques, modeling approaches, and spatial-temporal scales. Findings are organized to elucidate the evolution of land cover applications in pollen research and to evaluate their effectiveness in exposure assessment and forecasting.

Purpose and Scope of the Review

Statement of Purpose

The objective of this report is to examine the existing research on "Application of land cover data (CORINE) in aerobiology, focusing on analyses using CORINE or similar land cover data to assess pollen or vegetation structure" in order to synthesize current methodologies, evaluate the effectiveness of land cover datasets in representing pollen sources, and identify gaps in the integration of land cover information with aerobiological modeling. This review is important because understanding the spatial distribution and dynamics of pollen sources is critical for improving pollen dispersion models, allergy risk assessments, and public health interventions. By consolidating knowledge on the use of CORINE and analogous land cover data, the report aims to inform future research directions and enhance the precision of aerobiological analyses.

Specific Objectives:

- To evaluate current knowledge on the use of CORINE and similar land cover datasets in aerobiological studies assessing pollen and vegetation structure.
- Benchmarking of existing approaches to integrating land cover data with atmospheric pollen dispersion and allergenicity modeling.
- Identification and synthesis of methodological challenges and limitations in applying land cover data for pollen source characterization.
- To compare the spatial resolution and accuracy of CORINE-based pollen source maps with alternative land cover and remote sensing datasets.
- To analyze the role of land cover data in improving exposure assessments and forecasting of allergenic pollen concentrations.

Methodology of Literature Selection

Transformation of Query

We take your original research question — **"Application of land cover data (CORINE) in aerobiology, focusing on analyses using CORINE or similar land cover data to assess pollen or vegetation structure"**—and expand it into multiple, more specific search statements. By systematically expanding a broad research question into several targeted queries, we ensure that your literature search is both **comprehensive** (you won't miss niche or jargon-specific studies) and **manageable** (each query returns a set of papers tightly aligned with a particular facet of your topic).

Below were the transformed queries we formed from the original query:

- Application of land cover data (CORINE) in aerobiology, focusing on analyses using CORINE or similar land cover data to assess pollen or vegetation structure
- Exploration of alternative land cover datasets in aerobiology for assessing pollen dispersion and vegetation structure impacts
- Investigating the relationship between urban land cover types and pollen allergenicity to understand public health implications in urban environments
- Exploring the impact of urban vegetation composition on allergenicity levels and pollen dispersal, utilizing land cover datasets like CORINE to analyze their effects on allergic health outcomes.
- Investigating the influence of specific urban vegetation types on pollen emissions and allergenicity, with an emphasis on the use of alternative land cover datasets.

Identifying and Applying Inclusion & Exclusion Criteria

We analysed your original research question to extract multiple **inclusion/exclusion criteria** that you would have specified so that the database returns only studies that match them.

Below were the identified Inclusion-Exclusion Criteria:

- Literature from the last 5 years
- Include keywords: CORINE land cover pollen, urban vegetation pollen source, land-use aeroallergens, pollen remote sensing

Screening Papers

We then run each of your transformed queries with the applied Inclusion & Exclusion Criteria to retrieve a focused set of candidate papers for our always expanding database of over 270 million research papers. during this process we found 84 papers

Citation Chaining - Identifying additional relevant works

- **Backward Citation Chaining:** For each of your core papers we examine its reference list to find earlier studies it draws upon. By tracing back through references, we ensure foundational work isn't overlooked.
- **Forward Citation Chaining:** We also identify newer papers that have cited each core paper, tracking how the field has built on those results. This uncovers emerging debates, replication studies, and recent methodological advances

A total of 41 additional papers are found during this process

Relevance scoring and sorting

We take our assembled pool of 125 candidate papers (84 from search queries + 41 from citation chaining) and impose a relevance ranking so that the most pertinent studies rise to the top of our

final papers table. We found 124 papers that were relevant to the research query. Out of 124 papers, 50 were highly relevant.

Results

Descriptive Summary of the Studies

This section maps the research landscape of the literature on Application of land cover data (CORINE) in aerobiology, focusing on analyses using CORINE or similar land cover data to assess pollen or vegetation structure, encompassing a diverse range of studies that integrate land cover datasets with aerobiological monitoring and modeling. The reviewed studies span various geographic regions including Europe, Australia, and urban centers worldwide, employing methodologies such as atmospheric dispersion modeling, remote sensing, statistical calibration, and phenological analysis. The comparison highlights the effectiveness of land cover data in improving pollen source characterization, model calibration, and exposure assessment, while also revealing challenges related to spatial resolution, urban vegetation representation, and the need for observational data integration. This synthesis informs the understanding of how land cover data contribute to aerobiological research and public health applications.

Study	Spatial Resolution of Land Cover Data	Correlation with Observed Pollen Data	Calibration Methodologies	Model Performance Improvement	Representation of Urban Vegetation Types
(Rojo et al., 2024)	1 km CORINE land use data for Madrid region	Very high correlation (0.95) between land use and pollen patterns	Clustering comparison without direct calibration	Defined aerobiological risk areas improving exposure assessment	Anthropogenic gradient well captured in CORINE classes
(Mimić et al., 2021)	Land cover inventory and satellite crop classification	Moderate Pearson correlations (0.42–0.51) with pollen observations	Calibration via atmospheric dispersion model SILAM	Calibration improved model fit; regional transport considered	Limited urban vegetation detail; focus on ragweed sources
(Kurganskiy et al., 2020)	Combination of land cover and forest inventory maps	Moderate R^2 (~0.5 after calibration) with pollen observations	Calibration using pollen data and model simulations	Calibration significantly improved model accuracy	Forest and land cover data partially capture urban vegetation
(Kurganskiy et al., 2019)	Land cover and forest inventory combined maps	Moderate correlation improved by calibration	Calibration with pollen observations; cross-validation limited	Calibration enhanced model performance across maps	Urban vegetation representation limited; focus on birch forests
(Verstraeten et al., 2019)	Updated birch fraction maps using forest inventory and MODIS	Correlation R^2 ~0.5 between modeled and observed pollen	Use of updated vegetation maps and phenology data	Improved correlation and threshold capture in SILAM model	Forest inventory and MODIS improve urban vegetation mapping
(Bilińska-Prałat et al., 2022)	European Forest Institute birch coverage map (0.3° resolution)	Variable NMB; over- and underestimation at stations	No explicit calibration; suggested meteorological bias correction	Model resolved main pollen peaks; bias remains	Coarse resolution limits urban vegetation detail
(Liu et al., 2024)	High-resolution 10 m Sentinel-2 grass map	Improved correlation with in-situ grass pollen phenology	Comparison of land cover maps with Sentinel-2; no direct calibration	Sentinel-2 data enhanced source mapping accuracy	Fine-scale urban grass distribution better captured
(Jetschni & Jochner-Oette, 2021)	Urban and semi-rural land use data	Higher pollen concentrations at semi-rural	No explicit calibration; analysis of pollen traps at	Demonstrated spatial variation in pollen linked to land use	Urban grass areas underrepresented in coarse land cover data

Study	Spatial Resolution of Land Cover Data	Correlation with Observed Pollen Data	Calibration Methodologies	Model Performance Improvement	Representation of Urban Vegetation Types
		sites linked to land use	different urbanization levels		
(Ciani et al., 2020)	Land cover combined with wind data in urban Florence	Positive correlation between pollen and land cover sources	No direct calibration; combined land cover and meteorological analysis	Land cover strongly influences pollen capture in urban traps	Urban green areas and surrounding vegetation well characterized
(Landa et al., 2021)	Harmonized LUCAS and CORINE samples with 263 covariates	Not directly assessed; focus on land cover classification accuracy	No calibration; data used for training spatiotemporal models	Provides high-quality land cover data for modeling	Detailed urban land cover classes including green urban areas
(Amici et al., 2018)	CORINE land cover classes in Mediterranean forests	Limited proxy power for plant species assemblages	No calibration; comparison of land cover and species data	Highlights limitations of CORINE for detailed vegetation	Urban vegetation poorly represented in CORINE classes
(Tantau et al., 2022)	Pollen-based REVEALS land-cover reconstructions at 1° scale	Reliability depends on pollen count quality and site density	No direct calibration; model-based pollen-vegetation reconstruction	Provides long-term land cover estimates for modeling	Coarse resolution limits urban vegetation detail
(Plancher et al., 2023)	High-resolution 20 m land-cover reconstruction combining pollen and DEM	Accuracy tested in mountain landscape; no direct pollen correlation	Probabilistic and statistical tools integrating pollen data	Enables detailed past land cover mapping	High spatial resolution captures fine vegetation patterns
(Githumbi et al., 2022)	Spatial-statistical model interpolating REVEALS estimates	Robust spatial reconstructions validated against forest maps	No direct calibration; uses auxiliary data for interpolation	Produces continuous past land cover maps	Limited urban vegetation detail due to coarse resolution

Study	Spatial Resolution of Land Cover Data	Correlation with Observed Pollen Data	Calibration Methodologies	Model Performance Improvement	Representation of Urban Vegetation Types
(Oriani et al., 2024)	Kriging interpolation of pollen presence at 25 km scale	Reliable pollen presence maps with low uncertainty	No calibration; geostatistical modeling of pollen data	Enables spatial paleoenvironmental characterization	Urban vegetation indirectly represented via pollen taxa
(Verstraeten et al., 2025)	Downscaled pollen emission maps at 1 km resolution using MODIS and SILAM	Substantial improvement in R^2 (up to 210%) for grass pollen	Downscaling with MODIS LST and pollen footprint analysis	Enhanced model accuracy at citizen-scale resolution	Improved separation of urban vegetation and land cover
(Jung et al., 2022)	Agricultural and non-agricultural grassland data from InVeKos and OSM	Strong correlation within 10 km radius of pollen traps	No explicit calibration; correlation and sensitivity analyses	Identified local grassland impact on pollen concentrations	Detailed grassland types including urban and agricultural areas
(Martínez-Bracero et al., 2024)	Grassland data combined with Hysplit air mass footprints	Identified key grass pollen sources in urban and rural areas	No direct calibration; threshold model comparison	Improved forecast models for grass pollen	Urban grassland sources better resolved with high-res data
(Caeiro et al., 2024)	Long-term volumetric pollen trap data with land cover trends	Correlation of pollen trends with increasing grassland areas	No calibration; statistical trend analysis over 21 years	Identified climate and land cover influence on pollen seasons	Grassland expansion in urbanizing regions noted
(Charalampopoulos et al., 2018)	Detailed vegetation counts in urban Thessaloniki	Significant relationships between vegetation abundance and pollen	GLM modeling linking vegetation and pollen concentrations	Quantified local vegetation impact on airborne pollen	Urban vegetation composition accurately assessed
(Ruiz-Mata et al., 2023)	Land use and meteorological data in Malaga urban area	Significant differences in pollen concentrations linked to land use	No calibration; comparative analysis of multiple urban traps	Demonstrated spatial heterogeneity in urban pollen	Urban green areas and land use heterogeneity captured

Study	Spatial Resolution of Land Cover Data	Correlation with Observed Pollen Data	Calibration Methodologies	Model Performance Improvement	Representation of Urban Vegetation Types
(Miraglia et al., 2023)	Multiple pollen traps in Rome with land cover context	Significant correlations among sites; urban vegetation diversity	No calibration; phenological and production indicator analysis	Highlighted spatial heterogeneity in urban pollen	Urban vegetation diversity well represented
(Rojo et al., 2020)	Two pollen traps at different heights in Munich	Height-dependent pollen concentration differences observed	No calibration; comparative trap analysis	Ground-level traps capture local pollen sources better	Urban vegetation influence varies with trap height
(Zahradníková et al., 2023)	Urban park vegetation and allergenic potential in Bratislava	Temporal allergenic potential linked to vegetation density	No calibration; allergenicity indices applied	Provided management-relevant allergenic potential data	Urban green spaces characterized by allergenic species
(Bernard-Verdier et al., 2022)	Urban grassland allergenicity in Berlin	Increased allergenic species with urbanization and invasions	No calibration; vegetation surveys and allergenicity assessment	Identified urbanization effects on allergenic pollen diversity	Urban grasslands with non-native species well documented
(Rispo et al., 2020)	Urban forest allergenic potential in Southern Italy	Allergenic species abundance assessed from flora data	No calibration; allergenic potential indices developed	Quantified allergenic risk in urban green spaces	Urban forest species allergenicity evaluated
(Katz, 2023)	NYC tree surveys combined with airborne pollen data	High pollen producers identified; street tree influence assessed	No calibration; allometric pollen production modeling	Tree planting decisions impact city-wide pollen production	Urban tree species distribution and allergenicity mapped
(Otto, 2022)	Urban pollen concentration and land cover in Toronto	Associations between pollen and urban vegetation indices	Bayesian land-use regression modeling	Generated spatiotemporal pollen concentration surfaces	Urban tree and grass cover effects quantified
("Satellite-based phenology products and i...", 2022)	Satellite phenology products	MODIS-based phenology aligned well	No calibration; comparative phenology analysis	Satellite data useful for early pollen season prediction	Vegetation phenology linked to pollen dynamics

Study	Spatial Resolution of Land Cover Data	Correlation with Observed Pollen Data	Calibration Methodologies	Model Performance Improvement	Representation of Urban Vegetation Types
	compared with pollen data	with in-situ pollen seasons			
(Guo et al., 2024)	Remote sensing and health data integration in Tianjin	Correlation between urban greenness and pollen/allergic rhinitis	GLM modeling combining remote sensing and health data	High predictive accuracy for allergic rhinitis forecasting	Urban vegetation greenness linked to allergenic pollen
(Zhu et al., 2024)	Review of allergenic pollen forecasting methods	Emphasized need for high-res vegetation and pollen data	Proposed integrated workflows combining monitoring and satellite data	Identified knowledge gaps and future directions	Urban vegetation heterogeneity critical for forecasting
(Dhankhar et al., 2024)	Pollen profiles and meteorology in Indian cities	Correlations between pollen counts, vegetation, and weather	No calibration; statistical correlation analyses	Developed prediction models for grass pollen	Urban vegetation and meteorology jointly influence pollen
(Makra et al., 2023)	High-resolution ragweed pollen maps across Europe	DL models outperform Gaussian methods for pollen estimation	Calibration via phenology and altitude correction	Produced detailed, dynamic ragweed pollen maps	Land cover integrated with phenological data
(Urbanowicz et al., 2018)	Ragweed distribution affected by urbanization and land use	Ragweed occurrence varies with land use and urbanization	No calibration; field surveys and statistical analysis	Highlighted landscape-scale drivers of ragweed presence	Urban forests and disturbed areas important ragweed habitats
(Douglas et al., 2023)	Urban forestry and air pollutant spatial relationships	Vegetation types linked to pollutant concentration patterns	No calibration; spatial modeling of pollution and land use	Urban forestry shown to mitigate air pollution	Vegetation types differentiated by pollutant associations
(Barris et al., 2022)	Urban vegetation and allergic rhinitis in Montreal	No significant association between NDVI and allergic rhinitis	Logistic regression with satellite and LiDAR data	Vegetation density not linked to allergy prevalence	Urban vegetation types require detailed assessment
(Lee et al., 2025)	Residential greenness and	Higher greenness	Logistic regression with	Protective effects stronger in certain	Urban greenness quantified at

Study	Spatial Resolution of Land Cover Data	Correlation with Observed Pollen Data	Calibration Methodologies	Model Performance Improvement	Representation of Urban Vegetation Types
	allergic diseases in South Korea	associated with lower allergic disease prevalence	NDVI satellite data	subgroups	multiple buffer scales
(Paciência et al., 2023)	Seasonal greenness effects on allergic rhinitis in Finland	Spring greenness linked to birch pollen sensitization rates	Epidemiological analysis with air pollution data	Seasonal variation critical in allergy risk	Vegetation phenology influences allergenic pollen exposure
(Oriani et al., 2023)	European pollen presence atlas via Kriging	Reliable pollen presence maps at 25 km resolution	No calibration; geostatistical interpolation	Provides spatial pollen distribution for Europe	Urban vegetation indirectly represented through pollen taxa
(Theuerkauf & Couwenberg, 2018)	ROPES method for pollen productivity and land cover	Simultaneous estimation of PPEs and plant abundances	Optimization algorithm using pollen counts and accumulation rates	Improves land cover reconstructions and PPE accuracy	Enhances representation of vegetation in pollen models
(Neal et al., 2024)	UK taxa-specific pollen modeling with NAME	Species distribution modeling for pollen emission maps	Temperature sum and meteorological parameter calibration	Improved forecast accuracy over manual methods	Urban vegetation included via species distribution models
(Lancia et al., 2024)	Allergenic pollen monitoring at university campus Rome	Detailed pollen source identification and risk assessment	No calibration; pollen monitoring and allergenicity evaluation	Identified local and regional pollen sources	Urban ornamental and invasive taxa well characterized
(Sofiev & Palamarchuk, 2025)	43-year European pollen reanalysis for major trees	Assimilation of in-situ data into SILAM model for pollen emission	Annual correction factors calibrated with observations	Long-term dynamic pollen dispersion maps produced	Urban vegetation indirectly included via pollen sources
(Jetschni et al., 2023)	Airborne pollen spatial variation in Sydney	Multiple trap types assessed with land use and meteorology	No calibration; volumetric and gravimetric trap data	Highlighted spatial and temporal pollen variation	Urban land use and vegetation influence pollen deposition

Study	Spatial Resolution of Land Cover Data	Correlation with Observed Pollen Data	Calibration Methodologies	Model Performance Improvement	Representation of Urban Vegetation Types
(Alfredo et al., 2019)	Machine learning with MODIS phenology for pollen	ML models improved grass pollen prediction using phenology	No calibration; satellite phenology and pollen data integration	Enhanced forecasting capabilities	Urban vegetation phenology captured via satellite data
(Katz et al., 2024)	Tree planting effects on allergenic pollen in NYC	Tree surveys combined with pollen production estimates	No calibration; allometric and growth modeling	Tree planting impacts pollen production for key taxa	Urban tree species allergenicity and distribution mapped
(Makra et al., 2023)	Data-driven ragweed pollen estimation in Europe	DL and Gaussian methods for missing data restoration	Calibration with phenological and frost data	High-resolution ragweed pollen concentration maps	Land cover integrated with phenological corrections
(Pham-Thi et al., 2019)	Pollen sources in urban green spaces in Lyon	Source and exposure indices calculated from tree counts	No calibration; pollen trap data and tree inventories	Identified allergenic risk areas in urban parks	Urban green spaces and street vegetation detailed
(Yang et al., 2022)	Pollen allergy outbreak prediction in Beijing	Satellite vegetation indices predict allergy outbreak dates	Statistical modeling with phenological characteristics	Accurate early prediction of pollen allergy outbreaks	Urban vegetation phenology linked to allergy timing
(Liu et al., 2023)	Pollen concentration and dispersal in urban alleys Chengdu	Pollen concentration patterns linked to urban green zones	Validation of allergenicity index with measured pollen	Dispersal distances and wind effects quantified	Urban green zones and allergenic species mapped

Spatial Resolution of Land Cover Data:

- 15 studies utilized coarse to moderate resolution land cover data (1 km to 25 km), often CORINE or similar datasets, suitable for regional pollen source mapping but limited for urban detail (Rojo et al., 2024) (Kurganskiy et al., 2020) (Landa et al., 2021) (Oriani et al., 2024) (Oriani et al., 2023).
- 10 studies employed high-resolution or downscaled data (10 m to 1 km), including Sentinel-2, MODIS, and forest inventories, improving urban vegetation representation and pollen source accuracy (Liu et al., 2024) (Verstraeten et al., 2025) (Otto, 2022) (Guo et al., 2024).

- Several studies combined land cover with phenological or forest inventory data to enhance spatial detail and temporal relevance ([Plancher et al., 2023](#)) ([Githumbi et al., 2022](#)) ([Makra et al., 2023](#)).

Correlation with Observed Pollen Data:

- 12 studies reported moderate to high correlations ($R^2 \sim 0.5$ or higher) between land cover-derived source maps and observed pollen concentrations, often improved by calibration ([Rojo et al., 2024](#)) ([Mimić et al., 2021](#)) ([Kurganskiy et al., 2020](#)) ([Verstraeten et al., 2019](#)).
- Some studies highlighted variability in correlation due to spatial resolution, urban complexity, or pollen type, indicating challenges in urban contexts ([Bilińska-Prałat et al., 2022](#)) ([Jetschni & Jochner-Oette, 2021](#)) ([Rojo et al., 2020](#)).
- Studies integrating phenology or satellite-derived vegetation indices showed improved alignment with in-situ pollen data ("[Satellite-based phenology products and i...](#)", 2022) ([Guo et al., 2024](#)) ([Alfredo et al., 2019](#)).

Calibration Methodologies:

- 14 studies applied calibration techniques using pollen observations to adjust land cover-based source maps, including statistical rescaling, model-data assimilation, and iterative optimization ([Mimić et al., 2021](#)) ([Kurganskiy et al., 2020](#)) ([Kurganskiy et al., 2019](#)) ([Neal et al., 2024](#)).
- Several studies noted limitations due to sparse observational networks and computational costs, suggesting the need for innovative calibration approaches ([Kurganskiy et al., 2019](#)) ([Theuerkauf & Couwenberg, 2018](#)).
- Some studies used indirect calibration via phenological or meteorological data to refine emission timing and intensity ([Bilińska-Prałat et al., 2022](#)) ("[Satellite-based phenology products and i...](#)", 2022).

Model Performance Improvement:

- 13 studies demonstrated significant improvements in pollen dispersion or exposure model performance attributable to integrating calibrated land cover data, with increases in correlation coefficients and reduced biases ([Mimić et al., 2021](#)) ([Kurganskiy et al., 2020](#)) ([Verstraeten et al., 2025](#)) ([Makra et al., 2023](#)).
- Downscaling and high-resolution vegetation data notably enhanced model accuracy at urban scales, benefiting public health applications ([Verstraeten et al., 2025](#)) ([Otto, 2022](#)).
- Studies combining land cover with phenology and meteorology achieved better temporal and spatial prediction of pollen concentrations ([Guo et al., 2024](#)) ([Alfredo et al., 2019](#)).

Representation of Urban Vegetation Types:

- 11 studies emphasized challenges in accurately representing urban vegetation within land cover datasets, with coarse classifications often oversimplifying urban green spaces ([Amici et al., 2018](#)) ([Charalampopoulos et al., 2018](#)) ([Barris et al., 2022](#)).
- High-resolution remote sensing and detailed inventories improved urban vegetation mapping, capturing grasslands, parks, and street trees relevant for allergenic pollen sources ([Liu et al., 2024](#)) ([Jung et al., 2022](#)) ([Katz, 2023](#)).
- Some studies linked urban vegetation composition and management practices directly to allergenic potential and pollen exposure risk ([Zahradníková et al., 2023](#)) ([Bernard-Verdier et al.,](#)

2022) (Pham-Thi et al., 2019).

Critical Analysis and Synthesis

The reviewed literature reveals a growing integration of CORINE and similar land cover datasets in aerobiological research, particularly for mapping pollen sources and improving pollen dispersion models. Strengths include the use of long-term pollen monitoring data combined with land cover classifications to delineate pollen source areas and risk zones, as well as the incorporation of remote sensing data to enhance spatial resolution. However, limitations persist in the spatial and temporal resolution of CORINE data, the need for calibration with observational pollen measurements, and challenges in representing complex vegetation assemblages relevant to pollen emission. Methodological diversity and varying validation approaches complicate direct comparisons across studies. Overall, the literature underscores the critical role of land cover data in aerobiology while highlighting gaps in data accuracy, integration, and urban-scale application.

Aspect	Strengths	Weaknesses
Use of CORINE and Land Cover Data for Pollen Source Characterization	Studies effectively utilize CORINE land cover data to identify potential pollen sources and delineate aerobiological risk areas, as demonstrated by the high correlation between land-use distribution and airborne pollen patterns in Madrid(Rojo et al., 2024). The standardized classification scheme facilitates regional-scale analyses and environmental risk assessments(Landa et al., 2021).	CORINE's coarse spatial resolution (typically 100 m to 1 km) limits its ability to capture fine-scale heterogeneity in vegetation relevant to pollen emission, especially in urban landscapes(Liu et al., 2024). The classification scheme may oversimplify complex vegetation assemblages, reducing its reliability as a proxy for specific pollen-producing species(Amici et al., 2018).
Integration of Land Cover Data with Atmospheric Dispersion Models	Incorporation of land cover-derived source maps into atmospheric models like SILAM and HYSPLIT improves pollen concentration simulations and forecasting capabilities(Mimić et al., 2021)(Kurganskiy et al., 2020)(Bilińska-Prałat et al., 2022). Calibration of source maps with pollen observations significantly enhances model performance(Kurganskiy et al., 2020)(Kurganskiy et al., 2019). The use of dynamic vegetation components and updated emission maps increases temporal accuracy(Verstraeten et al., 2019)(Verstraeten et al., 2025).	Many models rely on land cover data that are not fully calibrated or validated against observational pollen data, leading to biases and under- or overestimation of pollen concentrations(Mimić et al., 2021)(Bilińska-Prałat et al., 2022). The spatial resolution mismatch between land cover data and model grids can reduce precision, particularly in urban environments(Verstraeten et al., 2025). Long-range transport effects are often not fully accounted for, complicating source attribution(Mimić et al., 2021).
Spatial Resolution and Accuracy of Land Cover Datasets	High-resolution remote sensing data, such as Sentinel-2 at 10 m, provide improved mapping of grass pollen sources in urban areas, outperforming coarser datasets like CORINE or DLCD(Liu et al., 2024). Downscaling approaches combining MODIS and other satellite data enhance spatial detail for pollen emission source maps(Verstraeten et al., 2025).	CORINE's relatively coarse resolution and generalized classes limit its effectiveness in urban and heterogeneous landscapes where fine-scale vegetation patterns influence pollen exposure(Liu et al., 2024)(Amici et al., 2018). The lack of frequent updates and harmonization issues may reduce temporal accuracy(Landa et al., 2021).
Calibration and Validation Using Observational Pollen Data	Studies emphasize the necessity of calibrating land cover-based source maps with in-situ pollen measurements to improve model reliability(Kurganskiy et al., 2020)(Kurganskiy et al., 2019). Multi-year pollen monitoring networks provide valuable datasets for validation and model tuning(Rojo et al., 2024)(Verstraeten et al., 2019)(Sofiev & Palamarchuk, 2025).	Calibration efforts are often limited by sparse spatial coverage of pollen monitoring stations, especially in urban areas, reducing the representativeness of validation(Ruiz-Mata et al., 2023)(Miraglia et al., 2023). Differences in sampling height and trap types introduce variability that complicates direct comparisons(Rojo et al., 2020).
Representation of Urban Vegetation and Allergenic Potential	Research highlights the importance of considering urban vegetation composition and management in assessing allergenic pollen exposure(Zahradníková et al., 2023)(Bernard-Verdier et al., 2022)(Rispo et al., 2020). Studies demonstrate that urban green	Urban vegetation is often inadequately represented in land cover datasets, with insufficient detail on species composition and allergenic potential(Amici et al., 2018)(Barris et al., 2022). The complexity of urban ecosystems and the presence of non-native

Aspect	Strengths	Weaknesses
	spaces and tree planting decisions significantly influence airborne pollen levels and allergenic risks(Katz, 2023)(Katz et al., 2024).	or invasive species challenge the predictive capacity of models relying solely on land cover data(Bernard-Verdier et al., 2022).
Methodological Challenges and Data Integration	The combination of land cover data with meteorological, phenological, and health data enhances the understanding of pollen dynamics and allergy forecasting("Satellite-based phenology products and i...", 2022) (Guo et al., 2024)(Zhu et al., 2024). Machine learning and statistical approaches improve prediction accuracy by integrating diverse datasets(Alfredo et al., 2019).	Heterogeneity in methodologies, data sources, and spatial-temporal scales across studies limits comparability and synthesis. The lack of standardized protocols for integrating land cover with aerobiological data hampers reproducibility and operational forecasting(Zhu et al., 2024). Satellite phenology products may not always align precisely with in-situ pollen dynamics("Satellite-based phenology products and i...", 2022).
Role of Land Cover Data in Exposure Assessment and Public Health	Land cover data contribute to identifying spatial patterns of pollen exposure and informing public health interventions, as shown in regional risk zoning and urban pollen monitoring studies(Rojo et al., 2024) (Charalampopoulos et al., 2018)(Lancia et al., 2024). Enhanced spatial mapping supports targeted allergy management and urban planning(Zhu et al., 2024)(Lee et al., 2025).	The indirect nature of land cover proxies for pollen sources and allergenic potential introduces uncertainties in exposure assessments. Socioeconomic and demographic factors influencing allergy prevalence are often not integrated with land cover analyses(Barris et al., 2022)(Lee et al., 2025). The temporal mismatch between land cover updates and pollen season dynamics may reduce the timeliness of exposure assessments(Verstraeten et al., 2025).

Thematic Review of Literature

Research exploring the application of land cover data such as CORINE in aerobiology highlights several major themes: the integration of land cover datasets with pollen source characterization and dispersion modeling; the calibration and validation of pollen source maps using observational data; and the influence of urban vegetation composition on allergenic pollen exposure and public health. Advancements in remote sensing and high-resolution vegetation mapping have enhanced the spatial precision and temporal monitoring of pollen sources, enabling improved forecasting and exposure assessments. Methodological challenges persist regarding spatial resolution limitations, the variability of pollen productivity, and the need for multi-source data fusion to refine model accuracy across diverse geographic and climatic contexts.

Theme	Appears In	Theme Description
Integration of Land Cover Data with Pollen Dispersion Modeling	28/50 Papers	Studies consistently emphasize the use of CORINE and other land cover datasets to delineate pollen source areas which are then integrated with atmospheric dispersion models like SILAM, HYSPLIT, and Enviro-HIRLAM for forecasting pollen concentrations and exposure. Calibration of these models with observed pollen data significantly improves performance, highlighting the sensitivity of dispersion outputs to the quality of land cover-based source maps(Mimić et al., 2021)(Kurganskiy et al., 2020)(Bilińska-Prałat et al., 2022) (Verstraeten et al., 2025)(Neal et al., 2024).
Calibration and Validation of Pollen Source Maps Using Observational Data	20/50 Papers	Research shows that calibrating land cover-derived pollen source maps with in-situ pollen measurements reduces biases and enhances model accuracy. However, limitations include sparse observational networks and spatial heterogeneity of vegetation, underscoring the need for multi-year data and advanced calibration techniques to capture small-scale patterns and temporal variability in pollen productivity(Kurganskiy et al., 2020)(Kurganskiy et al., 2019)(Verstraeten et al., 2019)(Rojo et al., 2020)(Makra et al., 2023).
Role of High-Resolution Remote Sensing in Improving Pollen Source Characterization	15/50 Papers	High-resolution satellite data, such as Sentinel-2 and MODIS, provide finer spatial detail of vegetation types and phenology, crucial for accurate mapping of allergenic pollen sources in urban and regional landscapes. These datasets improve correlations with observed pollen concentrations and support dynamic forecasting models by capturing seasonal and inter-annual variations(Liu et al., 2024)(Verstraeten et al., 2025)("Satellite-based phenology products and i...", 2022)(Alfredo et al., 2019).
Influence of Urban Vegetation Composition on Allergenic Pollen Exposure and Public Health	14/50 Papers	Urban green spaces, tree species composition, and grassland management significantly affect airborne pollen concentrations and allergenic potential. Studies reveal spatial heterogeneity in pollen exposure within cities, with implications for allergy risk assessment and urban planning. Emphasis is given to the selection of low-allergenicity tree species and the management of spontaneous vegetation to reduce public health impacts(Rojo et al., 2024) (Charalampopoulos et al., 2018)(Zahradníková et al., 2023)(Bernard-Verdier et al., 2022)(Katz, 2023)(Barris et al., 2022).
Spatial and Temporal Variability of Airborne Pollen in Urban and Regional Contexts	13/50 Papers	Research documents significant spatiotemporal variations in pollen concentrations influenced by land cover configuration, local vegetation, meteorological factors, and atmospheric transport. Multi-station monitoring within cities reveals heterogeneity in pollen types and seasonality, affecting exposure assessments and necessitating dense monitoring networks(Jetschni & Jochner-Oette, 2021)(Ciani et al., 2020)(Martínez-Bracero et al., 2024)(Ruiz-Mata et al., 2023)(Miraglia et al., 2023)(Otto, 2022).

Theme	Appears In	Theme Description
Methodological Challenges in Using Land Cover Data for Pollen Source Mapping	11/50 Papers	Identified challenges include the coarse spatial resolution of some land cover datasets, the oversimplification of vegetation classes, limited pollen productivity data, and inadequate accounting for small-scale heterogeneity in vegetation distribution. These limitations affect source map accuracy and model performance, driving the development of hybrid approaches combining land cover data with pollen and forest inventory information(Amici et al., 2018)(Plancher et al., 2023)(Rojo et al., 2020) (Urbanowicz et al., 2018).
Use of Pollen-Based Land Cover Reconstructions and Historical Vegetation Mapping	8/50 Papers	Pollen-based reconstruction models like REVEALS and BACKLAND enable temporal mapping of vegetation cover changes and pollen productivity over millennia. These approaches contribute to understanding long-term vegetation dynamics, regional pollen source shifts, and past land-use impacts, which can inform contemporary aerobiological modeling and environmental management(Tantau et al., 2022)(Plancher et al., 2023) (Githumbi et al., 2022)(Theuerkauf & Couwenberg, 2018).
Application of Data Assimilation and Statistical Approaches in Pollen Modeling	7/50 Papers	Advanced statistical methods, including deep learning, Gaussian methods, and kriging interpolation, have been applied to restore incomplete pollen datasets, refine spatial pollen distribution maps, and improve forecasting. Data assimilation techniques incorporating pollen observations help correct emission estimates, enhancing temporal and spatial resolution of pollen maps(Oriani et al., 2024)(Makra et al., 2023)(Sofiev & Palamarchuk, 2025) (Makra et al., 2023).
Impact of Land Cover and Land Use on Specific Allergenic Plant Distributions	6/50 Papers	Studies investigate how urbanization, land use, and disturbance influence the distribution of allergenic species such as ragweed and grasses, showing that landscape-scale processes often outweigh microenvironmental factors. This understanding aids in identifying high-risk areas and targeting management interventions to mitigate allergen exposure(Jung et al., 2022)(Urbanowicz et al., 2018)(Lee et al., 2025)(Paciência et al., 2023).
Integration of Meteorological and Health Data with Land Cover for Allergy Forecasting	5/50 Papers	Combining remote sensing vegetation data with meteorological and health records facilitates the development of predictive models for allergic rhinitis and pollen outbreaks. Such integrative approaches enable anticipatory healthcare planning and inform public health interventions tailored to spatial and temporal pollen exposure patterns(Guo et al., 2024)(Zhu et al., 2024) (Dhankhar et al., 2024)(Yang et al., 2022).

Chronological Review of Literature

Research on the application of land cover data, particularly CORINE and similar datasets, in aerobiology has evolved significantly over recent years. Early studies focused on evaluating the reliability of land cover classes as proxies for vegetation and pollen sources, while subsequent efforts incorporated pollen data to calibrate and improve dispersion models. More recent work emphasizes higher spatial resolution mapping using remote sensing technologies and integration with meteorological and health data, aiming to enhance pollen exposure assessment and

forecasting. The advancement of modeling techniques, data assimilation, and urban-specific studies reflects a growing complexity and precision in understanding pollen dynamics in relation to land cover.

Year Range	Research Direction	Description
2018–2019	Foundational Evaluation of Land Cover and Pollen Relationships	Initial research assessed the reliability of CORINE land cover classes as proxies for plant assemblages and vegetation complexity, highlighting limitations of coarse classification. Early modeling efforts demonstrated the importance of integrating pollen data into source maps to improve dispersion model accuracy. Studies also began examining the impact of urbanization and land use on allergenic pollen production and spatial representation.
2020–2021	Integration of Land Cover Data with Atmospheric Dispersion Models	Research expanded to incorporate land cover data with atmospheric models like SILAM and HYSPLIT, testing different source maps calibrated with pollen observations. These studies emphasized the critical role of calibration and validation using ground-based pollen measurements. Land-use classification refinements and the influence of wind and land cover on airborne pollen dynamics were also investigated during this period.
2022–2023	Enhanced Spatial Resolution and Urban-specific Analyses	Advances included the use of higher-resolution remote sensing data to capture urban grass pollen sources and the application of multi-station sampling within cities to address spatial variability. Novel approaches combined land cover, phenology, and pollen monitoring data to analyze allergenic potential and vegetation diversity in urban contexts. Efforts to reconstruct past vegetation cover from pollen data also improved to support long-term environmental understanding.
2024–2025	Advanced Modeling, Forecasting, and Health Integration	Recent research focuses on combining fine-scale land cover data with satellite phenology and meteorological variables to improve real-time pollen forecasting and allergic rhinitis prediction. Data assimilation techniques and long-term pollen reanalyses have enhanced the temporal and spatial resolution of pollen distribution maps. Additionally, modeling at citizen-scale resolution and the assessment of urban tree planting impacts on allergenic pollen production reflect a move towards actionable public health applications.

Agreement and Divergence Across Studies

Across the reviewed studies, there is broad consensus on the importance and utility of land cover data, especially CORINE and analogous datasets, in mapping vegetation relevant to pollen emission and improving aerobiological models. Most studies highlight the necessity of calibrating land cover-derived pollen source maps using observational pollen data to enhance model accuracy. However, divergences arise concerning the spatial resolution adequacy of CORINE data, particularly in urban contexts, where finer-scale remote sensing products outperform coarser land cover maps. Moreover, challenges related to capturing small-scale vegetation patterns and urban green space heterogeneity contribute to varying model performances and differing interpretations of land cover

data effectiveness. These divergences commonly stem from differences in geographic focus, pollen taxa studied, data resolution, and modeling approaches.

Comparison Criterion	Studies in Agreement	Studies in Divergence	Potential Explanations
Spatial Resolution of Land Cover Data	CORINE and similar datasets are widely used as baseline land cover sources in aerobiological studies; their standardization and broad availability make them valuable (Rojo et al., 2024) (Kurganskiy et al., 2020) (Landa et al., 2021). Higher resolution remote sensing data, such as Sentinel-2, provide improved mapping of urban and grassland vegetation (Liu et al., 2024) (Verstraeten et al., 2025).	Some studies report CORINE's coarse resolution limits accurately representing urban vegetation heterogeneity and small-scale pollen sources, leading to underperformance in urban pollen modeling (Liu et al., 2024). Remote sensing with finer spatial granularity outperforms CORINE in urban contexts (Liu et al., 2024) (Verstraeten et al., 2025).	Studies conducted in urban areas with complex vegetation mosaics require finer spatial resolution than CORINE's 100m to 1km pixels provide. Remote sensing products like Sentinel-2 (10m) capture urban green space heterogeneity better. Differences in study area scale and urban complexity explain discrepancies in spatial resolution adequacy.
Correlation with Observed Pollen Data	There is strong evidence that land cover classifications, when linked to pollen source maps, correlate well with airborne pollen concentrations, especially after clustering or calibration (Rojo et al., 2024) (Mimić et al., 2021) (Kurganskiy et al., 2020). The use of pollen observations to validate models is common and improves confidence in source representation (Kurganskiy et al., 2020) (Verstraeten et al., 2019).	Some studies find only moderate correlations between uncalibrated CORINE-based source maps and observed pollen concentrations, citing spatial misclassification or missing small-scale habitat features (Bilińska-Prałat et al., 2022) (Rojo et al., 2020). Differences in correlation strength are noted between taxa and regions.	Variability in pollen dispersion, differences in pollen taxa emission characteristics, and the inherent spatial resolution of land cover data affect correlation strength. The density and representativeness of pollen observation networks, along with model calibration methods, influence observed correlations. Regional ecological differences and types of pollen (e.g., grass vs. tree) also contribute to divergence.
Calibration Methodologies	Calibration of pollen source maps using in-situ pollen measurements significantly improves model fit and predictive capacity in numerous studies (Mimić et al., 2021) (Kurganskiy et al., 2020) (Kurganskiy et al., 2019). Hybrid or iterative calibration approaches combining land cover and observational data yield the best results (Kurganskiy et al., 2020).	The availability and density of pollen observation stations limit calibration quality in some regions, leading to reliance on averaged or less localized calibration methods (Kurganskiy et al., 2020) (Kurganskiy et al., 2019). Some studies highlight computational constraints limiting cross-validation or sensitivity analyses (Kurganskiy et al., 2019).	Calibration effectiveness depends on the spatial and temporal coverage of pollen observations, regional ecological variability, and computational resources. Sparse observational data restricts calibration granularity. Differences in modeling frameworks and computational cost further explain varied calibration approaches and their outcomes.

Comparison Criterion	Studies in Agreement	Studies in Divergence	Potential Explanations
Model Performance Improvement	Integration of calibrated land cover data into pollen dispersion models leads to measurable improvement in explaining variance of observed pollen levels, often around 50% or higher after calibration (Kurganskiy et al., 2020) (Verstraeten et al., 2019) (Verstraeten et al., 2025). Downscaling efforts using remote sensing enhance model accuracy in urban areas (Verstraeten et al., 2025).	Despite calibration, models often underperform in capturing medium to high pollen concentrations, and large seasonal or interannual emission variability remains challenging to model (Kurganskiy et al., 2020) (Bilińska-Prałat et al., 2022). Some models show reduced performance in complex urban or mountainous regions (Bilińska-Prałat et al., 2022) (Rojo et al., 2020).	Temporal variability in pollen production, insufficient small-scale source representation, meteorological factors, and modeling assumptions about pollen release timing contribute to performance limits. Differences in pollen species' dispersal behaviors and urban morphology explain regional variability in model success. Model resolution and emissions input quality also affect outcomes.
Representation of Urban Vegetation Types	Land cover datasets that include urban green classes (e.g., CORINE's Green Urban Areas) provide a basis for representing urban vegetation in aerobiological studies (Rojo et al., 2024) (Landa et al., 2021). Studies emphasize the importance of including urban vegetation for allergenic pollen exposure assessment (Charalampopoulos et al., 2018) (Bernard-Verdier et al., 2022) (Barris et al., 2022).	Several studies note that land cover classifications often oversimplify urban vegetation heterogeneity, failing to capture species composition and small-scale vegetation patches, leading to inaccuracies in allergenic potential estimations (Amici et al., 2018) (Charalampopoulos et al., 2018). Finer-scale remote sensing and field inventories are proposed to improve urban vegetation characterization (Liu et al., 2024) (Lancia et al., 2024).	Urban vegetation is highly heterogeneous and often composed of ornamental, invasive, and native species with varying allergenic potentials, which are inadequately resolved in broad land cover classes. Limitations of CORINE's classification scheme and the lack of species-level detail cause discrepancies. Finer spatial and thematic resolution or hybrid data sources are needed to better capture urban vegetation complexity relevant for pollen emission and allergenicity.

Theoretical and Practical Implications

Theoretical Implications

- The synthesis of studies underscores the critical role of land cover data, particularly CORINE and similar datasets, in representing pollen source distributions and their spatial heterogeneity. High correlations between land cover classifications and airborne pollen concentrations, as demonstrated in regional clustering analyses, support the theoretical premise that land cover is a strong proxy for pollen source characterization ([Rojo et al., 2024](#)) ([Ciani et al., 2020](#)) ([Charalampopoulos et al., 2018](#)).

- Calibration of pollen source maps with observational pollen data emerges as a pivotal theoretical advancement, improving the accuracy of atmospheric dispersion models. This calibration addresses the limitations of land cover data alone, which often fail to capture small-scale vegetation patterns and inter-annual variability in pollen productivity([Kurganskiy et al., 2020](#)) ([Kurganskiy et al., 2019](#)) ([Mimić et al., 2021](#)).
- The integration of remote sensing data with land cover information enhances the temporal and spatial resolution of pollen source mapping, advancing theoretical models of pollen emission and dispersion. High-resolution satellite data, such as Sentinel-2, provide refined vegetation characterization that better aligns with in-situ pollen phenology and concentrations, particularly in urban landscapes([Liu et al., 2024](#)) ([Verstraeten et al., 2025](#)) ("[Satellite-based phenology products and i...](#)", 2022).
- Theoretical frameworks now increasingly recognize the complexity of urban vegetation composition and its influence on allergenic pollen exposure. Studies reveal that urban green spaces and anthropogenic land use create heterogeneous pollen emission patterns, challenging simplistic assumptions of uniform pollen source distributions([Bernard-Verdier et al., 2022](#)) ([Rispo et al., 2020](#)) ([Barris et al., 2022](#)).
- The development of long-term, continuous pollen reconstructions using pollen-based land cover models (e.g., REVEALS, BACKLAND) contributes to theoretical understanding of vegetation-pollen relationships over millennial timescales, offering insights into past vegetation dynamics and their implications for current aerobiological modeling([Tantau et al., 2022](#)) ([Plancher et al., 2023](#)) ([Githumbi et al., 2022](#)).
- Theoretical models are evolving to incorporate multi-source data fusion approaches, combining land cover, pollen observations, meteorological variables, and phenological indicators to better simulate pollen dispersion and exposure. This holistic approach addresses the multifactorial nature of pollen dynamics and allergenic risk([Zhu et al., 2024](#)) ([Sofiev & Palamarchuk, 2025](#)) ([Yang et al., 2022](#)).

Practical Implications

- For aerobiological modeling and public health forecasting, the use of calibrated land cover-based pollen source maps significantly enhances the predictive performance of dispersion models, enabling more accurate allergy risk assessments and timely warnings for sensitive populations([Kurganskiy et al., 2020](#)) ([Mimić et al., 2021](#)) ([Verstraeten et al., 2025](#)).
- Urban planning and green space management can benefit from detailed land cover and pollen source data to mitigate allergenic pollen exposure. Strategic selection and management of urban vegetation, including the avoidance of monospecific plantings and consideration of allergenic potential, can reduce public health risks([Rispo et al., 2020](#)) ([Katz, 2023](#)) ([Pham-Thi et al., 2019](#)).
- The deployment of multiple pollen monitoring stations within urban areas, informed by land cover heterogeneity, improves spatial representativeness of pollen data and supports localized exposure assessments. This approach addresses the limitations of single-station monitoring and informs targeted interventions([Ruiz-Mata et al., 2023](#)) ([Miraglia et al., 2023](#)) ([Jetschni et al., 2023](#)).

- Integration of high-resolution remote sensing data with land cover and phenological information facilitates the development of fine-scale pollen forecasting systems. These systems can provide near-real-time, location-specific pollen concentration estimates, enhancing public health preparedness and individual preventive actions([Liu et al., 2024](#)) ([Verstraeten et al., 2025](#)) ([Guo et al., 2024](#)).
- Policymakers can leverage land cover and aerobiological data to design evidence-based regulations and urban greening policies that balance ecological benefits with allergenic risks, promoting healthier urban environments([Bernard-Verdier et al., 2022](#)) ([Barris et al., 2022](#)) ([Lee et al., 2025](#)).
- The advancement of data assimilation techniques combining land cover, pollen observations, and meteorological data supports the creation of long-term pollen reanalysis products. These products are valuable for climate impact studies, biodiversity monitoring, and the prioritization of allergen management strategies at regional and continental scales([Sofiev & Palamarchuk, 2025](#)) ([Makra et al., 2023](#)) ([Makra et al., 2023](#)).

Limitations of the Literature

Area of Limitation	Description of Limitation	Papers which have limitation
Limited Observational Networks	Many studies suffer from insufficient density and spatial coverage of pollen observation stations, limiting external validity and the robustness of calibration and validation of pollen source maps. This constraint hampers accurate representation of small-scale vegetation patterns and temporal variability.	(Kurganskiy et al., 2020) (Kurganskiy et al., 2019) (Bilińska-Prałat et al., 2022) (Rojo et al., 2020)
Coarse Spatial Resolution of Land Cover Data	The use of coarse-resolution land cover datasets such as CORINE often fails to capture fine-scale heterogeneity in vegetation relevant to pollen emission, reducing the precision of pollen source characterization and dispersion modeling. This affects the accuracy of exposure assessments in heterogeneous urban landscapes.	(Liu et al., 2024) (Amici et al., 2018) (Verstraeten et al., 2025)
Calibration Dependency on Pollen Data	Pollen dispersion models heavily rely on calibration with observed pollen data, which is often limited to few regions and years. This dependency restricts the generalizability of models and may not account for abrupt annual changes in pollen production, weakening predictive reliability.	(Mimić et al., 2021) (Kurganskiy et al., 2020) (Kurganskiy et al., 2019)
Temporal Variability and Inter-Annual Changes	Many studies do not adequately account for inter-annual variability in pollen production and phenology, which can cause significant fluctuations in pollen concentrations and season timing, thereby limiting the temporal validity of findings and forecasts.	(Kurganskiy et al., 2020) (Bilińska-Prałat et al., 2022) (Tantau et al., 2022) (Paciência et al., 2023)
Urban Heterogeneity and Sampling Height Effects	Variations in pollen concentrations within urban areas due to microclimatic differences, vegetation diversity, and sampling height introduce complexity that is often underrepresented, limiting the spatial representativeness and comparability of pollen data within cities.	(Rojo et al., 2020) (Miraglia et al., 2023) (Otto, 2022)
Limited Integration of Remote Sensing and Ground Data	While remote sensing offers high spatial resolution, many studies have limited integration with ground-based pollen observations, constraining the ability to fully exploit satellite data for accurate pollen source mapping and phenology assessment.	(Liu et al., 2024) (" Satellite-based phenology products and i... ", 2022) (Guo et al., 2024)
Computational Constraints on Model Validation	Advanced validation techniques such as cross-validation or leave-one-out procedures require extensive computational resources, which are often prohibitive, limiting thorough sensitivity analyses and robustness checks of pollen dispersion models.	(Kurganskiy et al., 2020) (Kurganskiy et al., 2019)

Area of Limitation	Description of Limitation	Papers which have limitation
Geographic Bias and Regional Focus	Several studies focus on specific regions or cities, limiting the geographic generalizability of findings. This regional bias affects the external validity of conclusions regarding land cover and pollen relationships across diverse landscapes.	(Rojo et al., 2024) (Verstraeten et al., 2019) (Jung et al., 2022) (Martínez-Bracero et al., 2024) (Ruiz-Mata et al., 2023)

Gaps and Future Research Directions

Gap Area	Description	Future Research Directions	Justification	Research Priority
Calibration of Land Cover-Based Pollen Source Maps	Existing pollen source maps derived from CORINE or similar land cover data often lack sufficient calibration with observational pollen data, limiting model accuracy.	Develop and implement scalable calibration frameworks that integrate multi-year, multi-site pollen observations with land cover data, including cross-validation and iterative optimization methods to improve source map reliability.	Calibration significantly improves model performance but is hindered by sparse observational networks and high computational costs, as shown in birch and ragweed studies (Kurganskiy et al., 2020) (Kurganskiy et al., 2019) (Mimić et al., 2021).	High
Spatial Resolution Limitations of CORINE Data in Urban Areas	CORINE's coarse spatial resolution (100 m to 1 km) inadequately captures fine-scale urban vegetation heterogeneity critical for accurate pollen source representation.	Integrate high-resolution remote sensing data (e.g., Sentinel-2, MODIS) and detailed urban vegetation inventories with CORINE to produce refined urban pollen source maps; develop downscaling techniques for urban environments.	High-resolution data improve urban pollen source mapping and model accuracy, addressing limitations of CORINE in urban contexts (Liu et al., 2024) (Verstraeten et al., 2025) (Landa et al., 2021).	High
Representation of Urban Vegetation Composition and Allergenicity	Land cover datasets often oversimplify urban vegetation, lacking species-level detail and allergenic potential information, which is crucial for exposure assessment.	Incorporate species-specific urban vegetation inventories and allergenicity indices into land cover datasets; develop dynamic urban vegetation models that account for invasive and non-native species affecting allergenic pollen production.	Urban vegetation composition strongly influences allergenic pollen exposure but is poorly represented in current land cover data, limiting public health applications (Bernard-Verdier et al., 2022) (Charalampopoulos et al., 2018) (Rispo et al., 2020).	High
Integration of Phenological Data with Land Cover for Temporal Accuracy	Static land cover data do not capture temporal dynamics of pollen emission related to vegetation phenology, reducing forecasting precision.	Combine satellite-derived phenology products (e.g., MODIS SOS) with land cover data to dynamically update pollen source maps; develop models linking phenology with pollen emission timing and intensity.	Phenology integration improves temporal alignment of pollen forecasts with observed pollen seasons, enhancing early warning systems (" Satellite-based phenology products and i... ", 2022) (Guo et al., 2024) (Alfredo et al., 2019).	Medium

Gap Area	Description	Future Research Directions	Justification	Research Priority
Sparse and Uneven Pollen Monitoring Networks	Limited spatial coverage and heterogeneity of pollen observation stations, especially in urban areas, constrain calibration, validation, and model generalizability.	Expand and densify pollen monitoring networks in urban and peri-urban areas; explore low-cost or automated pollen sampling technologies; integrate citizen science and crowdsourced data for spatially dense observations.	Sparse data limit calibration and validation efforts, reducing model accuracy and representativeness in complex urban landscapes (Kurganskiy et al., 2020) (Ruiz-Mata et al., 2023) (Miraglia et al., 2023).	High
Standardization of Methodologies for Land Cover and Aerobiological Data Integration	Diverse approaches and lack of standardized protocols hinder comparability and reproducibility of studies integrating land cover with pollen data.	Develop and promote standardized workflows and data formats for integrating land cover, phenology, meteorology, and pollen observations; encourage open data sharing and collaborative platforms.	Methodological heterogeneity complicates synthesis and operational forecasting, limiting progress in aerobiology (Zhu et al., 2024) (Landa et al., 2021).	Medium
Accounting for Small-Scale Vegetation Patterns and Microhabitats	Current land cover datasets and calibration methods inadequately capture small-scale vegetation heterogeneity and microhabitats influencing local pollen emissions.	Employ fine-scale vegetation mapping using UAVs, LiDAR, and ground surveys; integrate microhabitat data into pollen emission models; develop multi-scale modeling frameworks.	Small-scale patterns cause under- or overestimation of pollen concentrations, especially in urban and heterogeneous landscapes (Kurganskiy et al., 2020) (Rojo et al., 2020).	Medium
Incorporation of Long-Range Transport Effects in Source Attribution	Many models inadequately account for long-range pollen transport, complicating the attribution of local pollen concentrations to land cover sources.	Integrate atmospheric transport modeling with land cover and phenology data to separate local and regional pollen contributions; improve meteorological data assimilation and bias correction techniques.	Long-range transport influences pollen presence but is often insufficiently modeled, affecting source attribution accuracy (Mimić et al., 2021) (Bilińska-Prałat et al., 2022).	Medium

Gap Area	Description	Future Research Directions	Justification	Research Priority
Linking Land Cover Data with Health Outcomes and Socioeconomic Factors	Current studies rarely integrate land cover-based pollen exposure assessments with health data and socioeconomic variables, limiting public health relevance.	Develop interdisciplinary models combining land cover, pollen exposure, health records, and socioeconomic data; apply spatial epidemiology to assess allergy risk and inform urban planning.	Understanding exposure-health relationships requires integrating environmental and social data, which remains underexplored (Guo et al., 2024) (Barris et al., 2022) (Lee et al., 2025).	Medium
Dynamic Updating and Temporal Harmonization of Land Cover Data	Land cover datasets like CORINE are updated infrequently, leading to temporal mismatches with pollen season dynamics and vegetation changes.	Establish protocols for frequent updating of land cover data using near-real-time remote sensing; harmonize temporal scales of land cover and pollen data for improved model responsiveness.	Temporal mismatches reduce the timeliness and accuracy of pollen exposure assessments and forecasts (Landa et al., 2021) (Verstraeten et al., 2025).	Medium

Overall Synthesis and Conclusion

The body of literature collectively underscores the critical role of land cover datasets, particularly CORINE and analogous products, in advancing aerobiological research focused on pollen source characterization, dispersion modeling, and exposure assessment. CORINE land cover’s standardized classification scheme facilitates regional-scale analyses and the delineation of aerobiological risk areas, with studies demonstrating strong correlations between land cover-derived pollen source maps and observed airborne pollen concentrations. However, the relatively coarse spatial resolution and generalized vegetation classes of CORINE limit its ability to capture fine-scale heterogeneity, especially within complex urban landscapes where detailed representation of vegetation types and their allergenic potential is essential. This limitation has driven the incorporation of higher-resolution remote sensing data (e.g., Sentinel-2, MODIS) and forest inventory maps to improve the spatial accuracy and temporal relevance of pollen source mapping.

Integrating land cover data with atmospheric dispersion models significantly enhances the simulation and forecasting of pollen concentrations, particularly when source maps are calibrated and validated against observational pollen measurements. Calibration approaches, including statistical rescaling and data assimilation, have been shown to markedly improve model performance, though challenges such as sparse monitoring networks and methodological heterogeneity persist. The addition of phenological information and meteorological variables further refines temporal predictions by capturing seasonal dynamics of pollen emissions.

Urban vegetation representation remains a notable challenge. Coarse land cover classes often oversimplify urban green spaces, failing to account for species composition, invasive taxa, and management practices that directly influence allergenic pollen exposure and public health outcomes. Recent studies employing detailed vegetation inventories and high-resolution remote sensing better characterize urban grasslands, parks, and street trees, enabling more precise assessments of allergenic risk and informing urban planning and mitigation strategies.

Methodological diversity and scale mismatches across studies limit comparability and the development of standardized workflows. Nevertheless, the integration of land cover, phenology, meteorology, and health data, often enhanced by machine learning techniques, shows promise for advancing pollen forecasting systems and exposure assessments. Finally, while land cover data are valuable proxies for pollen sources, uncertainties remain due to indirect representation and temporal mismatches, indicating a need for improved data integration, urban-scale monitoring, and consideration of socioeconomic variables to fully capture allergenic pollen dynamics and their health impacts.

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