Turkish Journal of Geographic Information Systems
https://dergipark.org.tr/tr/pub/tucbis
e-ISSN 2687-5179

Implementing geographic information systems in academic paper search: A framework and case study: GISAPS

Halil Bölük*[1]

[1]Zonguldak Bulent Ecevit University, Caycuma Vocational School, Department of Mining and Mine Extraction, Zonguldak, Türkiye

Keywords
WebGIS,
Research Spatial Data,
GIS,
Academic Research

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Research Article
Received: 08/07/2024
Revised: 31/09/2024
Accepted: 06/09/2024
Published: 20/12/2024

Abstract

The Geographic Information Systems Academic Publication Search (GISAPS) project pioneers the integration of spatial data into academic research through a novel online platform. Utilizing Web Map Service (WMS) and advanced search functionalities, GISAPS enables efficient access and analysis of georeferenced academic publications. This paper outlines the development and capabilities of GISAPS, including experimental WMS layer integration for enhanced data visualization. Key contributions include facilitating interdisciplinary research, improving spatial data accessibility, and promoting open science through its open-source framework. GISAPS's implications for academia and the research community are significant, offering new avenues for data-driven research and education. Future enhancements aim to incorporate real-time data feeds, advanced spatial analysis tools, and mobile accessibility, ensuring GISAPS remains at the forefront of GIS technology in academic settings.

1. Introduction

The current academic landscape has been significantly influenced by the emergence of digital databases and search engines, which have revolutionized the way researchers access and retrieve scholarly information. Google Scholar and Microsoft Academic Search are two prominent academic search engines that have garnered significant attention due to their aspiration to compile a comprehensive index of present academic knowledge (Gusenbauer, 2019). These platforms have become essential tools for researchers, offering access to a vast array of scholarly documents available on the internet (Khabsa & Giles, 2014). The comprehensive nature of these search engines, particularly Google Scholar, with its estimated 389 million records, has positioned them as primary resources for academic literature searches (Orduña-Male, et al., 2015).

The shift towards open publishing and open educational resources has further transformed the academic landscape, accelerated changes and influencing the way scholarly information is disseminated and accessed (Scanlon, 2013). Additionally, the use of academic search engines has become integral to various fields of study, such as sustainability science, hydropower, and characterizing fitness landscapes (Kawabata, et al., 2010; Malan & Engelbrecht, 2013; Sasaki, et al., 2016). These platforms have enabled researchers to analyze citation networks, understand current research trends, and detect major sub-research fields within their respective domains (Kajikawa, et al., 2007; Sasaki, et al., 2016; Takata, et al., 2021).

However, concerns have been raised regarding the limitations of academic search engines. As noted by Li & Rainer (2022), while these engines are progressively becoming crucial in conducting systematic analyses, several usability issues have been reported by researchers. Specifically, these engines often struggle with user-friendliness and fail to accurately interpret complex queries, leading to incomplete or irrelevant search results. Furthermore, the limitations of their databases can hinder comprehensive reviews, making it challenging for researchers to retrieve all necessary literature efficiently. These challenges indicate that current academic search engines may not be fully optimized to support systematic reviews, thereby highlighting the need for improvements in their design and functionality. This study addresses some of these concerns by proposing a framework that integrates Geographic Information Systems (GIS) into academic paper search, aiming to enhance the search process's effectiveness and efficiency.

Considering these developments, it is evident that academic paper searches have been significantly

***Corresponding Author**
*(halil.boluk@beun.edu.tr) ORCID 0000-0002-9447-499X

Cite this article
Boluk, H. (2024). Implementing geographic information systems in academic paper search: A framework and case study: GISAPS. *Turkey Geographic Information Systems Journal*, 6(2), 59-66. https://doi.org/10.56130/tucbis.1512523

influenced by the proliferation of digital databases and search engines. While these platforms offer unprecedented access to scholarly information, concerns regarding their limitations and the quality of information they provide underscore the need for continued evaluation and improvement of academic search tools.

The challenges faced by location-based scientists in academic paper searches are significant and multifaceted. Information overload is a prominent issue, particularly for researchers dealing with spatial and location-based data. The vast amount of data available, including spatially relevant information, presents a challenge in filtering and identifying pertinent research. Additionally, the limitations of keyword-based searches further compound this issue, as the dynamic and evolving nature of location-based research topics can make it difficult to identify relevant keywords and phrases. This challenge is exacerbated by the need for efficient and effective search strategies to navigate the extensive databases and repositories of spatial and location-based scientific literature.

Additionally, the application of artificial intelligence (AI) in the process of searching and selecting literature, like within the PubMed database, is seen as a promising approach to overcome the issues associated with information excess and searches reliant on keywords. AI can assist in identifying relevant literature from the vast and continuously expanding repositories, aiding location-based scientists in efficiently accessing pertinent research. However, the scholarly use of information resources in the digital environment presents its own set of challenges, including time constraints, lack of awareness about available sources, and difficulty in finding information. These challenges are particularly relevant for location-based scientists who rely on specific and spatially oriented information resources.

Moreover, the need for querying specific messages from chat logs based on keyword expansion highlights the intricacies of information retrieval for location-based scientists, particularly in investigative and forensic contexts. This underscores the importance of developing advanced search techniques that can effectively handle location-specific queries and spatially relevant information. Overall, the challenges faced by location-based scientists in academic paper searches necessitate innovative approaches, such as AI-assisted literature search, to address information overload, keyword-based search limitations, and the unique requirements of spatial and location-based research.

These insights are supported by relevant literature. Cao et al. (2011) provide a thorough analysis of privacy-preserving multi-keyword ranked search over encrypted cloud data, which is relevant to the challenges of keyword-based searches and information overload. Additionally, Cai et al. (2020) discuss diversified spatial keyword search on RDF data, highlighting the importance of spatial semantics in location-based search Ma et al. (2022) offers insights into the use of AI in literature search and selection, particularly in the context of the PubMed database, addressing the challenges of information overload. Arshad & Ameen (2018) provide valuable perspectives on the scholarly use of information resources in the digital environment, emphasizing the challenges faced by scientists in accessing relevant literature. Finally, Xiao & Xu (2023) shed light on the complexities of querying specific messages from chat logs, which is relevant to the challenges of information retrieval for location-based scientists, especially in investigative and forensic contexts.

A (GIS) represents a digital framework combining both hardware and software components for the purpose of mapping, storing, and analyzing spatial information (Teixeira, 2016). It has been widely used in various fields such as public health for disease research (Cromley, 2003), transportation for managing and analyzing railway networks (Le & Tran, 2021), and environmental engineering for landfill design and management (Lukasheh, et al., 2001). GIS technology has also been integrated with other systems such as Building Information Modeling (BIM) to generate knowledge and intelligence (Liu, et al., 2017). Furthermore, GIS has shown potential for reducing social inequities and has become increasingly useful in many disciplines as it continues to develop and expand in capacity and applications (Kates & Coryn, 2021). The technology has also been recognized for its potential in health research and management in Africa (Tanser & Le Sueur, 2002).

To effectively integrate GIS in academic paper search, it is crucial to consider the benefits and barriers of using GIS in academic libraries. GIS can facilitate precise and informed delivery of services and resources, benefiting both library users and non-users (Mandel, et al., 2020). Additionally, GIS can be used as an automated space management system in academic libraries, which is crucial as collections grow and shift (Wade Bishop & Mandel, 2010). Furthermore, the evaluation and assessment of web GIS applications in academic libraries can provide valuable insights into information discovery and access (Kong, et al., 2015).

In academic research, the importance of spatial information and location-based search capabilities is increasingly recognized, particularly in disciplines that work with geographical data. Location-based search enables researchers to efficiently find studies focused on specific regions or geographic areas. For instance, in environmental engineering and geological engineering, understanding the spatial components of research is critical for assessing the applicability and impact of findings within a local context. In environmental engineering, this might involve identifying studies related to pollution control measures in a particular watershed. In geological engineering, location-based searches can be crucial for finding research on seismic activity in specific fault zones or assessing the potential for landslides in particular geographic regions.

This study aims to integrate spatial filtering and search capabilities into the academic paper search process, allowing researchers to more easily and quickly identify studies related to specific geographic areas. By reducing the challenges associated with finding studies containing geographic data, the proposed system enhances the efficiency of literature reviews and ensures that relevant research is more readily accessible. This approach addresses the limitations of current academic search engines by improving the discoverability of geographically relevant studies, thereby supporting a more comprehensive and effective review process in disciplines where location is a critical factor.

This study has been initiated to address the challenge of accessing academic publications that contain geographical data but are not discoverable through traditional keyword or title searches. The inspiration for integrating location-based search and filtering options—already prevalent in real estate, hotel bookings, car sales, and even second-hand goods applications—into academic research emerged from the realization of its potential utility in academic contexts. Initially designed for personal use, the concept has been expanded to incorporate global data, leading to the development of an integrated system compatible with academic publication databases. This innovation aims to enhance the accessibility of geographical data within academic research, broadening the scope and efficiency of academic literature search by leveraging GIS. The envisioned system not only facilitates the discovery of geographically relevant academic work beyond conventional search parameters but also sets a precedent for the application of location-based technology in scholarly research.

2. Method

To effectively capture the methodology and system architecture, the flow diagram illustrates the interactions and dependencies among the various technological components of the GISAPS system (Figure 1). It shows how client-side technologies like HTML, CSS, and JavaScript interface with server-side processes managed by PHP and MySQL, and how data flows seamlessly between these components. The diagram also demonstrates the role of geospatial visualization tools, such as OpenLayers, in enabling dynamic, interactive mapping features that are integral to the system's functionality. Together, these elements showcase the comprehensive and methodical approach taken to develop a tool that effectively combines traditional academic search functionalities with advanced GIS capabilities. The full implementation details and source code are available in the project's GitHub repository at https://github.com/haliljeo/gisaps.

2.1. System design and architecture

The GISAPS system was designed to provide a seamless integration of GIS technology with academic search functionalities. The system architecture is divided into client-side and server-side components to ensure scalability and robustness.

Client-Side Components: The user interface is designed using HTML, CSS, and JavaScript, providing a responsive and interactive experience. JavaScript libraries such as jQuery are employed to manage user inputs and interactions dynamically.

Server-Side Components: The server-side logic is handled by PHP, which processes user requests, interacts with the MySQL database, and manages data flow between the client-side and server-side. The choice of PHP and MySQL was based on their reliability, widespread use, and compatibility with various web technologies (Figure 1).

2.2. Data collection and integration

Data collection in GISAPS involves retrieving academic publication data from external sources, such as the ScienceDirect API. The data is then integrated into the GISAPS system with geographic metadata to support location-based searches.

ScienceDirect API is utilized to retrieve bibliographic metadata, such as the title, authors, abstract, keywords, and publication date of academic papers. While ScienceDirect provides comprehensive bibliographic data, it does not inherently include specific geospatial coordinates. To address this, users manually associate geographic locations with each publication using the GISAPS interface.

This process involves selecting a relevant point on the map that represents the geographical context or focus of the study. The selected location is then stored as part of the publication's metadata, enabling spatial filtering and visualization within the GISAPS system.API Interaction: jQuery and Ajax are used to send requests to the ScienceDirect API, retrieving relevant publication data in real-time. This data is structured in JSON format, which allows for easy manipulation and integration (Figure 2).

Geospatial Data Integration: Geographic metadata is manually assigned by users through an interactive map interface powered by the OpenLayers library. This step is crucial for ensuring that the publication data is accurately georeferenced, allowing for effective spatial filtering and visualization.

2.3. Visualization and user interaction

Visualization is a core component of GISAPS, enabling users to explore search results spatially through dynamic maps.

OpenLayers Integration: The OpenLayers library was chosen for its powerful mapping capabilities, allowing users to interact with geospatial data seamlessly. Search results are displayed on an interactive map, with options to zoom, pan, and click on markers for more information. When users click on a specific location marker, a pop-up window is generated using HTML and CSS, displaying detailed information about the selected publication. This feature enhances user interaction, providing a more engaging and informative search experience.

The GISAPS system represents a significant advancement in the integration of GIS technology with academic research tools. By systematically designing and evaluating the system, we have demonstrated its potential to enhance the accessibility and usability of geospatial data in academic contexts. The methodological framework outlined in this study provides a solid foundation for future developments and the continued evolution of GISAPS as a leading tool in academic research.

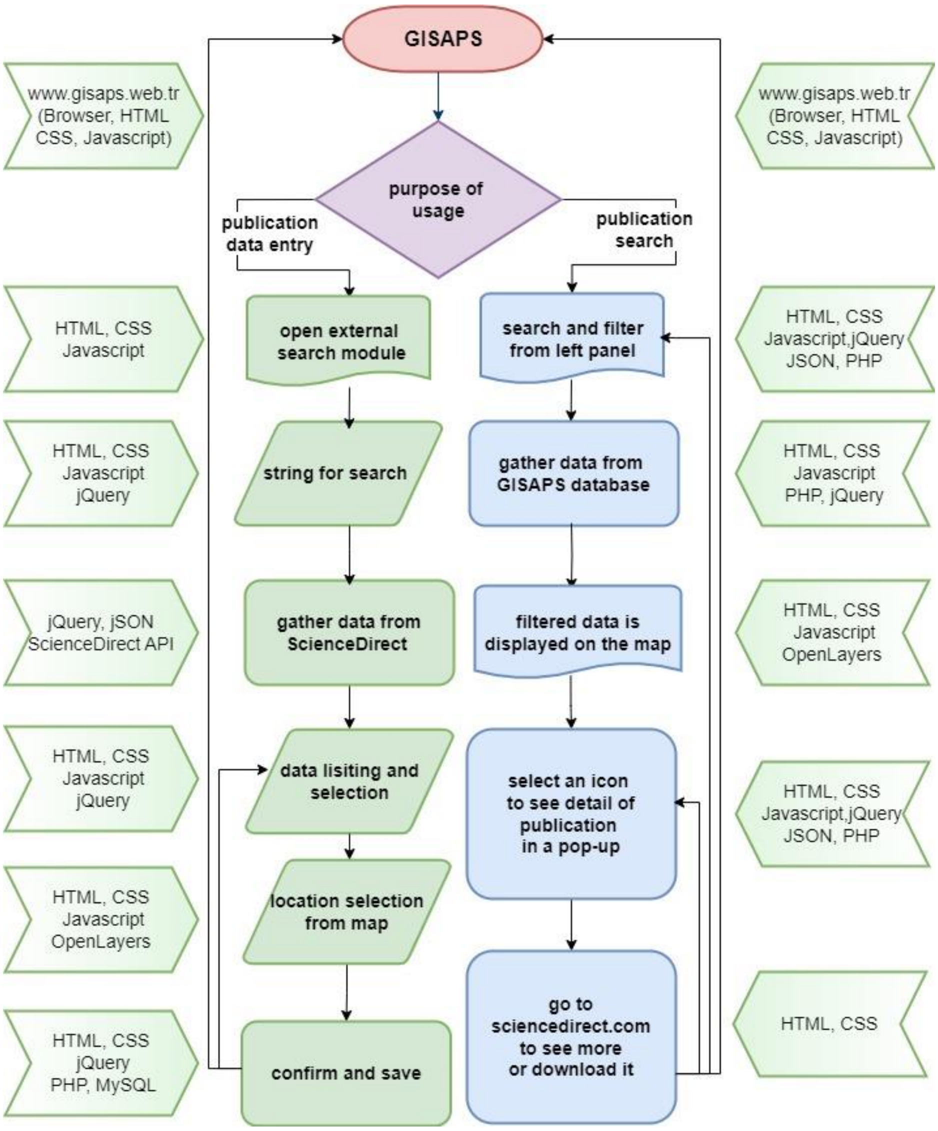

Figure 1. Flowchart for GISAPS all process with related technology

On the interactive map, each marker represents an academic publication that has been geospatially tagged. These markers are based on user-defined locations that reflect the geographical context of the research, rather than predefined coordinates from ScienceDirect. When a user clicks on a marker, details about the publication, such as the title, authors, and abstract, are displayed. This allows researchers to visualize the geographic distribution of academic research and explore studies relevant to specific locations.

The search module allows users to perform keyword searches across various fields of bibliographic data retrieved from ScienceDirect, such as title, abstract, and keywords. Additionally, users can apply spatial filters by selecting geographic areas on the map, which limits the search results to publications associated with those areas. The combination of keyword and spatial searches enables users to find publications that are both contextually relevant and geographically specific.

Figure 2: Example JSON data from ScienceDirect API response (search term: "istanbul,geology")

3. Results and Discussion

3.1. Exploring GISAPS: capabilities and customization opportunities

In the realm of digital mapping and GIS, Web Map Service (WMS) stands as a critical standard protocol developed by the Open Geospatial Consortium (OGC).

WMS enables the serving of georeferenced map images over the internet, which are generated from a map server using data from GIS databases. The beauty of WMS lies in its ability to facilitate the sharing and integration of spatial data from various national and international information providers, thereby enhancing the richness and utility of mapping applications. By supporting requests for map images in various formats, WMS allows users to access and interact with a vast array of spatial information without needing direct access to the underlying data sets.

Within the context of our project aimed at creating spatial layers for efficient searching of academic publications containing spatial data, the integration of WMS layers from both national and international providers offers a promising avenue to significantly expand our database's spatial capabilities. However, it's important to note that the current stage of the project has not yet fully implemented this feature. Despite this, we have experimentally integrated WMS into the system to demonstrate its potential.

The initial deployment and informal feedback from users indicate that GISAPS has the potential to significantly streamline the process of academic research by allowing users to conduct spatially-aware searches. By tagging publications with geographic data, GISAPS enables more targeted search results. Although formal user studies are planned for future phases, initial observations suggest that GISAPS could enhance the precision and relevance of academic searches by enabling researchers to easily locate studies relevant to specific geographic regions.

3.2. Advantages and limitations

GISAPS offers significant advantages by integrating Geographic Information Systems (GIS) into academic research searches. By visualizing geographic data on interactive maps, GISAPS allows researchers to better understand and analyze spatial distributions. This capability is particularly advantageous in disciplines like environmental engineering and geology, where reviewing all studies related to a specific geographic area via a map can be critical for assessing the applicability and local context of the research.

However, the effectiveness of GISAPS relies on the scope and quality of the data sources integrated into the system. Limited data coverage or poor data quality can negatively affect the accuracy and comprehensiveness of search results. Additionally, the integration of mapping libraries such as OpenLayers requires specific technical infrastructure, which can be a challenge for institutions with limited technical knowledge and resources. Finally, GISAPS's current inability to fully integrate real-time data feeds can be a limitation for users who require immediate, up-to-date information, especially in dynamic environmental events or emergency situations.

Looking forward, GISAPS presents several avenues for enhancement. Future developments may include the integration of advanced spatial analysis tools and real-time data feeds. These enhancements could provide researchers with more sophisticated capabilities for geospatial data analysis, making GISAPS a versatile tool for a wide range of academic disciplines.

3.3. Comparison with traditional search methods

Traditional search methods often rely on keyword matching, which can result in broad, sometimes irrelevant results. In contrast, GISAPS enhances search precision by leveraging spatial data through GIS technologies, enabling refined searches based on geographic location and spatial relationships. This capability allows researchers to find more relevant studies and better contextualize their findings within specific geographic areas.

Unlike traditional search platforms, which typically present text-based results, GISAPS incorporates interactive maps and spatial visualizations, providing a more intuitive way to explore data. This feature not only helps users understand geographic contexts but also supports more informed decision-making by highlighting spatial patterns that text alone cannot convey.

Furthermore, GISAPS offers customization options that traditional methods lack, allowing users to tailor their search experience to their specific spatial data needs. This flexibility enhances user experience and aligns search results more closely with individual research requirements.

While this study focuses on presenting the concept and feasibility of the GISAPS system, demonstrating its practical benefits to users could be the subject of future research. Such studies could provide empirical evidence on how GISAPS improves research efficiency and effectiveness compared to traditional search methods.

By integrating spatial search capabilities and interactive visualizations, GISAPS presents a significant advancement over traditional academic search engines. These features are particularly valuable in fields like environmental science, geography, and urban planning, where understanding spatial relationships is essential. The potential to expand these capabilities further underscores the value of GISAPS as a versatile tool for academic research.

3.4. Potential enhancements and future research directions

Integration of Advanced Spatial Analysis Tools: Enhancing GISAPS with more sophisticated spatial analysis capabilities, such as predictive modeling, terrain analysis, and spatial statistics, could significantly broaden its utility. This would allow users to not only search and visualize spatial data but also perform complex analyses within the same platform.

Incorporation of Real-Time Data Feeds: Integrating real-time data feeds, such as weather conditions, traffic information, or social media data, could make GISAPS a more dynamic and versatile tool. This would enable the analysis of spatial data in the context of current events, adding a new dimension to the research and decision-making processes.

Expansion of Data Sources and Interoperability: Expanding the range of data sources GISAPS can access, including more diverse spatial datasets and enhancing interoperability with other GIS software and data formats, would significantly increase its versatility and appeal to a broader audience.

Collaboration and Crowdsourcing Features: Implementing features that facilitate collaboration among users, such as shared projects, data annotation, and crowdsourcing capabilities, could transform GISAPS into a more interactive and community-driven platform. This would also enhance the quality and quantity of spatial data available.

Focus on Sustainability and Environmental Monitoring: Developing specialized modules or features focused on sustainability and environmental monitoring could position GISAPS as a key tool in climate change research, conservation efforts, and sustainable development projects.

Artificial Intelligence and Machine Learning Integration: Leveraging AI and machine learning algorithms to automate data processing, pattern recognition, and predictive analysis within GISAPS could enhance its efficiency and provide users with deeper insights into spatial datasets.

GISAPS's current capabilities set the stage for further enhancements that could significantly expand its utility. The potential integration of real-time data feeds and advanced spatial analysis tools represents just the beginning of what GISAPS could achieve. By continuously adapting to user feedback and technological advancements, GISAPS can evolve to meet the diverse and changing needs of the academic research community.

4. Conclusion

This study has highlighted the transformative potential of integrating GIS technology into the academic article search process through the development and application of the GISAPS framework (Figure 3). By combining traditional search methods with geospatial data capabilities, GISAPS significantly enhances the efficiency and accuracy of academic research. This integration not only facilitates more precise identification of relevant literature but also provides a spatial dimension to the research, which is invaluable for studies focused on geographic and environmental contexts.

The GISAPS framework serves as a powerful tool for academic researchers, enabling them to perform spatially-aware searches that are not possible with traditional academic search engines. This capability allows for a deeper understanding of the spatial distribution of research topics and their contextual relevance, thus broadening the scope of academic work. By supporting the identification of geographically relevant studies, GISAPS encourages interdisciplinary research and fosters new research opportunities across various fields, including environmental science, urban planning, and geography.

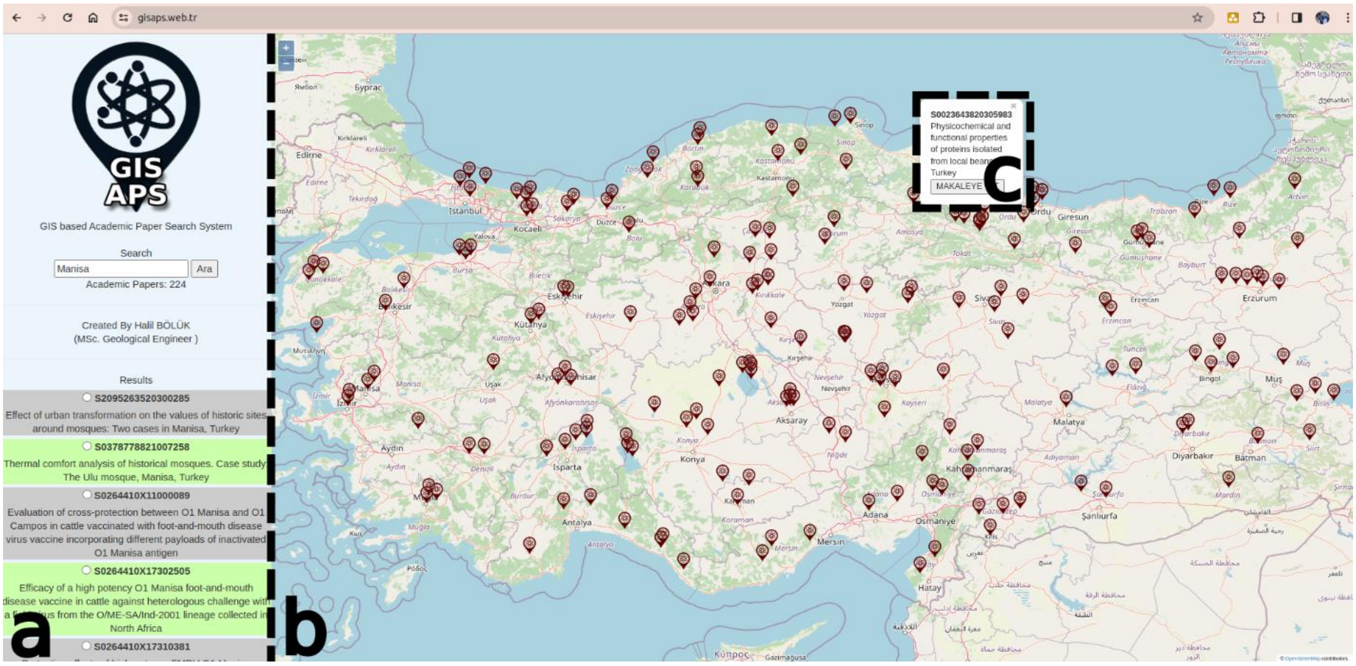

Figure 3. The screenshot of the main screen of the GISAPS application (www.gisaps.web.tr) and the sections that make up its main structure (a: search and result(s), b: map and viewing, c: popup window opened for detailed information).

Furthermore, this study reveals that the application of GIS technology in academic research extends beyond conventional geographic data analysis. GISAPS demonstrates how GIS can be used effectively for information access and management, making it a valuable asset for academic institutions. The integration of GIS with academic search processes not only enhances research productivity but also offers a platform for innovative educational applications, supporting a more holistic approach to learning and knowledge dissemination.

Looking ahead, the GISAPS framework presents several promising avenues for future development. Enhancements such as incorporating real-time data feeds, advanced spatial analysis tools, and machine learning capabilities could further augment its functionality, making it an even more versatile and powerful tool for academic research. These advancements would not only improve the system's ability to handle complex research queries but also provide researchers with the tools necessary to conduct more sophisticated analyses and gain deeper insights into their areas of study.

In conclusion, GISAPS exemplifies the potential of GIS technology to revolutionize the academic research process, offering a novel approach to accessing and managing academic knowledge. As the academic community continues to explore the possibilities of GIS and other emerging technologies, frameworks like GISAPS will play a crucial role in shaping the future of research and education. This study serves as a foundation for further exploration and innovation, inspiring future research and development efforts to harness the full potential of GIS in academia.

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