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Deep Learning: an Integrative Systematic Review of Its Applications in Mapping Using UAV Imagery

Deep Learning: uma Revisão Sistemática Integrativa de suas Aplicações em Mapeamento Utilizando Imagens de RPA

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Abstract: The advances in Deep Learning (DL) techniques have expanded the use of Unmanned Aerial Vehicles (UAVs) for cartographic mapping and remote sensing, enhancing automation and the accuracy of geospatial products. Given the rapid growth of such applications, this article aims to systematize and critically analyze research integrating DL and UAV imagery in the mapping context, focusing on the main neural network architectures, sensors, and application domains. An integrative systematic review was conducted using the *Web of Science*, *Scopus*, and *ScienceDirect* databases, covering the period from 2020 to 2025. The screening process resulted in 22 selected studies, grouped into five thematic categories: agriculture, object detection, inspections, wildfires, and LiDAR. The findings highlight the predominance of YOLO and U-Net architectures, the increasing use of multispectral and thermal data, and the lack of methodological standardization in training and validation processes. The integrative analysis revealed trends, gaps, and ethical and technical challenges in applying DL with UAV imagery for mapping purposes. This research contributes to consolidating technical and scientific knowledge in this field and reinforces the need for standardized protocols and practices in the development of AI-based cartographic products.
Keywords: Computer Vision. Convolutional Neural Networks. YOLO. U-Net. Cartographic Updating.

Resumo: O avanço das técnicas de aprendizado profundo (*Deep Learning* - DL) tem ampliado o uso de Aeronaves Remotamente Pilotadas (RPAs) no mapeamento cartográfico e no sensoriamento remoto, impulsionando a automação e a precisão dos produtos geoespaciais. Diante do crescimento expressivo dessas aplicações, este artigo tem como objetivo sistematizar e analisar criticamente as pesquisas que integram DL e RPAs no contexto do mapeamento**,** considerando as principais arquiteturas de redes neurais, sensores empregados e áreas de aplicação. Foi conduzida uma revisão sistemática integrativa nas bases *Web of Science*, *Scopus* e *ScienceDirect*, abrangendo o período de 2020 a 2025. A triagem resultou em 22 artigos incluídos, classificados em cinco categorias temáticas: agricultura, detecção de objetos, inspeções, incêndios e LiDAR. Os resultados evidenciam o predomínio das arquiteturas YOLO e U-Net, a crescente adoção de dados multiespectrais e térmicos e a carência de padronização metodológica nos procedimentos de treinamento e validação. A análise integrativa permitiu identificar tendências, lacunas e desafios éticos e técnicos na aplicação de DL com RPAs para o mapeamento cartográfico. A pesquisa contribui para a consolidação do conhecimento técnico-científico sobre o tema e reforça a importância de protocolos e práticas padronizadas no desenvolvimento de produtos cartográficos baseados em inteligência artificial.
Palavras-chave: Visão Computacional. Redes Neurais Convolucionais. YOLO. U-Net. Atualização Cartográfica.

1 INTRODUCTION

In recent decades, advances in Deep Learning (DL) techniques have driven significant transformations in remote sensing and cartographic mapping. The ability of neural networks to automatically extract complex patterns and learn high-level representations from large volumes of visual data has expanded the possibilities for automation and analysis across various areas of geoinformation (Yigitcanlar et al., 2024a). This technological evolution has been accompanied by the growing availability of optical, multispectral, and LiDAR sensors onboard Remotely Piloted Aircraft (RPAs), which provide high spatial and temporal resolution data at increasingly affordable costs (Prince, 2023; Zhang et al., 2024).

The combined use of DL and RPAs has emerged as one of the most relevant approaches for automatic mapping, feature detection, and cartographic updating. These techniques enable the recognition of targets, object classification, and surface segmentation with high precision and repeatability, overcoming the limitations of traditional visual interpretation. Moreover, the adoption of convolutional neural network (CNN) workflows such as YOLO, U-Net, DeepLab, and Mask R-CNN has expanded the analytical scope and improved the efficiency of generating cartographic products derived from aerial imagery (Aszkowski et al., 2023; Park et al., 2024).

Despite the considerable growth of studies integrating DL and RPAs in remote sensing, the literature still exhibits substantial methodological and thematic heterogeneity. Differences in network architectures, sensor configurations, spatial resolutions, and evaluation metrics make it difficult to compare results and establish best practices in the field. Furthermore, there is a lack of recent critical systematizations addressing these applications' technical, methodological, and cartographic aspects, especially updating geospatial databases and representing urban and rural spaces. This gap hinders the assessment of the field's scientific maturity and the identification of consistent research trends.

Given this context, the present study seeks to answer the following research question: What are the main methodological, technological, and thematic characteristics that define the use of Deep Learning in cartographic applications based on imagery acquired by RPAs between 2020 and 2025?

To address this question, a systematic literature review was conducted using the Web of Science, Scopus, and ScienceDirect databases to ensure transparency, reproducibility, and standardization in the search, screening, and analysis process. The time frame from 2020 to 2025 was selected to cover the most recent period of consolidation of DL techniques applied to mapping, considering the advances resulting from the widespread adoption of RPAs and the availability of open-source tools for geospatial data processing.

The contribution of this review lies in articulating, from a critical and integrative perspective, the technological, cartographic, and methodological dimensions of DL applications in RPAs, analyzing the types of onboard sensors, the most frequently used neural network architectures, and the predominant thematic domains. By presenting this synthesis, the study aims to enhance the understanding of recent trends, standardization gaps, and ethical and operational challenges surrounding the application of artificial intelligence in geospatial mapping. The article seeks to provide a consolidated reference for researchers and professionals in cartography, fostering advances in integrating deep learning, remote sensing, and geographic information science.

2 METHODOLOGICAL APPROACH

The integrative systematic review was structured into three main stages: (i) review planning, (ii) search execution and data systematization, and (iii) quantitative and interpretative analysis of the results. This approach was selected because it enables the synthesis of different types of evidence - both empirical and theoretical - in a critical and interpretative manner, as proposed by Snyder (2019), integrating recent research findings on using DL and RPAs from multiple technical and cartographic perspectives.

This framework guided the careful selection of sources, the application of inclusion and exclusion criteria, and the organization of the articles into thematic categories, ensuring transparency and reproducibility throughout the review process. The methodological procedure comprised the following stages of investigation:

(a) identifying the types of sensors embedded in RPAs for cartographic purposes;

(b) verifying the open-source software and platforms used for data processing;

(c) recognizing the main application areas that combine RPAs and DL algorithms in cartographic production.

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2.1 Review planning

The review planning was structured to gather and organize the primary references on the topic, with the following objectives: (a) to perform a comprehensive search of articles within the overall observation universe; (b) to define the five analytical categories; (c) to identify the central search databases; and (d) to carry out thematic categorization to confirm the relevance of the articles within each group. Thus, the systematic review aimed to examine the innovations and applications of DL using imagery acquired by RPAs. The 2020–2025 time frame was established as it represents the consolidation period of deep learning applications using RPA data, marking a phase of significant advances in neural network architectures and the availability of open-source platforms for geospatial mapping.

The search strategy was designed around the following questions:

(i) Based on the predefined research topic, what general and specific objectives should be prioritized?

(ii) Considering the search results, which three objectives would be most feasible for the project?

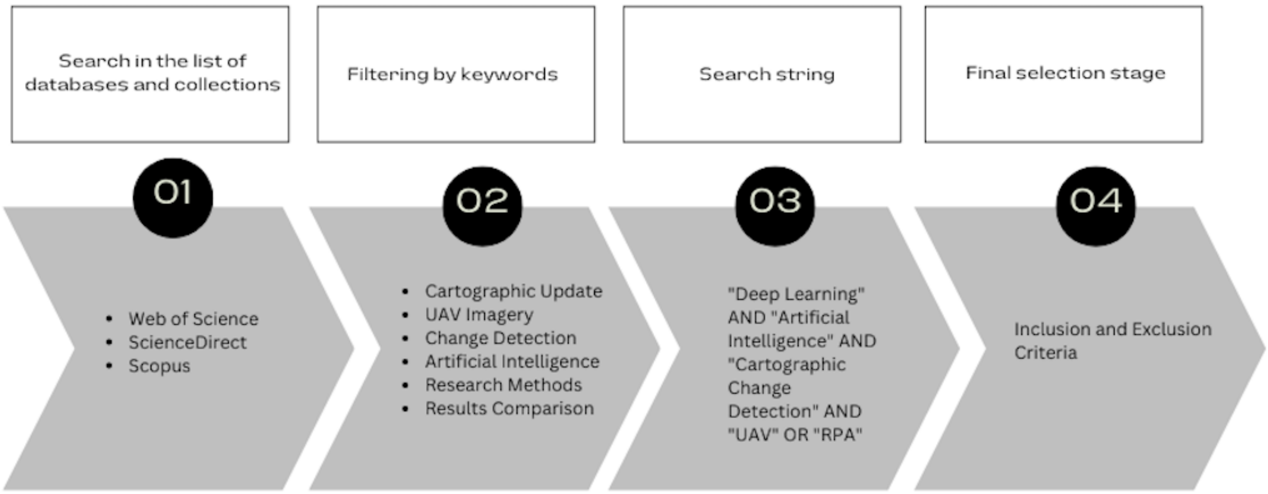
(iii) What research questions should be explored from these selected objectives?

(iv) Based on this information, what keywords would be most suitable for the research project?

The keywords adopted in the search process were: “Cartographic Updating”, “UAV Imagery”, “Change Detection”, “Artificial Intelligence”, “Research Methods”, and “Results Comparison”. Searches were conducted in the Web of Science, Scopus, and ScienceDirect databases. The selection of these databases was justified by their broad coverage of peer-reviewed journals, research-oriented access environment, and efficient filtering capabilities.

The exclusion criteria were: review papers, early access publications, secondary references, and documents not classified within Web of Science categories. The inclusion criteria were: open-access articles published between 2020 and 2025. Figure 1 presents the workflow diagram illustrating the stages adopted in this study.

Figure 1 – Stages of the methodological process of the integrative review



Source: The authors (2025).

Although the inclusion and exclusion criteria were previously defined, clarifying the rationale for the decision-making and article screening process is important. The selection stage involved reading the titles, abstracts, and subsequently the full texts, considering their thematic relevance to the scope of the study, namely, the use of Deep Learning (DL) applied to data acquired by Remotely Piloted Aircraft (RPAs) for cartographic mapping purposes.

Table 1 presents a summary of the main criteria used, along with their descriptions and methodological justifications. This approach allows for understanding the reasons for exclusions and the classification of the selected articles into the five defined thematic categories: agriculture, object detection, fire monitoring, inspections, and LiDAR.

Table 1 – Inclusion and exclusion criteria adopted in the integrative review

Type of criterion	Applied description	Methodological justification
Publication period	Articles published between 2020 and 2025	Represents the most recent period of consolidation of DL and RPA applications in cartographic mapping.
Document type	Exclusion of reviews, preprints, and technical reports	Ensure a focus on original empirical research presenting experimental results and replicable methodologies.
Idiom	Inclusion of articles in English, Portuguese, and Spanish	International scope with an emphasis on scientific literature accessible to researchers in the geotechnology field.
Document access	Preferential inclusion of open-access articles	Promote transparency, reproducibility, and public access to the reviewed methodologies.
Data source	Web of Science, Scopus, and ScienceDirect databases	Represent the most relevant and consolidated repositories in the fields of Engineering, Remote Sensing, and Cartography.
Main theme	Deep learning (DL) applications using data acquired by RPAs	Ensure direct relevance to the study's objective and exclude articles that use only satellite data, ground sensors, or traditional machine learning.
Thematic categorization	Final classification of articles into five groups: agriculture, object detection, fire monitoring, inspections, and LiDAR	Facilitate comparative analysis and integrative synthesis of application trends and employed architectures.

Source: The authors (2025).

After the final screening, a full-text reading and systematic extraction of information were performed for the 22 articles included. For each study, the type of onboard sensor, neural network architecture used, application area, data type (RGB, multispectral, thermal, or LiDAR), main results, and limitations reported by the authors were identified.

These data were organized into comparative spreadsheets and qualitatively synthesized through thematic analysis, considering convergences, methodological innovations, and technical gaps. The integration process was based on categorizing studies into five thematic axes: agriculture, object detection, inspections, fire monitoring, and LiDAR, allowing for identifying trends and recurring patterns in deep learning applications using RPAs.

This extraction and integration stage consolidated the interpretative and reflective character of the integrative review, ensuring coherence between the research objective and the critical analysis of the reviewed studies.

2.2 Research selection technique

The search strings used across the three databases, based on the selected keywords, were: ("LiDAR" OR "Deep Learning" OR "Artificial Intelligence" OR "Cartographic Change Detection" OR "UAV" OR "UAS").

Applying this string in the Web of Science database resulted in 123 articles after applying the inclusion and exclusion criteria. In the Scopus database, 42 articles were retrieved; in ScienceDirect, 47 articles were identified, as shown in Table 2. It is worth noting that, even after the data refinement stage, an additional filtering process was carried out in Zotero (a reference management software) to remove articles with overlapping or redundant themes.

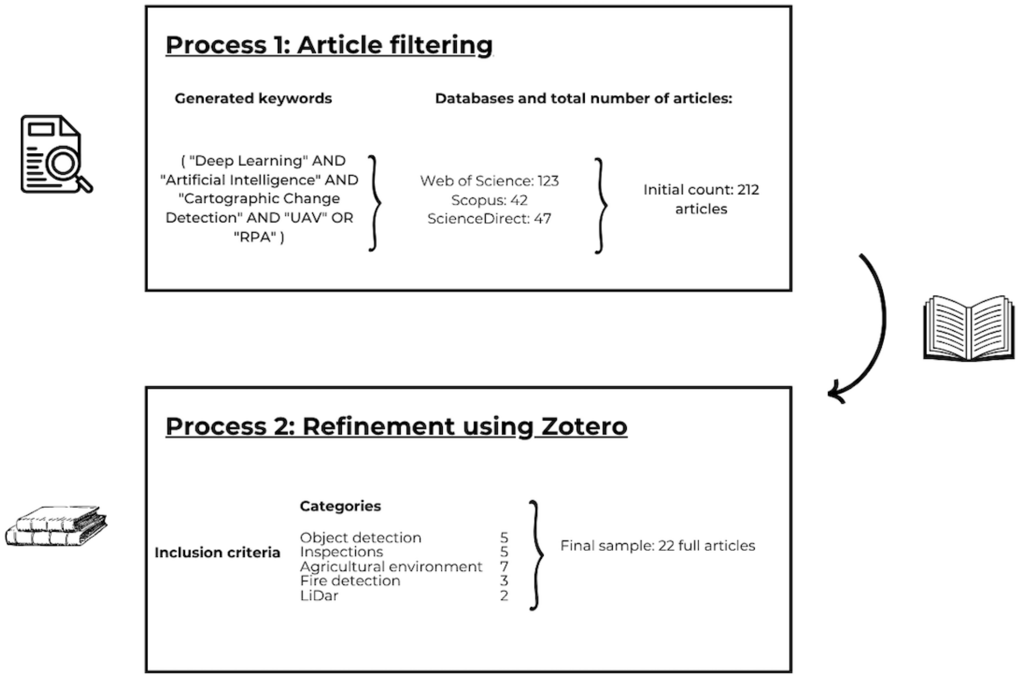
Table 2 – Number of Articles Identified in the Scientific Databases

Database	Articles identified	Articles included after screening	Inclusion rate (%)
Web of Science	123	8	6,5
Scopus	42	9	21,4
ScienceDirect	47	5	10,6
Total	**212**	**22**	**10,3**

Source: The authors (2025).

The thematic categories were defined based on the recurrence of applications identified in the selected studies, combining technological criteria (sensor type and network architecture) with cartographic purposes (agricultural mapping, infrastructure inspection, object detection, environmental monitoring, and LiDAR use). This categorization made it possible to organize the results and facilitate the comparative and interpretative analysis of application trends, resulting in the selection of 22 articles that best aligned with the scope of the research, as shown in Figure 2.

Figure 2 – Stages of article selection



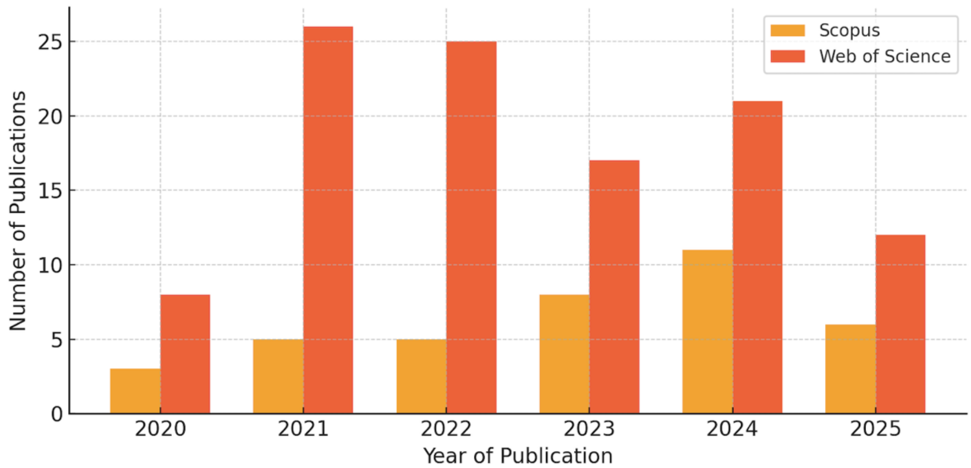
Source: The authors (2025).

3 RESULTS ANALYSIS

3.1 Analysis of articles by publication period and location

Based on the results obtained, it was possible to understand the extensive use of RPAs equipped with RGB, thermal, multispectral, or LiDAR sensors integrated with various convolutional neural networks. The importance and continuous improvement of these networks were observed for different purposes. The number of published articles per year is shown in Figure 3. Moreover, the absence of the bar corresponding to the ScienceDirect database in the graph became evident, since, unlike the Web of Science and Scopus databases, its information was not accessible.

Figure 3 – Number of articles published per year in the Scopus and Web of Science databases



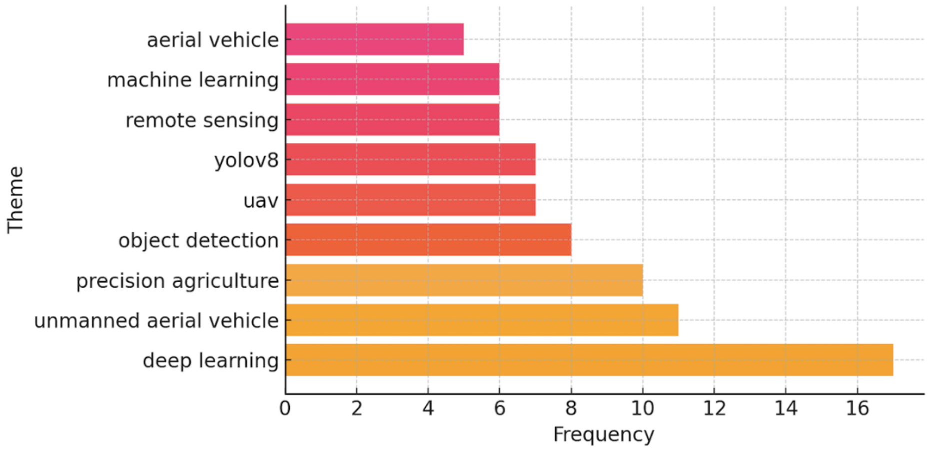
Source: The authors (2025).

Many articles used RPA data integrated with DL for various purposes, which is likely associated with the growing availability and popularization of these devices in different fields of knowledge. The geographical distribution of publications revealed a significant concentration in China, followed by the United States and India. This result corroborates previous analyses that highlight China's leading role in the fields of Artificial Intelligence (AI) and remote sensing, resulting from strong government investments, integration with the private sector, and policies that encourage technological innovation (Tiwari et al., 2022). Similarly, Alotaibi and Nassif (2024) emphasize the prominence of these countries in applying AI and machine learning to environmental monitoring, while Yigitcanlar et al. (2024b) associate such leadership with national policies promoting technological development and adoption. Thus, the observed predominance reflects both scientific support and the technological infrastructure required for research involving RPAs and DL algorithms.

3.2 Analysis of articles by most frequent themes

The data extracted from the articles provided information on the most researched and discussed topics. Figure 4 shows the themes according to their frequency.

Figure 4 – Frequency of the most researched themes



Source: The authors (2025).

The term *Unmanned Aerial Vehicle (UAV),* as well as *RPAs,* was the second most frequently researched topic, following *Precision Agriculture*, and was closely followed by *Object Detection*. DL is intrinsically related to the advancement of research involving the use of RPAs, whether for inspections, object detection, fire monitoring, automatic classification of point clouds derived from LiDAR data, predictive analyses in agricultural environments, or other related processes.

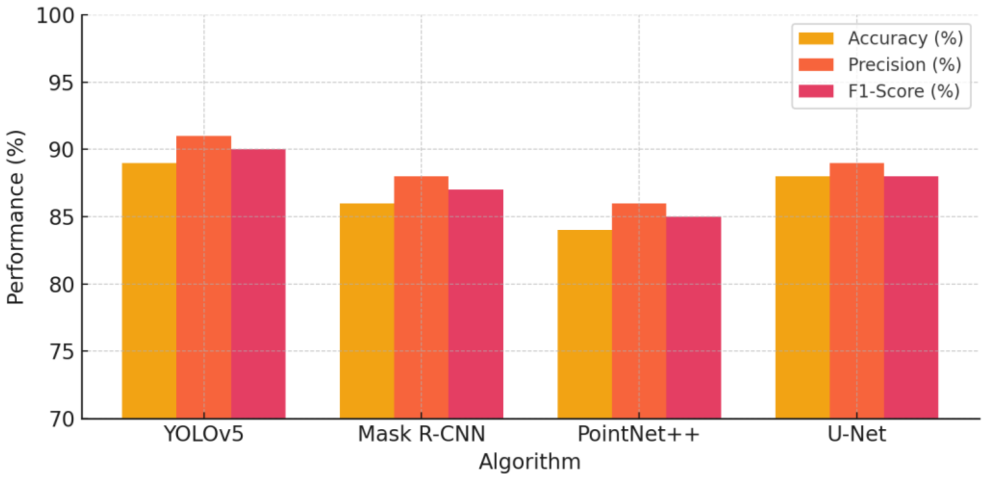
3.3 Analysis of articles based on the indicators of the convolutional neural networks used

In analyzing the convolutional neural network (CNN) architectures used in the selected articles (Figure 5), a predominance of the YOLO family networks was observed, followed by U-Net, DeepLab, and other specific CNNs. Traditional machine learning methods, such as Random Forest (RF) or Support Vector Machines (SVM), were not considered in the final analysis, as they do not fall within the definition of DL. The presence of these algorithms in the preliminary review stemmed from the initial breadth of the search string, which included broader AI-related terms. This limitation was corrected to ensure only studies based on DL architectures integrated with RPAs were included.

Regarding the YOLO family, its high performance was evident, particularly in versions YOLOv5, YOLOv8, and later releases, which have been widely applied to real-time detection tasks. The most recent version, YOLOv12 (2025), features improved computational efficiency and detection accuracy in complex contexts. This continuous development highlights the rapid evolution of DL architectures and their consolidation as a core tool in RPA-based applications.

Another open-source algorithm that achieved good results was Deepness (a QGIS plugin) developed by Aszkowski et al. (2023). In a 17.6-hectare orthophoto, the algorithm successfully segmented 208 features, and a summary of these results was presented by the authors at the XII Colloquium on Geodetic Sciences at UFPR in November 2024. In addition to *Deepness*, other tools and libraries employing DL techniques for semantic segmentation and geographic image classification stand out, such as *Detectree2*, focused on tree canopy identification, Kartoza's experimental QGIS plugin, and external libraries like *TorchGeo* (within the PyTorch ecosystem) and *Raster Vision*, which provide robust pipelines for model training and inference using remote sensing data. These solutions have expanded the range of AI applications in cartography, promoting greater automation and accuracy in traditionally manual segmentation tasks.

Figure 5 – Convolutional neural network architectures used



Source: The authors (2025).

The segmentation results enable valuable analyses for cartographic updating, as they incorporate temporal information. Compared with earlier orthophotos, such outputs allow precise identification of changes in buildings or environmental areas, deforestation detection, or vegetation regeneration assessment.

3.4 Applications in object detection

This section discusses the selected studies that explore the application of Deep Learning (DL) techniques to images acquired by RPAs, with a focus on various mapping and automatic detection problems. To facilitate readability, the studies are organized by application domain, highlighting the main methodological innovations and the challenges associated with the use of these technologies.

In the context of small-target detection in road environments, Aibibu et al. (2024) propose a convolutional network called ERGW-net (repetitive Gaussian–Wasserstein style), developed specifically to improve the accuracy of detecting small targets in infrared aerial imagery. The dataset was obtained using a DJI Matrice M210 V2 RPA equipped with a DJI Zenmuse XT2 thermal camera, with a resolution of 640 × 512 pixels and a 25 mm lens, illustrating the integration of specialized sensors and DL models for continuous road monitoring, including under low-light conditions.

Still within the realm of practical applications, but with an emphasis on software infrastructure, Aszkowski et al. (2023) develop an open-source plugin for QGIS that enables the direct application of convolutional neural networks to any raster layer, whether it represents a numerical matrix or an image. The plugin supports regression, segmentation, and target detection tasks. Also, it provides a repository of pre-trained models that can be adapted to different research contexts, thereby lowering the technical barrier to the use of DL in geoprocessing workflows.

Regarding object detection in aerial images, Li et al. (2023a) address one of the primary challenges in this task: reliably identifying small targets, whose limited pixel representation often leads to interpretation errors and incomplete detection. The authors propose a detection model inspired by the YOLOv8-s architecture, aiming to enhance real-time performance in object detection from aerial imagery. The results are considered satisfactory and promising for applications that require rapid response.

The application of DL to environmental monitoring is also highlighted in the study by Park et al. (2024), which compares the performance of YOLOv8 and DeepLabv3+ for detecting and recognizing piles of solid waste derived from human activities, which represent potential pollution sources for aquifers. Qualitative analysis indicates that YOLOv8 outperforms DeepLabv3+ in both the detection and classification of these waste piles, suggesting that the integration of RPAs and DL can support more efficient systems for controlling, monitoring, and logistics in waste management in aquatic environments and their surrounding areas.

Finally, Soeleman et al. (2023) investigate the use of deep learning models applied to thermal images acquired by RPAs equipped with onboard thermal cameras, with an emphasis on object detection under nighttime conditions. In such scenarios, low illumination renders conventional RGB cameras insufficient, whereas thermal sensors operate based on the radiation emitted by targets. The analyses are conducted using the publicly available HIT-UAV dataset, which comprises 2,898 images and multiple classes (person, car, bicycle, vehicles, animals, among others), demonstrating the potential of combining thermal imagery and DL for object recognition in surveillance, security, and nighttime monitoring contexts.

The main advantages and research gaps identified in the aforementioned studies are summarized in Table 3 below.

Table 3 – Summary of studies on object detection.

Authors	Year	Objective	Advantage	Limitation
Aibibu et al.	2024	To develop an efficient neural network architecture for urban road surveillance applications using UAV infrared imagery.	High efficiency in processing complex infrared datasets and improved detection accuracy for small objects.	Limited scalability when applied to large and heterogeneous urban environments.
Aszkowski et al.	2023	To present the “Deepness” plugin for QGIS, which is focused on integrating deep learning models directly within the GIS environment.	Seamless integration with QGIS expands the platform’s capabilities for computer vision and remote sensing tasks.	The interface still requires improvement to support larger datasets and GPU acceleration.
Li et al.	2023	To modify the YOLOv8 architecture to enhance small-object detection performance in UAV-based imagery.	Increased accuracy in detecting small and complex objects in high-resolution scenes.	Model adaptation to diverse land-use scenarios remains challenging.
Park et al.	2024	To develop a detection and classification system for solid waste piles using deep learning and UAV imagery	High detection and classification accuracy for waste piles, supporting monitoring and management of pollution sources in aquatic environments.	Generalization to different landscapes, illumination conditions, and waste types still needs to be assessed.
Soeleman & Supriyanto	2023	To apply deep learning models to UAV-based thermal imagery for object detection under low-light/nighttime conditions.	Improved detection accuracy for multiple object classes in thermal images acquired at night	Validation is limited to a specific dataset (HIT-UAV) and scenarios; broader testing in diverse environments is needed.

Source: The authors (2025).

3.5 Summaries of applications in various inspections

In the context of linear infrastructure inspection, Jeon et al. (2024) propose an innovative methodology for optimizing autonomous flight in overhead power transmission facilities. The flight strategy relies on multimodal information from 3D LiDAR sensors and an optical camera. While the 3D LiDAR provides detailed three-dimensional geometric information about the surroundings of the structures, the optical camera complements these data with visual attributes, resulting in a more accurate representation of the transmission lines. To further enhance the inspection process, the authors introduce a new deep neural network, termed RoMP (Rotational Bounding Box with Multi-Level Feature Pyramid Transformer), designed for object detection. This model enables the RPA to adjust its altitude and heading autonomously, tracking the transmission line with greater precision and safety.

From a different perspective, focused on geological characterization, Nakamura et al. (2024) conduct a quantitative survey of outcrops in three coastal areas of Japan, aiming to estimate the relationship between surface morphology and visual information from well-exposed rocks using drone-based aerial photogrammetry. Based on the acquired data, three-dimensional digital models of the outcrops are generated and used to produce images in the HSV color space (hue, saturation, and value) and digital elevation models

(DEMs), as well as to compute the terrain ruggedness index (TRI) from the DEM. Using these inputs, a machine learning model (MLM) is trained to predict surface roughness at the millimetre scale. The resulting mean squared error (0.0051) indicates that the algorithm achieves roughness predictions that are reasonably accurate for geoscientific applications.

Pan et al. (2024) address the problem of planning inspection routes under uncertainties related to resources and constraints originating from multiple sources, proposing an approach based on deep reinforcement learning (DRL). The authors introduce a new attention-based deep neural network, termed A-DNN, designed to learn optimal routing strategies. The A-DNN architecture comprises a dual encoder–decoder structure designed explicitly for RPA inspection scenarios. The model is compared with other algorithms, such as the dual multi-head attention mechanism (DAM), in both simulation experiments and a real-world case study involving wind farm inspections. Overall, the DRL-based approach demonstrates strong potential to support decision-making in selecting more efficient inspection methodologies, providing adaptable and interpretable solutions for RPAs operating in complex and dynamic engineering environments.

Focusing on road markings inspection, Rahnamayiezekavat et al. (2024) propose an RPA-based platform to overcome limitations related to access, operational inefficiency, and digital image processing in traditional systems for monitoring pavement markings. The study uses images with a resolution of 5472 × 3080 pixels and an 8.8 mm focal length. Image processing is performed using the K-means clustering algorithm, which exploits the intensity differences between pixels associated with pavement markings and the asphalt background. To assess the quality of the markings, Otsu's thresholding method is applied. The research is initially conducted in a pilot area (a parking lot), with the intention of scaling up the methodology to the urban level in future studies.

Zhao et al. (2024) developed an autonomous navigation methodology for RPAs, aiming to detect anomalies in oil and gas pipelines, based on an enhanced version of the YOLOv7 algorithm. The processing chain includes the use of the Canny edge detector to highlight pipeline edges and the application of the Hough transform to identify linear segments corresponding to the pipeline route. An intelligent RPA of the P600 model is employed to inspect oil and gas connections along the infrastructure, guided by the outputs of the YOLOv7-trained model. The authors emphasize that the precise definition of the methodology and the datasets used facilitates fair comparisons in future inspection assessment studies.

The main advantages and gaps identified in these studies are synthesized and discussed in Table 4.

Table 4 – Summary of studies on inspection applications.

Authors	Year	Objective	Advantage	Limitation
Jeon et al.	2024	To develop an autonomous flight strategy for Unmanned Aerial Vehicles (UAVs).	Higher efficiency in executing autonomous missions.	Limited applicability in environments with constrained or complex infrastructure.
Nakamura et al.	2024	To estimate the surface roughness of rocks at a millimeter scale using UAVs.	High accuracy in estimating roughness on natural surfaces.	The methodology needs to be expanded to different surface types and materials.
Pan et al.	2024	To develop a collaborative route between Unmanned Aerial Vehicles and human operators.	Improved coordination and operational efficiency between UAVs and humans.	Integration of systems for greater UAV autonomy in adverse environments.
Rahnamayiezekavat et al.	2024	To assess pavement marking integrity using automated techniques.	Increased precision and speed in road marking assessments.	Adaptation to different marking types and variable environmental conditions.
Zhao et al.	2024	To develop a pipeline inspection system using UAVs and computer vision techniques.	Enhanced safety and efficiency in critical infrastructure inspections.	Need to extend the methodology to other infrastructure types beyond pipelines.

Source: The authors (2025).

3.6 Summaries of applications in agricultural environments

The agricultural applications category encompasses studies that investigate the combined potential of RPAs, multispectral/RGB sensors, and machine learning and deep learning techniques for crop monitoring, yield prediction, and support in precision agriculture management.

Yuan (2024) presents AriAplBud, a dataset of apple flower buds captured from different angles using an RGB camera embedded in an RPA. The dataset comprises 3,600 images of buds in six growth stages, from which 110,467 bounding-box annotations were generated and used as positive samples. In addition, 2,520 images of empty orchards without flower buds were included as negative samples. The results show that AriAplBud can be integrated into different object detection models, as it adopts the Darknet annotation format, which is compatible with the YOLOv8 framework, thereby expanding its applicability to automatic detection tasks in the context of fruit production.

In the work of Fei et al. (2021), the capabilities of multispectral imagery acquired by RPAs, combined with ensemble learning methods, are investigated to increase the accuracy of grain yield prediction in breeding programs. The authors develop an ensemble learning framework that integrates different base models, including Random Forest (RF), Support Vector Machine (SVM), Gaussian Process (GP), and ridge regression (RR). The best grain yield prediction results are observed at the intermediate grain-filling stage under full irrigation conditions. The study also suggests that further advances in DL may accelerate the use of RPA-based multispectral data for accurate prediction of complex agronomic traits, such as wheat yield.

The study by Skobalski et al. (2024) aims to analyze the transferability and performance of yield prediction models for soybean breeding across test sites distributed in North and South America. To this end, different machine learning techniques are evaluated, including Random Forest Regressor (RF), Gradient Boosting Regression (GB), and Deep Neural Networks (DNN), in experiments conducted under diverse climatic and growth conditions. The authors propose a novel transfer learning methodology to support genotype selection and soybean yield categorization, aiming to identify high-yielding varieties. Additionally, they investigate the importance of temporal resolution in yield prediction, exploring critical crop development stages and different aerial survey frequencies. In total, 31,404 samples are used to train the models, underscoring the robustness of the dataset employed.

In the study by Li et al. (2023b), the central hypothesis is that yield prediction accuracy can be improved by integrating multispectral data acquired by RPAs with deep learning algorithms. The authors develop 16 yield-sensitive vegetation indices, whose relationships are analyzed based on multispectral data from winter wheat collected at heading, flowering, and grain-filling stages. Detailed monitoring throughout the reproductive period is considered strategic for decision-making in agricultural production. From the combination of data from these three stages, seven sets of input variables are defined and used in four generalized machine learning algorithms-Random Forest (RF), K-Nearest Neighbor (KNN), Bagging, and Gradient Boosting Regression (GBR)-as well as in a deep learning model based on a 1D Convolutional Neural Network (1D-CNN). The results indicate that the CNN model provides the highest prediction accuracy among the tested approaches, reinforcing the potential of deep learning for this type of application.

Hooshyar et al. (2024) propose an RPA-based imaging solution for tree species detection and fruit tree classification in steep and hard-to-access terrains. RPAs equipped with multispectral and RGB cameras are used to capture imagery and generate orthomosaics that support classification into different categories, such as fruit trees, roads, and buildings. In parallel, convolutional neural networks (CNNs) are applied for pattern recognition in the images, testing architectures such as VGG-16, VGG-19, and ResNet-50. Among the evaluated models, VGG-16 yields the most accurate results in analyzing multispectral imagery. The authors highlight that the proposed approach can contribute to more efficient management of fruit crops in rugged areas.

In the work of Mohammadi et al. (2024), the potential of RPAs equipped with multispectral and RGB sensors for plant phenotyping in agricultural research is explored. In this context, phenotyping is related to plant height, yield prediction, and chlorophyll content. The experiments involve 38 faba bean (Vicia faba L.) cultivations, conducted in four replications in southeastern Norway. To estimate productivity values, Support Vector Regression (SVR) and Random Forest (RF) models are employed, utilizing combinations of multispectral bands, vegetation indices, and plant height estimates derived from RPA data at four stages of crop development. The strong correlation between manual measurements and RPA-based height estimates ($R^2 = 0.97$) demonstrates high agreement between methods. The results indicate that integrating RPAs with RGB and multispectral cameras, combined with machine learning algorithms, constitutes an accurate approach for quantifying agronomically relevant traits in faba beans.

Finally, Yu et al. (2021) investigate the use of multispectral RPA imagery, vegetation indices (VI), crop height, topographic metrics, and soil properties to predict canopy nitrogen weight (g/m²) in a maize field in southwestern Ontario, Canada. The training models employed are Random Forest (RF) and Support Vector Regression (SVR). Based on these models, 29 samples are selected to assess the predictive capacity for canopy nitrogen weight. The results show that RF outperforms SVR, using 15 selected variables (height, spectral, and topographic), achieving an R^2 of 0.73 and a root mean square error (RMSE) of 2.21 g/m².

Table 5 presents a synthesis of the main characteristics, advantages, and limitations of the articles included in this category of agricultural applications.

Table 5 – Summary of studies on agricultural applications

Authors	Year	Objective (short)	Advantage (short)	Limitation (short)
Yuan et al.	2024	Create an RPA based dataset of apple flower buds for object detection.	Provides an annotated and standardized dataset for training and benchmarking models.	Restricted to one species and region; needs testing on other crops and contexts.
Fei et al.	2021	Predict wheat yield using multispectral RPA imagery.	Ensemble learning improves prediction accuracy at key phenological stages.	Needs integration with deep learning and testing under different climates and management.
Skobalski et al.	2024	Assess transferability of soybean yield models across multiple test sites.	Shows potential for model transfer between environments in North and South America.	Should be extended to other regions, crops, and operational decision support systems.
Li et al.	2023	Compare 1D CNN and traditional models for winter wheat yield prediction.	1D CNN achieves higher accuracy with RPA multispectral data.	Requires validation on larger datasets and in different agro ecological contexts.
Hooshyar et al.	2024	Detect and classify fruit trees on steep slopes using RPA imagery.	High accuracy in identifying fruit trees in rugged terrain.	Model performance under varying illumination and sensor setups still needs optimization.
Mohammadi et al.	2024	Improve faba bean phenotyping using RPA data and machine learning.	Increases efficiency and accuracy of field phenotyping.	Needs testing on other species and breeding scenarios.
Yu et al.	2021	Estimate maize canopy nitrogen using RPA derived variables.	Random Forest performs well with a reduced set of spectral, structural and topographic variables.	Additional metrics and sites are needed to improve generalization and accuracy.

Source: The authors (2025).

3.7 Summaries of applications in fire detection

This group of studies examines the potential of RPAs combined with deep learning techniques for the early detection of forest fires and mapping of burned areas, with a focus on accuracy, rapid response, and spatial generalization.

In the paper of Saydirasulovich et al. (2023), a training model based on YOLOv8 is developed for accurate smoke detection from forest fires in images acquired by RPAs. To enhance target localization performance, the authors incorporate the Wise-IoU (WIou) regression loss, improving the spatial delineation of regions of interest. In addition, they integrate the BiFormer mechanism, which steers the model's attention toward the specific visual characteristics of smoke in forest environments. The results demonstrate the effectiveness of the enhanced YOLOv8 model for smoke detection, reinforcing its potential for operational applications in monitoring and early warning systems.

In a complementary approach, Shamta and Demir (2024) propose a surveillance system dedicated to early forest fire detection, also grounded in deep learning applied to RPA imagery. The core of the system is a CNN-RCNN-type neural network, trained to classify areas as fire or no fire. To enable field deployment, the authors develop a ground-station interface that is responsible for receiving and displaying, in near real-time, both the images and the georeferenced coordinates of detected hotspots, thereby facilitating rapid intervention by response teams. The RPA follows pre-planned flight missions and integrates an NVIDIA Jetson Nano device, used as an onboard hardware platform for real-time data processing and fire detection, which highlights the feasibility of embedded solutions in operational scenarios.

Sui et al. (2024) present an approach focused on burned area mapping, proposing a new U-Net-based pre-training scheme termed BiAU-Net. The model incorporates attention mechanisms that concentrate on regions associated with burn scars, increasing segmentation accuracy and efficiency. One of the main advantages of

BiAU-Net is its explicit use of temporal change information derived from paired Sentinel-2 images (pre- and post-fire), which enhances performance across diverse environmental contexts. Five independent areas, distributed across distinct continents, are selected for the study-one for model training and the others for testing-to demonstrate its generalization capability. Validation is carried out using the Fire Disturbance Climate Change Initiative v5.1 product from the European Space Agency, and the results show that BiAU-Net significantly outperforms this reference, with improvements of 11.56%, evidencing its potential for global burned area monitoring.

Table 6 presents a summary of studies on fire detection applications.

Table 6 – Summary of studies on fire detection applications

Authors	Year	Objective	Advantage	Limitation
Saydirasulovich et al.	2023	To improve wildfire smoke detection using YOLOv8.	Significant reduction of false positives and increased accuracy.	Need for adaptation to nighttime detection and edge-device deployment.
Shamta & Demir	2024	To develop a deep learning-based UAV surveillance system for early forest fire detection.	High fire/no-fire classification accuracy using an embedded CNN-RCNN model and a real-time ground-station interface.	System robustness still needs improvement for real-time field implementations.
Sui et al.	2024	To detect burned areas using U-Net and bi-temporal models.	Significant improvement in burned-area detection with enhanced edge sensitivity.	Optimization required for detection in lower temporal resolution scenarios, such as Nairobi and Sumatra.

Source: The authors (2025).

3.8 Summaries of applications in airborne LiDAR

At the interface between remote sensing and forest ecology, Lang et al. (2025) compare three methodologies for quantifying canopy gap fraction: (i) analysis of frames extracted from videos captured by RPAs, (ii) digital hemispherical photography acquired below the canopy, and (iii) Light Detection and Ranging (LiDAR) scanning. The aim is to assess the accuracy and applicability of these techniques across different zenith angles. The authors identify a moderate linear relationship between RPA-derived data and the reference obtained from hemispherical photography ($R^2 = 0.67$), with more pronounced discrepancies at gap edges. The results indicate that, although drones represent a more cost-effective and agile alternative, their accuracy decreases at low zenith angles when compared with LiDAR. The main contribution of the study lies in its integrated assessment of these technologies, highlighting their strengths and limitations in forest contexts, with direct implications for planning mapping missions and environmental monitoring strategies.

At the frontier of model development for three-dimensional data, Lu et al. (2025) propose 3D-UMamba, a neural network for semantic segmentation of multi-source LiDAR point clouds that integrates the Mamba model into a U-Net architecture. The core innovation lies in its ability to capture global contextual information with linear computational complexity, thus overcoming performance limitations typically associated with transformer-based approaches. Using a voxel-based token serialization strategy (Voxel-based Token Serialization – VTS), 3D-UMamba achieves high accuracy (mIoU greater than 84.5%) across different LiDAR datasets, including multispectral and urban scenarios. The results demonstrate the feasibility of the model for complex segmentation tasks, underscoring its efficiency and adaptability; as a remaining gap, the authors emphasize the need to test the model in dynamic contexts and under high noise levels to consolidate its robustness in real-world applications.

Table 7 presents a summary of studies on airborne LiDAR applications.

Table 7 – Summary of studies on airborne LiDAR applications

Authors	Year	Objective	Advantage	Disadvantage	Limitation
Lang et al.	2025	To compare canopy gap fractions in forest environments.	UAVs provide rapid coverage for estimating canopy gap fractions in forests.	Lower accuracy in estimating gap fractions at low zenith angles.	Need to optimize algorithms for interpreting drone imagery.
Lu et al.	2025	To develop 3D-UMamba, a neural network for semantic segmentation of LiDAR point clouds.	Higher efficiency and lower computational cost compared to Transformer-based models.	Requires a token serialization process (Voxel-based Token Serialization).	Explore the performance of 3D-UMamba in highly dynamic scenarios.

Source: The authors (2025).

3.9 Summary of approaches using UAVs and automatic pavement defect detection

The contributions of Peixoto et al. (2024) stand out in advancing methodologies for identifying defects in asphalt pavements, combining traditional approaches with innovations based on artificial intelligence and remote sensing using RPA. The studies conducted by the authors range from comparative analyses between classical visual survey methods and the use of aerial imagery to bibliometric reviews of emerging technologies applied to pavement distress detection.

In one of their studies, the effectiveness of using RPAs for image acquisition in inspection tasks is demonstrated, with reductions in time and resource requirements compared to traditional methods. However, limitations remain in detecting certain types of defects, such as undulations. In another line of investigation, the authors propose a technique based on the YOLO algorithm for automatic anomaly detection, reinforcing the potential of machine learning in pavement management and maintenance. The bibliometric review conducted by the group maps the main international trends, highlighting the scarcity of nationally produced studies with greater methodological detail and the absence of technical regulations in Brazil governing the use of these tools. Among the identified gaps, the most prominent are the need for field validation, improvements in the spatial resolution of the employed imagery, and the development of public policies that integrate digital technologies into pavement management systems.

Table 8 – Summary of approaches using UAVs and automatic pavement defect detection

Authors	Year	Objective	Advantage	Disadvantage	Limitation
Peixoto et al.	2024	To identify and analyze AI and image processing applications in road transport engineering.	Comprehensive overview of recent research across different domains (infrastructure, traffic, etc.).	Lack of integration among studied regions and segments.	There is a need for more cross-sectoral studies and integration between AI and public transport policies.
Peixoto et al.	2024	To comparatively analyze methods for identifying asphalt pavement defects using traditional visual surveys and drone imagery.	Reduced time and resources when using UAVs, achieving results comparable to traditional methods.	Lower accuracy in identifying transversal defects such as rutting and undulations.	Need to improve image resolution and analysis techniques to enhance accuracy.
Peixoto et al.	2024	To conduct a bibliometric survey on technologies applied to pavement defect identification.	Mapping of key emerging technologies, especially the use of AI and YOLO-based models.	Limited national production with insufficient technical detailing.	Absence of specific standards to regulate the use of AI and UAV surveys in technical diagnostics.
Peixoto et al.	2024	To evaluate machine learning-based approaches with drone imagery for pavement defect detection.	Proposal of a new technique to improve road inspection systems using machine learning (YOLO).	Dependence on image quality and flight parameterization for accurate results.	Need for field validation under diverse environmental conditions.

Source: The authors (2025).

4 DISCUSSION

The integrative analysis of the 22 studies, conducted following Snyder's (2019) approach, enabled the synthesis of trends, gaps, and perspectives using deep learning techniques applied to cartographic mapping based on RPA imagery. Although the literature demonstrates significant advances in performance and accuracy, methodological fragmentation remains relevant, particularly regarding data standardization, evaluation metrics, and cross-validation procedures.

The results show the predominance of convolutional neural network (CNN) architectures - such as YOLO, U-Net, and Mask R-CNN - widely adopted for their efficiency in object detection and segmentation tasks. However, few studies provide detailed information about training parameters, number of epochs, or learning rate variations, which limits experimental reproducibility. Moreover, inconsistencies in accuracy measurement were observed, with metrics such as mAP, IoU, and F1-Score being used unevenly. This lack of uniformity compromises comparability among results and reinforces the need for standardized methodological protocols.

In terms of applications, precision agriculture stands out as the most consolidated field, reflecting the maturity of RPA-based approaches for crop analysis and water stress detection. Conversely, infrastructure inspection and fire monitoring are emerging areas that still lack studies using time series and multisensor data. The use of LiDAR sensors onboard RPAs is also increasing, suggesting a transition from purely spectral analyses to the fusion of three-dimensional data, enhancing cartographic products' geometric and thematic accuracy.

From a technical perspective, there is a growing integration between open-source libraries - such as PyTorch and TensorFlow - and geospatial tools like QGIS and Google Earth Engine. This interoperability strengthens the development of automated and reproducible workflows. Nevertheless, the literature remains limited in adopting best documentation and code-sharing practices, which affects scientific transparency and hinders experiment replication. Establishing standardized repositories for geospatial data and trained models could mitigate these limitations.

The analysis also revealed ethical and epistemological challenges associated with using AI in automated mapping. Issues related to model explainability, data privacy in RPA-acquired imagery, and responsibility in cartographic decision-making remain underexplored. These gaps highlight the importance of incorporating ethical considerations into technical discussions, particularly when derived products influence public policies, spatial planning, and environmental management.

Overall, the findings confirm that the application of deep learning in RPA-based mapping constitutes a rapidly expanding field that still lacks methodological standardization, cross-context validation, and integration with official cartographic databases. The heterogeneity of sensors, resolutions, and data annotation strategies underscores this domain's interdisciplinary and challenging nature.

The results corroborate recent literature by demonstrating that integrative reviews are valuable for mapping research maturity and identifying gaps in emerging fields, as proposed by Snyder (2019). Consolidating comparable and transparent methodologies represents an essential step toward the scientific advancement of the field and the strengthening of cartography as a discipline guided by evidence and technological innovation.

The findings also emphasize the importance of institutionalizing national protocols for quality, interoperability, and ethics in applying artificial intelligence to cartography. By integrating deep learning and RPAs under a critical cartographic perspective, Brazil has the potential to develop a research and innovation agenda that combines technical rigor, social responsibility, and scientific sovereignty within the field of geotechnologies.

5 FINAL CONSIDERATIONS

This integrative systematic review demonstrated that DL techniques applied to imagery acquired by RPAs have become a strategic field in contemporary cartographic mapping. Between 2020 and 2025, there has been substantial progress in research focused on feature detection, segmentation, and classification, driven by advances in convolutional neural network architectures and the growing availability of open-source platforms and high-resolution onboard sensors.

The results revealed the predominance of YOLO and U-Net architectures, which are widely applied across domains - particularly in precision agriculture, infrastructure inspection, and environmental monitoring. However, the review also identified recurring limitations, such as the absence of unified validation and result comparison protocols, the scarcity of open datasets, and the lack of detailed documentation on training and calibration processes. These gaps compromise the reproducibility of experiments and hinder the establishment of scientific standards for applying DL in cartographic mapping.

Beyond technical aspects, the analysis also emphasized ethical and epistemological challenges associated with the automation of cartographic interpretation. Using RPAs and AI algorithms requires incorporating principles of transparency, explainability, and social responsibility, especially when the generated products support spatial decisions with public impact. Discussions on ethics, interoperability, and model reliability should therefore be integrated into the research agenda of cartography and geotechnologies.

This review contributes by systematizing the state of the art and proposing guidelines for developing more consistent and reproducible methodologies. It recommends the creation of national protocols for integrating DL, RPAs, and cartographic practices, considering data quality, interoperability, and security standards. Such initiatives can strengthen the country's scientific and technological innovation capacity in geotechnologies, aligning with the Sustainable Development Goals (SDGs) and digital transformation policies.

It is concluded that the consolidation of AI-driven cartography represents a unique opportunity for Brazil to advance in modernizing its spatial data infrastructures and produce more accurate, up-to-date, and accessible cartographic products.

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Authors contributions

E. B. Oliveira was responsible for conducting the study, including data acquisition and initial processing, organization of the results, manuscript writing, and final editing; V. de O. Fernandes defined the methodological approach, carried out the critical review of the content, and supervised the research; and M. J. A. Júnior contributed to data curation, formal analysis, and the technical review of the manuscript.

Conflicts of Interest

The authors declare that there is no conflict of interest.

References

Aibibu, T., Lan, J., Zeng, Y., Lu, W., & Gu, N. (2023). An Efficient Rep-Style Gaussian–Wasserstein Network: Improved UAV Infrared Small Object Detection for Urban Road Surveillance and Safety. *Remote Sensing*, 16(1), 25. https://doi.org/10.3390/rs16010025

Alotaibi, E., & Nassif, N. (2024). Artificial intelligence in environmental monitoring: in-depth analysis. *Discover Artificial Intelligence*, 4(1). https://doi.org/10.1007/s44163-024-00198-1

Aszkowski, P., Ptak, B., Kraft, M., Pieczyński, D., & Drapikowski, P. (2023). Deepness: Deep neural remote sensing plugin for QGIS. SoftwareX, 23, 101495. https://doi.org/10.1016/j.softx.2023.101495

Fei, S., Hassan, M. A., He, Z., Chen, Z., Shu, M., Wang, J., Li, C., & Xiao, Y. (2021). Assessment of Ensemble Learning to Predict Wheat Grain Yield Based on UAV-Multispectral Reflectance. *Remote Sensing*, 13(12), 2338. https://doi.org/10.3390/rs13122338

Hooshyar, M., Li, Y.-S., Chun Tang, W., Chen, L.-W., & Huang, Y.-M. (2024). Economic Fruit Trees Recognition in Hillsides: A CNN-Based Approach Using Enhanced UAV Imagery. *IEEE Access*, 12, 61991–62005. https://doi.org/10.1109/access.2024.3391371

Jeon, M., Moon, J., Jeong, S., & Oh, K. (2024). Autonomous flight strategy of an unmanned aerial vehicle with multimodal information for autonomous inspection of overhead transmission facilities. *Computer-Aided Civil and Infrastructure Engineering*, 39(14), 2159–2186. https://doi.org/10.1111/mice.13188

Lang, M., Antsov, M., Mumma, A., Suitso, I., Kuusk, A., & Piip, K. (2025). Comparison of forest canopy gap fraction measurements from drone-based video frames, below-canopy hemispherical photography, and airborne laser scanning. *European Journal of Remote Sensing*, 58(1). https://doi.org/10.1080/22797254.2025.2456629

Li, Y., Fan, Q., Huang, H., Han, Z., & Gu, Q. (2023). A Modified YOLOv8 Detection Network for UAV Aerial Image Recognition. *Drones*, 7(5), 304. https://doi.org/10.3390/drones7050304

Lu, D., Xu, L., Zhou, J., Gao, K., Gong, Z., & Zhang, D. (2025). 3D-UMamba: 3D U-Net with state space model for semantic segmentation of multi-source LiDAR point clouds. *International Journal of Applied Earth Observation and Geoinformation*, 136, 104401. https://doi.org/10.1016/j.jag.2025.104401

Mohammadi, S., Uhlen, A. K., Lillemo, M., Ergon, Å., & Shafiee, S. (2024). Enhancing phenotyping efficiency in faba bean breeding: integrating UAV imaging and machine learning. *Precision Agriculture*, 25(3), 1502–1528. https://doi.org/10.1007/s11119-024-10121-4

Nakamura, T., Kioka, A., Egawa, K., Ishii, T., & Yamada, Y. (2024). Estimating millimeter-scale surface roughness of rock outcrops using drone-flyover structure-from-motion (SfM) photogrammetry by applying machine learning model. *Earth Science Informatics*, 17(3), 2399–2416. https://doi.org/10.1007/s12145-024-01280-z

Pan, Y., Li, L., Qin, J., Chen, J., & Gardoni, P. (2024). Unmanned aerial vehicle–human collaboration route planning for intelligent infrastructure inspection. *Computer-Aided Civil and Infrastructure Engineering*, 39(14), 2074–2104. https://doi.org/10.1111/mice.13176

Park, M., Kim, H., & Lee, J. (2024). Detection and grading of compost heap using UAV and deep learning. *Korean Journal of Remote Sensing*, 40(1), 33–43. https://doi.org/10.7780/kjrs.2024.40.1.4

Peixoto Oliveira, L. T., Oliveira, E. B., Fernandes, V. O., Lima, C. D. A. (2024). *Análise comparativa de métodos para identificação de defeitos em pavimento com uso de imagens de RPA*. In: Anais do 38º Congresso de Pesquisa e Ensino em Transportes. Galoá. https://proceedings.science/anpet/anpet-2024/trabalhos/analise-comparativa-de-metodos-para-identificacao-de-defeitos-em-pavimento-com-u?lang=pt-br

Prince, Simon J. D. Understanding deep learning. Cambridge: MIT Press. (2023) https://udlbook.github.io/udlbook/

Rahnamayiezekavat, P., Wang, D., Chai, J., Moon, S., Rashidi, M., & Wang, X. (2024). Automated pavement marking integrity assessment using a UAV platform – a test case of public parking. *Journal of Asian Architecture and Building Engineering*, 24(3), 1594–1605. https://doi.org/10.1080/13467581.2024.2329358

Saydirasulovich, S. N., Mukhiddinov, M., Djuraev, O., Abdusalomov, A., & Cho, Y.-I. (2023). An Improved Wildfire Smoke Detection Based on YOLOv8 and UAV Images. *Sensors*, 23(20), 8374. https://doi.org/10.3390/s23208374

Shamta, I., & Demir, B. E. (2024). Development of a deep learning-based surveillance system for forest fire detection and monitoring using UAV. *PLOS ONE*, 19(3), e0299058. https://doi.org/10.1371/journal.pone.0299058

Skobalski, J., Sagan, V., Alifu, H., Al Akkad, O., Lopes, F. A., & Grignola, F. (2024). Bridging the gap between crop breeding and GeoAI: Soybean yield prediction from multispectral UAV images with transfer learning. *ISPRS Journal of Photogrammetry and Remote Sensing*, 210, 260–281. https://doi.org/10.1016/j.isprsjprs.2024.03.015

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Soeleman, M. A., Supriyanto, C., & Purwanto. (2023). Deep Learning Model for Unmanned Aerial Vehicle-based Object Detection on Thermal Images. *Revue d'Intelligence Artificielle*, 37(6), 1441–1447. https://doi.org/10.18280/ria.370608

Sui, T., Huang, Q., Wu, M., Wu, M., & Zhang, Z. (2024). BiAU-Net: Wildfire burnt area mapping using bi-temporal Sentinel-2 imagery and U-Net with attention mechanism. *International Journal of Applied Earth Observation and Geoinformation*, 132, 104034. https://doi.org/10.1016/j.jag.2024.104034

Tiwari, A., Bardhan, S., & Kumar, V. (2022). A Bibliographic Study on Artificial Intelligence Research: Global Panorama and Indian Appearance. *Library Herald*, 60(4), 15–36. https://doi.org/10.5958/0976-2469.2022.00036.7

Yigitcanlar, T., David, A., Li, W., Fookes, C., Bibri, S. E., & Ye, X. (2024). Unlocking Artificial Intelligence Adoption in Local Governments: Best Practice Lessons from Real-World Implementations. *Smart Cities*, 7(4), 1576–1625. https://doi.org/10.3390/smartcities7040064

Yigitcanlar, T., Senadheera, S., Marasinghe, R., Bibri, S. E., Sanchez, T., Cugurullo, F., & Sieber, R. (2024). Artificial intelligence and the local government: A five-decade scientometric analysis on the evolution, state-of-the-art, and emerging trends. *Cities*, 152, 105151. https://doi.org/10.1016/j.cities.2024.105151

Yu, J., Wang, J., & Leblon, B. (2021). Evaluation of Soil Properties, Topographic Metrics, Plant Height, and Unmanned Aerial Vehicle Multispectral Imagery Using Machine Learning Methods to Estimate Canopy Nitrogen Weight in Corn. *Remote Sensing*, 13(16), 3105. https://doi.org/10.3390/rs13163105

Yuan, W. (2024). AriAplBud: An Aerial Multi-Growth Stage Apple Flower Bud Dataset for Agricultural Object Detection Benchmarking. *Data*, 9(2), 36. https://doi.org/10.3390/data9020036

Zhang, J., Zhou, X., Shen, D., Yu, Q., Yuan, L., & Dong, Y. (2024). Development of Spectral Features for Monitoring Rice Bacterial Leaf Blight Disease Using Broad-Band Remote Sensing Systems. *Phyton-International Journal of Experimental Botany*, 93(4), 745–762. https://doi.org/10.32604/phyton.2024.049734

Zhao, Y., Luo, W., Wang, Z., Zhang, G., Liu, J., Li, X., & Wang, Q. (2024). An oil and gas pipeline inspection UAV based on improved YOLOv7. *Measurement and Control*, 57(8), 1068–1086. https://doi.org/10.1177/00202940241230426

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