








Cotton Plant Pests and Phenology Knowledge Management in Côte d'Ivoire Using Semantic Web Technologies

Kouaho N'Guessan Narcisse Tehia^{1,3}  , Sadouanouan Malo¹ ,
Appoh Kouamé² , Malanno Kouakou³ , Kouadio Kra Norbert Bini³,
and Ochou Germain Ochou³

¹ Université Nazi Boni, Bobo-Dioulasso, Burkina Faso
tehiako@gmail.com

² Institut National Polytechnique Félix Houphouët Boigny, Yamoussoukro, Côte d'Ivoire

³ Centre National de Recherche Agronomique, Bouaké, Côte d'Ivoire

Abstract. In this paper, we are interested in the management of knowledge on the dynamics of pests and the phenology of cotton plant. This issue is a serious concern for the cotton sector in Côte d'Ivoire. Indeed, enormous parasitic pressures cause crop losses that vary between 30% and 100% of the production potential. A phytosanitary surveillance strategy for cotton has therefore been put in place. It is in this context that an ontologically based decision support system has been proposed. This system includes a mobile application for data collection and an ontology-based semantic wiki for knowledge management. The mobile application is deployed, and an ontology dedicated to the phytosanitary surveillance of cotton plant has been proposed. This ontology should be used as a knowledge base for the semantic wiki. We present in this paper the implementation of this semantic wiki that we call SYSPARCOT-CI WikiS. This platform is the first of its kind in cotton cultivation, mainly in phytosanitary surveillance. It is based on Semantic MediaWiki. The data from this semantic wiki as well as the data from the mobile application will be used to populate the ontology and to enrich it. The construction approach of our semantic wiki platform is based on *ontologies for wikis*. Using the ontology we built, we constructed a semantic web platform. Then, using a Python script, this ontology was imported into the semantic wiki.

Keywords: Knowledge management · Semantic MediaWiki · Ontology · Web platform · SPARQL · RDF

1 Introduction

Cotton is largely cultivated in the countries of the West African sub-region [1]. In Côte d'Ivoire, it is mainly cultivated in the central and northern regions. It allows the producers who cultivate it to prosper financially [2]. Unfortunately, cotton cultivation is confronted with enormous parasitic pressures. These pressures cause crop losses that vary between 30% and 100% of production potential [3, 4]. To reduce pest damage and limit crop losses, it is necessary to update knowledge on cotton plant pests and phenology. Indeed, this knowledge is influenced by climatic and environmental changes [5].

To update knowledge, a systematic surveillance was set up in the ivoirian production zones. The implementation of this surveillance for more than forty years is not without difficulty. To overcome these problems, we proposed in [6] a solution to facilitate the collection and transfer of phytosanitary data in real time from cotton plant parcels. This surveillance is the main activity that allows us to update our knowledge of cotton plant pest population dynamics and phenology every year. To build a collaborative platform for the management of knowledge from cotton plant surveillance, we proposed in [7] a domain ontology, ontoSYSPARCOTCI. Based on this ontology, we propose in this paper a collaborative platform for homogeneous communication between cotton sector actors and management of knowledge on pests and phenology of cotton plant. Indeed, by this platform, actors will be able to share, reuse and capitalize on knowledge and experiences in the domain of cotton plant phytosanitary surveillance [19]. The implementation of this platform is done with MediaWiki which is a powerful and flexible web wiki platform for collaborative content creation and management. The integration of semantics MediaWiki, an extension of MediaWiki, allows for easier semantic search and exploration of the dataset contained in the platform, which we name SYSPARCOT-CI WikiS. The construction approach of our semantic wiki platform is based on ontologies for wikis.

Except introduction and conclusion, this paper is structured in three parts. The first part deals with the related works. The second part is devoted to the implementation of SYSPARCOT-CI WikiS. Finally, the third part presents the results and discussion of part two.

2 Related Works

2.1 Brief State of the Art on Semantic Wikis

The notion of a Wiki was first introduced by Ward Cunningham in 1995 [8]. The term Wiki means “quickly” [9]. It is of Hawaiian origin and can be defined as a class of groupware that allows to co-construct a knowledge base in an agile way. It is presented in the form of a website that can be accessed, modified, or enriched according to the privileges defined for each user. There are several wikis platform, the most famous of which is Wikipedia¹. In practice, Wikis are generally composed of a set of editable pages, organized in categories, and linked together by hypertext links. The content, structuring, layout, and organization of Wiki pages are the result of the collaboration of a community of users. The limitations of wikis have led to integration of semantics web [10]. Thus, Semantic Wikis were born. Contrary to traditional Wikis, Semantic Wiki considers the meaning of the terms. Indeed, Semantic Wikis characterize resources and the links between them by formalizing them in the form of triplets to make them exploitable by machines through artificial reasoning processes. The power of Semantic Wikis comes from the fact that they combine Wikis and Semantic Web technologies [11]. To build a semantic Wiki, two types of approaches exist namely ontologies for wiki (OFW) and wiki for ontologies (WFO) [10]. The first approach consists in building a Semantic Wiki from an ontology. The second approach consists in building a vocabulary and a knowledge base from a wiki, i.e., an ontology. There are several Wikis, the most popular of which is MediaWiki. This last is an open-source wiki engine, which is used by all projects of the Wikimedia Foundation [8]. It is constantly updated and is maintained by a strong community.

¹ <https://www.wikipedia.org/> accessed in April 2023.

One of the additional reasons for choosing MediaWiki are its features. Indeed, MediaWiki facilitates a good co-elaboration of knowledge, thematic search, contributions, traceability of contributions, constitution of a knowledge base [8, 9]. The extension that transforms MediaWiki into a semantic web platform is Semantic MediaWiki. Thanks to the latter, the MediaWiki technology is able to facilitate the construction of a virtual community related to a domain for knowledge management with query and export capabilities. Semantic MediaWiki can implement both approaches. Given the existence of an ontology for cotton plant surveillance [7], we opted for the ontologies for Wiki approach in the construction of our Semantic Wiki. There are semantic Wikis based on the ontologies for wiki approach such as IKE WIKI², Kiwi³. Kiwi being the improved version of IKE WIKI. Unfortunately, they aren't maintained anymore.

2.2 Semantic Wikis as Platforms for Sharing and Co-constructing Knowledge

There are several projects in the literature relating to semantic web platforms. Based on knowledge graphs, these platforms enable multi-scale data to be integrated, as was the case in [12], whose objective was to build networks of molecular interactions from scattered data in order to identify key genes for plant improvement, specifically rice. Semantic web technologies enable content to be created, reused, linked and shared across the web [13]. In [14], Eric Leclercq *et al.* proposed an information system using the semantic wiki approach for knowledge production by developing WikiBridge. WikiBridge was developed by [14] from the MediaWiki wiki. It is of ontologies for wikis type. Papa F. Diallo in [9] has set up a virtual community made up of three layers, namely GUI, persistence, and semantics. This platform uses Semantic MediaWiki and Exhibit for the GUI layer, Jena, SPARQL engines and rules for the semantic layer and Virtuoso for persistence. To share endogenous knowledge for adaptation of cropping techniques in a context of climate change, Trawina [11] set up a virtual semantic web platform combining semantic Media Wiki, SweetWiki, Virtuoso and Jena EE, which enabled it to implement a Java API for management of its ontology. There is a plethora of methods in literature for building a semantic web platform. However, each author justifies his or her choices because there is no set construction methodology. Our field of study is the phytosanitary surveillance of cotton in Côte d'Ivoire. KOFIS (Knowledge for Organic Farming and Innovative System) is an ontology-based knowledge management system for agriculture [15]. It provides practical solutions to sharing and shortages of information in organic farming. Unfortunately, it does not deal specifically with plant health monitoring in cotton culture. Lack of farmer input into data collection and decision-making raises issues of trust between farmers and smart farming technologies, which led [16] to set up a platform for integrating textual data in agriculture to detect natural hazards. [17] has proposed a platform for integrating heterogeneous data into knowledge bases to support and inform farmers and researchers in their activities in real time using semantic technologies and linked data. To our knowledge, no work has been done on the construction of a semantic web platform in the domain of phytosanitary surveillance of cotton, particularly in Côte d'Ivoire. Having an ontology at our disposal, we plan to build a semantic web platform that will communicate with a FUSEKI server. Despite Virtuoso's storage capacity [9], our choice to use FUSEKI is explained by the fact that

² <https://wiki.c2.com/?IkeWiki> accessed in April 2023.

³ <https://wiki.c2.com/?KiWi> accessed in April 2023.

initially, we have a PostgreSQL database of phytosanitary surveillance of cotton in Côte d’Ivoire, which is populated by a mobile application that we designed and developed. FUSEKI server also offers improved execution time for SPARQL queries [18]. FUSEKI server is dedicated to storing RDF triples, SPARQL query management and is able to function as a high-performance operating system service [11].

3 Implementation of SYSPARCOT-CI WikiS

The construction of our collaborative virtual community is based on the ontology proposed in [7], realized using Protégé (Fig. 1).

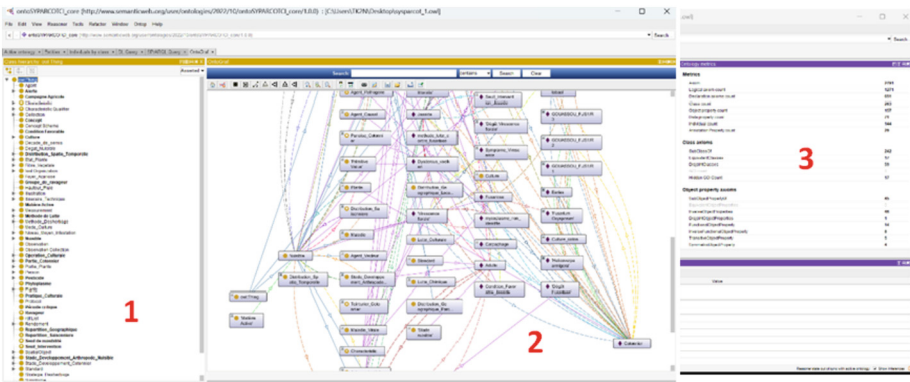


Fig. 1. Extract from ontology in Protégé (concepts (1) + knowledge graph (2)) and metrics (3)

Relative to competence questions, some evaluation results of this ontology are presented in Fig. 2, Fig. 3 and Fig. 4. Formulated in French and noted CQ1, CQ2 and CQ3, these questions have their English translation in titles of Fig. 2, Fig. 3 and Fig. 4 respectively.

CQ 1 : Quels sont les maladies du cotonnier en Côte d’Ivoire ?

Algorithme 1 : Requête SPARQL

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ontosys: <http://www.semanticweb.org/user/ontologies/2022/10/ontoSYPARCOTCI_core#>
SELECT ?maladie_cotonnier
WHERE {
  ?maladie_cotonnier rdf:type ?nuisible.
  ?maladie_cotonnier ontosys:est_nuisible_de ontosys:Cotonnier.
  FILTER(?nuisible=ontosys:Maladie)
}

```

Résultat de CQ1

	maladie_cotonnier
Virescence florale	
Fusariose	

Fig. 2. SPARQL query and answer to the competency question “What are diseases of cotton plant in Côte d’Ivoire?”

CQ 2 : Quels sont les ravageurs du cotonnier en Côte d'Ivoire ?**Algorithme 2 : Requête SPARQL**

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ontosys: <http://www.semanticweb.org/user/ontologies/2022/10/ontoSYPARCOTCI_core#>
SELECT ?ravageur_cotonnier
      WHERE {?ravageur_cotonnier rdf:type ?arthropode.
            ?ravageur_cotonnier ontosys:est_nuisible_de ontosys:Cotonnier.
            FILTER(?arthropode=ontosys:Arthropode_Nuisible)
      }

```

Résultat de CQ2

	ravageur_cotonnier
Pectinophora gossypiella	
Haritalodes derogata	
Anomis flava	
Spodoptera littoralis	
Dysdercus voelkeri	
Diparopsis watersi	
Earias insulana	
Helicoverpa armigera	
Thaumalatobia leucoteta	
Polyphagotarsonemus latus	
Jacobieilla fascialis	

Fig. 3. SPARQL query and answer to the skill question “What are arthropod pest of cotton plant in Côte d'Ivoire?”

CQ 3 : Quelles sont les variétés locales de coton cultivées en Côte d'Ivoire ?**Algorithme 3 : Requête SPARQL**

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ontosys: <http://www.semanticweb.org/user/ontologies/2022/10/ontoSYPARCOTCI_core#>
SELECT (?subject as ?plante) (?object as ?variété)
      WHERE {?subject rdf:type ontosys:Plante.
            ?subject ontosys:a_pour_variete_locale ?object.
            FILTER(?subject = ontosys:Cotonnier)
      }

```

Résultat de CQ3

	plante	variété
Cotonnier		Y331_BLTAR2
Cotonnier		Y331_BLTAR3
Cotonnier		Y331_BLTAR1
Cotonnier		SICAMA_VIR1R3
Cotonnier		SICAMA_VIR1R1
Cotonnier		SICAMA_VIR1R2
Cotonnier		GOUASSOU_FUS1R3
Cotonnier		GOUASSOU_FUS1R2
Cotonnier		GOUASSOU_FUS1R1

Fig. 4. SPARQL query and answer to the skill question “What are local cotton plant varieties cultivated in Côte d'Ivoire?”

The evaluation allowed to verify that the ontology meets the specifications of the requirements defined from the exchanges with the domain experts. This evaluation consisted in formulating and executing SPARQL queries on the ontology in the Protégé software.

3.1 General System Architecture

In [6], we proposed an original global architecture of our system composed of three technological machines and tools. This general architecture of cotton plant phytosanitary surveillance system is here recalled (Fig. 5). The first part of our architecture allows domain experts to dispose of real-time plant health surveillance data during the cotton campaign. The second part gives back raw data from the data collection in time to domain experts. These two parts constitute a major innovation in the domain of phytosanitary surveillance of cotton in Côte d'Ivoire. Indeed, the acquisition of data in real time was an obstacle to regular monitoring of the phytosanitary situation of cotton plant in production zones. This work concerns the third and last part of this architecture (Fig. 5) which is represented by technology machine 3 (circled black).

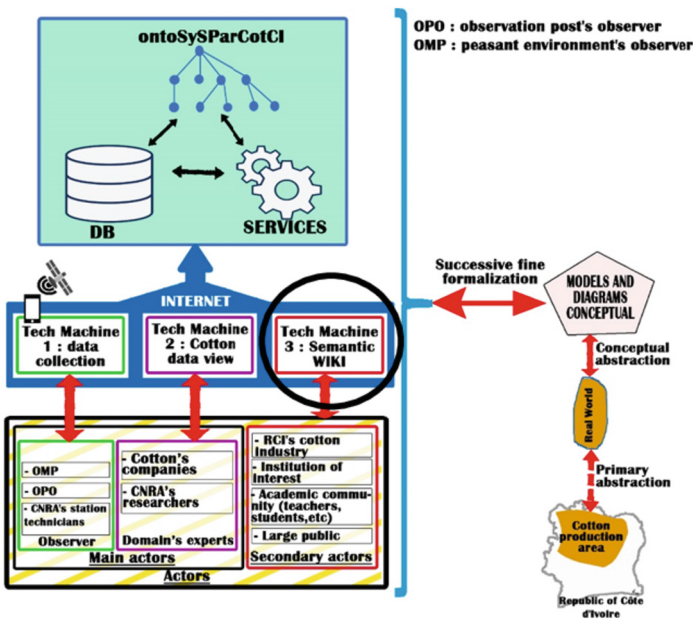


Fig. 5. General architecture of the cotton plant phytosanitary surveillance system

Realization of the last part of our architecture consists in Semantic Wiki implementation for cotton plant pest and phenology management in Côte d'Ivoire.

3.2 SYSPARCOT-CI Wikis Use Cases

The main use cases of SYSPARCOT-CI Wikis are presented in Fig. 6. This Wiki is used to update knowledge on the spatiotemporal dynamics of pests and the phenology of cotton plant in Côte d'Ivoire. It is also used to know the spatiotemporal dynamics of pests and the phenology of cotton plant for those who are interested in them. No account creation is required for a visitor of SYSPARCOT-CI Wikis to get information.

However, any modification must be done in a secure access account that is managed by the agricultural research team in collaboration with ontologist. SYSPARCOT-CI WikiS is not closed, so it is possible to extend it by adding other use cases.

Contributions to wikis are mainly made by creating pages. In our case study, this creation has restrictions. Any visitor can create one or more pages. However, validation of these pages is reserved for experts (researchers and technicians) in the field. The creation of pages in our case study is guided by the ontology ontoSYSPARCOTCI [7]. This ontology is maintained by an ontology specialist assisted by domain experts. Administrators (domain experts and ontologists) maintain the platform and manage users. A visitor is any person in addition to administrators who visits our semantic web platform. A visitor can consult information on the wiki by browsing its various pages and create new pages.

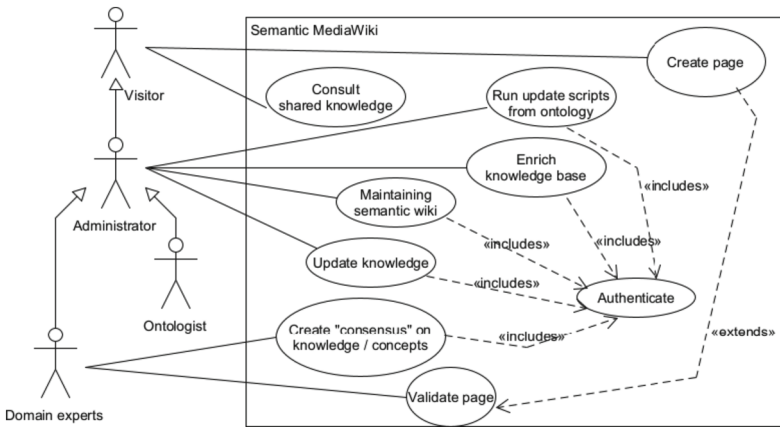


Fig. 6. Some use cases of SYSPARCOT-CI WikiS

3.3 Implementation Description

Figure 7 represents the third step in the implementation of our general architecture (Fig. 5). This third step concerns the implementation of a semantic web platform (red color). Figure 7 details connections and interactions that underlie Semantic MediaWiki implementation.

SYSPARCOT-CI WikiS is based on three main layers (Fig. 7), namely the user layer, the semantic layer, and the persistence layer. In this work, user layer is represented by Semantic MediaWiki (SMW). Semantic layer consists of the SPARQL query and Jena inference engines. Persistence layer is constituted by relational databases, an ontology, and RDF depot.

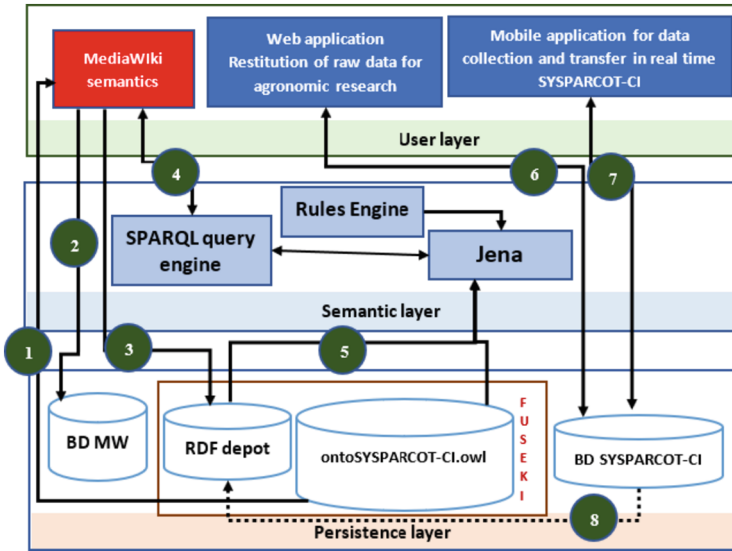


Fig. 7. Detailed internal architecture of SYSPARCOT-CI as presented in [6] according to 3 layers with focus on Semantic MediaWiki. (Color figure online)

To understand our approach, we proceed by steps. These steps show the composition of our persistence layer and how we build it. They also describe how we set up our semantic wiki.

- Step 1: It concerns the import of ontoSYSPARCOTCI into Semantic MediaWiki. The ontology was exported from Protégé in RDF format. Then, thanks to ontology2smw [10], from this RDF format, we imported it into the Semantic MediaWiki platform.
- Step 2: Semantic Platform textual data is saved directly in a database. This last created during installation and configuration of Semantic MediaWiki while the annotated data is saved in an RDF repository created in the FUSEKI server; this is Step 3.
- Step 4: From MediaWiki Semantics, SPARQL queries are performed on the FUSEKI server implementing Jena Apache. The latter exploits the RDF repositories available in the FUSEKI server (this is Step 5). SPARQL queries from SMW are possible using LinkedWiki, an extension of MW. To import ontoSYSPARCOTCI into the FUSEKI server, we exported it from Protégé in RDF format. An interface in the FUSEKI server allowed us to create an RDF repository and then import the exported ontology.
- Step 6: allows the team of the laboratory of agricultural entomology and cotton companies to extract the raw data from the relational database SYSPARCOTCI-BD. This database is fed during each cotton season by agents of cotton companies who carry out observations and measurements on the parcels via digital tablets [6] (this is Step 7).

- Step 8: Thanks to the D2RQ⁴ platform, the main tool for generating RDF files from a relational database, the relational database of SYSPARCOT-CI (SYSPARCOTCI-BD) is transformed into an RDF file and then loaded as an RDF repository in the FUSEKI server by a script in an automatic way. The communication between the RDF repository from SYSPARCOTCI-BD and the ontology ontoSYSPARCOTCI is possible thanks to a mapping file that establishes the correspondences.

The import of the ontology into Semantics MediaWiki (see Step 1 of Fig. 7) allows to dispose of a vocabulary specific to the study domain to guide the administrators of the platform in the knowledge management. A series of transforms are observed during the ontology import as shown in Table 1.

Table 1. Matching the ontology syntax to the Semantic MediaWiki syntax

Ontology	OWL syntax	SMW	SMW syntax
Concept	owl: Class	Category	[[Category:Pest]]
Subconcept	rdfs:subClassOf	Subcategory	Subcategory of [[:Category: Observed Plant]] [[Category: Observed Plant]]
Instance	owl:NamedIndividual	Page	Individual Name + its category, relations, and attributes
Attribute	owl:DatatypeProperty	Attribute	[[Attribute:sowing date:: '2022-05-25']]
Relation	owl:ObjectProperty	Hyperlink	[[Attribute:is disease of::Cotton_Plant]]

Attribute is relationship between a page and a predefined type. Hyperlink is relationship between two pages.

4 Results and Discussion

Concepts or classes of the ontology have been transformed into categories (Fig. 8). One of these categories, namely Pest, is shown in Fig. 9.

⁴ <http://d2rq.org/> accessed in April 2023.

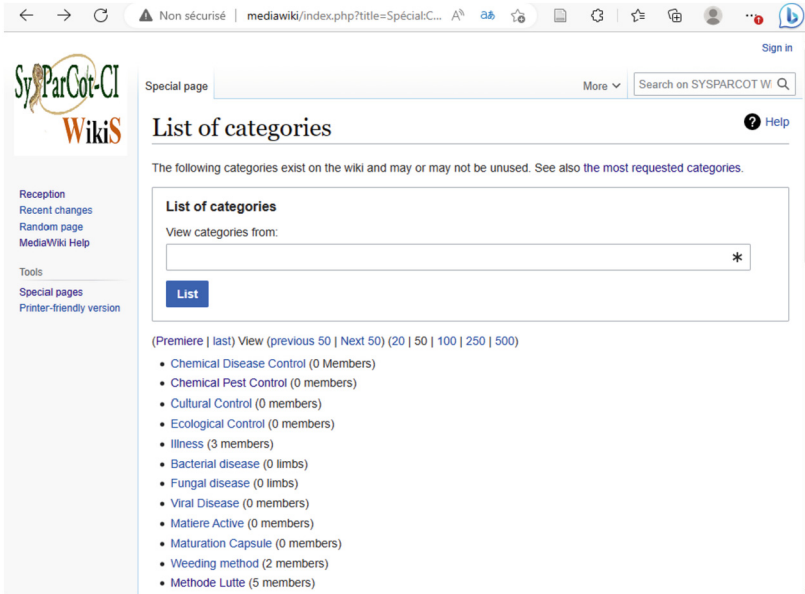


Fig. 8. Extract of the category list in SYSPARCOT-CI WikiS

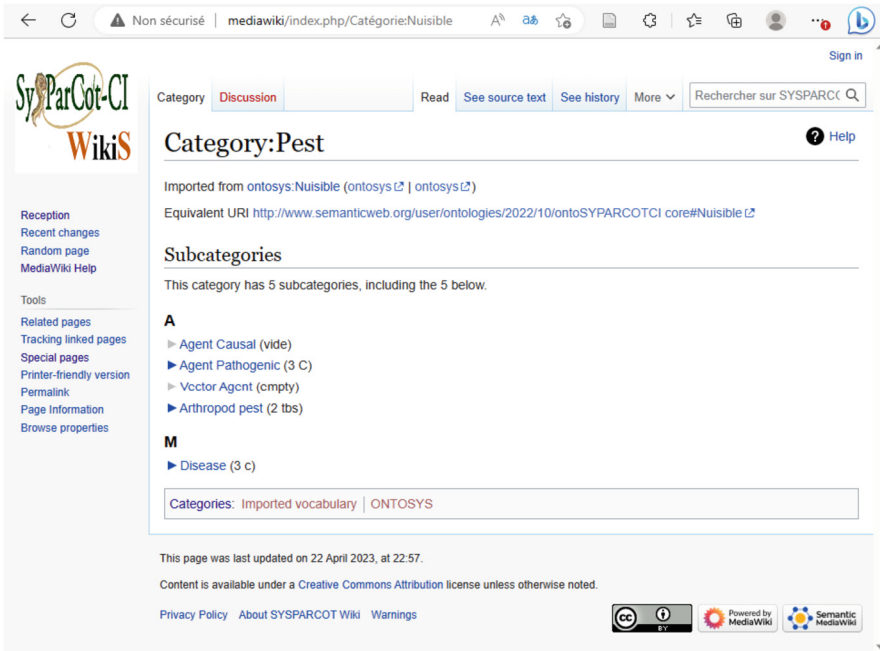


Fig. 9. Category Pests and its subcategories in SYSPARCOT-CI WikiS provided by ontoSYS-PARCOTCI (see Step 1 Fig. 7)

Detailed architecture presented and proposed approach to implement our MediaWiki semantics is one proposal among many others. We think it could be improved. However, there is no imposed methodology or tool to implement a Semantic Wiki. Respecting the ontology approach for wikis, our tests proved to be conclusive. Transforming relational DB into RDF and loading it into the FUSEKI server can be time consuming as the RDB becomes voluminous. Studies will be conducted in this direction to reduce the execution time.

Using a triple store in this case, FUSEKI server is justified by the fact that a relational database is not an ideal storage type for semantic data. However, Semantic MediaWiki uses a relational database. Also, a triple store that supports the SPARQL standard allows other applications to query it without going through the Semantic MediaWiki web frontend. This allows for independence from the semantic database for reuse. FUSEKI server allowed us also to create an endpoint to facilitate data exploitation.

Compared to traditional web, semantic web adds semantic information to web content and gives machines the ability to distinguish their meaning. In semantic web, data is linked together, and inferences are made automatically by the machine.

Currently, ontology and semantic wiki are accessible locally. Tests have been done locally as well.

5 Conclusion

A semantic wiki dedicated to knowledge resulting from cotton plant phytosanitary surveillance in Côte d'Ivoire exists. It allows to manage cotton plant pests and phenology knowledge in Côte d'Ivoire. To our knowledge, we believe that it is the first of its kind. It implements several technologies and tools that are not easy to use. These include the FUSEKI server, RDF repository, Ontology, MediaWiki and its extensions, especially Semantic MediaWiki. Finally, we were able to do it. This semantic web platform will allow to enrich the ontology that was the basis of its implementation and provided a domain vocabulary. The next part of our work will focus on three major points: wiki validation, considering user requests written in natural language and wiki improvement. Validating the wiki will involve conducting a survey to measure user satisfaction using a Likert scale. Likert is a psychometric tool used to measure attitudes in individuals. Given the inability of experts to perform SPARQL queries and master data graph schemas, we will develop an extension to take into account queries written in natural language.

References

1. Doffou, N.M.: Impact de la gestion de la résistance aux pyréthrinoides sur les populations de *Cryptophlebia leucotreta* (meyrick, 1913) (Lepidoptera : Tortricidae) et de *Pectinophora gossypiella saunders*, 1843 (Lepidoptera : Gelechiidae) en culture cotonnière en Côte d'Ivoire: de la sensibilité au mécanisme de résistance. UNIVERSITÉ FÉLIX HOU-PHOUËT-BOIGNY, Abidjan, Côte d'Ivoire (2013)
2. Koné, P.W.E.: Evolution spatiale et temporelle, diversité taxonomique et génétique, et mécanisme de résistance aux insecticides chez les cicadelles du cotonnier en Côte d'Ivoire: approches de lutte intégrée. Université NANGUI ABROGOUA (2019)

3. Ochou, G.O., Matthews, G.A., Mumford, J.D.: Farmers' knowledge and perception of cotton insect pest problems in Cote d'Ivoire. *Int. J. Pest Manag.* **44**(1), 5–9 (1998). <https://doi.org/10.1080/096708798228455>
4. PR-PICA. Acte de la douzième réunion bilan du PR-PICA: restitution des résultats des activités de recherche-développement de la campagne 2018/2019 (2019)
5. Huffaker, C., Berryman, A., Turchin, P.: Dynamics and regulation of insect populations. *Ecol. Entomol.* **2**, 269–305 (1999)
6. Téhia, K.N.N., Malo, S., Kouamé, A., Kouakou, M., Bini, K.K.N., Ochou, O.G.: Towards an ontology-based cotton phytosanitary surveillance system: a case study in Côte d'Ivoire. In: Arai, K. (ed.) *FTC 2021. LNNS*, vol. 358, pp. 962–974. Springer, Cham (2022). https://doi.org/10.1007/978-3-030-89906-6_61
7. Téhia, K.N.N., Malo, S., Kouamé, A., Kouakou, M., Bini, K.K.N., Ochou, O.G.: Contribution to the construction of an ontology for the phytosanitary surveillance of cotton in Côte d'Ivoire. In: *2023 IEEE Multi-conference on Natural and Engineering Sciences for Sahel's Sustainable Development (MNE3SD)*, Bobo-Dioulasso, Burkina Faso, pp. 1–8. IEEE, févr (2023). <https://doi.org/10.1109/MNE3SD57078.2023.10079897>
8. Cunningham, W.: What is wiki. *WikiWikiWeb Httpwww Wiki Orgwiki Cgi* (2002)
9. Diallo, P.F.: Aspects socioculturels et temporels dans les ontologies pour les communautés virtuelles. phdthesis, COMUE Université Côte d'Azur (2015–2019); Université de Saint-Louis (Sénégal), 2016. Consulté le: 9 avril 2023. [En ligne]. Disponible sur: <https://theses.hal.science/tel-01402394>
10. Meilender, T.: Un wiki sémantique pour la gestion des connaissances décisionnelles - Application à la cancérologie. phdthesis, Université de Lorraine, 2013. Consulté le: 11 avril 2023. [En ligne]. Disponible sur: <https://theses.hal.science/tel-00919997>
11. Trawina, H.: Vers une plateforme web social et sémantique de partage de connaissances endogènes pour l'adaptation des techniques culturelles dans un contexte de changement climatique. Université Nazi BONI, Bobo-Dioulasso, Burkina Faso (2022)
12. Larmande, P.: Intégration de données multi-échelles et extraction de connaissances en agronomie: exemples et perspectives. Ph.D. thesis, Montpellier II (2019)
13. Kinsella, S., Passant, A., Breslin, J.G., Decker, S., Jaokar, A.: The future of social web sites. In: *Advances in Computers*, pp. 121–175. Elsevier (2009). [https://doi.org/10.1016/S0065-2458\(09\)01004-3](https://doi.org/10.1016/S0065-2458(09)01004-3)
14. Leclercq, É., Savonnet, M.: Système d'information pour la production de connaissances. L'approche wiki sémantique. *Rev. Sci. Technol. Inf.-Sér. ISI Ingénierie Systèmes Inf.* **17**(3), 143–166 (2012)
15. Géraldine, A., Stephan, B., Daniel, B., Eva, L., Anais, W.: TR Irstea Motive, équipe COPAIN, Systèmes d'information communicants et agri-environnementaux. *Assoc. Fr. Pour L'Intelligence Artif.*, p. 22 (2012)
16. Jiang, S.: Intégration de données textuelles pour la détection des risques naturels en agriculture. These de doctorat, Reims (2022). Consulté le: 13 août 2023. [En ligne]. Disponible sur: <https://www.theses.fr/2022REIMS025>
17. Jiang, S., Angarita, R., Chiky, R., Cormier, S., Rousseaux, F.: Towards the integration of agricultural data from heterogeneous sources: perspectives for the French agricultural context using semantic technologies. In: Dupuy-Chessa, S., Proper, H.A. (eds.) *CAiSE 2020. LNBIP*, vol. 382, pp. 89–94. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-49165-9_8

18. Rivault, Y., Dameron, O., Le Meur, N.: Une infrastructure générique basée sur les apports du Web Sémantique pour l'analyse des bases médico-administratives. In: Plate-forme Intelligence Artificielle 2015, conférence Ingénierie des Connaissances, Rennes, France, juin 2015. Consulté le: 15 août 2023. [En ligne]. Disponible sur: <https://hal.science/hal-01678828>
19. Kouame, A., Brou, K.M., Lo, M., Lamy, J.B.: Vers un système iconique d'aide à la décision pour les praticiens de la médecine traditionnelle. In: Colloque Africain sur la Recherche en Informatique et en Mathématiques Appliquées (CARI 2016), Hammamet, Tunisia, oct. 2016. Consulté le: 17 août 2023. [En ligne]. Disponible sur: <https://hal.science/hal-03491875>