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A Bibliometric Analysis on The Use of Unmanned Aerial Vehicles: A Comparative Study of Russia and Türkiye

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Research Article

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Abstract

In recent years, rapid technological developments in information and communication technologies have increased the strategic value of UAVs. In this study, the development processes in terms of UAV technology in Turkey and Russia and their integration into the civil and defense sectors are analyzed comparatively. The two countries have pursued alternative strategies in terms of geographical, industrial, and strategic environments and have invested heavily in UAV technology. This study aims to contribute to scientific studies by determining thematic trends, technological areas, and strategic priorities in terms of UAV studies and applications in both countries. Using bibliometric analysis techniques, annual publications, keyword analysis, and trends in cooperation networks were analyzed in terms of information obtained from the Scopus database between 2005-2025. According to the analysis, Russia focuses on military use of UAV technology and has developed significant improvements in terms of swarm control systems, energy efficiency, and secure communication. Turkey, on the other hand, supports domestic production in the defense sector as well as in civilian applications such as agriculture, disaster management, and infrastructure monitoring, and focuses on 5G integration with artificial intelligence-based optimizations. In this study, individual approaches of Türkiye and Russia in terms of UAV technology and their value in terms of international defense and sustainable development were emphasized and it was determined that UAV technology has a widespread potential in terms of both scientific and applicable studies.

Keywords: Unmanned aerial vehicles, drones, bibliometric analysis, Turkiye, Russia.

İnsansız Hava Araçlarının Kullanımına İlişkin Bibliyometrik Analiz: Rusya ve Türkiye'nin Karşılaştırmalı Araştırması

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Özet

Son yıllarda bilgi ve iletişim teknolojilerindeki hızlı teknolojik gelişmeler, İHA'ların stratejik değerini artırmıştır. Bu çalışmada, Türkiye ve Rusya'da İHA teknolojisi açısından gelişim süreçleri ve bunların sivil ve savunma sektörlerine entegrasyonu karşılaştırmalı olarak analiz edilmiştir. İki ülke coğrafi, endüstriyel ve stratejik ortamlar açısından alternatif stratejiler izlemiş ve İHA teknolojisine büyük yatırımlar yapmıştır. Bu çalışma, her iki ülkede İHA çalışmaları ve uygulamaları açısından tematik eğilimleri, teknolojik alanları ve stratejik öncelikleri belirleyerek bilimsel çalışmalara katkıda bulunmayı amaçlamaktadır. Bibliyometrik analiz tekniği kullanılarak, 2005-2025 yılları arasında Scopus veri tabanından elde edilen bilgiler açısından yıllık yayınlar, anahtar kelime analizi ve işbirliği ağlarındaki eğilimler analiz edilmiştir. Analize göre, Rusya'nın İHA teknolojisinin askeri kullanımına odaklandığı ve sürü kontrol sistemleri, enerji verimliliği ve güvenli iletişim açısından önemli iyileştirmeler geliştirdiği görülmektedir. Türkiye ise savunma sektörünün yanı sıra tarım, afet yönetimi ve altyapı izleme gibi sivil uygulamalarda yerli üretimi desteklemekte ve yapay zeka tabanlı optimizasyonlarla 5G entegrasyonuna odaklanmaktadır. Bu çalışmada, Türkiye ve Rusya'nın İHA teknolojisine ilişkin bireysel yaklaşımları ve uluslararası savunma ve sürdürülebilir kalkınma açısından değeri vurgulanmış olup, İHA teknolojisinin hem bilimsel hem de uygulanabilir çalışmalar açısından yaygın bir potansiyele sahip olduğu belirlenmiştir.

Anahtar Kelimeler: İnsansız hava araçları, dronlar, bibliyometrik analiz, Türkiye, Rusya.

1. Introduction

Rapid advances in information and communications technology over the past decade have immensely boosted the strategic value of unmanned aerial vehicles (UAVs). With no pilot and with provisions for autonomous and remotely operated use (Eisenbeiss, 2004; Kiss et al., 2024), these aerial platforms have changed civilian and defense use with ease, efficiency, and cost-effectiveness (Ayamga et al., 2021). Today, UAVs have numerous civilian uses such as agricultural use, infrastructure observation, and disaster management, and even in real-time intelligence, observation, scouting, and target accuracy in operations in the military (Abdelmaboud, 2021; De Rango et al., 2017; Elmokadem & Savkin, 2021; Telli et al., 2023). As seen in the ongoing conflict between Russia and Ukraine, the use of UAVs on modern battlefields has transformed operational capabilities for armies and significantly enhanced their value in the defense sector (Erceg et al., 2017). Despite that, UAVs have not been restricted to defense but have played an important role in scientific and industrial sectors (Sivakumar & TYJ, 2021). That confirms multi-purpose use potential for technology in UAVs and its value at a worldwide level.

Many countries in the world have significant investments in UAV technology in an attempt to make both civilian and defense problem-solving a reality. In such a scenario, Turkiye and Russia have emerged two significant players with contrasting geopolitical standings and industrial settings. With a specific consideration for its use in the military, Russia has developed cutting-edge technology in terms of decentralized swarm management, ultra-reliable low-latency communications, and blockchain in an attempt to enhance operational capabilities, particularly in hostile environments (Izhboldina & Lebedev, 2023; Kapitonov et al., 2017). Russia's effectiveness in utilizing its application of its use of military UAVs is backed through a robust technology base in intelligence, observation, and accuracy in targeting. On the other hand, state-of-the-art technology in efficiency in terms of information and energy distribution possesses effective alternatives for new forms of warfare (Abdelmaboud, 2021; Telli et al., 2023).

Similarly, Turkiye, in recent years, has developed immensely in technology in terms of UAVs. Turkey’s transition in this direction has been driven by the motive of reducing dependence on external sources in the defense sector and achieving self-sufficiency. Besides, civilian use of UAVs, too, have been discovered. With software and artificial intelligence-based network technology, Turkiye optimized performance in 5G communications, disaster management, agricultural use, and infrastructure observation (Abdulsalam et al., 2023; Yazici et al., 2023). Turkiye, which is situated in a high-risk zone for natural disasters, is a forerunner in developing new approaches for utilizing such technology in civilian operations and in disaster management. In such a scenario, use of UAVs comes out to be a multi-purpose tool in both civilian and defense sectors (Tahir et al., 2023).

This study highlights Russia and Turkiye's innovations in UAV technologies from a comparative perspective in the context of their operational applications and strategic priorities. By reviewing the existing literature in detail and analyzing current trends, the strengths and weaknesses of these two countries in UAV technologies and their future perspectives are evaluated. Also, the impact of UAVs, which plays a pivotal role in the defense industry, on civilian sectors are emphasized and the diverse dimensions of these technologies are discussed. Although there are studies that separately address the developments in the UAV field of Russia and Turkiye, comparative studies focusing on the integration of these two countries into defense as well as civilian applications are limited. This study aims to fill this gap in current literature by comprehensively examining the dual-use potential and strategic outcomes and effects of these technologies.

2. Background

UAVs have become cutting-edge systems with widespread use in technology and defense in a relatively short period of time. They function with no operators, working in an autonomous manner, and remotely, and their key strengths include minimizing danger to humans, continuity in operations, efficiency in terms of weight, and economy (Miller & Chadwick, 2018). These benefits have firmly positioned UAVs as important assets, specifically in regards to use in the military, for use in spying, observation, and real-time intelligence collection in an effort to target enemy locations and assess scenarios.

Advanced UAVs with guided ammunition have entered most nations' arsenal with capabilities for delivering pinpointed attack with minimum loss (Hemmati et al., 2023; Kotsemir, 2019). For instance, in the case of the Russia-Ukraine war, UAVs revolutionized military operations with new dimensions in observation and intervention processes(Horowitz and Fuhrmann 2014). Historically, UAV technology traces back to rudimentary examples like the explosive-laden balloons used in Venice in 1849 (Daly, 2025). Significant advancements followed during the World Wars, where UAVs were employed for reconnaissance and training (Gonzalez-Aguilera & Rodriguez-Gonzalvez, 2017). Today, UAVs serve

diverse functions ranging from air strikes to missile defense and border security.

Beyond military applications, UAVs have transformative potential in both scientific research and civilian use. With its adaptability and versatility, its use in infrastructure planning, agricultural use, and disaster management make it a transformation in such sectors. With 5G networks and software-defined networks, UAVs make operations efficient in commercial and logistic operations worldwide. For example, 5G-integrated networks for UAVs allow for increased communication between drones and optimized path planning, enhancing its use in commercial and defense-related logistically (Solomitckii et al., 2018; Ullah et al., 2020).

This global development situates Turkiye and Russia, both of whom have been actively investing in technology for UAVs, in a certain position. Turkiye and Russia have a complex and ever-evolving past, with a history of both confrontations and cooperation, including wars, territorial disputes, and shifting alliances. However, in the post-Cold War era, economic cooperation and regional security have become defining features of their interactions (Balta & Özel, 2021). Economic collaboration accelerated in the early 2000s, particularly with energy projects like the Blue Stream and TurkStream pipelines, which positioned Russia as a key supplier of natural gas to Turkiye (Sapmaz, 2023). Additionally, the Akkuyu Nuclear Power Plant symbolizes strategic partnerships between the two nations (Kıllıoğlu, 2023)

Despite these events, political contradictions can nevertheless be seen. There have been conflicting interests heightened through the Syrian civil war, with Turkiye supporting anti-regime groups and with Russia supporting the regime, with direct confrontations in areas of dispute (Köstem, 2021). Similarly, differences in Libya—where Russia backed General Haftar and Turkiye supported the Tripoli-based government—exemplify ongoing tensions in their foreign policy agendas (Bayhan et al., 2021).

In terms of UAV improvements, Russia's research focuses mostly on military applications, emphasizing swarm dynamics, decentralized control, and energy efficient path planning (Izhboldina & Lebedev, 2023). Technological developments like more steady low-latency communication (uRLLC) and blockchain integration enhance Russia's UAV operations, ensuring secure and more reliable data sharing in challenging environments (Kapitonov et al., 2017). Moreover, detection technology with artificial intelligence and remote sensing secure airspace, and range and source improvement through microwave radiation work towards extending range for UAV (Zhukov et al., 2017).

UAV development reflects both domestic and global aspirations — with a focus on integrating artificial intelligence and optimization techniques into UAV systems for 5G and beyond in Turkiye (Yazici et al., 2023). Turkiye's improvements in its native platforms such as Bayraktar TB2 and ANKA have proven successful in countries such as: Syria, Libya, and Nagorno-Karabakh. Military, civilian, and commercial requirements have been addressed through these technologies, with use in precision agriculture, infrastructure observation, and disaster management (Abdulsalam et al., 2023). Also, Turkiye's geographical structure and agricultural potential position UAVs as essential for improving productivity in tasks such as crop monitoring and yield estimation (Uysal et al., 2015)

As a result, Turkiye and Russia's investments in technology for UAVs says a lot about its worth in modern warfare and overall usage. Energy efficiency, real-time processing, and technological versatility are areas that must see ongoing innovation. All these breakthroughs highlight a lot about each country's personal concerns and present an illustration of the role of UAVs in redefining modern trends in international security areas.

3. Methodology

Bibliometric analysis is a general tool used to examine the scientific environment in a specific field in terms of publications, keywords, collaborations, and trends over the years. These analyses cover both quantitative and qualitative data, allowing for a comprehensive assessment of the scientific output of the field. Thanks to bibliometric analysis methods, important elements such as fundamental studies, most cited articles, influential authors, and leading research institutions in the relevant field can be determined. These analyses, which reveal research trends by examining the distribution of publications over the years, visualize the frequency and common use of keywords with network structures, and clarify the relationship between the topics. It also determines the basic themes and their subcategories through conceptual maps and presents the collaboration structure between authors and institutions in the form of collaboration networks. Within the scope of this study, the trends in the technological and strategic approaches of Turkey and Russia in the field of unmanned aerial vehicles (UAVs) were comprehensively examined using these analysis methods. Both countries make significant contributions in terms of UAV technologies and strategic applications on a global scale. Therefore, the bibliometric methods and visual tools used play a critical role in presenting the historical development,

current status, and potential future directions of the relevant field systematically and understandably.

Data preprocessing constitutes an important basis for any bibliometric analysis and text mining. First, variation in keyword forms, synonyms, and abbreviations have been addressed in this study in an effort to make the dataset uniformed. Names of authors have also been checked in an effort to map intellectually accurately. In this study, similar keywords have been merged, singular and plural forms have been normalized, and no variation in name of authors have been encountered. All these processes count in providing strong results and in curving any kind of noise in bibliometric studies (Zupic & Čater, 2015).

This study utilized a tool, namely, Bibliometrix (Aria & Cuccurullo, 2017), a proven tool for use in bibliometric analysis, and its friendly companion tool, Biblioshiny. We chose to use Bibliometrix for its ease in providing in-depth analysis of bibliometric information. Those features include keyword mapping, collaboration networks, and theme development. We chose to use the Scopus database for its multidisciplinary and aptitude for use in required bibliometric analysis (Mongeon & Paul-Hus, 2016). By using these tools, we were able to perform in depth analyses of publication trends, keyword frequencies, and collaborative networks.

The flowchart (Figure 1) highlights the methodological steps which are undertaken in this study. That capsulates the process starting from initial data extraction to advanced bibliometric analyses. The flowchart highlights the number of documents retrieved and the systematic process used to conduct this research. These processes included formulating correct search queries, well-refining the dataset through given filters, and performing manual screenings to ensure steady relevance level.

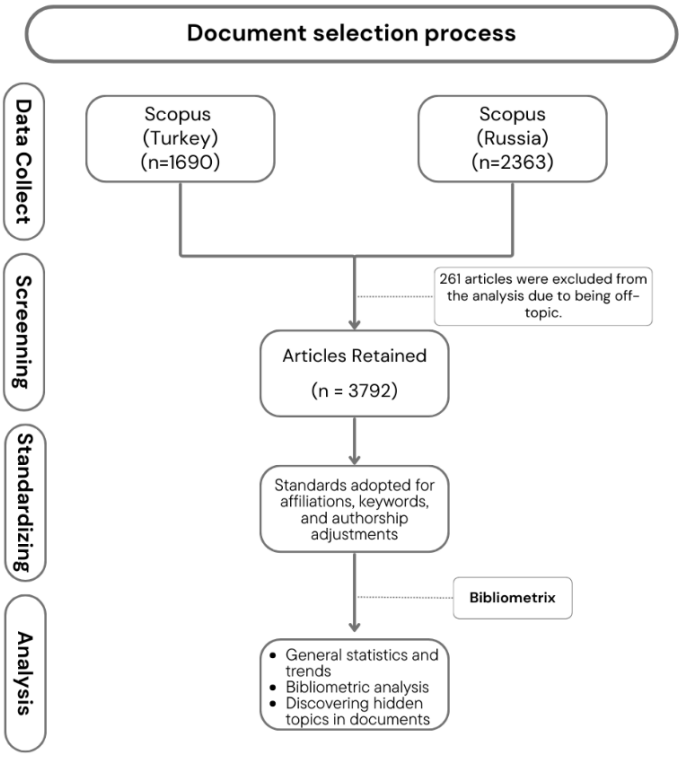


Figure 1. Flowchart of the Methodological Steps in Bibliometric Analysis.

3.1. Bibliographic Base

In order to find research trends, technology advancement, and strategic agenda regarding unmanned aerial vehicles (UAVs) in Turkiye and Russia, we searched publication histories between 2005 and 2025. Scopus was selected as the primary bibliographic database because of its wide diverse coverage and valuable indexing capabilities. Scopus is known well as a trustworthy tool for bibliometric studies, and it provides consistent and comprehensive access to literature (Elsevier, 2020).

3.2. Bibliographic Base Search Strategy and Screening Records

Queries were carefully constructed to capture publications explicitly associated with UAVs while ensuring precision and relevance. The search queries targeted publications in English to maintain consistency and focused on scientific contributions explicitly related to Russia and Turkiye. The detailed queries (Table 1) were structured as follows.

The inclusion of a specific timeframe (2005–2025) ensured that the analysis captured two decades of

research activity, reflecting long term trends and recent improvements. The focus on English-language publications enhanced comparability and reduced linguistic inconsistencies.

After retrieving the datasets, the records underwent multiple refinement steps:

1. ***Filtering***: Initial filtering excluded non research articles, that is, editorials, book chapters, and conference abstracts, to include only peer reviewed scientific contributions.

2. ***Manual screening***: Titles and abstracts were screened to verify the relevance of every publication. Entries that were not related to UAVs or not directly connected with either Russian or Turkish research were excluded.

3. *Data Cleaning:* Standardized terminology was applied to keywords, and author affiliations were checked for potential inconsistencies to improve accuracy.

The datasets extracted from Scopus were processed using the package Bibliometrix and its tool Biblioshiny. These tools enabled the generation of visualizations such as:

1. *Annual Scientific Production:* Identifying trends in publication volume over the specified timeframe.

2. *Keyword Co-occurrence Networks:* Mapping the relationships between frequently used terms.

3. *Collaboration Networks:* Depicting institutional and international research partnerships.

4. *Thematic Evolution:* Highlighting emerging research topics and their progression.

5. *Conceptual Structure Maps:* Visualizing clusters of research focus areas.

The results were further refined by manually screening retrieved records to exclude irrelevant entries. The inclusion of only English-language publications may exclude regionally significant research published in other languages. Additionally, the study focuses solely on UAV research explicitly attributed to Russia and Turkiye, potentially overlooking collaborative works that are not directly affiliated with these countries.

To account for the differing research dynamics in Russia and Turkiye, the analysis is structured into two distinct sections. Each country's contributions are assessed individually, followed by a comparative evaluation of developments, trends, and potential. This approach ensures a nuanced understanding of UAV research trends in both nations.

Table 1. Detailed research query

Country	Query	Description
Russia	*TITLE-ABS-KEY ("UAV" OR "unmanned aerial vehicle" OR "military drone" OR "defense drone" OR "combat drone") AND PUBYEAR > 2004 AND PUBYEAR < 2026 AND (LIMIT-TO (AFFILCOUNTRY , "Russian Federation")) AND (LIMIT-TO (LANGUAGE , "English"))*	This query specifically searched for publications containing terms such as "UAV," "unmanned aerial vehicle," "military drone," "defense drone," or "combat drone" in the title, abstract, or keywords. It restricted the results to articles affiliated with the Russian Federation and published in English between 2005 and 2025.
Türkiye	*TITLE-ABS-KEY ("UAV" OR "unmanned aerial vehicle" OR "military drone" OR "defense drone" OR "combat drone") AND PUBYEAR > 2004 AND PUBYEAR < 2026 AND (LIMIT-TO (AFFILCOUNTRY , "Turkey")) AND (LIMIT-TO (LANGUAGE , "English"))*	Similarly, this query was designed to retrieve publications associated with UAV research in Turkiye, applying the same terms and timeframe as the Russian query while limiting the results to Turkish affiliations

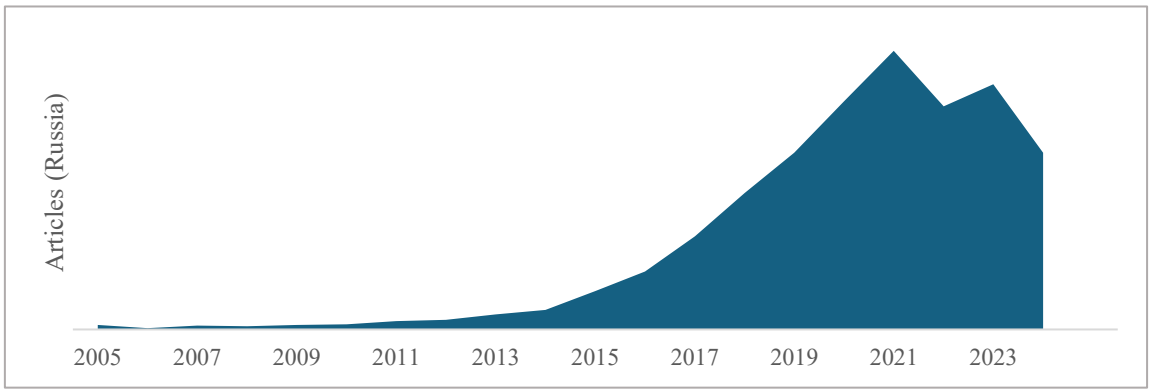
4. Analysis and Results

Given that Turkey and Russia exhibit different technological and strategic dynamics, their UAV-related data and analyses are addressed separately. This section presents the developments in UAV technologies for each country, accompanied by relevant bibliometric findings and thematic insights.

Figure 2 (a) shows from 2005 to around 2010 that the number of published scientific articles remained relatively low and stable. There was little change in the number of publications during this period. This phase likely reflects the nascent stage of UAV research and development in Russia, where foundational technologies and initial exploratory studies were being established.

Starting around 2011, there is a significant and steady increase in the number of articles published annually. This trend peaks around 2020 or 2021, showing the highest annual production. This steep curve indicates heightened interest, with Russia focusing on UAV applications in military, agriculture, and environmental sectors. Increased research activity is linked to developments in artificial intelligence, hyperspectral imaging and IoT applications in UAV systems, such as studies Lu et al. (2023) and Podlesnykh et al. (2024).

a) Russia



b) Turkiye

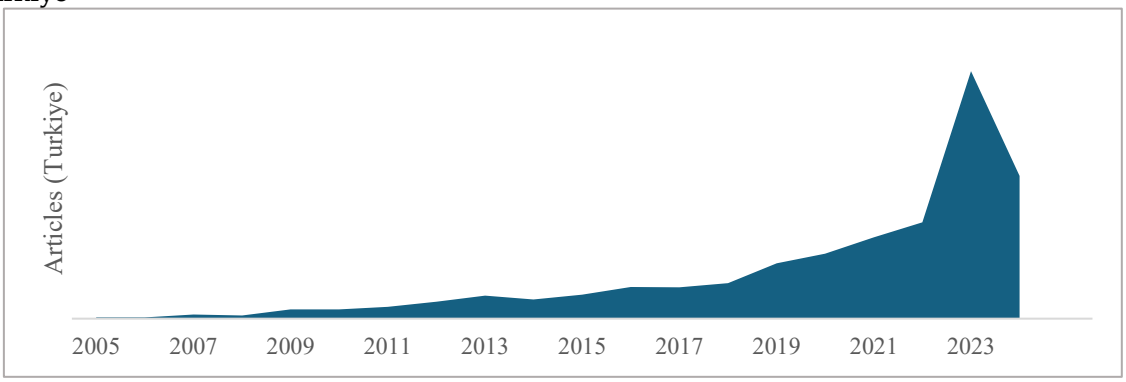


Figure 2. Annual Publication Trends in UAV Research for Russia and Turkey (2005-2025).

Scientific production in UAV research peaked in 2021, followed by a gradual decline in 2022 and 2023, likely due to topic saturation and emerging new research fields such as 5G communications. Causes for the decline are possible due to saturation in research topics, other more global constraints such as COVID-19, and possibly new priority interests in communications research with the latest systems like 5G and NOMA VLC systems. This shift indicates a transition from basic exploratory research to more application-oriented UAV studies. This trend indicates a change in focus from basic to applied research on UAVs.

Figure 2 (b) shows a significant increase in Turkiye's studies on UAV and drone technologies after 2015. The increase observed in UAV and drone technologies in Turkiye after 2015 can be associated with multiple internal and external dynamics. Following 2016, Turkey intensified efforts to reduce external defense dependency, leading to increased investments in both military and civilian UAV applications.

The increase after 2020 can be explained by the innovative needs brought about by the pandemic Mohsan et al. (2022) and the acceleration of the integration of advanced technologies such as artificial intelligence with UAVs. Increasing security threats and cross-border operations in Turkiye have increased the importance of military UAVs. Strategic investments in defense and R&D initiatives aimed at both military and civilian UAV applications significantly accelerated scientific output in the field. The graph confirms that UAV technology is rapidly developing, multidisciplinary, and application-oriented field in the literature, while also highlighting the strategic importance of growth in this field.

"Antennas" is the most frequently occurring keyword with 1,188 occurrences (Figure 3 (a)). This indicates its centrality in UAV research, particularly in enhancing communication, navigation, and sensing capabilities. Remote Sensing" appears second with 346 occurrences, pivotal in environmental monitoring, military operations, and navigation. Similar to Gyrichidi et al. (2024) work, "Air Navigation" (251 occurrences) emphasizes the importance of aviation technologies. "Aircraft Control" (245 occurrences) and together with "Aircraft Detection" (206 occurrences) emphasize automation, safety, and defense systems Keywords like "Robotics" (205 occurrences), "Computer Vision" (164 occurrences), and "Deep Learning" (156 occurrences) demonstrate the integration of AI in UAV applications.

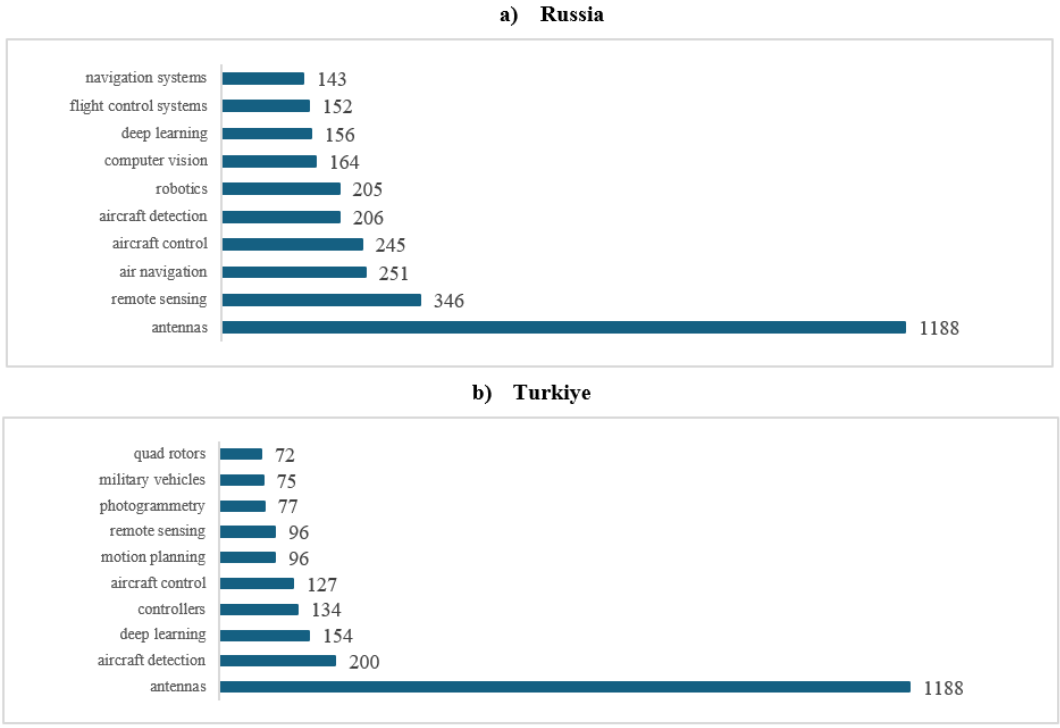


Figure 3. Frequency Distribution of Keywords in UAV Studies for Russia and Turkey.

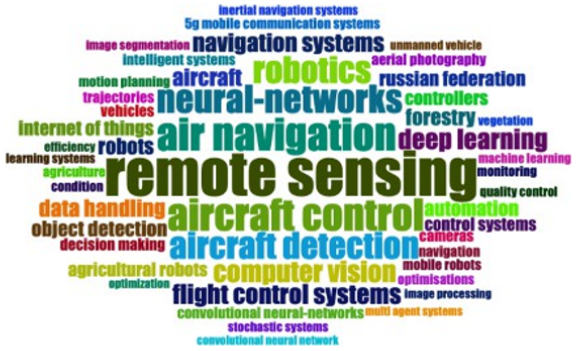
The prolific diversity of keywords, from AI-related topics to domain-specific terms, highlights a multidisciplinary approach. IoT and optimization technologies highlight the integration of connected systems and computational advancements in traditional UAV fields. Similar to the studies by Gyrichidi et al. (2024), Uzhinskiy (2023), and Zvezdina et al. (2024), keywords such as "Agricultural Robots," "Aerial Photography," and "Forestry" show practical applications in environmental, industrial, and aviation contexts. The prevalence of terms such as "Deep Learning," "Computer Vision," and "Convolutional Neural Networks" reflects the increasing adoption of AI-driven methodologies, as in the studies by Podlesnykh et al. (2024) and Uzhinskiy (2023).

Figure 3 (b) shows that Turkiye's research focuses on UAV and drone technologies, especially in areas such as "antennas" and "aircraft detection". This supports the strategic importance of UAVs in communication systems and security applications emphasized by Al-Turjman et al. (2020) and Yazici et al. (2023). This intense emphasis on antenna technologies is in line with Turkiye's goals of reducing external dependency on border security and the defense industry. Keywords such as "deep learning" and "motion planning" reveal the critical role of artificial intelligence and route planning technologies to improve the autonomous functions of UAVs. In addition, the interest observed in areas such as "photogrammetry" and "remote sensing" supports Turkiye's efforts to disseminate UAV technologies in civilian applications such as agriculture, environmental monitoring, and disaster management.

Smaller terms like "multi-agent systems" and "control systems" suggest areas where research is still growing but holds potential for future breakthroughs (Figure 4(a)). Deep Learning, Optimizations, and Learning Systems show increased relevance, marking a shift towards AI and optimization techniques. Keywords like "Kalman Filters," "Control Systems," and "Navigation" show spikes, likely due to breakthroughs or project-focused research.

The weight of terms such as "antennas" and "aircraft detection" in the word cloud in Figure 4 (b) shows that Turkiye focuses on communication infrastructure and detection systems in UAV technologies. While Ullah, Al-Turjman, & Mostarda (2020) and Yazici et al. (2023) emphasize the critical role of these technologies in in- creasing the operational effectiveness of UAVs, Zaid et al. (2024) state that artificial intelligence-based detection systems provide strategic advantage, especially in military operations. In addition, the prominence of concepts such as "deep learning" and "motion planning" reflects the increasing work on algorithms that support the autonomous functions of UAVs. In addition, the keywords "photogrammetry" and "remote sensing" indicate that the use of UAVs in agricultural and environmental monitoring applications is becoming widespread, in line with studies such as Uysal et al. (2015) and Aslan et al. (2022). According to these data, it has been observed that Turkiye gives strategic priority to communication and artificial intelligence-based innovations in UAV research focusing on both defense and civilian applications.

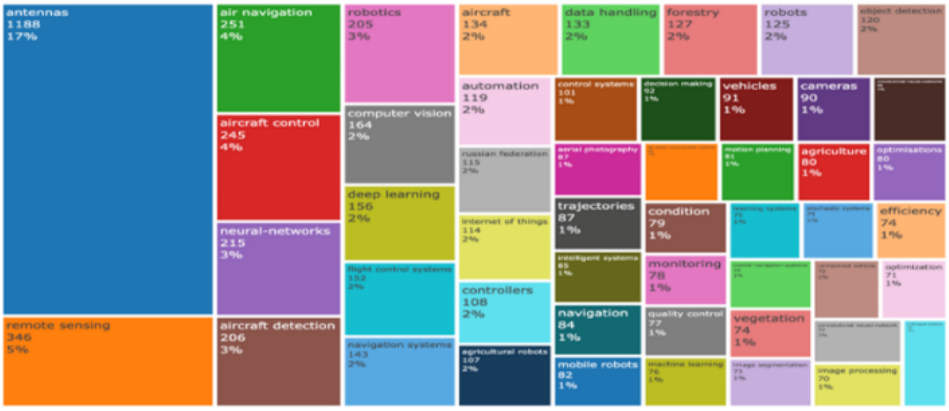
a) Russia



b) Türkiye

Figure 4. Keyword Cloud Representation Highlighting Research Focus Areas.

a) Russia



b) Turkiye

Figure 5. Keyword Occurrence Trends in UAV Research.

Foundational bold topics like “Algorithms” and “Vehicles” appeared early in UAV research. These subjects laid the groundwork for advancements in UAV systems, emphasizing the development of essential technologies like navigation, control, and sensing mechanisms. The early focus on these foundational topics helped establish critical pathways for integrating advanced technologies later, such as AI and IoT (Figure 5 (a)). Over time, these foundational studies were instrumental in transitioning the field towards more application-driven innovations in agriculture, defense, and environmental monitoring.

Figure 5 (b) clearly shows the focal points of research in the field of UAVs and is consistent with current trends in literature. For example, the fact that antenna technologies occupy the largest area in the graph with 22% supports the fact that communication infrastructure is a critical component for UAVs, as emphasized in studies such as Ullah, Al-Turjman, & Mostarda (2020) and Yazici et al. (2023). Similarly, the prominent presence of deep learning (4%) and machine learning (3%) categories reflects the increasing interest in using UAVs in artificial intelligence-based applications such as object detection, route optimization, and autonomous movement. The lower representation of environmental applications such as photogrammetry (2%) and forest monitoring (2%) show that the use of UAVs in precision agriculture and environmental protection areas is still in the development stage in Turkiye. While this situation arises as a result of Turkiye's concentration on UAVs in the defense industry Altan & Hacıoğlu (2020), it also points to the need to focus more on civil and environmental applications.

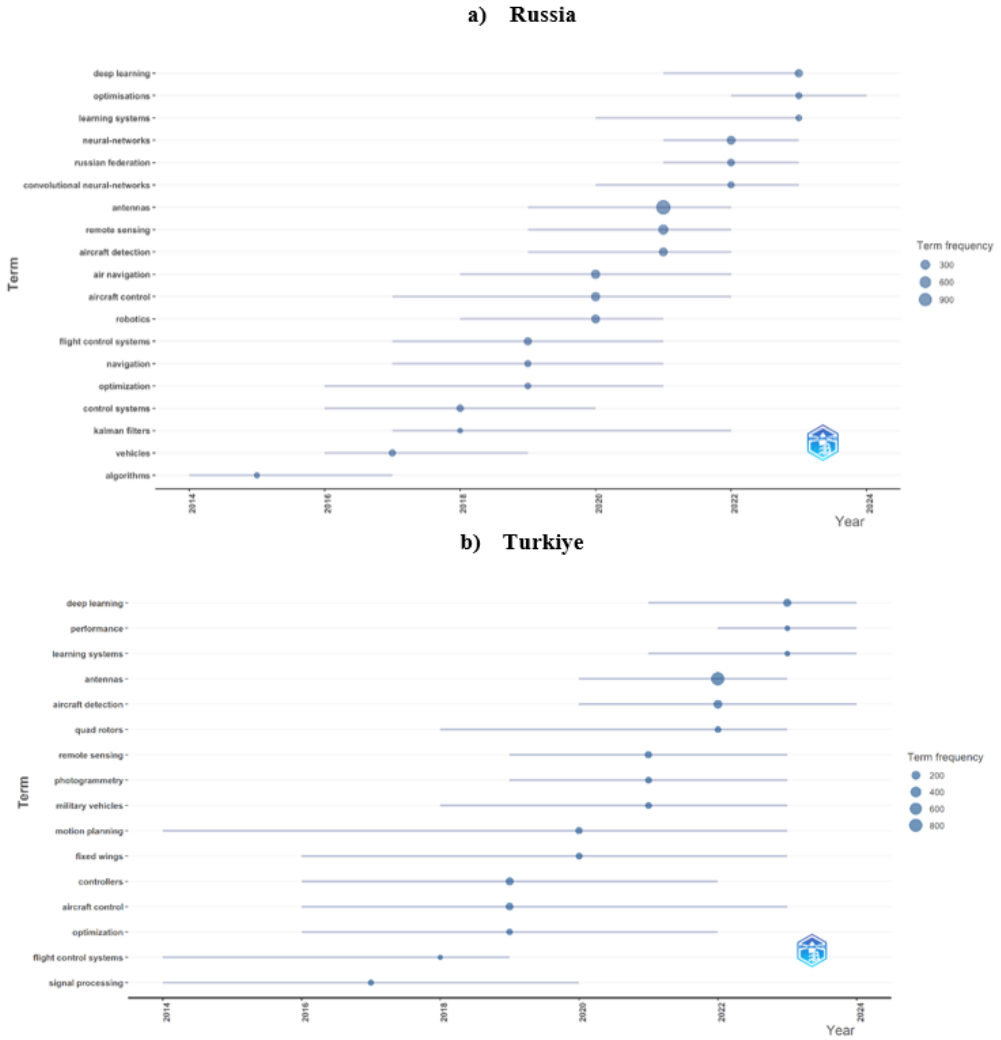


Figure 6. Thematic Trend Evolution in UAV-Related Studies.

The corelated relation between foundational engineering topics and applied AI technologies demonstrates a multidisciplinary approach to UAV research (Figure 6 (a)). Keywords like "Navigation Systems," "Aircraft Detection," and "Control Systems" exemplify the bridging of traditional engineering concepts with cutting-edge AI applications. This integration underscores the importance of interdisciplinary collaboration in advancing UAV capabilities across diverse domains.

Figure 6 (b) shows how exactly the main trends in UAV technologies have improved over the years. In particular, the frequency of the terms "antennas" and "aircraft detection" reflects Turkiye's heavy investments to make its UAVs more effective in the defense industry. Also, the rise of AI focused concepts such as "deep learning" and "motion planning" reveals a global trend toward developing the autonomous capabilities of UAVs, consistent with studies such as Abdulsalam et al. (2023) and Zaid et al. (2024).

The more prominent use of the term's "photogrammetry" and "remote sensing", especially after 2015, shows that Turkiye has begun to benefit

from these technologies in areas such as agriculture and environmental monitoring. On the other word, the frequency of concepts such as "military vehicles" and "controllers" confirms the critical importance of UAVs in military and border security applications emphasized by Altan & Hacıoğlu (2020) and Sözen & Craparo (2016).

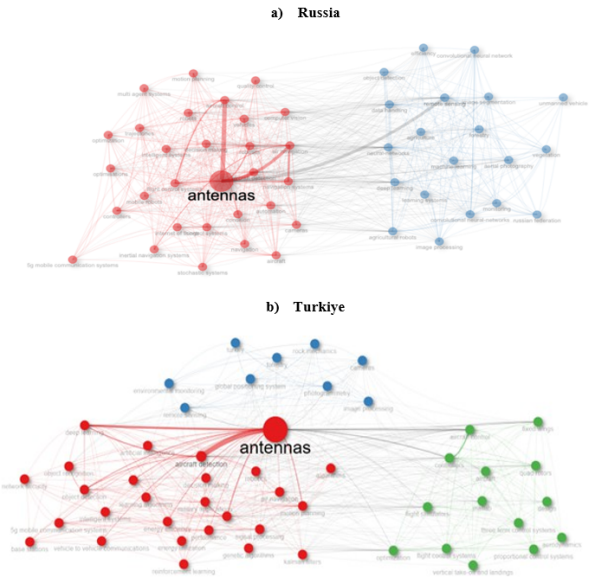


Figure 7. Conceptual Relationships and Clusters in UAV Research Keywords.

"Antennas," "Remote Sensing," and "Aircraft Detection" dominate research, indicating their importance in communication, sensing, and aviation (Figure 7 (a)). Topics like "Air Navigation" and "Robotics" hold foundational relevance but need further exploration (Figure 8 (a))

Figure 7 (b) shows the conceptual correlations and focal points in those studies exported. In this graph, the most important node is "antennas", reflecting the vital role of UAVs in the communication infrastructure. More concretely, in another paper authors underline the fact that antenna technologies are too critical to UAVs' data transfer performance over large networks (Ullah, Al-Turjman, & Mostarda (2020). The importance of the concepts related to "aircraft detection" is strengthened through the use of artificial intelligence and deep learning algorithms for object detection and security applications by Zaid et al. (2024) and Shayea et al. (2022). It is a strategic reflection of investments in UAVs by Turkiye for border security and military applications.

Green nodes such as "optimization" and "motion planning" represent solutions to increase the operational effectiveness of UAVs. The control algorithms which are developed by (Altan & Hacıoğlu, 2020) and the route planning approaches which are proposed by (Pehlivanoglu (2012) support innovative efforts in these prominent areas. Also, blue nodes such as "remote sensing" and "photogrammetry" shows how photogrammetry techniques discussed by Uysal et al. (2015) and Yaprak et al. (2018) provide an effective solution in environmental monitoring and precision agriculture applications. This indicates the potential of Turkiye to use UAVs in civil applications as well.

The wide network of connections in the graph reflects the different nature of UAV research. For example, the physical layer security techniques have been discussed by Hamamreh et al. (2019) are mostly linked to "signal processing" and are of utmost importance for ensuring data security in UAV communication. Also in the same manner, Malekloo et al. (2022) emphasized the use of UAVs in structural health monitoring systems by the evaluation of the non-interruptible connection of machine learning algorithms with the newly introduced "deep learning" node.

Also keywords like "antennas", "motion planning" and "military vehicles" in the "Basic Themes" section in Figure 8 (b) emphasize Turkiye's strategic priorities in improved UAV technologies. Al-Turjman et al. (2020) and Yazici et al. (2023) drew huge attention to the most important role of antenna technologies in the communication infrastructure and stated that this area is a fundamental research focus for UAVs. At the same time, some studies on "motion planning", aligned with studies such as Pehlivanoglu (2012) and Altan & Hacıoğlu (2020) shows the importance of auto-path optimization and stability in the realization of autonomous missions. The theme of "military vehicles" reflects Turkiye's strong investments in the defense industry and its technological independence goals in this area.

"Niche Themes", "aircraft detection", "deep learning" and "remote sensing" focus on advanced technologies Abdulsalam et al. (2023) and Ullah, Al-Turjman, & Mostarda (2020) have demonstrated how deep learning algorithms improve the autonomous functions of UAVs in applications such as object detection and environmental monitoring. This situation overlaps with Turkiye's efforts to increase its potential in civil applications such as agriculture and environmental management. Among the developing or declining themes, "controllers", "aircraft control" and "quad rotors" may indicate that previous studies on the development of basic systems are maturing. Altan & Hacıoğlu (2020) emphasized the im- portance of control algorithms in the stabilization and precision of UAVs and stated that these technologies have a critical role in defense and commercial applications.

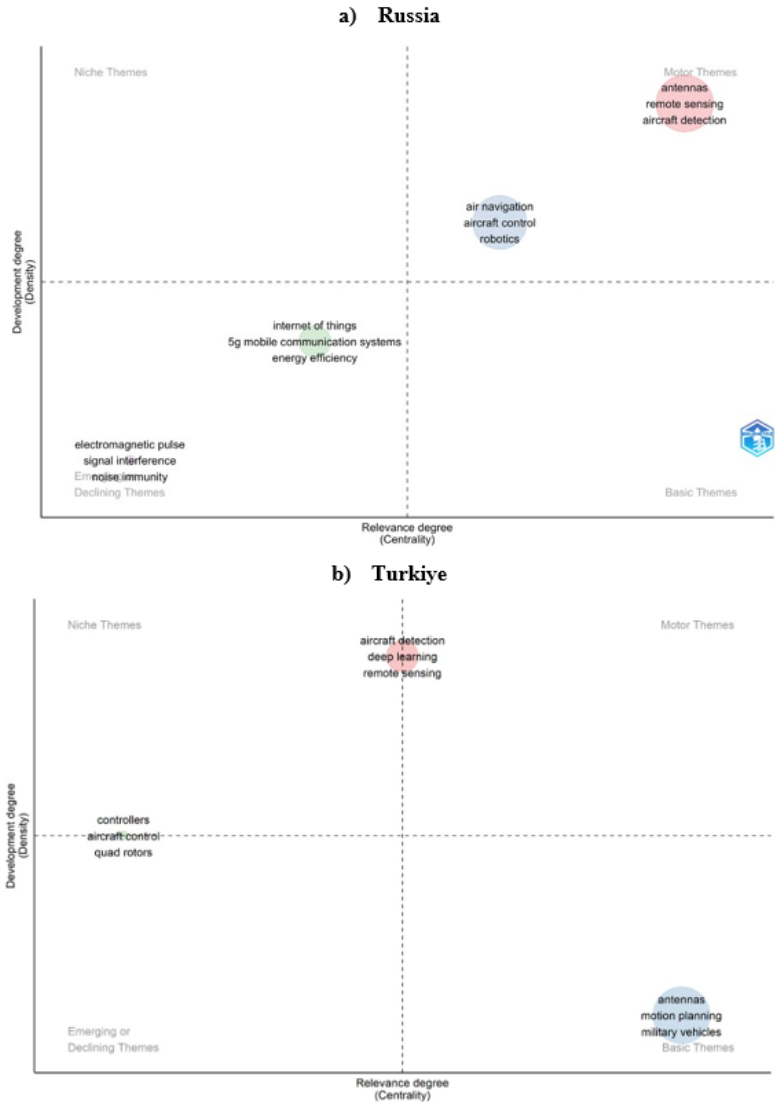


Figure 8. Centrality Analysis of Keywords in UAV Research Themes.

In Figure 9 (a), the Blue Cluster focuses on keywords such as Aircraft, Deep Learning, and Remote Sensing, and highlights AI-powered decision-making processes in aviation. The Pink Cluster focuses on computational techniques, drawing attention to optimization and intelligent systems. The Red Cluster addresses forestry, aerial photography, and remote sensing, and reflects environmental monitoring applications. The Green Cluster includes IoT and 5G mobile communication systems, which symbolize the advances in connectivity technologies, in line with the Ma et al. (2023) study. According to Dimensional Importance, it represents a wide range from environmental and sensing applications to AI, automation, and IoT, with a rate of 16.75% on the horizontal axis. The vertical axis reflects the progress from basic research to advanced technologies, with a rate of 6.72%. Under the heading of Key Trends, methods such as "Deep Learning" and "Optimizations" in AI and Automation emphasize the connections between different areas - technologies such as IoT and 5G show effective application areas in literature.

Figure 9 (b) examines the conceptual structure of the studies through the connections established between thematic clusters. Topics including “military vehicles”, “aircraft detection”, “deep learning” and “motion planning” in the blue area shows the most critical role of UAVs in the defense industry. Al-Turjman et al. (2020) and Yazici et al. (2023) have demonstrated the strategic importance of UAVs’ huge data transfer and object detection abilities in military operations. Also, studies such as Abdulsalam et al. (2023) and Zaid et al. (2024) have shown that deep learning algorithms have a very important place, especially in the development of various autonomous functions. Concepts such as “remote sensing” and “photogrammetry” in the same cluster reflect the relationship between civilian applications and military reconnaissance activities and connect to topics like agriculture and environmental monitoring which also addressed by Uysal et al. (2015) and Yaprak et al. (2018).

Figure 9. Conceptual Structure Mapping of UAV Research Themes and Subtopics.

Terms like "controllers," "flight control systems" and "optimization" seen in the red zone focus on the technical design and development of control mechanisms of UAVs. While Altan & Hacıoğlu (2020) focused on the contribution of control algorithms to UAV stability, Pehlivanoglu (2012) detailed the role of route optimization in increasing operational efficiency. The fact that words such as "Matlab" and "flight simulators" belong to this category implies the level of design, and simulation steps involved in control system development. The green area covers energy efficiency and communications infrastructure of UAV systems. Important words such as "5G mobile communication system", "intelligent systems" and "energy efficiency" justify the integration of communications and energy management technologies into UAV systems, investigated by Alshaibani et al. (2022) and Hamamreh et al. (2019). In addition, the presence of the term "vehicle-to-vehicle communications" shows the potential of UAVs in collaborative systems.

Based on the bibliometric analyses conducted, the study identifies several key findings. Both Turkey and Russia have demonstrated notable growth in UAV-related scientific output, with Turkey's research activity significantly accelerating after 2016, driven by geopolitical challenges and strategic objectives aimed at achieving defense independence. In contrast, Russia maintained a steadier growth trajectory, with an early emphasis on communication technologies. Strategic differences between the two countries are evident: Turkey's research increasingly focuses on the integration of artificial intelligence, 5G networks, and dual-use military and civilian applications, while Russia concentrates on strengthening communication infrastructure and enhancing operational precision. Additionally, emerging technological themes such as deep learning, motion planning, and environmental monitoring are reshaping the UAV research landscape in both contexts. Collaboration network analyses further reveal that although domestic partnerships dominate in both countries, Turkey exhibits broader international engagement, indicating a more globally oriented research approach compared to Russia.

5. Discussion and Conclusion

This research establishes Turkiye and Russia's technological development gaps, technological advancement, strategic aims, and industries' application of UAVs. Even with both nations' considerable efforts in studying UAVs, the both of them have moved through a path under a disparate reality of national capabilities, national aspirations, and geopolitics.

Russia nailed a leading position in military UAV technologies, they focus on swarm control systems, ultra-reliable low-latency communication (uRLLC), and energy-efficient designs (Izhboldina and Lebedev 2023; Kapitonov et al. 2017). Such development cycle aligns with Russia's defense-oriented strategy for secure data transfer and increased battlefield capability. The accent of words such as "antennas" and "remote sensing" in Russian UAV studies highlights how critical it is for it to make communication security, airspace monitoring, and operational precision priorities (Zhukov et al. 2017). Also, the saturation of research outputs after 2021 (Podlesnykh et al. 2024) may indicate that Russia has shifted its focus or that innovations in this area have reached a stage of diminishing returns.

However, Turkiye has managed to integrate UAV technologies into a two faceted approach of the military and civilian sides. Adding artificial intelligence, 5G networks, and optimisation methods, it has developed multifunctional platforms such as Bayraktar TB2 and ANKA. These platforms are deployed for various purposes like disaster response, agriculture, and infrastructure monitoring (Abdulsalam et al., 2023; Yazici et al., 2023). The significant hype in UAV related publications after 2016 is directly related to Turkiye's response to geopolitical challenges and its goal of technological independence in the defense industry. However, despite the interdisciplinary focus, Turkiye's research on energy efficiency and control mechanisms is relatively limited, indicating that there is room for further development (Altan & Hacıoğlu, 2020; Uysal et al., 2015).

In competition between both countries in technological capabilities in such defense technology areas such as energy management and swarm management and general sectors of general research in comparison with Turkiye's success in developing state-of-the-art technology in artificial intelligence and deep learning for civilian and defense use, reflects inner and geopolitical requirements in technological development. Turkiye's growing use of civilian sectors such as agricultural yields and environment observation in comparison with a practically purely defense-related orientation in Russia and reflects competing future conceptions for UAV technology (Gyrichidi et al. 2024; Tahir et al. 2023).

The findings of this work have implications for international development of UAVs, in a larger context, too. Russia can reorient its direction of work towards civilian use of its capabilities in secure and efficient technology and contribute towards worldwide concerns such as disaster management or climate change, for instance. Turkiye, for its part, can develop its technological base through filling gaps in basic control and efficiency in terms of energy and become a developing world pioneer in terms of UAV technology.

Both countries have, in conclusion, been remarkably successful in terms of UAV-related R&D work. Wherein its overall orientation is monofocal in terms of its orientation towards industries and sectors, Turkiye's orientation is multidimensional and balanced in terms of its overall orientation towards sectors and industries. By overcoming its weaknesses discussed and taking its cross-sectoral utilizations, Russia and Turkiye will not only maintain its leadership in terms of UAV technology but contribute towards developing secure and sustainable worldwide networks, too.

Future research could extend the findings of this study by focusing on cross-national collaboration networks, technology transfer mechanisms, and the influence of emerging fields such as AI-driven swarm management on the UAV ecosystem. It is important to acknowledge that the present findings are limited by the scope of the Scopus database and the selected publication timeframe; thus, future studies may benefit from incorporating additional data sources and employing longitudinal bibliometric tracking to capture evolving trends more comprehensively. Additionally, the divergent trajectories observed between Turkey and Russia in UAV development could be further explored through the lens of innovation system theories and national security policy frameworks, providing deeper theoretical insights into the underlying drivers of technological advancement in each country.

Authors' contributions

MA: Writing, editing. OO: Application, writing, editing. All author(s) read and approved the final manuscript.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

The author declares that they have no conflict of interest.

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