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The Application of Linked Data for the visibility of Moroccan Scientific Publications

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Environmental research plays a central role in addressing global challenges such as climate change, pollution and ecosystem degradation. However, the visibility and interoperability of scientific publications from the Global South, particularly Morocco, remain limited due to absence of dedicated dispositive and open repositories, along with the insufficient adoption of international standards. This study applies Semantic Web and Linked Data technologies to improve the discoverability and reuse of Moroccan environmental publications. A methodological framework was developed combining a literature review, a comparative study of semantic web tools (Protégé, VocBench, RDFlib, RMLMapper, Open Refine, Apache Jena Fuseki, GraphDB and Virtuoso), and an experimental implementation on a corpus of 27 open access articles. The proof of concept generated an RDF knowledge graph comprising 1120 triples. This structure supported advanced SPARQL queries and demonstrated improvements in resource discoverability, semantic interconnection and metadata enrichment. The corpus analysis showed complete metadata coverage, with all records including DOIs, publication years and institutional affiliations. It revealed a sparse but structured graph (density= 0.007), where research outputs were largely oriented toward climate change (85%) and water-related topics (52%). The results highlight the feasibility of lightweight, open-source solutions as the proof of concept was achieved with modest resources and standard open-source tools, yet still delivered metadata enrichment and advanced querying. The findings also emphasize the strategic importance of developing national ontologies, dedicated triple stores, and infrastructures aligned with FAIR principles. This approach provides a transferable model for Southern countries aiming to improve the international visibility of their scientific production.

Keywords: Linked Data, Semantic Web, Knowledge Graph, Open Science, Environmental Research, Morocco.

1. Introduction

Environmental research has become central to addressing pressing global challenges, including climate change, pollution, and ecosystem degradation. Although scientific production in this field has increased considerably, many research outputs remain difficult to access and are not sufficiently interoperable, which limits their visibility, sharing and reproducibility in international scientific networks.[1] This issue is particularly pronounced in Southern countries, where the richness of environmental work is often constrained by the lack of institutional repositories that are poorly connected to major open data platforms. The lack of visibility of scientific publications is not only an academic issue but also has strategic repercussions[2]. The international recognition of research contributes to scientific diplomacy, international cooperation and a country's positioning in the global governance of science[4]. For Morocco, improving access, structuring and disseminating environmental research output directly aligns with the objectives of open science and global sustainability[3].

In this context, the Semantic Web and the Linked Data paradigm offer a major opportunity to enhance scientific research. Conceptualized as early as 2006 by Berners-Lee[5], this paradigm relies on the use of URIs to identify entities, the RDF model to describe their relationships, and the creation of links between datasets. Based on the use of open standards such as RDF, Web Ontology Language (OWL) and Protocol and RDF Query Language (SPARQL), these approaches allow for the transformation of heterogeneous sets of publications into interconnected knowledge graphs, thereby promoting their

discoverability, traceability and reuse[6] [7]. The FAIR principles (Findable, Accessible, Interoperable and Reusable) complement this technical framework by proposing an ethical and practical governance of scientific data, enhancing the transparency and reproducibility of results[6]. Beyond their technical scope, these principles are increasingly recognized as strategic tools for fostering international collaboration and accelerating scientific innovation[8] [9].

The application of the Web of data to scientific publishing has opened a field of innovations ranging from the semantic annotation of texts to the automated extraction of methods and datasets, up to semantic recommendation systems and knowledge graph visualization[10] [11] [12] [13]. These applications improve the discoverability of scholarly outputs and facilitate their integration into international scientific networks[14]. They also demonstrate that Linked Data approaches extend beyond the field of information sciences and progressively permeate environmental research, medicine and social sciences, which confirms their multidisciplinary relevance[15].

Several representative initiatives highlight this potential of Linked Data for scholarly communication and electronic resources management. For instance, the Global Open Knowledge base (GOKb) provides an open linked data infrastructure to improve interoperability among information resources[16]. The adventures in Semantic Publishing project [10] demonstrated that a single scientific article could be enriched by thousands of RDF triples, enhancing reproducibility and enabling secondary analysis. Likewise, Erkimbaey et al. [17]showed that converting an institutional repository into Linked Open Data makes it possible to connect previously isolated collections and improve document sharing. In a similar vein, the OpenCSDB initiative automatically links publications to crystallographic data, considerably reducing the search time for analogous compounds.[18] The ISSA project[19], applied to the Agritrop archive, further confirms that RDF-based structuring optimizes the querying of agronomic corpora. At a larger scale, platforms such as SemOpenAlex[20], which reorganizes over 26 billion scientific triples, and CovidPubGraph[1], developed to support rapid monitoring of 210,000 CORD-19 articles, confirm the increasing maturity of Linked Data. Beyond data integration, another work has also emphasized the contribution of knowledge graphs to scientometric analyses, enabling richer evaluations of research outputs and collaboration networks[21]. Finally, recent studies in Uganda highlight the concrete benefits of adopting Linked Data in university libraries, notably duplicate reduction, metadata enrichment and improved resource sharing[22].

These achievements converge toward a clear conclusion: Linked Data is no longer just an experimental demonstration but an informational infrastructure capable of articulating scientific production, associated data and advanced value-added services. However, the majority of these projects rely on heavy infrastructures and advanced skills, which are rarely available in academic environments with limited resources[23,24]. In this regard, the experience of many Southern countries is particularly revealing, as they face common technical, linguistic and governance challenges in implementing Linked Data [23] These obstacles are also acknowledged at the policy level, as highlighted by UNESCO [4](2021) which stresses the need to address infrastructural and capacity gaps in the Global South to achieve equitable Open Science.

Morocco represents a relevant example of these strategic challenges. Despite a strong political commitment to emphasize open science[25], the operational deployment of the Web of Data infrastructures remains at an early stage. Most university repositories rely primarily on basic Dublin Core metadata, no SPARQL endpoint is publicly accessible, and no national URI resolution service is established. The current situation is also linked to practical and institutional factors. In many Moroccan universities, semantic technologies such as RDF and SPARQL are not yet systematically included in training programs, and FAIR-oriented data management remains marginally integrated into academic practice, while linguistic constraints related to multilingualism (French and Arabic) add further complexity[26].

In addition, although Moroccan researchers demonstrate a significant level of international collaboration through co-publications, the country continues to occupy a relatively peripheral position within regional scientific networks[27], which limits the strategic impact of its research. These findings confirm the need for corrective actions such as establishing a national triple store, creating a bilingual ontology for priority themes and strengthening technical training.

Therefore, a central question arises: How to adapt the potential of Linked Data to academic environments where technical infrastructures and skills are limited, while ensuring visibility and scientific interoperability? To answer this question, the present research pursues three objectives: first, to present an overview of research addressing the application of Linked Data in scientific publishing, with the aim of positioning the current state of the art and identifying foundational concepts and relevant international initiatives in the field. Second, to evaluate the deployable semantic technologies (standards, vocabularies and tools) in order to justify the chosen methodological approaches. Finally, to develop a proof of concept applied to a corpus of Moroccan environmental publications, in order to demonstrate its technical feasibility and measure its contribution in terms of visibility and interconnection.

This research stands out for its application in a resource-limited academic context, a characteristic that is rarely explored in the international literature. The article begins with a presentation of the adopted methodology, followed by the experimental results and their discussion, and concludes with the contributions, limitations and perspectives of this work.

2. Materials and Methods

2.1. Documentary Research

Recognized for its international and multidisciplinary coverage, The Scopus database was used to conduct a documentary analysis of the scientific literature. The objective was to identify recent works related to the application of Linked Data in scientific publishing and the discoverability of resources. Using Boolean operators to refine results, the search strategy was designed around a combination of keywords including Linked Data, open science, discoverability, scientific publication, Morocco and environmental research. The selected period (2016-2024) was chosen to capture the most recent advancements in the field. This process initially retrieved a total of 143 articles. After eliminating duplicates and screening out studies not directly aligned with the research objectives, a final corpus of 55 articles was retained for detailed analysis. For each selected study, key information was extracted including research objectives, methodology, results and identified limitations.

2.2. Comparative analysis

The implementation of Linked Data is based on the integration of several Semantic Web technologies. Considering the wide range of tools available in this ecosystem, a rigorous comparative analysis was conducted to determine the most appropriate solutions for our experimentation. This section aims to present the principal technologies required for building and using a knowledge graph dedicated to scientific publications, in order to justify the technological choices made for our proof of concept. We detail the methodology adopted for this benchmark, the evaluation criteria used, the technologies analyzed by functional category. Finally, we will justify the technological choices that guided the design of our experimental architecture.

The process of identifying and evaluating tools involved an extensive literature review in the scientific literature and open-source ecosystems to identify candidate technologies. Each tool was then subjected to a detailed analysis of its official documentation and specifications. This systematic approach allowed for an objective assessment and selection of the most relevant tools for our project.

The technologies were evaluated based on functional criteria (compliance with RDF/OWL/ SPARQL standards, inference capabilities, performance and scalability) and non-functional criteria (multilinguialsm, usability, community support and cost). Three families of tools were studied:

- **Ontological modeling**: Protégé [28,29] VocBench [30,31] and TopBraid composer[32];
- **ETL to RDF** / Python/RDFlib[33], RML Mapper [34] and OpenRefine[35-36];
- **RDF triple stores**: Apache Jena Fuseki[37], GraphDB [38]and Virtuoso[39].

A detailed summary of this comparative analysis, intersecting the identified tool families with the selected evaluation criteria, is presented below in Table 1. Similar comparative approaches have also been adopted in other fields, such as construction safety[40].This comparative table summarizes the advantages and limitations of the different solutions and justifies the technological choices adopted within the framework of this research.

The benchmarking phase made it possible to identify tools that were both technically relevant and realistically deployable in our context. For ontological modeling, Protégé emerged as the most practical

Table 1 — Comparative analysis of semantic web technologies for Linked Data implementation

Tool family	Technologies	Standards compliance (RDF/OWL/SPARQL)	Inference	Performance/ Scalability	Multilingual support	Usability	Community support	Cost
Ontological Modeling	Protégé	Yes	Yes	Good (medium size models)	Yes Arabic supported	Easy	Large	Free
	VocBench	Yes	Yes	Good	Yes	Medium	Large	Free
	TopBraid Composer	Yes	Yes	Good	No (Arabic not optimized)	Complex	Medium (proprietary)	Paid
ETL to RDF	Python/RDFlib	Yes	Yes	Good	Yes	Complex (requires programming)	Large	Free
	RML Mapper	Yes	Yes	Good	Yes	Complex	Medium	Free
	OpenRefine	Partial (via RDF extensions)	No	Medium	Yes	Easy (user-friendly interface)	Large	Free
RDF Triple Store	Apache Jena Fuseki	Yes	Yes	Medium (for large volumes)	No	Complex	Medium	Free
	GraphDB	Yes	Yes	Good	Yes	Easy	Medium	Freemium/ Paid
	Virtuoso	Yes	Yes	Good	Yes	Complex	Medium	Paid

option, mainly because of its wide adoption, documentation, and ease of use in academic environments.

For the transformation process (ETL), Python combined with RDFlib appeared particularly appropriate. Its flexibility and compatibility with the wider Python ecosystem enabled us to manage data cleaning and RDF conversion within a unified working environment.

Concerning data storage and querying, Apache Jena Fuseki was selected as a balanced solution. While it does not offer the scalability of more advanced commercial platforms, its open-source nature and ease of deployment made it appropriate for a proof of concept implementation.

Overall, these technological choices were guided not only by performance criteria, but also by contextual constraints. In a Moroccan academic environment marked by limited technical resources and multilingual requirements, accessibility, cost, and ease of maintenance were decisive factors.

2.3. Experimental construction

Based on this comparative study, an experiment was implemented. The selected corpus consists of 27 open access scientific articles (from DOAJ and the IMIST institutional repository). The articles were selected based on two criteria: (i) the presence of complete metadata (title, authors, affiliations, year, DOI/URL); and (ii) their publication between 2016 and 2024. This sample size was deemed sufficient to conduct a proof of concept, as it ensured both representativeness of recent moroccan environmental research and feasibility of RDF processing and querying within limited resources. The choice of a focused corpus also allowed for a controlled evaluation of metadata quality, semantic enrichment and querying performance.

The metadata of the 27 selected articles were first consolidated in Zotero and then exported in CSV format which served as a reference dataset for the different processing stages.

- Data cleaning and normalization: Using Python (pandas), author names were harmonized, inconsistencies corrected and duplicate articles removed to ensure dataset coherence.
- Ontological design: The ontology was developed in Protégé around the three core entities: Article, Person and Organization, and aligned with widely adopted vocabularies such as BIBO, FOAF and DCTERMS.
- Transformation into RDF: Dedicated Python scripts based on the RDFlib library were used to automatically transform the CSV dataset into RDF triples, producing a Turtle file compliant with Semantic Web standards.
- Graph implementation: The RDF triples were loaded into Apache Jena Fuseki, creating a knowledge graph linking articles, authors and affiliated institutions.
- Interrogation: representative SPARQL queries were executed (search by title and year, author-institution join, publication-keyword navigation).

These tests allowed for assessment of the discoverability and interconnectivity offered by the model.

This research is distinguished by an approach entirely based on the use of open standards and open source tools, thus ensuring its transferability to other academic contexts. By combining a thorough documentary analysis, a comparative benchmark of semantic web technologies, and applied experimentation on a Moroccan environment corpus, the adopted approach provides a clear and rigorous framework for the application of Linked Data to scientific publishing. It particularly highlights the feasibility of lightweight and accessible solutions, tailored to resource-limited environments, and proposes a reproducible conceptual model that can serve as a reference for other similar initiatives in the field of open science.

3. Results

The experiment focused on a corpus of 27 scientific articles relating to environmental issues, describing a group of 138 authors affiliated with 67 institutions. The transformation into an RDF graph generated 586 nodes and 1,120 edges, indicating a moderately connected network. Structural analysis shows a graph density of 0.007 and an average degree of 3.82, confirming limited interconnectivity between entities while ensuring a sufficient level of connectivity to support the proof of concept objectives.

In terms of documentation, the metadata is notable for its completeness: all articles have a DOI, publication date, and institutional affiliations. This result attests to the quality of the corpus and its high potential for integration into larger knowledge graphs.

Thematic analysis highlights a clear predominance of work on climate change (23 articles, or 85.2 % of the corpus) and, to a lesser extent, water management (14 articles, 51.91 %). On the other hand, topics related to pollution and biodiversity appear to be very marginal, with no articles identified on pollution and only one article devoted to biodiversity (3.7%). This distribution highlights both the vitality of Moroccan research on climate and water issues and the need for future expansion into other environmental dimensions that have yet to be explored.

3.1. Conceptual ontology:

The first step of the experimentation consisted of developing a domain ontology to represent the entities and relationships specific to environmental scientific publications. Fig. 1 illustrates an excerpt of the ontology developed in Protégé (Ontograf), where the main classes (Article, Person/Author, Organization) and their semantic relationships, enriched by standard vocabularies such as FOAF, BIBO and DCTERMS.

In addition, Fig. 2 summarizes the data properties retained to describe the entities. These properties cover the essential metadata of publications (title, abstract, year, DOI, URI, usage rights) as well as the identifiers of authors and organizations. The use of established standards (Dublin Core, FOAF, BIBO) ensures the interoperability of the model with other RDF graphs and promotes its reuse in broader contexts.

3.2. Experimental Graph

Based on the ontology, a corpus of Moroccan environmental scientific publications was converted into RDF and loaded into Apache Jena Fuseki. The operation generated approximately 1120 RDF triples,

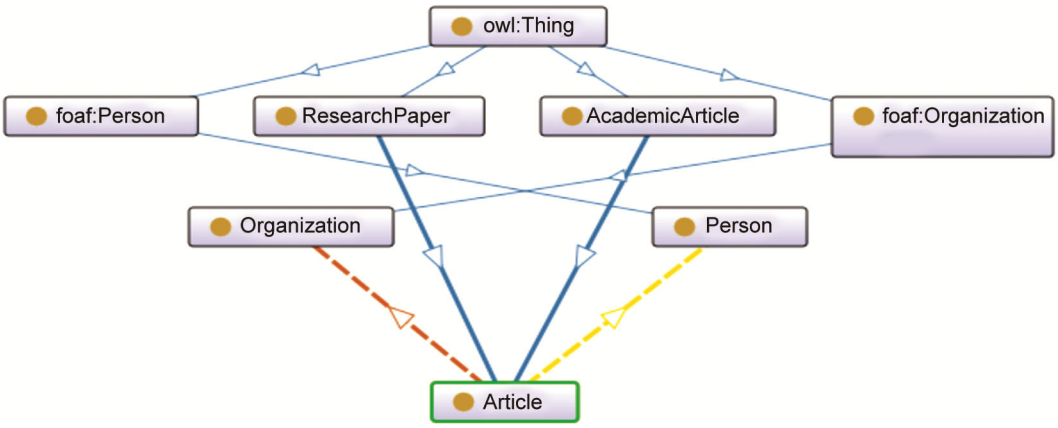

Fig. 1 — Excerpt from the conceptual ontology developed with Protégé (OntoGraf)

representing the links between articles, authors and institutions. Figure 3 presents a representative subgraph illustrating the interconnection of the different entities.

This representation clearly shows the structuring role of Linked Data: entities that were previously scattered in different repositories are now explicitly connected, which facilitates exploration and the discovery of new associations.

SPARQL queries and discoverability

The interrogation of the graph made it possible to evaluate the discoverability of publications as well as the relevance of their semantic interconnection. Several representative scenarios were tested, namely:

Simple query (bibliographic metadata): Figure 4 shows a SPARQL query that retrieves simultaneously the title, author institution, year and DOI of articles on climate change affiliated with Mohammed V University. The query returned 17 results in 0.347 seconds. This test demonstrates that the RDF graph can bring together information that is scattered across different sources and makes it easy to search in a unified environment.

Propriété	Type	Domain	Range
dcterms:title	DataProp	Article	xsd:string
dcterms:abstract	DataProp	Article	xsd:string
dcterms:issued	DataProp	Article	xsd:gYear
bibo:doi	DataProp	Article	xsd:string
foaf:homepage	DataProp	Article	xsd:anyURI
dcterms:rights	DataProp	Article	xsd:string
foaf:name	DataProp	Person, Organization	xsd:string

Fig. 2 — Data properties defined in the ontology (Dublin Core, FOAF, BIBO)

***Complex query*:** Figure 5 presents a targeted query on publications affiliated with Cadi Ayyad University, containing the terms water or eau in the title or abstract, and published since 2020. The query execution returned two results in 0.075 seconds, with complete metadata including title, abstract, DOI and URL.

These two examples illustrate the added value of Linked Data for querying multiple dimensions simultaneously such as institutional affiliation, research theme, period covered, and language, while generating precise results that remain difficult to obtain through traditional information retrieval systems.

3.3. Scientific and strategic contributions

The findings obtained highlight several key contributions:

1. Enhanced discoverability: thanks to SPARQL queries, publications can be found through complex combinations of criteria, including multilingualism.
2. Semantic interrogation: the graph reveals implicit links between authors, institutions and themes, promoting the analysis of collaborations.
3. Metadata enrichment: the integration of DOI, URIs and affiliations improves the semantic

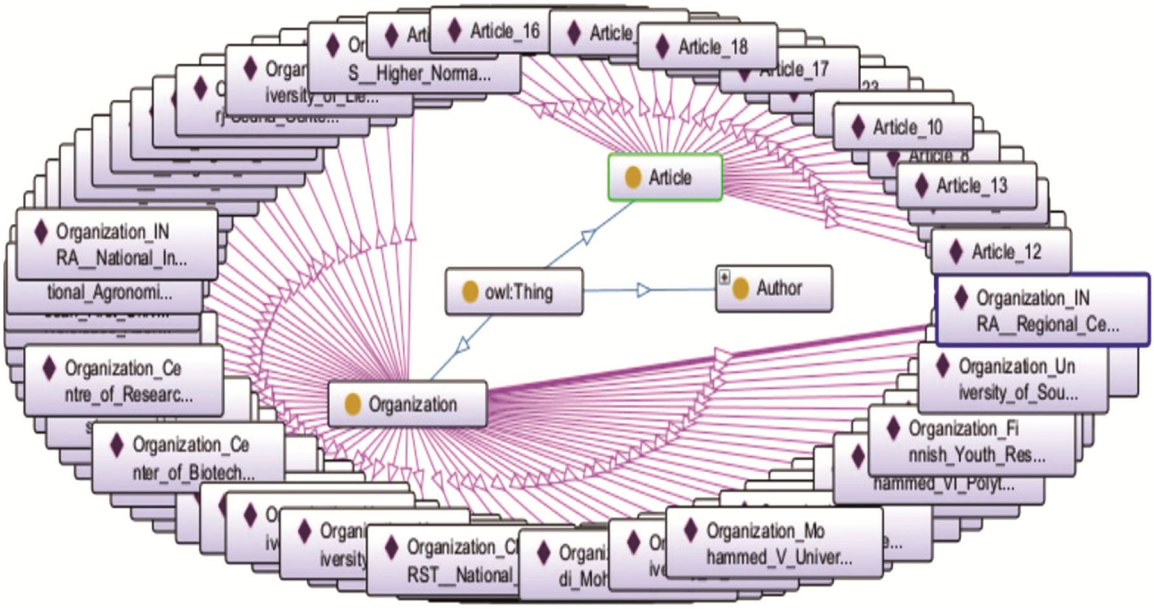

Fig. 3 — Visualization of an RDF subgraph linking articles, authors and organizations

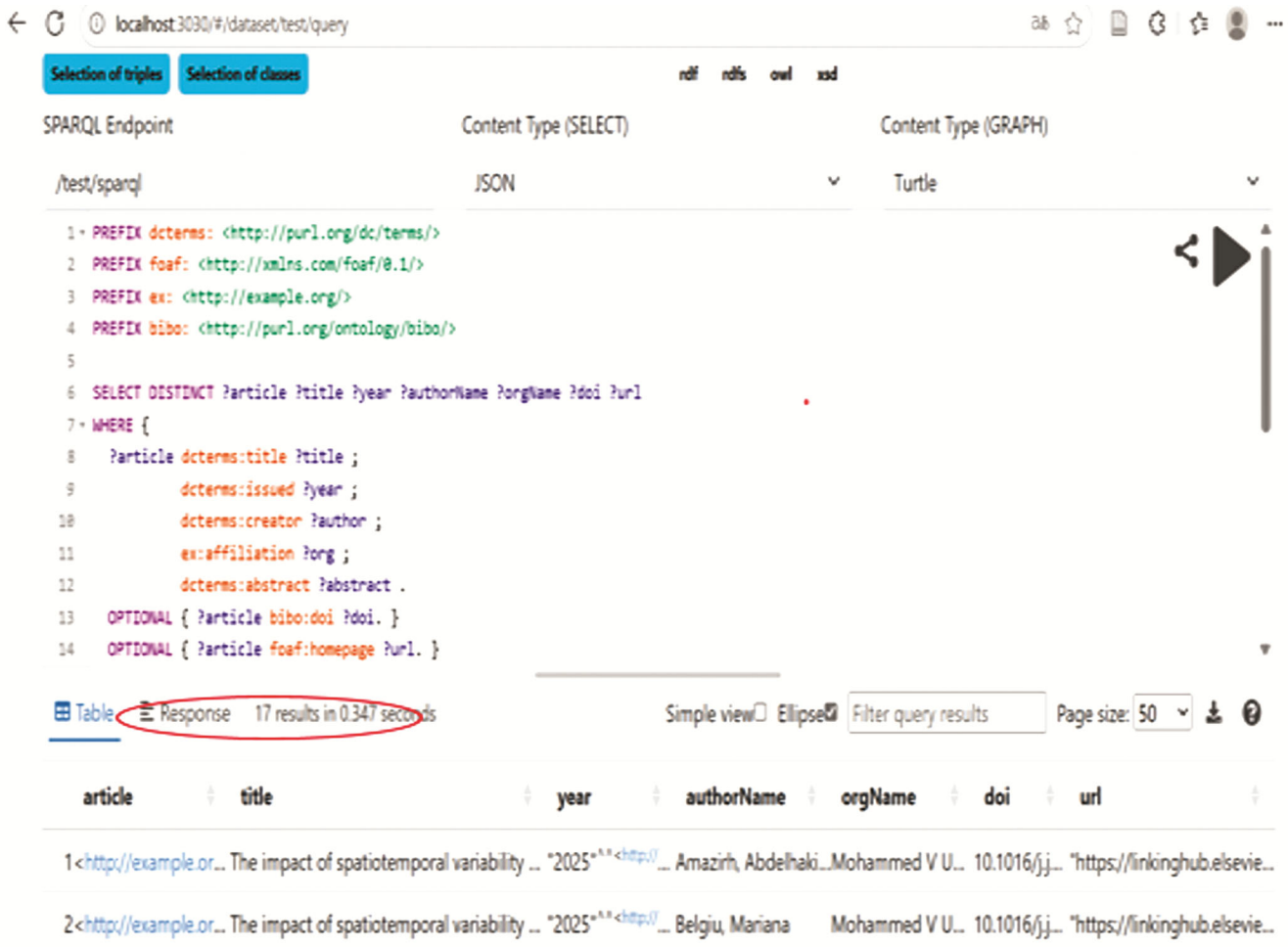

Fig. 4 — Example of a SPARQL query returning articles on climate change affiliated with Mohammed V University

richness of publication records and strengthens their interoperability and potential for reuse across research environments of descriptive value of publications and facilitates their reuse.

4. Technical efficiency: Query response times below 0.4 seconds indicate that the proposed approach remains operationally efficient and technically feasible within an experimental implementation setting.

Beyond the technical proof, these results also suggest several strategic perspectives for Moroccan research:

- Development of a bilingual national ontology adapted to environmental research priorities.
- Implementation of a national triple store and a URI resolution service, in order to support the sustainable integration of moroccan scientific production into global knowledge graph infrastructures.

4. Discussion and Implications

These results support both the technical feasibility and scientific relevance of the proposed approach, as reflected in the completeness of metadata, the presence of a structured graph, and the thematic concentration around climate and water issues. However, the restricted size of the corpus (27 articles) positions the study mainly as a proof of concept rather than a comprehensive evaluation of Moroccan environmental research production. This methodological choice ensures internal validity but calls for future extensions to larger and more diverse datasets in order to consolidate these preliminary trends and strengthen the generalizability of the results.

The results obtained confirm that the application of Linked Data to environmental scientific publications significantly improves their discoverability, interconnection and reuse. The implementation of an

Fig. 5 — SPARQL query filtering water-related environmental publications affiliated with Cadi Ayyad University (≥2020)

RDF graph based on open standards (Dublin Core, FOAF, BIBO) has demonstrated its ability to centralize dispersed information and make it queryable through complex queries incorporating thematic, institutional and multilingual filters. This level of technical performance illustrates the potential of Linked Data as an effective means of improving the openness and the visibility of Moroccan scientific publications.

These results are of particular interest for environmental sciences, beyond their technical dimension. Better structuring and interconnection of publications not only enhances their visibility but also facilitates access to strategic knowledge for the sustainable management of natural resources, combating pollution, and adapting to climate change. In this sense, Linked Data appears as a decision support tool, capable of strengthening the flow of knowledge between researchers, public decision-makers and ground-level stakeholders.

Compared to large-scale international initiatives such as SemOpenAlex or Bio2RDF, our results confirm that the benefits of Linked Data are not limited to environments with massive infrastructures. On the contrary, they show that a pragmatic and adapted approach, based on accessible tools (Protégé, Python/RDFlib, Jena Fuseki), can produce tangible results in a resource-limited context. Unlike many works focused on complex infrastructures, this study demonstrates the relevance of lightweight and contextualized approaches, a dimension that had been little explored in the international literature. This positioning constitutes an original contribution by highlighting the feasibility of a reproducible and transferable processing chain to countries in the Global South.

5. Limitations and future work

However, this study has certain limitations. The corpus selected remains small (27 articles), which restricts the scope of the conclusions and highlights the need to broaden the sample in future work. Furthermore, the use of Apache Jena Fuseki, while suitable for a prototype, does not meet high scalability needs. Finally, mastery of RDF/OWL/SPARQL technologies requires expertise that is still not widely distributed in the Moroccan academic environment, highlighting the need for institutional efforts in training and skills enhancement.

On a practical level, the results open up several perspectives. For researchers, they indicate that improved semantic structuring enhances the visibility

of scientific articles and facilitates their reuse. For institutions, they highlight the importance of establishing a national triple store, developing bilingual ontologies tailored to national priorities, and integrating FAIR standards into scientific repositories. For Southern countries in general, this research provides a reproducible model that can help reduce the gap in terms of international scientific visibility.

From a theoretical perspective, this experimentation shows that Linked Data goes beyond its technical dimension to assert itself as a true infrastructure for scientific governance. By strengthening the integration of Moroccan research into global networks of Linked Knowledge, it contributes to achieving the objectives of open science and is part of a global sustainability dynamic. These results invite a rethink of scientific publishing not only as a dissemination process but also as a mechanism for strategic interconnection between knowledge, actors and institutions. Future work could extend this model to other scientific disciplines, test larger-scale environments, and explore its integration with international open data platforms.

6. Conclusion

This research has demonstrated that the application of Linked Data technologies to environmental publications is a powerful lever to enhance their visibility and interconnection within the international scientific ecosystem. By mobilizing, a chain of open and accessible tools (Protégé, Python/RDFlib, Apache Jena Fuseki), we have shown that it is possible to transform heterogeneous metadata into interoperable RDF graphs, usable by SPARQL queries. This approach not only contributes to the discoverability of moroccan environmental work, but also illustrates a pathway for the democratization of open science practices in resource-limited contexts.

The conducted experiments confirm that Linked Data offers tangible advantages: better integration of publications into knowledge graphs, enrichment of metadata through semantic interconnection, and enhancement of multilinguism. However, the study also highlights several limitations, notably those related to the restricted size of the corpus, the technical constraints of local infrastructures, and the need to further develop expertise in ontological modeling. These observations underline the importance of coordinated action at both institutional and scientific levels.

In this perspective, the establishment of a national triple store and the development of bilingual ontologies aligned with environmental priorities emerges as strategic levers to sustainable integration of Moroccan research within the global knowledge networks. More broadly, the proposed approach offers a transferable model for other countries in the Global South facing similar challenges related to the visibility and valorization of their scientific production.

Ultimately, Linked Data should be viewed not merely as a technical solution but as a knowledge infrastructure capable of enhancing the circulation, interpretation and reuse of environmental scientific results. Its progressive adoption may contribute to transforming scholarly publishing practices toward a more open and interconnected scientific ecosystem aligned with global sustainability objectives.

References

1 Pestryakova S, Vollmers D, Sherif MA, Heindorf S, Saleem M, Moussallem D and Ngomo CAN, CovidPubGraph: a FAIR knowledge graph of COVID-19 publications, Sci Data,9 (2022) 389. https://doi.org/10.1038/s41597-022-01298-2.

2 Madsen RR, Scientific impact and the quest for visibility, FEBS Journal, 286 (20) (2019). https: //doi.org/10.1111/febs.15043.

3 Gulliver S, Demeshko A, Harle J and Drake T, How Science Diplomacy can reshape Global Research publishing: A theory of change, Center for Global development, Washington DC, 2024. Available at: https://www.cgdev.org/ publication/how-science-diplomacy-can-reshape-global-research-publishing-theory-change (Accessed on 20 April 2025).

4 UNESCO, UNESCO Recommendations on Open Science, UNESCO; Paris, 2021. Available at: https://unescodoc.unesco.org/ark:/48223/pf0000379949 (Accessed on 20 April 2025).

5 Berners-Lee T, Linked data, World Wide Web Consortium (W3C), 2006. Available at: https://www.w3.org/ DesignIssues/LinkedData.html (Accessed on 27 April 2025).

6 Wilkinson MD, Dumontier M, Aalbersberg IJ, Appleton G, Axton M, Baak A, Blomberg N, Boiten JW, Da Silva Santos LB, E.Bourne P, Bouwman J, Brookes AJ, Clark, T, Crosas M, Dillo I, Dumon O, Edmunds S, Evelo CT, Finkers R, Gonzalez-Beltran A, Gray AJG, Groth P, Goble C, Grethe JS, Heringa J, Hoen PAC, Hooft R, Kuhn T, Kok R, Kok J, Lusher SJ, Martone ME, Mons A, Packer AL, Persson B, Rocca-Serra P, Roos M, Van Shaik R, Sansone SA, Schultes E, Sengstag T, Slater T, Strawn G, Swertz MA, Thompson M, Van der Lei J, Van Mulligen E, Velterop J, Waagmeester A, Wittenburg P, Wolstencroft K, Zhao J and Mons B, The FAIR guiding principles for scientific data management and stewardship, Scientific Data, 3(2016). https://doi.org/10.1038/sdata.2016.18.

7 Allen BP ,Linked data standards and infrastructure for scientific publishing, In Proceedings of the W3C Workshop

on Linked Enterprise Data Patterns, Elsevier position paper, 2011.

8 Mons, B, Neylon C, Velterop J, Dumontier M, Da silva Santos LOB and Wilkinson MD, Cloudy, increasingly FAIR: revisiting the FAIR Data guiding principles for the European Open Science Cloud, Information Services and Use, 37(1) (2017).

9 Jacobsen A, de Miranda Azevedo R, Juty N, Bastista D, Coles S, Cornet R, Courtot M, Crosas M, Dumontier M, Evelo CT, Goble C, Guizzardi G, Hassen KK, Hasnain A, Hettne K, Heringa J , Hooft RWW, Imming M, Jeffery KG, Kaliyaperumal R, Kesloot MG, Kirkpatrick CR, Kuhn T, Labastida I, Magagna B, McQuilton P, Meyers N, Montesanti A, van Reisen M, Rocca-Serra P, Pergl R, Sansone SA, da Silva Santos LOB, Schneider J, Strawn G, Thompson M, Waagmeester A, Weigel T, Wilkinson MD, Willighagen EL, Wittenburg P, Roos M, Mons B and Schultes E,FAIR principles: Interpretations and implementation considerations. Data Intelligence, 2(1-2) (2020).

10 Shotton D, Portwin K, Klyne G and Miles A ,Adventures in semantic publishing: exemplar semantic enhancements of a research article, PLoS Computational Biology, 5(4) (2009). https://doi/org/10.1371/journal.pcbi.1000361.

11 Mesbah S, Fragkeskos k, Lotfi C, Bozzon A and Houben GJ, Semantic annotation of data processing pipelines in scientific publications, *In Proceedings of ESWC 2017*, Lecture Notes in Computer Science. https://doi.org/10.1007/978-3-319-58068-5-20.

12 Thanapalasingam T, Osborne F, Birukou A and Motta E, Ontology-based recommendation of editorial products. *In Proceedings of ISWC 2018*, Lecture Notes in Computer Science. https://doi.org/10.48550/arXiv.2103.13526.

13 Auer S and Mann S, Towards an open research knowledge graph, Serials Librarian, 76(1-4) (2019) https://doi.org/10.1080/0361526X.2019.1540272.

14 Ghorbani Bousari R, Ghiasi M and Razavi SAA, Studying the status of productivity efficiency and scientific influence of researchers in the field of linked data, Scientometrics Research Journal 9(2) (2023). https://doi.org/10.22070/RSCI.2022.16188.1588.

15 Guha RV, Brickley D and Macbeth S Schema.org: Evolution of Structered Data on the web. *Communications of the ACM*, 59 (2) (2016)44-51. https://doi.org/10.1145/2844544.

16 Antelman K and Wilson K, The Global Open Knowledge base (GOKb): open linked data supporting electronic resources management and scholarly communication, *Insights*, 28(1) (2015) https://doi.org/10.1629/uksg.217.

17 Erkimbaey AO, Zitserman VY, Kobzev GA, Serebrjakov VA and Teymurazov KB, Publishing scientific data as linked open data, *Sci Tech Inf Process* ,40(4) (2013) . https://doi.org/10.3103/S014768821304014X.

18 Shen Z, Erkimbaev AO, Zitserman VY,Kobzev GA, Serebrjakov VA and Teymurazov KB, Opencsdb : research on the application of linked data in scientific databases, *Data Sci J*, 14(4) (2015). https://doi.org/10.5334/dsj-2015-004.

19 Toulet A, Michel F, Bobasheva A, Menin A, Dupré S, Deboin MC, Winckler M, Tchechmedjiev A (2022) ISSA: generic pipeline, knowledge model and visualization tools to help scientists search and make sense of a scientific archive. In: Sattler U, d'Amato C, Dragoni M, Goncalves and Gentile AL (eds) ISWC 2022, Lecture Notes in Computer Science. https://doi.org/10.1007/978-3-031-19433-7-38.

20 Farber M, Lamprecht D, Krause J and Haase P, SemOpenAlex : the scientific landscape in 26 billion RDF triples. *In Proceeding* of ISWC 2023, Lecture Notes in Computer Science, vol 14266 (2023), pp 94-112. https://doi.org/10.1007/978-3-031-47243-5-6.

21 Rautenberg S, Marx E, Gomes Filho AC and Auer S, Apoiando estudos cientometricos com linked open data. Perspect Cienc Inf 22(4) (2017). https://doi.org/10.1590/1981-5344/2817.

22 Akullo E and Nsibirwa MS, Linked Data adoption in university libraries in Uganda: the potential benefits. Library Hi Tech (2024). https://doi.org/10.1080/ 1941126X.2024.2415868.

23 Al Mashai A, The open Research Divide : A Comparative Analysis of Policy, Infrastructure, and Practice in North Africa, SSRN (2025). http://dx.doi.org/10.2139/ssrn.5516358.

24 Nwakaego OF, Linked Data Technology and Linked Open Data in Academic Libraries in Nigeria: Level of Integration, Challenges and Potential Solution.*International Journal of Intelligent Information Systems*.InternationalJournal of Intelligent Information Systems, 12(2)(2023)31-38. https://doi.org/10.11648/j.ijiis.20231202.12.

25 Ministry of Higher Education, Scientific Research and Innovation.National Strategy for Open Science in Morocco, 2024.

26 Gandon F, Web de données liées et web sémantique. *In: Bouzeghoub M, Mosseri R(eds) Les Big Data a decouvert*, CNRS, 2017. Available at : https://hal.archives-ouvertes.fr/hal-01709800.

27 El-Ouahi J, Robinson-Garcia N and Costas R. Analysing scientific mobility and collaboration in the Middle East and North Africa. *Quantitative Science Studies*, 2(3) (2021) 1023-1069. https://doi.org/10.1162/qss_a_00149.

28 Musen MA, The Protégé project: a look back and a look forward, *AI Matters* 1(4)(2015)4-12 https://doi.org/10.1145/2757001.2757003.

29 Stanford University, Protégé ontology editor. Available at: https://protege.standford.edu/ (Accessed on 08 April 2025).

30 Stellato A, Fiorelli M, Turbati A, Lorenzetti T, Van Gemert W, Dechandon D, Laaboudi-Spoiden C, Gerencsér A, Waniart A, Costetchi E and Keizer J, VocBench 3: a collaborative semantic web editor for ontologies thesauri and lexicons, *Semant Web* 11(1) (2020). https://doi.org/10.3233/SW-200370.

31 VocBench Project, VocBench platform. Available at: https://vocbench.uniroma2.it (Accessed on 05 April 2025).

32 TopQuadrant, TopBraid Composer. Available at: https://topbraidcomposer.org/html/ (Accessed on 01 April 2025).

33 RDFlib Developers, rdflib-a Python library for workin with RDF. Available at: https://rdflib.readthedocs.io (Accessed on 16 April 2025).

34 RMLMapper Project, RMLMapper- Java implementation. Available at: https://github.com/RMLio/rmlmapper-java (Accessed on 22 April 2025).

35 OpenRefine Project, OpenRefine. Available at: https://openrefine.org (accessed on 24 April 2025).

36 OpenRefine RDF Extension, Working with RDF in OpenRefine. Available at: https://github.com/

stkenny/grefine-rdf(extension/wiki (Accessed on 24 April 2025).

37 Apache Software Foundation, Fuseki-SPARQL server. Available at: https://jena.apache.org/documentation/fuseki2/ (Accessed on 27 April 2025).

38 Ontotext, Graph DB documentation. Available at : https//graphdb.ontotext.com/documentation/ (Accessed on 28 april 2025).

39 OpenLink Software, Virtuoso universal server open-source edition. Available at: https://virtuoso.openlinksw.com/ (Accessed on 29 April 2025).

40 Pedro A, Pham-Hang AT, Nguyen PT, Pham HC, Data-driven construction safety information sharing system based on linked data, ontologies, and knowledge graph technologies, *Int J Environ Res Public Health*, 19(2) (2022). https://doi.org/10.3390/ijerph19020794.