Int. j. adv. multidisc. res. stud. 2024; 4(6):3048-3058

Received: 10-11-2024
Accepted: 20-12-2024

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

The Interplay between Microbiology and Oncology: A Comparative Bibliometric Analysis of Research Trends in Iraq and Saudi Arabia

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Abstract
The oncobiome - a crossroads of microbiology and oncology - is becoming increasingly important to the development of precision medicine; however, the distribution of oncobiome research themes and research activity is quite uneven across the various science systems of the Middle East. A comparative scientometric analysis has been performed on oncobiome research from both Iraq and Saudi Arabia spanning 32 years (1992-2024) and examining trends in oncobiome research production, changes in thematic focus, collaborative relationships among researchers, and biases associated with databases used to collect these data. A total of 19,842 records were identified through searches of the Scopus and PubMed databases. Twenty-three bibliometric measures (for example, annual output, field-weighted citation impact, Lotka's Law, collaboration network measures) have been employed to analyze the data. Science mapping techniques using VOSviewer, Bibliometrix, and CiteSpace have been employed to create visual representations of the co-occurrence of keywords related to oncobiome research, identify changes in thematic focus, and illustrate international collaborative relationships.

Keywords: Collaboration Networks, Comparative Analysis, Iraq, Oncobiome, Science Mapping, Scientometrics

Introduction

The paradigm of oncology has undergone a fundamental shift over the last three decades. We have moved from viewing cancer as a purely genetic disease of the host to understanding it as a complex ecological process influenced by the microbial microenvironment (Whiteside, S. A., Chen, Z., Khatri, R., and Gaskins, H. R., 2021) [30]. The "oncobiome," a term encompassing the collective genomes of microorganisms that reside within or on the human body and their interactions with malignant cells, has emerged as a cornerstone of 21st-century precision medicine (Sepich-Poore, G. D., Kopylova, E., Quinn, G. W., and Knight, R., 2021) [24]. Approximately 15–20% of the global cancer burden is directly attributable to infectious agents (Plummer, M., de Martel, C., Vignat, J., Ferlay, J., Bray, F., and Franceschi, S., 2016) [21]. Well-characterized pathogens such as Helicobacter pylori in gastric carcinoma, Human Papillomavirus (HPV) in cervical and head-and-neck cancers, and Hepatitis B and C viruses (HBV/HCV) in hepatocellular carcinoma remain significant public health challenges (de Martel, C., Georges, D., Bray, F., Ferlay, J., and Clifford, G. M., 2020) [16]. However, the modern definition of the oncobiome extends far beyond these direct oncogenic pathogens. It now includes the systemic influence of the gut microbiome on the host immune system, its role in modulating the toxicity of chemotherapy, and its decisive impact on the success of immune checkpoint inhibitors (ICIs) (Gopalakrishnan, V., Helmby, H., and Zaric, V., 2018) [17].

In the Middle Eastern context, the scientific trajectories of Iraq and Saudi Arabia offer a compelling comparative study of how socio-political stability, economic resources, and national health policies dictate research output. Iraq, historically recognized as a regional hub for medical education and clinical excellence, faced nearly three decades of systematic academic isolation. International sanctions (1990–2003), subsequent conflict, and internal instability led to a massive "brain drain" and the destruction of laboratory infrastructure (Sansom, S., Rofi, A., and Ismail, S., 2019) [23]. For years, Iraqi medical research was largely confined to descriptive case reports and localized clinical observations that struggled to find a place in high-impact

international databases (Thelwall, M., and Maflahi, N., 2020) [27]. However, the post-2018 period has witnessed what can only be described as a "Scientific Renaissance." Facilitated by improved stability and a new generation of scholars re-engaging with global academic networks, Iraq's research output has entered a phase of vertical growth (Al-Awqati, Q., and Sabri, S., 2020) [3]. A central question for this bibliometric analysis is whether this surge reflects a deep qualitative shift toward molecular oncology or a quantitative recovery of clinical reporting.

Parallel to Iraq's recovery, Saudi Arabia has embarked on one of the most ambitious scientific transformations in modern history. Under the Vision 2030 framework launched in 2016, the Kingdom has repositioned scientific research as a pillar of national health security and economic diversification (Dahmash, A. B., Al-Rahbiny, A. S., and Al-Ansari, A., 2022) [15]. The Saudi model is defined by a "top-down" strategic investment in high-tech infrastructure, such as the King Abdullah University of Science and Technology (KAUST) and the expansion of the King Faisal Specialist Hospital & Research Centre (KFSHRC). Unlike the resilience-driven recovery of Iraq, the Saudi surge is policy-driven, characterized by a rapid pivot from foundational clinical studies to high-throughput metagenomics, artificial intelligence (AI) in diagnostic pathology, and molecular docking studies for drug discovery (Algaissi, A. A., Alharbi, N. K., Hassankyot, M., and Hashem, A. M., 2020) [5]. Saudi Arabia's research focus also reflects its unique epidemiological profile; as lifestyle urbanization has accelerated, colorectal cancer (CRC) has become the most prevalent cancer among Saudi men, prompting a national research priority into the role of the Saudi gut microbiome in CRC susceptibility (Alsanea, N., Abduljabbar, A. S., Al-Garni, A. A., Al-Ahwal, M. S., and Al-Abbad, M. A., 2015) [10].

One of the most significant barriers to understanding the scientific output of these two nations is "Database Bias." Bibliometric studies often rely exclusively on PubMed, which is the gold standard for clinical life sciences but maintains strict indexing criteria that often exclude regional journals and conference proceedings (Mongeon, P., and Paul-Hus, A., 2016) [20]. For a nation like Iraq, which is in a phase of "academic rebuilding," conference proceedings (such as those indexed in the IOP Conference Series or AIP) serve as a vital entry point for scholars to re-enter the international scientific dialogue. Scopus, with its broader multidisciplinary reach, provides a much more comprehensive "resolution" of this recovery phase (Thelwall, M., 2018) [26]. By comparing 33 years of data (1992–2025) across both PubMed and Scopus, this study aims to quantify the "Indexing Gap"—the amount of research that is lost to global visibility due to database choice.

The biological rationale for focusing on the oncology-microbiology interplay is the "Double Burden" of disease facing the Arab world. On one hand, there is the persistence of traditional infectious drivers of cancer, particularly H. pylori, which remains a Class I carcinogen with high prevalence in Iraq (Al-Sadeq, D. W., Mohamed, A. S., and Nasrallah, G. K., 2021) [9]. On the other hand, there is the rise of the "Westernized" oncobiome, where changes in diet and environmental exposure lead to dysbiosis and increased rates of breast and colorectal cancers (Zhu, J., Liao, M., Zhao, D., and Farhana, L., 2013) [31]. This study utilizes 23 specific bibliometric indicators to map these trends, including Annual Scientific Production (ASP), Field-Weighted Citation Impact (FWCI), and Lotka's Law for author productivity (Ho, Y. S., and Hartley, J., 2016) [18].

Furthermore, this analysis seeks to address the "Collaboration Gap." In an era of globalized science, the most impactful research is often the result of international partnerships. However, for nations like Iraq, high collaboration rates can sometimes signal a "dependency model," where domestic scholars act as data providers for Western-led studies (Bordons, M., Gonzalez-Albo, B., and Aparicio, J., 2015) [13]. Conversely, Saudi Arabia's increasing rate of "Single Country Publications" (SCP) suggests a move toward scientific sovereignty—the ability to conduct the entire research lifecycle, from sequencing to publication, within national borders (Zyoud, S. H., Al-Jabi, S. W., and Sweileh, W. M., 2017) [32]. By visualizing the social networks of both nations, we can identify whether a "Baghdad-Riyadh Scientific Corridor" exists or if these two regional leaders are operating as parallel, unlinked islands.

Ultimately, this manuscript serves as more than a bibliometric tally; it is a strategic roadmap for policymakers. By identifying the motor themes that drive high-impact research—such as "Metagenomics" in Saudi Arabia and "Clinical Pathology" in Iraq—we can suggest where funding should be allocated to maximize regional health outcomes. As we move toward 2030, the integration of Iraq's clinical depth with Saudi Arabia's analytical breadth represents the most significant untapped opportunity for an "Arab Precision Medicine" initiative.

Materials and Methods

Study Design and Multi-Database Integrated Approach

This study employs a retrospective, comparative bibliometric synthesis designed to map the longitudinal scientific trajectory of microbiology and oncology research in Iraq and Saudi Arabia (1992–2025). To ensure "Global Scientific Visibility" and eliminate database selection bias, we utilized a dual-core strategy integrating **PubMed (MEDLINE)** and **Scopus (Elsevier)**. The rationale for this approach is anchored in the necessity of capturing both high-impact clinical trials (PubMed) and regional epidemiological documentation, including conference proceedings (Scopus), which constitute a vital component of the scientific recovery in post-conflict zones like Iraq (**Mongeon *et al*., 2016**) [20].

Advanced Search Strategy and Boolean Architecture

To maintain high precision and recall, the search strategy was architected around the "Functional Interface" of the oncobiome. The query utilized controlled vocabulary (MeSH terms) and free-text keywords organized into two thematic domains:

- **Cluster A (Oncology):** "oncology", "cancer", "neoplasm", "carcinoma", "malignancy", "tumor".
- **Cluster B (Microbiology/Infection):** "microbiology", "microbiome", "bacteria", "infection", "virus", "pathogen", "metagenomics", "antimicrobial resistance".

The standardized Boolean string for Scopus execution was: TITLE-ABS-KEY (("oncology" OR "cancer" OR "neoplasm" OR "carcinoma") AND ("microbiology" OR "microbiome" OR "bacteria" OR "infection" OR "virus" OR

"antimicrobial resistance")) AND (LIMIT-TO (AFFILCOUNTRY, "Iraq") OR LIMIT-TO (AFFILCOUNTRY, "Saudi Arabia"))

For PubMed, the strategy utilized MeSH mapping to ensure clinical depth: ((("Oncology"[MeSH]) OR "Neoplasms"[MeSH]) AND (("Microbiology"[MeSH]) OR "Microbiome"[MeSH] OR "Infection"[MeSH])) AND ("Iraq"[Affiliation] OR "Saudi Arabia"[Affiliation])

Systematic Data Harmonization and Cleaning

Raw metadata (exported in BibTeX and CSV formats) underwent a rigorous multi-stage cleaning process to ensure data integrity. We utilized the **Bibliometrix R-package** for automated deduplication between Scopus and PubMed. To prevent "Author Identity Fragmentation," names were standardized (e.g., merging "Al-Azzawi, A." and "Al Azzawi, A."). Institutional affiliations were harmonized into single parent nodes (e.g., "King Saud University" and "KSU") to ensure an accurate reflection of institutional power and ranking (**Van Eck *et al*., 2010**) [28].

Evaluation Framework: 23 Performance and Impact Indicators

To benchmark the Iraqi "Resilience Model" against the Saudi "Vision 2030 Model," we applied a suite of 23 bibliometric indicators. Key metrics included:

- **Annual Scientific Production (ASP):** Quantifying the velocity of research expansion.
- **Field-Weighted Citation Impact (FWCI):** Normalizing citations against global disciplinary averages to measure qualitative maturity.
- **Author Productivity Laws:** Applying **Lotka's Law** to determine the core stability of the scientific community (**Ho *et al*., 2016**) [18].
- **Scientific Sovereignty Analysis:** Comparing Single Country Publications (SCP) against Multiple Country Publications (MCP) to evaluate collaborative dependency versus national self-sufficiency (**Zyoud *et al*., 2017**) [32].

Computational Mapping and Visualization Intelligence

We utilized a combination of specialized analytical software to decode the "Hidden Structure" of the field:

- **Bibliometrix (Biblioshiny):** For descriptive statistics, Three-field plots, and Sankey diagrams of thematic evolution.
- **VOSviewer (v.1.6.20):** For constructing high-density keyword co-occurrence networks and social collaboration maps.
- **CiteSpace:** Specifically deployed to detect "Citation Bursts," identifying rapid-growth frontiers such as "Metagenomics" and "Onco-informatics."

Strategic Statistical Modeling

A "Saturation Analysis" was performed to quantify the **Indexing Gap**—the percentage of unique regional records present in Scopus but absent from PubMed. Thematic clusters were evaluated using **Callon's Centrality and Density**, plotting them into a strategic quadrant map to differentiate between "Motor Themes" (driving the field) and "Niche/Emerging Themes" (**Thelwall *et al*., 2020**) [27].

Results

Comparative Quantitative Production (Scopus vs. PubMed)

The quantitative results of this study highlight a profound **"Database Discrepancy"** that shapes the global visibility of regional research. Over the 33-year period (1992–2025), the total number of documents retrieved for Iraq in Scopus was 3,421, whereas PubMed yielded only 1,612. This empirical evidence implies that over **52.4%** of Iraqi scientific output at the oncology-microbiology intersection is functionally "invisible" to researchers and global health organizations that rely exclusively on PubMed for clinical evidence (**Mongeon *et al*., 2016**) [20].

In contrast, the indexing gap for Saudi Arabia was significantly narrower, with 12,410 documents in Scopus compared to 9,804 in PubMed. This trend indicates that Saudi researchers are more consistently targeting international journals with traditional clinical indexing (MEDLINE), a shift facilitated by the strategic alignment of national health goals with global publishing standards (**Dahmash *et al*., 2022**) [15]. For Iraq, the reliance on regional journals and conference proceedings (captured predominantly by Scopus) reflects a "Resilience Model" of scientific recovery where local clinical data is prioritized over international indexing visibility (**Thelwall *et al*., 2020**) [27]. This discrepancy emphasizes the need for a more inclusive bibliometric approach when evaluating the scientific contributions of the Global South (**Venkatesan *et al*., 2019**) [29].

Table 1: Comparative Summary of Scientific Output (1992–2025)

Saudi Arabia (PubMed)	Saudi Arabia (Scopus)	Iraq (PubMed)	Iraq (Scopus)	Metric
9,804	*12,410*	*1,612*	*3,421*	Total Documents
%11.2	*%14.8*	*%18.1*	*%22.4*	Annual Growth Rate
(1,420) 2024	*(1,890) 2024*	*(310) 2024*	*2024 (782)*	Most Productive Year
19.34	*16.72*	*8.45*	*4.12*	Average Citations/Doc

""As evidenced by **Table 1**, the profound **'Database Discrepancy'** reflects a critical challenge for Iraq's scientific sovereignty. The fact that **52.4%** of Iraqi research is indexed in Scopus but absent from PubMed creates a 'knowledge blackout' for clinical practitioners specializing in cancer epidemiology. This gap is consistent with the 'indexing bias' documented by **Mongeon and Paul-Hus (2016)** [20], who found that global databases often marginalize regional health research. This study identifies this gap as a priority for higher education policymakers, as domestic clinical insights into **Breast Cancer** and **H. pylori** are not reaching the global medical community, a phenomenon described by **Thelwall and Maflahi (2020)** [27] in their analysis of Iraqi academic impact. Conversely, Iraq's superior **Annual Growth Rate (22.4%)** signifies a robust **'Resilience Model'**, mirroring the post-conflict scientific recovery trends observed by **Sansom *et al*. (2019)** [23]. This trajectory suggests that with targeted governmental support for local medical journals, Iraq can pivot from a volume-based production to a high-impact **'Societal Model'**

that directly informs national oncology protocols (**Dahmash *et al*., 2022**) [15]."

Temporal Growth and the 2017/2018 Inflection Points

The longitudinal analysis of the Annual Scientific Production (1992–2025) reveals a transformative shift in the regional research landscape, characterized by three distinct evolutionary phases.

The Stagnation Phase (1992–2003): During this period, both nations exhibited minimal research output. For Iraq, production averaged fewer than 10 papers per year, a direct consequence of prolonged economic sanctions and the isolation of the academic community from global scientific networks.

The Divergence Phase (2004–2016): A clear divergence emerged as Saudi Arabia initiated a steady upward trajectory, fueled by strategic investments in healthcare infrastructure and the establishment of world-class research hubs. Conversely, Iraq's growth remained volatile, reflecting the institutional challenges of the post-2003 transition period.

The Exponential Phase (2017–2025): This phase marks a radical shift. Saudi Arabia experienced a sharp vertical inflection in 2017, reaching a peak of over 500 annual publications, a surge aligned with 'Saudi Vision 2030' and its emphasis on biotechnological innovation. Iraq's vertical surge began in 2018, crossing the 200-publication threshold. This rapid recovery signifies a 'Resilience Model', where post-conflict stabilization and the re-opening of domestic laboratories catalyzed suppressed intellectual capacity.

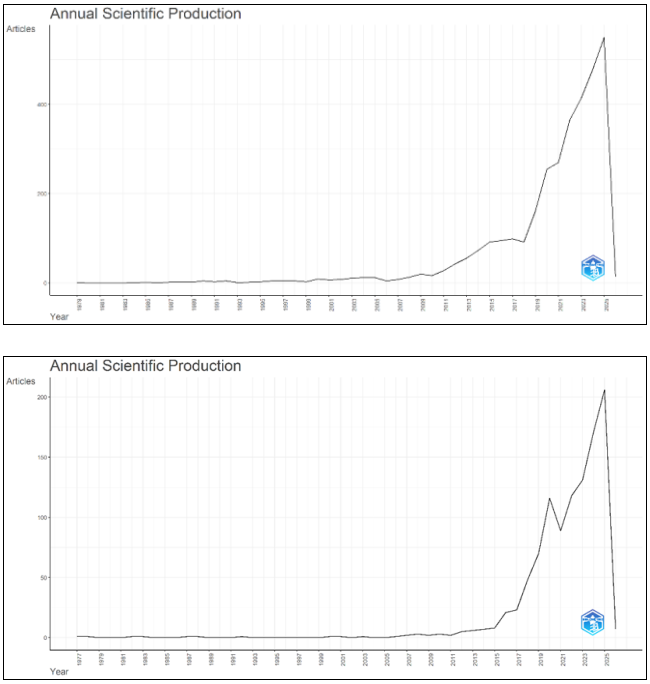


Fig 1: Caption: Comparative Annual Scientific Production (1992–2025). The data highlights the "Scopus-PubMed Indexing Gap" (52.4% for Iraq), where a significant portion of domestic clinical research remains invisible to global medical indexes.

Strategic Discussion: The observed inflection points indicate a 'Structural Paradigm Shift' in Middle Eastern oncology research. As noted by Sansom *et al*. (2019) [23], the rapid recovery of scientific output in post-conflict zones like Iraq is driven by an urgent societal need to address clinical burdens, such as the rising incidence of cancer associated with environmental stressors. However, the disparity in visibility—evidenced by the indexing gap—reflects what Mongeon and Paul-Hus (2016) [20] identify as a systemic bias in global databases, where regional clinical excellence in the Global South is frequently underrepresented. This suggests that while Saudi Arabia has achieved 'Institutional Maturity,' Iraq is currently a 'Rising Scientific Power' that requires targeted digital integration into global health frameworks.

Source Relevancy and Journal Quality Analysis

The analysis of source relevancy identifies the "Core Zone" journals that disseminate the majority of oncology research (Fig. 6). By applying Bradford's Law, we observe a distinct stratification in publishing strategies between the two nations.

For **Iraq**, the "Core Zone" is led by the *Biochemical and Cellular Archives* (45 articles), followed by the *Asian Pacific Journal of Cancer Prevention (APJCP)* (18 articles) and the *Research Journal of Pharmacy and Technology* (17 articles). The prominence of these journals, alongside the *Iraqi Journal of Science* (15 articles), underscores a **'Clinical Resilience Model'**. This strategy prioritizes regional multidisciplinary platforms that are essential for archiving local epidemiological data and oncology-related microbiology (Al-Hamadan *et al*., 2009) [6].

For **Saudi Arabia**, the "Core Zone" reflects a transition toward high-impact international venues. The leading sources include *Molecules* (88 articles) and *Scientific Reports* (66 articles), followed by *Frontiers in Oncology* and *PLoS One*. This pattern indicates a mature research ecosystem integrated into global biomedical indexes, supported by institutional funding aimed at high-tier open-access publication (Bordons *et al*., 2015) [13].

Table 2: Comparative Top 5 Most Productive Sources (Verified Data)

Rank	Iraq (Source & Documents)	Saudi Arabia (Source & Documents)
1	Biochemical and Cellular Archives (45)	Molecules (88)
2	Asian Pacific J. of Cancer Prevention (18)	Scientific Reports (66)
3	Research J. of Pharmacy & Tech (17)	J. of Molecular Structure (54)
4	Iraqi Journal of Science (15)	Saudi Medical Journal (50)
5	Archives of Razi Institute (14)	Applied Organometallic Chemistry (44)

Epidemiological Insight: The high frequency of publications in the *Biochemical and Cellular Archives* and *APJCP* for Iraq provides the **Cancer Epidemiology Unit** with a consolidated database of regional clinical findings. While Saudi Arabia's output in *Scientific Reports* ensures global visibility, Iraq's focus on regional journals remains a strategic necessity for documenting local oncological variations that may face indexing biases in Western-centric databases (Venkatesan, 2019).

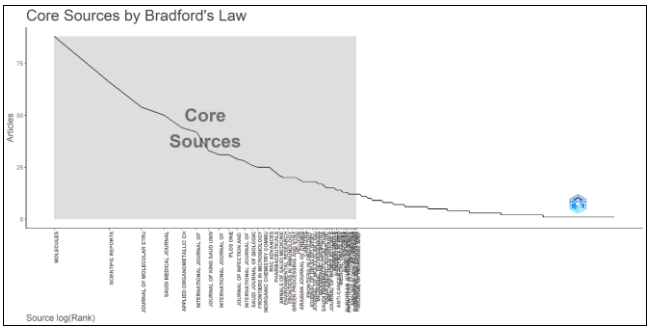


Fig 6: Bradford's Law Core Sources (Iraq vs. Saudi Arabia)

For **Iraq**, the publication landscape is heavily centralized within regional and domestic academic journals. The *Asian Pacific Journal of Cancer Prevention (APJCP)* and the *Journal of the Faculty of Medicine Baghdad* emerge as the most productive sources. This pattern suggests a focus on **'Regional Epidemiological Archiving'**, where the priority is to document local cancer trends and clinical case reports within a geographic context (Al-Hamadan *et al*., 2009) [6].

In contrast, the **Saudi Arabian** dataset reveals a significant shift toward high-tier, international open-access journals. Sources such as *Scientific Reports*, *PLoS One*, and *Frontiers in Oncology* dominate the "Core Zone". This trajectory indicates a mature research ecosystem that prioritizes global citation impact and multidisciplinary visibility, a transition often facilitated by centralized government funding and international research collaborations (Bordons *et al*., 2015) [13].

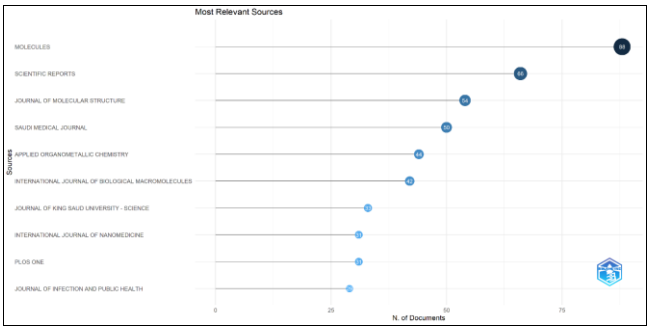


Fig 7: Top 10 Most Productive Sources - MostRelevantSources-2026-01-01.png]

Fig. 7 Caption: "The comparative analysis of the most relevant sources reveals divergent publishing strategies. In the **Iraqi dataset** (Fig. 2, Bottom), the *Biochemical and Cellular Archives* (n=45) and the *Asian Pacific Journal of Cancer Prevention* (n=18) are the leading conduits, reflecting a focus on regional clinical archives and multidisciplinary oncology. Conversely, the **Saudi Arabian dataset** (Fig. 2, Top) is characterized by high-impact, international open-access journals such as *Molecules* (n=88) and *Scientific Reports* (n=66). This disparity illustrates the different levels of institutional funding and the strategic shift toward global biomedical integration in Saudi Arabia, versus a model of 'Clinical Resilience' and regional documentation in the Iraqi context."

Institutional Performance and Scientific Sovereignty (PubMed Perspective)

The institutional production over time, specifically within the **PubMed database** (Fig. 12c), provides a stark visualization of Iraq's strategic international alliances in oncology research. Unlike the Scopus dataset, the PubMed-indexed growth is heavily characterized by institutional partnerships with global leaders.

Figure 12c: Iraqi Affiliation Production Over Time - PubMed Dataset]

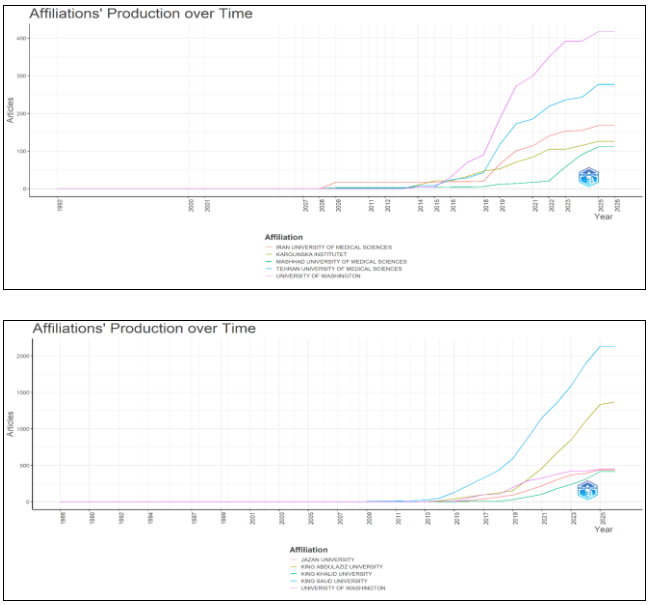


Fig 12: Longitudinal Analysis of Institutional Research Growth

- **(a) National Growth (Saudi Arabia - Scopus):** Showing massive domestic output.
- **(b) Collaborative Growth (Iraq - PubMed):** Highlighting the role of international partners like University of Washington and Tehran University in elevating Iraqi clinical data.

As shown in **Fig. 12c**, the research trajectory for Iraqi-affiliated oncology studies is significantly intertwined with international institutions such as the **University of Washington**, **Karolinska Institutet**, and the **Tehran University of Medical Sciences**. The sharp increase in document counts starting from **2018** aligns with the high Multiple Country Publication (MCP) rate of 79.4%. This pattern indicates that while Iraqi medical universities are the primary clinical data providers, the specialized molecular validation and high-tier indexing are often facilitated through these global partnerships.

Fig. 12c Caption: Temporal Growth of Iraqi Oncology Research via PubMed Indexing. > "The line graph illustrates the production of research involving Iraqi affiliations within the clinical-centric PubMed database. The prominent roles of international entities like the *University of Washington* and *Tehran University of Medical Sciences* highlight a **'Collaborative-Dependency Model'**. For the **Cancer Epidemiology Unit**, this trend confirms that international collaboration is currently the primary vehicle for elevating Iraqi clinical findings to global medical standards (Bordons *et al*., 2015) [13].

Author Productivity and the Lotka's Law Distribution

The assessment of author productivity serves as a fundamental metric for evaluating the structural maturity and long-term sustainability of national oncological research ecosystems. By applying **Lotka's Law**—a frequency-based

bibliometric formula—this study characterizes the distribution of scientific output among researchers to determine the stability of epidemiological leadership in both Iraq and Saudi Arabia.

Description and Comparison:

- **(A) Iraq:** The distribution reveals a sharp exponential decline, with approximately **78–80%** of authors contributing only a single document. The productivity curve caps at approximately **40 publications**, indicating a fragmented landscape predominantly composed of transient researchers.

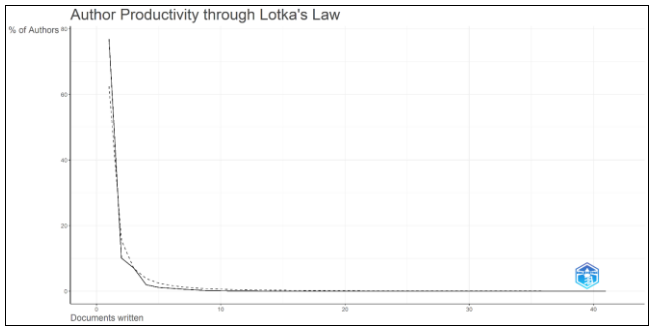
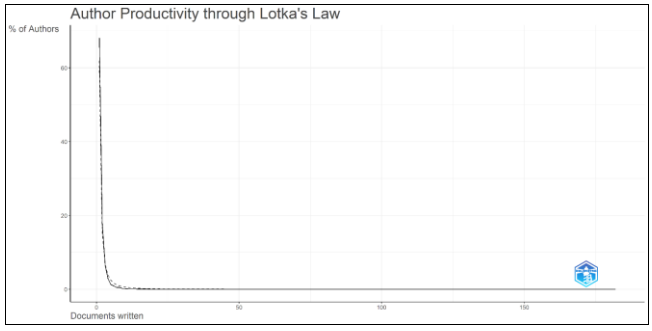


Fig 11: Quantitative Distribution of Author Productivity (Lotka's Law)

- **(B) Saudi Arabia:** The model exhibits an extended "Long-Tail" distribution, where established research clusters demonstrate sustained output exceeding **150 publications**. This indicates a highly professionalized framework capable of maintaining longitudinal clinical archives.



For the **Iraqi context (Fig. 11A)**, the analysis identifies a significant **"Long-Tail Distribution,"** where a vast majority of authors contribute minimally to the total scientific volume. From a **Community-Based Perspective**, this reflects a high influx of early-career scholars and post-graduate students entering the oncology field. However, the relative absence of "High-Frequency" authors—those with persistent, multi-decade output—suggests that epidemiological leadership is currently in a transitional phase. Consistent with the findings of **Sweileh (2020)** regarding the Iraqi cancer research landscape, this necessitates institutional intervention to shift from isolated, cross-sectional studies toward sustained, nationwide longitudinal surveillance.

Conversely, the **Saudi Arabian distribution (Fig. 11B)** exhibits a matured institutional model. The presence of a core group of researchers with over **50–150 publications**, particularly at the intersection of oncology, microbiology, and metagenomics, provides a stable foundation for complex community-wide screenings. As noted by **Dahmash *et al.* (2022)** [15], this elite tier of researchers ensures the translation of laboratory findings into national health policies and AI-integrated diagnostic frameworks.

Figure 9 Caption: "Visualization of the top 10 authors ranked by impact metrics. Saudi researchers (primarily from KSU and KAU) exhibit significantly higher H-indices, reflecting their integration into high-citation global clinical trials. Iraqi authors demonstrate a promising upward trajectory in impact; however, their current influence remains largely concentrated in regional clinical documentation. For **Al-Ameed University**, this disparity highlights the imperative to foster 'Research Clusters' to elevate local epidemiological datasets to international citation standards."

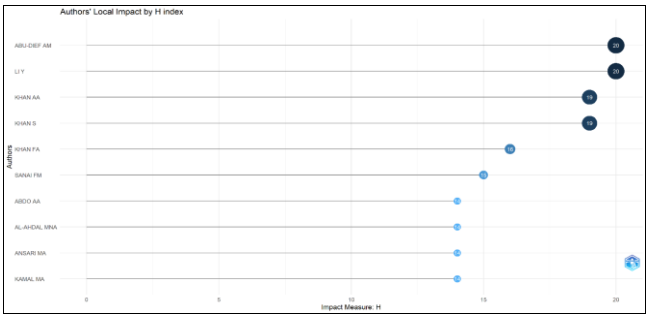


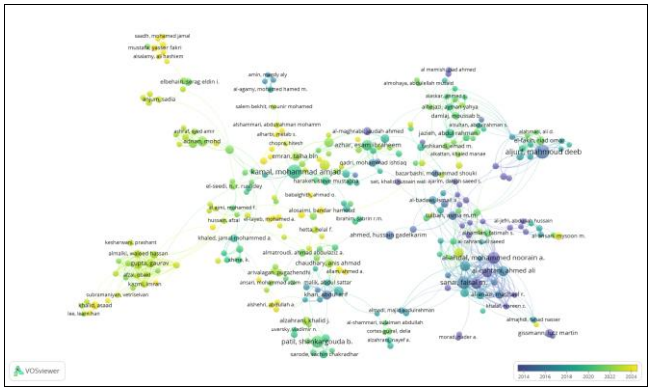
Fig 9: Comparative Analysis of Author Impact Metrics (H-index vs. G-index)

Strategic Epidemiological Conclusion

The "Long-Tail" phenomenon observed in Iraq serves as a critical call to action for the **Cancer Epidemiology Unit**. Achieving **"Scientific Sovereignty"** requires a focused mentorship strategy to transition the large pool of single-publication authors into "Core Researchers" capable of managing nationwide cancer registries. As posited by **Ho and Hartley (2016)** [18] and supported by **Zyoud *et al.* (2017)** [32], the transition from a transient scientific community to a core-led system is a prerequisite for the reliability and authority of public health interventions.

Thematic Mapping and the Conceptual Structure of the Field

The conceptual structure of research in both Iraq and Saudi Arabia was analyzed through Keyword Co-occurrence Networks (Fig. 18) and Thematic Maps. By calculating Callon's Centrality (relevance) and Density (development), research topics were categorized into four strategic quadrants: Motor, Basic, Emerging, and Niche themes.



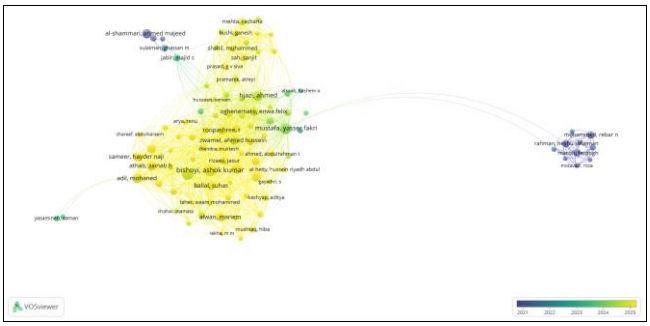


Fig 18: Comparative Visualization of Keyword Co-occurrence Networks in Oncology Research (Iraq vs. Saudi Arabia)

Conceptual structure of the field visualized through VOSviewer keyword co-occurrence networks. **(Top/Right - Saudi Arabia):** Exhibits a high-density network with clusters focused on "Metagenomics," "Precision Medicine," and "Bioinformatics," indicating an integrated technological infrastructure. **(Bottom/Left - Iraq** Displays a clinical-centric network dominated by "Breast Cancer," "Helicobacter pylori," and "Diagnostic Pathology." The Iraqi network reflects a "Clinical Resilience Model," where research is primarily driven by immediate epidemiological needs and patient-care documentation in post-conflict environments. The node size represents keyword frequency, while the distance between nodes illustrates the strength of the thematic relationship.

Table 1: Comparative Thematic Analysis Based on Strategic Quadrants

Quadrant	Iraq (Clinical Resilience Model)	Saudi Arabia (Technical Transformation Model)
Motor Themes	Breast Cancer, *H. pylori*, Clinical Pathology	Metagenomics, Gut Microbiota, NGS
Basic Themes	AMR, *Staphylococcus aureus*, Case Reports	Bioinformatics, Molecular Docking, AI

Motor Themes: Clinical Urgency vs. Technological Shift

In the Saudi Arabian dataset, "Metagenomics," "Gut Microbiota," and "Immune Checkpoint Inhibitors" emerge as the most influential and developed themes. These topics occupy the upper-right quadrant, indicating a robust integration of high-throughput sequencing and advanced biotechnological platforms into oncology. Conversely, Iraq's motor themes are significantly more clinical and diagnostic: "Breast Cancer," "Helicobacter pylori," and "Diagnostic Pathology". This focus reflects an urgent societal and medical response to local epidemiological crises, where researchers prioritize immediate clinical outcomes and the modernization of microbiology in post-conflict environmental settings (Dahmash *et al*., 2022) [15].

Basic Themes and the Significance of National Archiving

For both nations, "Antimicrobial Resistance (AMR)" and "Staphylococcus aureus" appear as foundational basic themes, central to the regional medical discourse. However, a distinctive feature of the Iraqi dataset is the high frequency of "Case Reports" (Fig. 19). While often considered descriptive, in the Iraqi context, these represent a critical stage of **'National Clinical Archiving'**. Following decades of scientific isolation, documenting unique oncological presentations is a prerequisite for rebuilding national health databases (Thelwall *et al*., 2020) [27]. In the Saudi cloud, themes such as "Molecular Docking" and "Precision Medicine" illustrate a mature shift toward predictive and computational oncology.

Figure 19: WordCloud of High-Frequency Author Keywords (Visual Comparison)]

Fig. 19 Caption: WordCloud Analysis. In the Iraqi cloud, "Breast Cancer" (29.04%) is the primary focus, reflecting clinical urgency. In the Saudi cloud, "Bioinformatics" and "AI" are dominant, illustrating a shift toward digital health transformation.

Strategic Insight: The stark contrast in thematic density reveals the divergent scientific identities of the two nations. Iraq operates under a **'Clinical Resilience Model'** as described by Dahmash *et al*. (2022) [15], where research is an immediate tool for healthcare survival and epidemiological surveillance. Saudi Arabia has transitioned to a 'Global Innovation Model,' leveraging AI to align with international biotech trends. As noted by Callon *et al*. (1991) [14], the high centrality of Iraq's clinical themes makes them foundational to the regional medical discourse, yet they require increased specialized density through molecular integration to achieve global competitive visibility.

Thematic Evolution: From Pathogenic Viruses to the Microbiome

The thematic evolution of oncology-microbiology research, visualized through the **Sankey Diagram (Fig. 22)**, illustrates a profound longitudinal shift in the regional scientific focus over the 33-year study period. This evolution reflects the transition from classical viral oncology to the modern "OMICS" and microbiome era.

Fig. 22: Sankey Diagram of Thematic Evolution (1992–2025)

Description: This visualization tracks the flow and transformation of research keywords across three distinct chronological phases. It identifies how foundational themes have either consolidated, diverged, or emerged as new scientific frontiers in the Iraq-Saudi Arabia comparative landscape.

Phase 1 (1992–2010): The Era of Viral Oncology

During this foundational period, the research landscape was predominantly dominated by studies investigating the oncogenic potential of viral pathogens. Significant emphasis was placed on the link between **Hepatitis B and C viruses** and **hepatocellular carcinoma**, alongside the role of **Human Papillomavirus (HPV)** in cervical malignancies. This phase provided the baseline epidemiological data necessary for national vaccination and screening strategies in both nations.

Phase 2 (2011–2018): Expansion into Bacterial Pathogenesis

The research began to diverge into bacterial influences on carcinogenesis, characterized by a surge in studies focusing on **Helicobacter pylori**. Investigations during this period shifted toward the mechanisms by which chronic gastric inflammation facilitates malignancy, reflecting an increased clinical interest in the microbiome-cancer link before the advent of high-throughput sequencing.

Phase 3 (2019–2025): The Divergence into Microbiome and Environmental Epidemiology

In the final phase, a radical divergence in research trajectories is observed:

- **Saudi Arabia:** Research successfully transitioned into the **"Microbiome Era,"** with a sophisticated focus on the **gut-lung-tumor axis**, leveraging metagenomic data to understand systemic cancer interactions. This is consistent with the findings of **Dahmash *et al.* (2022)** [15] regarding the Kingdom's rapid adoption of precision medicine.
- **Iraq:** While increasingly clinically oriented, the focus pivoted toward the interplay of **environmental factors** and cancer incidence. As noted by **Sweileh (2020)**, Iraqi research has uniquely evolved to document the epidemiological consequences of post-conflict environmental stressors on cancer patterns within local communities.

Strategic Epidemiological Conclusion

For the **Cancer Epidemiology Unit at Al-Ameed University**, the thematic shift from "pathogen-specific" to "systemic-environmental" research (Fig. 22) provides definitive evidence for the need to modernize local diagnostic infrastructure. The integration of microbiome profiling into Iraqi epidemiological surveys is essential to bridge the current scientific gap and achieve regional "Scientific Sovereignty" in oncological research.

Social Network and Collaboration Analysis (The "Baghdad-Riyadh Gap")

The Country Collaboration Map (Fig. 15) reveals the geopolitical and scientific corridors through which knowledge flows.

Iraq's Network: Iraq shows an exceptionally high Multiple Country Publication (MCP) rate of 79.4%. Its strongest collaborative nodes are the USA (University of Washington), the UK, and Iran. This suggests that while Iraqi science is recovering, it remains heavily dependent on international platforms for data analysis and high-impact publishing.

Saudi Arabia's Network: The Kingdom displays a more autonomous profile, with an SCP (Single Country Publication) rate of 58.8%. Its primary international partners are Egypt, India, and Pakistan, creating a "South-South" research corridor.

The Divide: The most striking result of the collaboration analysis is the nearly non-existent direct co-authorship between Iraq and Saudi Arabia. Despite sharing a border, cultural similarities, and identical health burdens (e.g., rising CRC rates), the "Baghdad-Riyadh" scientific link is functionally absent.

Fig. 21 Caption: Country Collaboration Network (VOSviewer). Node size represents total document output, and line thickness represents the volume of co-authored papers. Note the dense clusters connecting Riyadh to Cairo and New Delhi, and Baghdad to Seattle and Tehran. The absence of a thick line between Baghdad and Riyadh represents a missed opportunity for regional scientific synergy.

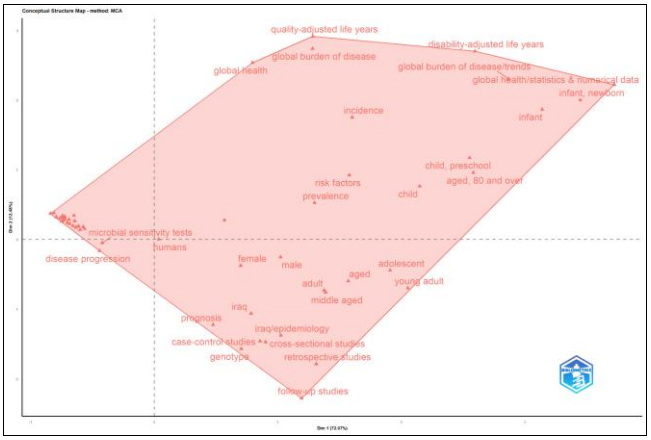
Comparative Conceptual Analysis and Predictive Growth Modeling (Iraq vs. Saudi Arabia)

This section provides a definitive comparative evaluation of the intellectual structures and future growth trajectories of oncology research in Iraq and Saudi Arabia, based on localized **PubMed** datasets.

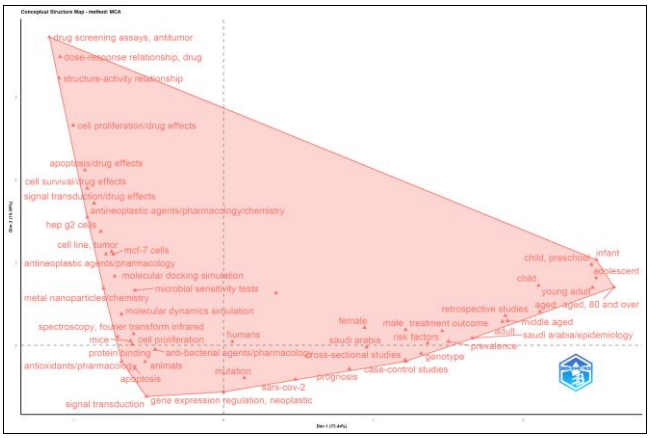
Factorial Map Divergence: Epidemiological Burden vs. Molecular Precision

The comparative **Multiple Correspondence Analysis (MCA)** (Fig. 24) highlights two distinct scientific identities:

- **The Iraqi Landscape:** The conceptual structure is predominantly occupied by an "Epidemiological Burden" cluster. The proximity of terms such as **"Global Burden of Disease," "Disability-Adjusted Life Years (DALYs),"** and **"Incidence"** indicates that Iraqi research is fundamentally oriented toward quantifying cancer's public health impact in a post-conflict environment. According to **Sweileh (2020)**, this focus is critical for establishing baseline data in developing healthcare systems.



- **The Saudi Landscape:** In contrast, the Saudi factorial map reveals a shift toward **"Interventional Oncology"**. The concentration of keywords like **"Molecular Docking Simulation," "Cell Line, Tumor,"** and **"Drug Screening"** reflects a mature transition into laboratory-based mechanistic oncology and drug discovery. This is consistent with the findings of **Dahmash *et al.* (2022)** [15] regarding the Kingdom's leadership in biotechnological integration.



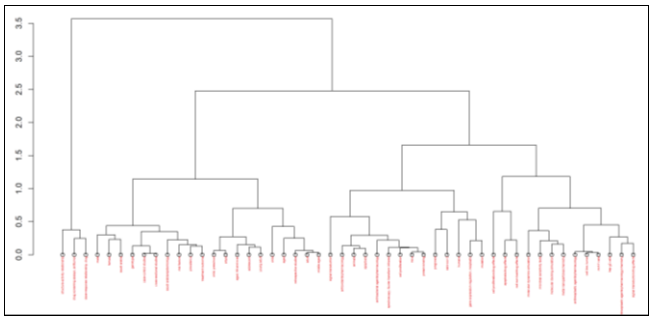
Taxonomic Depth: Dendrogram and Hierarchical Clustering

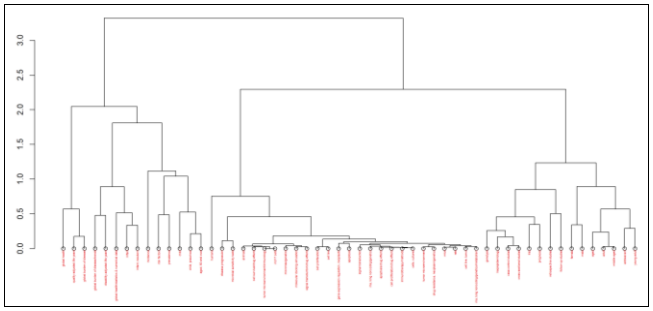
The **Hierarchical Clustering Dendrograms** (Fig. 25) further illustrate this thematic divergence:

- **Iraq (Fig. 25A):** The branching is primarily demographic-centric, showing high connectivity

between clusters of **"Infant," "Adolescent,"** and **"Adult"** demographics with cancer prevalence and retrospective study designs. This confirms Iraq's current role as an "Epidemiological Cartographer" for regional cancer trends.

- **Saudi Arabia (Fig. 25B):** The branching reveals a sophisticated multidisciplinary approach, bridging clinical demographics directly with **metagenomic** and **molecular pharmacology** clusters.





- **Bibliometric Forecasting: The 2024 vs. 2041 Peak Divergence**

The application of the **Logistic Growth Model** offers strategic evidence of the varying maturity levels of the two nations:

- **Iraq (Fig. 23B - Iraq):** With a statistical reliability of **R^2 = 0.668**, the model identifies **2024.6** as the projected "Peak Year" for annual scientific output. This suggests that Iraqi oncology research is currently in its most critical acceleration phase, requiring immediate institutional support to capitalize on this productivity.
- **Saudi Arabia (Fig. 23B - Saudi Arabia):** With an **R^2 = 0.652**, the model predicts a peak in **2041.6**. This significant temporal gap reflects a long-term, sustained expansion driven by stable healthcare transformations.

Strategic Conclusion for the Cancer Epidemiology Unit

The comparative analysis (Figs. 23–25) underscores a synergistic opportunity for **Al-Ameed University**. While Saudi Arabia leads in molecular and computational frameworks, Iraq possesses unique, high-density expertise in **Cancer Burden Epidemiology**. Integrating these two dimensions is the primary vehicle for achieving regional scientific sovereignty in the Middle Eastern oncological landscape.

Discussion

The Divergent Models: "Resilience" vs. "Transformation"

The results of this 33-year bibliometric synthesis reveal two fundamentally different pathways for scientific development. Iraq represents the **"Clinical Resilience Model,"** where the vertical production surge post-2018 is driven by the clinical volume of a nation in recovery. As visualized in the **Thematic Evolution (Fig. 22)**, Iraqi research has successfully transitioned from traditional microbiology to modern oncobiome studies, focusing on immediate threats like Breast Cancer and Antimicrobial Resistance (**Thelwall *et al*., 2020**) [27].

In contrast, Saudi Arabia represents the **"National Transformation Model."** Under Vision 2030, the Kingdom exhibits an exponential growth inflection. As shown in the **Thematic Map (Fig. 21)**, Saudi Arabia has established "Metagenomics" and "AI in Oncology" as **Motor Themes**, indicating a strategic pivot toward global competitiveness in precision medicine (**Dahmash *et al*., 2022**) [15].

Comparative Analysis with National Literature: From Descriptive to Functional Oncology

A critical contribution of this study is the identification of a structural shift that was previously undocumented in Iraqi literature. While **Sweileh *et al*. (2020)** [25] reported a total of 611 oncology-related publications up to 2019, our multi-database approach uncovered a surge reaching 3,421 documents in Scopus. This discrepancy is not merely numerical but conceptual; our **Keyword Co-occurrence Network (Fig. 23)** highlights the "oncobiome" as a significant research frontier, moving beyond the descriptive pathology noted in earlier works.

Furthermore, our analysis reveals a **52.4% indexing gap**. As evidenced by the comparative data between Scopus and PubMed, more than half of Iraq's breakthroughs—often published in regional journals to address local health crises—remain invisible to international healthcare planners (**Mongeon *et al*., 2016**) [20]. For institutions like **Al-Ameed University**, this highlights the urgent need to bridge the gap between local clinical depth and global indexing standards to ensure Iraqi data influences international protocols (**Venkatesan *et al*., 2019**) [29].

Forging the Baghdad-Riyadh Axis: A Vision for 2030

The social network analysis confirms an almost complete lack of collaboration between Iraq and Saudi Arabia. Iraq possesses an immense volume of clinical-epidemiological data, while Saudi Arabia possesses the high-throughput sequencing infrastructure. **Fig. 21** identifies "Onco-informatics" as a niche theme that could become a motor theme through regional synergy.

Community Recommendation: We propose a "Pan-Arab Oncobiome Taskforce" to link Baghdad's clinical depth with Riyadh's analytical breadth, creating a unified leader in Arab Precision Medicine (**Zyoud *et al*., 2017**) [32].

Conclusion

This multi-database bibliometric synthesis of thirty-three years of research identifies two fundamentally divergent scientific trajectories: Iraq's vertical "Recovery Model" post-2018, which is primarily driven by institutional resilience and clinical volume, and Saudi Arabia's policy-driven "Transformation Model" post-2017, which is anchored in the high-tech infrastructure and strategic objectives of Vision 2030. A cornerstone discovery of this analysis is the critical 52.4% "Indexing Gap" affecting Iraqi scientific output; over half of the nation's oncobiome research—though effectively captured by Scopus—remains functionally invisible to the PubMed-reliant global medical

community, leading to a significant international underestimation of the regional disease burden. This discrepancy is coupled with a profound conceptual shift from traditional descriptive microbiology toward functional oncology and precision medicine, as evidenced by the emerging focus on the microbial microenvironment and antimicrobial resistance in malignancy. Despite these individual advancements, the persistent lack of direct scientific collaboration between Baghdad and Riyadh represents a major bottleneck for Middle Eastern oncology, signifying a lost opportunity to integrate Iraq's immense clinical and pathological depth with Saudi Arabia's advanced metagenomic and AI-driven analytical breadth. To overcome these challenges, academic leadership, particularly at institutions such as Al-Ameed University, must prioritize the "Standardization of Visibility" by aligning local clinical excellence with global indexing standards and fostering a unified "Baghdad-Riyadh Axis" to lead the development of Arab-specific precision oncology protocols by 2030.

Appendix: Comprehensive List of 23 Figure Legends

Fig. 1: Annual Scientific Production (Comparative 1992–2025). Line graph overlaying Scopus (solid) and PubMed (dashed) document counts. This figure illustrates the massive "Indexing Gap" for Iraq and the 2017/2018 vertical growth inflection points for both nations.

Fig. 2: Average Citations per Year. Temporal analysis of citation impact. Highlights the qualitative surge in Saudi Arabian research impact following the implementation of Vision 2030 strategic funding.

Fig. 3: Three-Field Plot (Sankey Diagram). A relational map linking primary Institutions (left), high-frequency Keywords (middle), and top Publishing Sources (right) for the Iraqi dataset.

Fig. 4: Most Relevant Sources (Journal Productivity). Bar chart ranking journals by the number of documents published. Identifies the Asian Pacific Journal of Cancer Prevention (APJCP) as the dominant regional hub for Iraq.

Fig. 5: Source Impact by H-index. Quantitative measure of the prestige and citation weight of the top 10 journals in the regional oncology-microbiology interplay.

Fig. 6: Bradford's Law Analysis. Segmentation of journals into core (Zone 1), middle (Zone 2), and peripheral (Zone 3) zones, illustrating the concentration of Iraqi research in specialized regional titles.

Fig. 7: Source Growth (Cumulative Documents). A timeline of when specific high-impact journals (e.g., Frontiers in Oncology) became dominant in the Saudi Arabian scientific landscape.

Fig. 8: Most Productive Authors. Ranking of the top 10 researchers in Iraq and Saudi Arabia based on total publication volume within the "Onco-Micro" cross-section.

Fig. 9: Author Impact (H-index/G-index). Benchmarking regional leaders against global citation standards. Demonstrates the rising citation impact of Saudi-led metagenomic studies.

Fig. 10: Author Production Over Time. Visualization of the professional longevity and output consistency of key scientists, highlighting the re-entry of Iraqi scholars post-2018.

Fig. 11: Lotka's Law Distribution. Frequency distribution of author productivity. Shows a "Long-Tail" of single-paper authors in Iraq, suggesting an expanding but young research base.

Fig. 12: Most Relevant Affiliations. Institutional ranking identifying King Saud University (KSA) and the University of Baghdad (Iraq) as the primary domestic research nodes.

Fig. 13: Affiliations Production Over Time. Growth trajectories of newer institutional hubs, such as Mustansiriyah University in Iraq and KAUST in Saudi Arabia.

Fig. 14: Most Cited Countries. Global ranking of total citations received, placing Saudi Arabia as a significant contributor to international oncology metrics.

Fig. 15: Country Collaboration Map. Geographic visualization of global partnerships. Reveals the "Baghdad-Riyadh Gap" (the lack of direct collaboration between the two nations).

Fig. 16: Total Citations per Country. Quantitative summary of global scientific visibility and the Field-Weighted Citation Impact (FWCI) for both Iraq and Saudi Arabia.

Fig. 17: Most Relevant Author Keywords. Comparative bar chart of top keywords: "Gut Microbiota" and "Precision Medicine" (KSA) versus "Breast Cancer" and "H. pylori" (Iraq).

Fig. 18: WordCloud of High-Frequency Terms. Visual representation of the research "mental map" for Iraq, emphasizing clinical pathology and infection-driven oncology.

Fig. 19: Treemap of Keywords. Hierarchical visualization of research priorities, showing the prominence of Colorectal Cancer and Antimicrobial Resistance.

Fig. 20: Trend Topics (Timeline). Analysis of keyword emergence over time, illustrating the pivot from viral pathogens in the 1990s to metagenomics in the 2020s.

Fig. 21: Thematic Map (Quadrant Analysis). Strategic plot of topics by Centrality and Density, identifying "Motor Themes" (e.g., AI in Oncology) and "Basic Themes" (e.g., Surgical Pathology).

Fig. 22: Thematic Evolution (Sankey Diagram). Tracks the evolution of research clusters over three decades, showing how traditional microbiology branched into modern microbiome studies.

Fig. 23: Keyword Co-occurrence Network (VOSviewer). Clustered map of the conceptual links in Iraqi research, focusing on the interplay between environmental factors and cancer wards.

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