AN OWL BASED ONTOLOGY MODEL FOR CLIMATIC CONDITIONS KNOWLEDGE ON MAIZE CROP FARMING: SCENARIO FOR ENHANCING OWL' OBJECT PROPERTY FOR INTELLIGENT SYSTEMS

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ABSTRACT
The exponential growths of data in heterogeneous forms cut across all human endeavors and disciplines, agriculture for instance. Accessing knowledge in respect to climatic conditions that affects maize crop during planting stage is very significant in order to boost and maintain the crop's maximum yields. However, retrieving or accessing the relevant knowledge to a user's query intension becomes an issue. Therefore, a promising solution towards mitigating this challenge of retrieving relevant information as a result of natural language ambiguity is by modeling data ontologically. Ontology is a data modeling technique for knowledge representation in a machine understandable format. To this end, this paper aims to model an OWL-based ontology for climatic conditions knowledge affecting maize crop during planting stage and enhance the object properties of the concepts in terms of synonyms by using hybridization of Fox-Gruninger, Methontology and FAO-Based ontology development methodologies and written using OWL2 Web Ontology Language RDF/XML syntax. The correctness of the ontology's content and correctness of the ontology development have been constantly validated by the domain experts and via experiments. Thus, the proposed JENA based system provided a relevant knowledge based on user's queries of the subject matter in a more accurate and timely information.

Keywords: Ontology, Object Properties, Climatic Condition, Information Retrieval, Maize

1.0 INTRODUCTION

The existing Web is becoming more interesting as a result of its capability to provide access and platforms to different data repositories in different formats and sizes. This is a good development on one hand because of availability of information but also poses inherent challenge on the other hand because, the accuracy of (relevant) information retrieval becomes a serious research issues. According to literature, this shortcoming is a fall out of lack of cutting edge technology to develop structured data repositories (Iqbal, et al., 2013) and also ambiguities of the natural languages in terms of synonyms, polysemy, meronyms, hyponyms and the likes. However, in order to solve the problem; semantic web is promising.

Semantic web, according to the inventor is not a parallel web to the existing one but meant to gradually evolve from it (Antoniou and Harmelen, 2004). Semantic web or Web 3.0 is an extension of the World Wide Web (W3C) in which documents are filled by annotation in machine understandable markup languages (Choudhury, 2014). As a matter of facts from literature (Sanchez, *et al*., 2011), semantic web is one hand ontology and on the other hand information retrieval. In other words, ontology is most often described as the stronghold of semantic web. In recent research time, the development of ontology and semantic search has attracted so many research attentions. The cutting edge technology – ontology has proven well to address the problem of unstructured data repositories and issues of search as a result of word mismatch.

Different definitions have been given to ontology as a derived field in Artificial Intelligent (AI) but the most popular one is that Gruber (1993) which states ontology as a formal and explicit specification of a shared conceptualization. In this definition, ―formal‖ refers to machine-readable, ―shared‖ refers to agree upon by a group and ―conceptualization‖ is what defines an abstract model describing a particular field of knowledge. Similarly, ontology represent a description of knowledge level or conceptual specification that describe a domain knowledge in a manner that is independent of epistemic state and state of the world (Zacek, 2017). The domain knowledge in this context refers to any real life scenarios. For example; agriculture, medicine, arts and religions. Agriculture largely depends on climate. Hence, climatic factors such as precipitation, solar radiation, wind, temperature, relative humidity all these factors determine distribution of crops and their productivity (Sokoto, *et al*., 2016).

In most regions with rain fed or irrigation crops, there is highly dependency on precipitation during peak month of precipitation (Neenu, *et al*., 2013). Too much precipitation can cause disease infestation in crops, while too little can be detrimental to crop yields, especially if dry periods occur during critical development stages. Moisture stress during the flowering, pollination, and grain-filling stages is especially harmful to maize (Kidane, 2018). Maize or corn (*zea* mays L.) is an important annual cereal crop of the world belonging to family Poaceae. The term –zea‖ is an ancient Greek world with meaning –sustaining life‖ and ―mays‖ is a word from Taino language meaning –life giver‖. Maize production is highly influence by climatic condition which includes water, light, temperature, relative humidity, air and wind. In this paper, we identified three major seasons during which maize crop are affected by climatic conditions. namely: pre-planting season where maize's seeds are affected, planting season where maize plants are affected and post planting where maize (grains) harvest are affected. However, this work only considers the planting season.

Ontology development includes activities to be carried out, techniques used and steps involved for developing ontology, clarification of point related to the formalisms, tools and language to be use in the development process and the likes (Slimani, 2015). In order to develop ontology just like any other systems a set of guideline called methodologies have to be clearly defined either by adoption or by adaption. These ontology methodologies include Methontology, Uschold and King, Noy and Mc Guinnies, Gruninger and Fox, Tove and the likes (da Silva, 2012). Ontology languages are used to encode ontology as knowledge representation language. There are some bases for selecting any knowledge representation language either expressivity or formality. Ontology languages includes DAML+OIL, Ontology interchange language (OIL), Web Ontology Language (OWL), Resource description framework (RDF), RDF Schema (RDFS), Extensible Markup Language(XML). Ontology tools use in creation and manipulation of ontology are Protégé, OntoEdit, WebODE, WebOnto Swoop and the likes (Alatrish, 2013). OWL provides a means for describing properties and concept in a human and machine-understandable format, Antonius and Harmelen (2009).

Therefore, the proposed paper aims to model climatic conditions knowledge for maize crop farming ontologically. This is by taken into account the relevance of OWL's relations (object property) and its inherent effects of synonyms. For example, the term *affects* is a relation that connects concepts *Heavy Rainfall* and *Maize Crop*. Similarly, the term *influences* is also encoded as a synonyms of relation affects.

2.0 LITERATURE REVIEW

Web Ontology Language (OWL) amongst others is one of the foremost ontology knowledge representation languages. Currently, aside from the existing OWL1, it has improved upon and thereby gave birth to OWL2 in 2012. OWL provides sophisticated modelling constraints such as explicit cardinalities, universally and existentially quantified property constraints, and class definitions based on the union, intersection, or complement of other classes. OWL consists of namespace, classes, properties, and individuals (Cardoso and Pinto, 2015). OWL's properties basically consist of object property and data property. Meanwhile, annotation property is another type. However, object property clearly defines the relations between classes. As such, the property has to be diligently explored as it forms the basis on how intelligent an ontology based system is designed.

According to Neenu *et al* (2013); changes in temperature that can affect air vapor pressure deficits were identified, thus impacted the water use in agricultural landscapes. Similarly, the research of Kidane, (2018) also presented that plant having C4 photosynthesis reacts little to the rising of atmospheric CO_2 compare to that of C3 plant. This is due to the mechanism that increases the concentration of CO_2 in the leave which leads to CO_2 saturation of photosynthesis of this plant. However, in this paper more climatic conditions are considered. Some typical example of C4 crops are maize (corn), millet, sorghum, sugarcane and the like.

Considering Kuashik and Chatterjee (2017), the researchers proposed a schema for designing an ontology for agriculture domain with a focus on Indian context, the proposed schema worked in two step. In step one it uses domain-dependent regular expression and natural language procession techniques for automatic extraction of vocabulary related to the agricultural domain. Then the second step entails semantic relationships between the extracted terms and the candidate terms to be identified, which were carried out based on the rule-based reasoning algorithm called RelExOnt.

Moreover, Narayana, (2017) proposed a collaborative system that can support the management and sharing of multifaceted and large scale data source, which provide valuable and indispensable information for researcher. The proposed solutions relay semantic interoperability, construction of complex knowledge representation model bydesigning an ontology based decision support system for cotton crop farmers.

Furthermore, Bonacin *et al, (*2015) proposed an ontological model on impact of agriculture and climatic changes on water resource. This work describes interoperability issues in the engineering process of the OntoAgroHidro water resources. The research work emphasizes on the reuse of existing ontological models (Cauhsi and Sweet). However, in the case of this proposed paper, we created our ontological model for climatic conditions from scratch. A domain specialist read and analyzed each of the documents and marked the result as relevant or irrelevant. The paper presents representative scenarios and questions, and discusses the reuse and integration of concepts using knowledge visualization techniques. Experiments on the information recovery scenario point out the potential and limitations of the OntoAgroHidro.

Technically and based on literature, the application of ontology in agriculture is gradually gaining visibility like that of biomedicine. The research work of Malik et. al. (2018) developed fertilizer based ontology for the domain of agriculture and as well designed a user interface for query. The project is aimed to function in future as real time system by intending to merge it with existing ontologies within the domain such as crop or soil. Similarly, Chougule, et. al. (2019) advanced a research to developed an OWL based ontology recommended system for appropriate fertilizer to crop and appropriate soil for crop by considering a particular location in India.

Considering literature; there is no acceptable techniques for ontology validation and evaluation, which is very significant in ontology design as that determine the quality of ontology. Preference of technique is dependent on agreeing factors by ontology developers and/or domain experts (Walisadeera, et. al. 2016). Similarly, Dnyanesh and Rahul (2011) asserted in their work that the existing methodologies for ontology development fall short of comprehensive coverage for different activities such as pre-development, development and post-development stages. Consequently, to determine the appropriate methodology, some researches combined the activities of Methontology and Gruninger and Fox to design a given ontology (Iqbal, *et al.* 2013). Therefore, this literature forms the basis or the rationale behind the hybridization of the engineering processes used in this paper having reviewed the strengths and weaknesses of the existing work.

3.0 METHODOLOGY: THE ONTOLOGY ENGINEERING PROCESS

As earlier stated in the previous sections, there are available and different ontological development methodologies but not without shortcomings (Aminu et al. 2019). For example, while Methontology lacks competency question process, Gruninger-Fox lacks the process of ontology evolution and FAO-Based approach is limited in terms of specification of term or concepts. In view of these aforementioned limitations, the paper hybridized the three methodologies or ontology engineering processes to model the ontology under the domain of climatic conditions for maize crop farming. The hybridized approach used in this work consists of six processes namely as; collections of domain knowledge, specification of concepts (in this case, according to OWL‘s axioms), set competency questions to determine ontology‘s purpose and scope, ontology formalization, ontology validation and evaluation and ontology evolution as represented by Figure 1.

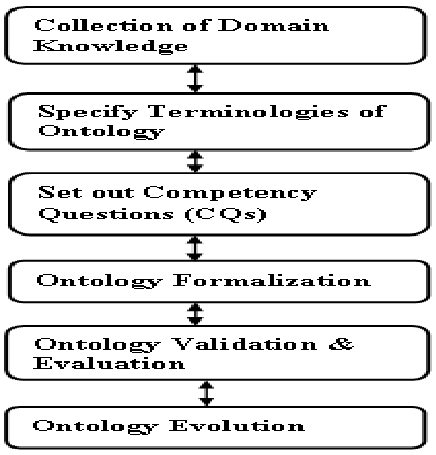

Figure1 : Ontology Engineering Process

For instance, the terms *maize*, *climaticCondition*, *Precipitation*, *Humidity*, *Sunlight*, *Rainfall*, *Wind* are specified classes components or sub concepts of the default class owl:Thing. Terms such as *affect* along with its synonyms *influences*, *change*, *involves* are specified and encoded as object property. Table1 presents some of the competency questions that would define the intelligent capability of the ontology as formulated and duly validated by both ontology developers and domain experts.

Table1: Ontology‘s Competency Questions

Competency question (CQs)	Contextual information required
What are the factors affecting maize?	• Is it the climatic condition during the pre-planting season? • Is it the climatic condition during the post-plant season? • Is it the climatic condition during the post-planting season
What are the factors that trigger physiological process and morphogenesis process?	• Physical attribute or characteristic involve. • Change occur based of color, height and the light • Simplex of complex development of maize
What are the factors that affect development process of maize?	• Stages of maize could be involving • Is it Physical development or biological development

Because of the model involved, it is expected that each query or question is put in context (meaning) as shown by the second column of the Table in order to achieve relevant precision and recall. In this section also we present the conceptual design or framework of the proposed system as shown by Figure2.

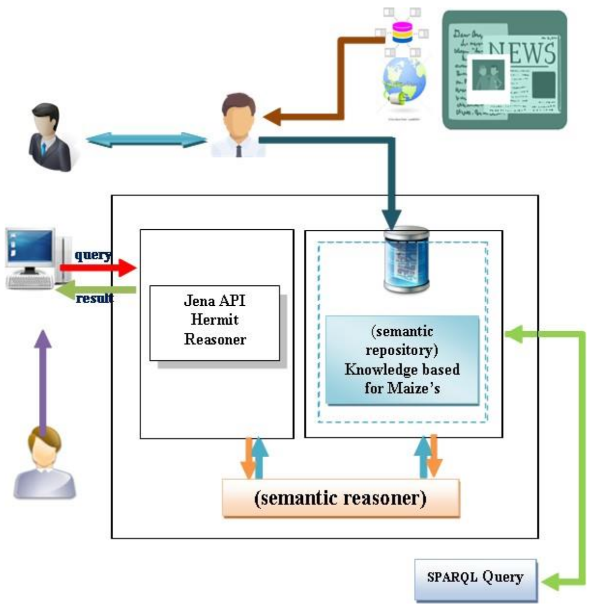

Figure 2: System Architecture of the Proposed

From the Figure 2, developer(s) collect domain related knowledge from various sources (such as trusted web documents, articles, books and institutions) and validated by domain experts. As soon as the knowledge are validated, the developer formalize the knowledge ontologically with the aid of Protégé editor and as well validated by its reasoners (Hermit, Pellet and ELK: reasoner) to develop the semantic repository. While developer uses SPARQL to query the ontology, a java based user interface is created taken into account the JENA Application Programming Interface (API) for end user‘s accessibility of the system. Besides, the proposed system‘s scenarios are furthered depicted by use case diagram of Figure3 and the data flow diagram of Figure 4.

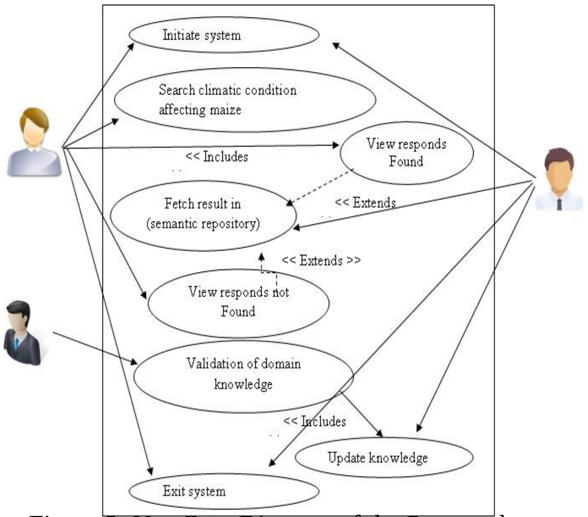

Figure 3: Use Case Diagram of the Proposed

Scenarios such as initiate or startup the system and search for climatic condition affecting maize can be performed by end user. While on one hand, ontology developer can engage in updating knowledge, domain experts on the other hand verify and validate the knowledge before being used by developer.

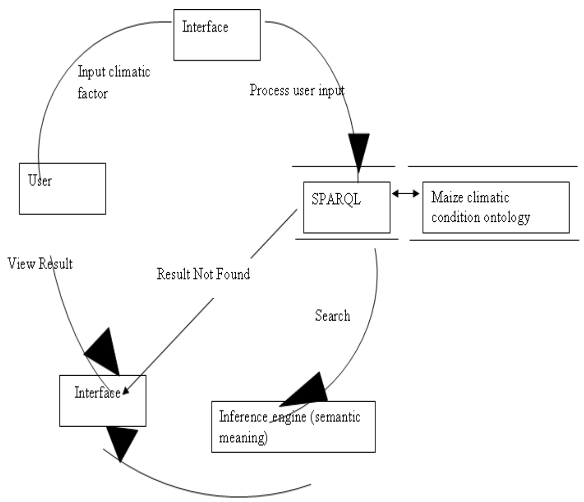

Figure 4: Dataflow Diagram of the proposed system

Considering the figure that describes how data serve as input or output for the next entity in the system. User input knowledge related to maize climatic condition through the interface as the front end. The communication between the front end and the ontology (back end) becomes possible as a result of the JENA API. Then the user interface forward user input for further processing by the reasoned. Ontology developer uses the SPARQL to perform query where the result can be displayed either at the back end or front end.

4.0 RESULTS AND DISCUSSION

This section accounts for the results of the ontology model of climatic condition for maize crop farming developed based on the axioms of OWL. As shown by Figure 5, terms have been specified as classes (both super and sub classes), relations (object property) and instances (individuals) appropriately and encoded using Protégé 5.2.2 version.

Figure 5 showed the graphical representation of the axioms specifically, the classes and how they are been related to each other via an object property with the aid of OntoGraf tab of protégé. The yellow colour circles represent the classes along with their various instances represent in purples. From the results of experiment currently, the metrics for the proposed ontology in general consists of 1150 axioms, 155 classes include the root class of owl:Thing. Climatic Conditions have 11 classes with 45 individuals and overall usage of 1526. This includes *climaticCondition* as a class and its other related or sub classes for instance, *rainfall, precipitation, wind, temperature and humidity*. Maize_Crop have 4 classes with 26 instances and a total usage of 2458 that is, the overall usage of the class *maize_crop* and other related classes or components. 119 object properties include owl:topObjectProperty the root property and 23 data properties include owl:topDataProperty. Although, the work is still ongoing, however, we were able to formulate fifteen numbers of competency questions which were validated by domain experts and users to evaluate the efficiency and effectiveness of the proposed system.

Figure 6 depicts the OntoGraph (Ontology Graph representation) represent a class using rectangular boxes and use arrow head line to indicate the relationship that exist between concept or class, in either symmetric manner or asymmetric. More so, with the aid of JENA API encoded in Java as shown in Figure7, we were able to develop a graphical user interface which made it easier for end users to use the ontology model to query or search related climatic conditions that can affect maize crop. The results of this feat are equally represented by Figure 8a and b.

Figure 8a represents the ontology user interface as search box which tested at the runtime of the system‘s execution. Figure8b had shown the results of user input query as ―climatic condition affecting maize‖.

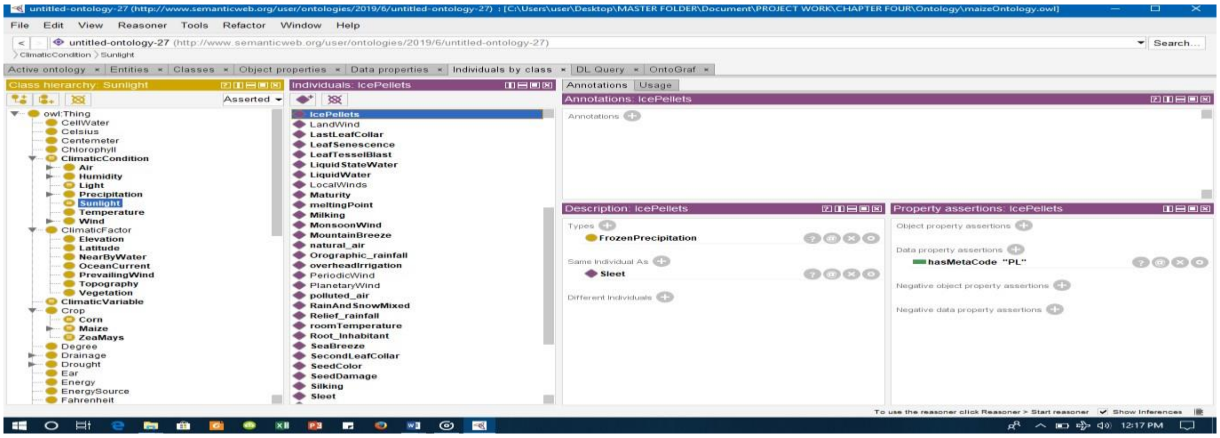

Figure 5: OWL Axioms using Protégé

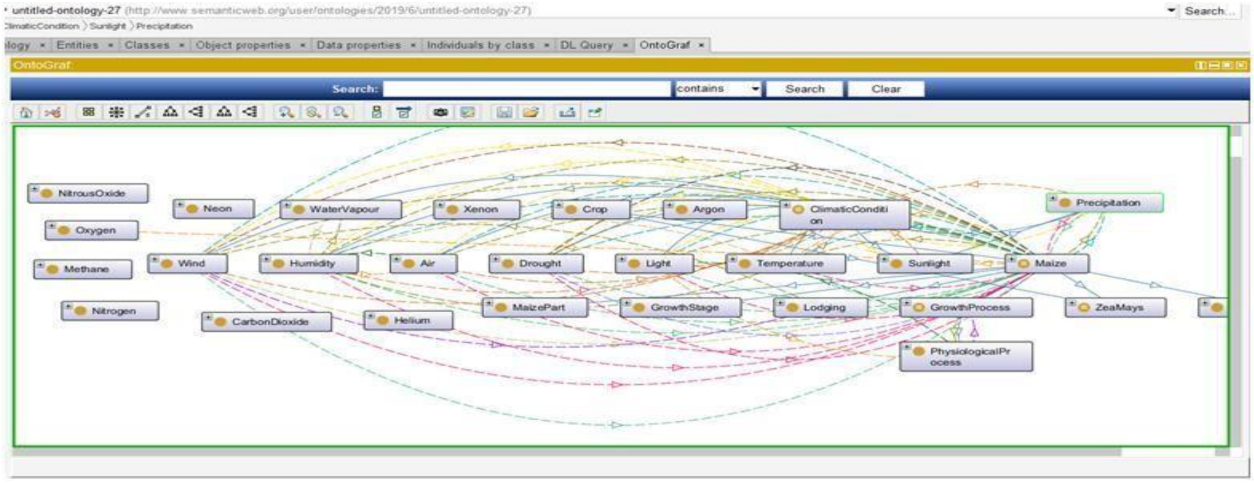

Figure 6: The Graph Representation of the Ontology

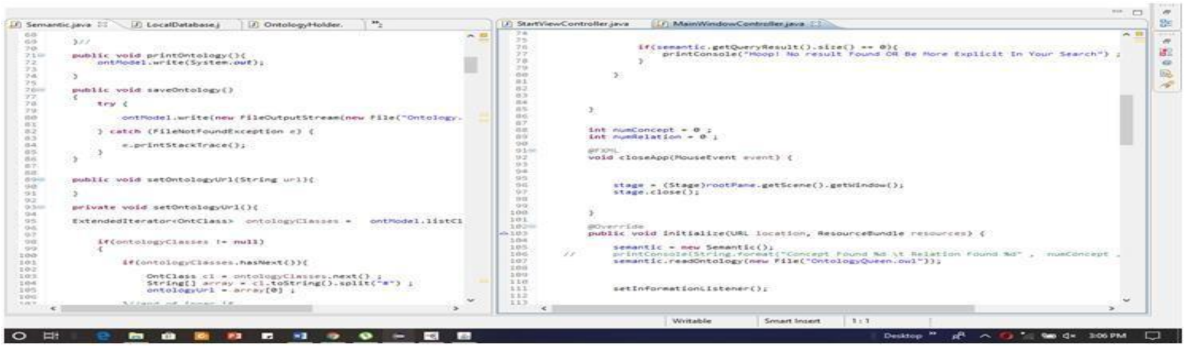

Figure7: Java Based Code Fragment of the JENA

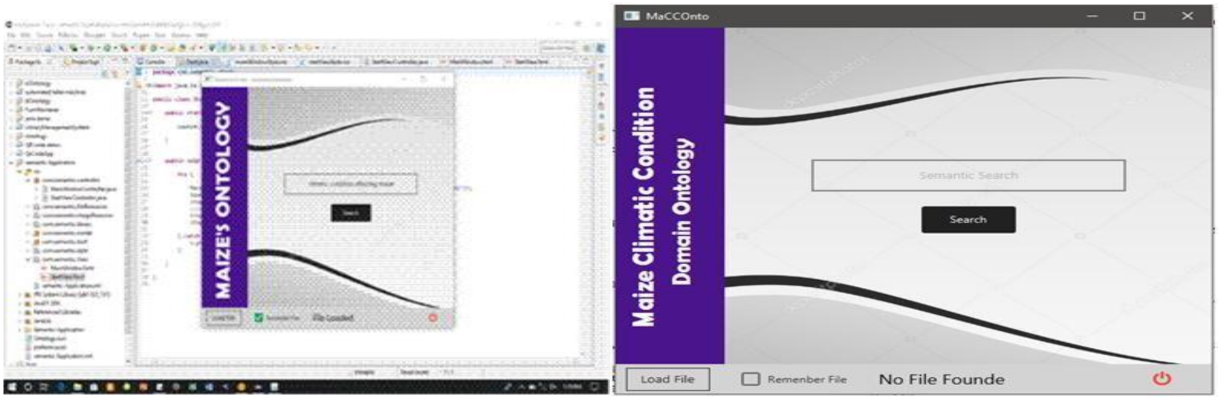

Figure 8a: Ontology GUI at Runtime

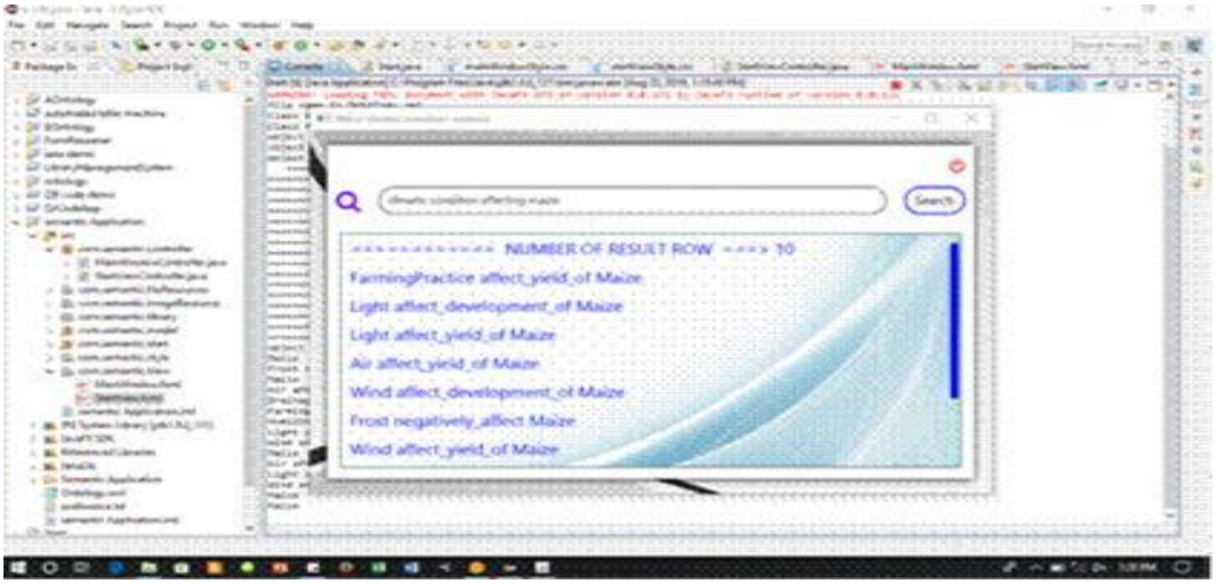

Figure 8b: Ontology GUI at Runtime

5.0 SUMMARY AND CONCLUSION

In this research work, we model climatic conditions knowledge for maize crop farming. The maize farming ontology is developed using hybridization of Fox-Gruninger, Methontology and FAO-Based methodologies. The hybridization of these methodologies led to a six iterative ontology engineering process to model the ontology. It is created manually and written using OWL2 Web Ontology Language RDF/XML syntax. In the quest to design application based ontology in this project, the domain ontology is progressively developed into task ontology capable of answering questions in natural languages form. This research work aims to take ontology modeling beyond mere classification of domain knowledge like taxonomy but proposed to make the ontology an application support system; in order words, an intelligent system. This is so because, synonyms of object properties encoded in the ontology model were taken into account. In the overall experiment, the metrics for the ontology consists of 155 and 1150 classes and axioms respectively.

The competency questions were formulated and validated by the domain experts and were modelled into ontology design by considering about fifteen queries. At this point of the work, it has been validated based on experiments as indicated by the results and domain experts. The project is still work in progress because in the closest future, we hope to carry out evaluations on the efficiency of information retrieval considering precision and recall metrics. We will consider the metrics to judge the proposed project against the existing works. It is also recommended that an interested researcher can reuse and adapt the ontology. However, it is important to mention that this work only consider maize crop‘s climatic condition during planting season. This implies that further research on pre-planting and post- planting seasons can be carried out as well. That is, model climatic conditions knowledge for maize seeds and maize grains for pre-planting and post-planting seasons respectively.

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