An OWL Based Ontology Model for Soils and Fertilizations Knowledge on Maize Crop Farming: Scenario for Developing Intelligent Systems

Enesi Femi Aminu
Department of Computer Science, Federal University of Technology Minna
Minna, Nigeria
enesifa@futminna.edu.ng

Ishaq Oyebisi Oyefolahan
Department of Information & Media Technology,
Federal University of Technology Minna
Minna, Nigeria
o.ishaq@futminna.edu.ng

Muhammad Bashir Abdullahi
Department of Computer Science, Federal University of Technology Minna
Minna, Nigeria
el.bashir02@futminna.edu.ng

Muhammadu Tajudeen Salaudeen
Department of Crop Production, Federal University of Technology Minna,
Minna, Nigeria
mtsalaudeen@futminna.edu.ng

***Abstract*—** The exponential growths of electronic data in heterogeneous forms cut across all real-life scenarios and disciplines, agriculture for instance. Besides, the volume and varieties of these data in various repositories across the global space is on one hand a heartwarming development and on the other hand, gradually becoming a challenge in terms of relevant information retrieval as a result of ambiguities in natural languages. Accessing knowledge in respect to soils and fertilizers that can affects maize crop during planting stage is very significant in order to improve and maintain the crop's maximum yields. In lieu of this, a cutting-edge technology that is promising towards mitigating this challenge of retrieving relevant information is by modeling data ontologically. Ontology is a data modeling technique for knowledge representation in a machine understandable format. Therefore, this paper aims to model an OWL-based ontology for soils and fertilization knowledge that can assist in a better knowledge of soil and appropriate measures of fertilizers to apply for maize crop. The domain-based ontology is designed using hybridization of Fox-Gruninger, Methontology and FAO-Based 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. The proposed system would provide a well-structured knowledge-based system for complex queries on soils and fertilizers knowledge that can affect maize crop in a more accurate and timely information.

***Keywords*—** *Ontology, Soils and Fertilizers Knowledge, Competency Questions, Concepts, OWL Properties*

I. Introduction

Maize (*Zea mays* L.) also known as corn, has been identified as one of the most three significant cereal crops globally. This is owing to its productive strengths [1]. While in Sub Sahara Africa, maize is recognized as the most momentous cereal crops alongside with rice and wheat; in Nigeria, it is described as staple food of huge social economic values [2]. In this research work, the rationale behind the choice of maize crop is as a result of its social economic value. More importantly, in this 21st century, food supply remains a challenge as the world's population increases [3][4]. Therefore, there is an urgent demand to advance the productivity of agricultural crops, which solely depends on various factors such as soil types, fertilizers, irrigations (which depends on geographical locations or weather conditions),[5]. This knowledge may be regarded as crops factors that have the capacity to influence the growth of maize and thereby leads to more yields. However, in this paper, we concentrate on soils and fertilization knowledge.

According to the research carried out on maize by CGIAR as Proposal 2017 – 2022, the significance of soil is well accounted for. Soil is described as medium that offers an indispensible supports to the growth of plants. A farm land is not without soil which implies that no soil no farm. Basically, soils may be classified as Loamy, Sandy and Clay. But globally, according to FAO/UNESCO, soils have been categorized considering their prime features into a number of soil units such as ultisols, oxisols, alfisols, vertisols, nitosols and planosols. The contribution of water and oxygen to plant roots and plant nutrients is not without the soil. And this is actually what defines the soil fertility as this serves as a measure that would influence the decision of fertilizer and the appropriate requirements.

Fertilizers are natural or synthetic materials (substances) used for the growth of agricultural crops. Based on literature including the study carried out by FAO, the level of crop yields has direct connection to the level of fertilizer application. According to the study, approximately 50 percent of the incremental success recorded in crops yield for some period of time in developing nations is not unconnected to the application of fertilizers. And this is why fertilizer is tagged as essential agricultural inputs next only to water resources that have added maximally to the growing crop production. Nitrogen fertilizer in nearly all types of soils with their conditions has the potential to enhance maize yield. Similarly, phosphorus is also very significant for best possible growth and high yield of maize crop. In the same vein, if a situation demands for high proportion of nitrogen fertilizer and also high expectation of maize yield, potassium fertilizer becomes very essential [6].

It is noteworthy to mention that knowledge of appropriate quantity of fertilizer to apply is highly essential and necessary because of its consequential effects on both crop and soil. For instance, fertilization as a rigorous control process in the farming ecosystem could portend serious effects on soil processes such as soil respiration or microbial activity [7]. In summary, considering the heterogeneity of this knowledge in terms of its sources of different formats and huge volume of ambiguities that characterized agricultural data, there is need to implore a data modeling technique that can represent the complex knowledge [8][9]. Consequently, the knowledge would become more useful to researchers and other agro-allied stakeholders. This is in furtherance to the fact that Nigeria has no structured agriculture data repositories that guarantee easier and timely access unlike other countries of the world such as China with formal representation of agricultural, medical or ecological data [10].

Therefore, based on literature, ontology has proven to be a technique that can represent the complex knowledge of different real life scenarios including agricultures [11]. Ontology, according to Gruber, 1993 is an explicit and formal specification of shared conceptualizations. Indeed, this is most acceptable definition because the key terms that form the building blocks of ontology as a data modeling technique for developing intelligent systems are all involved namely; explicit, formal, shared and conceptualization [10][12]. Similarly, Gruber equally categorized ontology as top-level ontology, domain ontology, task ontology and application ontology [10] considering the scale of detail and dependence on the fields. Domain ontology is said to express or model concepts of a given area of study or related to a generic domain. Task ontology expresses the expected activities to be carried out in domain ontology with the aid of axioms and rules. On the other hand, the combination of domain and task ontology forms the Application ontology [13].

Ontology development demands a great deal of time and efforts by both ontology's curator and domain experts [14]. The domain ontology in this paper is developed using hybridization of Fox-Gruninger, Methontology and FAO-Based methodologies. It is created and written using OWL2 Web Ontology Language RDF/XML syntax which is based on Description Logic (DL). These methodologies are not limited to W3C standard but equally applied to ISO based knowledge representation for example, XML Topic Maps (XTM) [15]. The activities of the methodologies are being encoded using the ontology management tools.

In this research work, we proposed to develop maize domain ontology by modeling soils and fertilizer knowledge and also make the ontology a task based. The task ontology was achieved by modeling the competency questions using First-Order-Logic (FOL). In the overall, an application based ontology that is useful to both experts and non-experts was designed.

A. Problem and Background Work

Agricultural extension is another field of study amongst others with huge volume of heterogeneous data in different format and media which poses difficulty in modeling for machine understandable. In this work, section B presents the challenges of the heterogeneous forms of soils and fertilizers data for maize crop farming. It aims to ontologically model the data in order to develop an intelligent system. Section II presented the related studies in terms of subject granularity under consideration in this project, methodologies or knowledge representation management tools used. The section equally highlights the limitations and concepts from the existing literature that were considered into our proposed solution.

B. Challenges of heterogeneous forms of Soils and Fertilizers data for Maize Crop Farming

According to the CGIAR research on maize Proposal 2017- 2022, maize is described as the foremost cereal globally in terms of production because it can be grown across temperate and seasons. Hypothetically, as a C4 plant, maize has a higher yield potential than wheat and rice. The maize cereal yield per unit of land could be improved in developing countries to combat hunger [16]. In order to realize this goal, maize yields' determinant factors such as soils, fertilization, irrigations, and climatic conditions knowledge need to be formally represented in other words, the knowledge have to be machine understandable to take care of ambiguity associated with natural languages. However, this research work concentrates on soils and fertilizers knowledge. This is owing to the fact that maize yield is directly and/or indirectly proportional to the nutrients available in soil, hence fertilizer substances have to be control in accordance to the soil requirement. The importance of fertilizers generally in agriculture and crop yields specifically, cannot be overemphasis; especially in some countries of the world. For instance, in China; studies have been carried out to forestall the losses of fertilizers to most essential grain crops like maize [17]. Therefore, appropriate fertilizers application is a cardinal point to consider besides three other principles in Sub Sahara Africa when crop yield is of focal point to farmers [18].

On the contrary, most developing countries for example, Nigeria; do not have common and well-structured agricultural data repositories where this knowledge could be easily and timely accessed. This position was reechoed on 1st June 2017 in the press release titled "Nigeria to improve data collection on agriculture" by FAO in Nigeria during the handover ceremony of Computer Assisted Personal Interview (CAPI) System to the Federal Ministry of Agriculture and Rural Development. Different data of shared and non-shared concepts and characteristics with different formats and media are what is readily available. Consequently, pertinent questions or knowledge that may defines maize farming's intelligent system for precise fertilizer's application and appropriate soil becomes a research issues. Examples of such questions obtained from set of domain experts and other agro-allied stakeholders in the course of this research are; can maize be grown in any type of soil? Who can grow maize crop? What is/are appropriate method of fertilizers application for maize crop? What could be the appropriate rate of Basal or Top dressing application? For instance, if recommended fertilizer rate for a given plot of land to grow maize is 72-30-30kg of N, P_2O_5 and K_2O per ha respectively and you have a Compound Fertilizer 15-15-15 and Urea. How a decision would be made on what would be the rate of Basal application of N, P_2O_5 and K_2O per ha? This is because appropriate quantity and/or frequency of fertilizer to maize crop have positive consequence on maize yields based on different soil types.

Basically, methods of fertilizer application can be classified as Broadcasting, Placement, Band Placement, pellet and Aerial applications. Broadcasting, which is appropriate for crops with dense stands involves Basal application and Top dressing. While, the later emphasis more on Nitrogenous fertilizers (N), the former uniformly broadcasting the Nitrogen fertilizer (N), Phosphorus and Potassium fertilizers as (P) and (K) respectively. Irrespective of any method, before apply fertilizer factors such as soil type, growth stage, soil fertility, soil test, type of available fertilizer, costs and facilities involved have to be thoroughly determined. In a related study, [19] in their work designed an ontology based system that can take decision on the amount and type of fertilizer for plants.

All these entities and so many other factors of fertilizers on soil coupled with the ambiguity nature of the concepts make them complex knowledge which requires machine readable data modeling technique. Therefore, in order to have a well-structured knowledge based system for complex knowledge representation that can offer a more accurate and timely information; ontology according to references [8][20][21] who has demonstrated its potentialities in this regard is implored.

II. BACKGROUND STUDIES

The following related work partly considered similar subject area that is proposed in this project along with their methodologies and tools. Soil and Fertilization form part of the Chinese eight points charter of agriculture in line with their social economic importance given to agriculture. As a result of this feat, [11] were motivated to developed citrus ontology based on the plant production knowledge framework. To describe the citrus knowledge framework, fertilization ontology was developed and its validation and evaluation were ascertained by numbers of competency questions. Similarly, [22] in their work aim at semantic modeling of citrus production knowledge from heterogeneous dataset to specifically developed hilly citrus ontology by considering three thematic areas as irrigation, fertilization and nutrient imbalance services. The ontology was encoded in RDF triple format using TopBraid Composer editor. The decision services based ontology supports applications rather than simply classify domain knowledge. This is owing to the competency questions that were query via SPARQL and reasoning tool. However, word mismatch (synonyms or polysemy) still an issue to contend with.

More so, reference [14] 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. Appropriate crop to an appropriate soil and also appropriate fertilizer to apply have drawn a good research attention because of its importance to food security and nutrient values to soil. It is as a result of this research development that propelled the interest of [23]' work to advance a research by developed an OWL based ontology recommended system for appropriate fertilizer to crop and appropriate soil for crop by considering a particular location in India.

Based on 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. Consequently, to determine the appropriate methodology, some researches combined the activities of Methontology and Gruninger and Fox to design a given ontology [24]. 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.

The importance of soil knowledge to farmers remains a key factor in agriculture. This fact forms the center of [25] research work, where soil knowledge ontology based system was developed that would aid farmers in information processing for the underlying domain.

Domain ontology and task ontology were considered in the work of [10] for crop cultivation standard. Pepper was used to demonstrate the application of the crop cultivation standard based ontology. The former ontology was encoded and designed in OWL representation language with the aid of protégé editor while, the latter ontology was designed with V-model system. The two types of ontology are combined via property values to form a representation method because the study aims at projecting ontology to be empirical. Also, the research work of [26] presented ontology as an effective data modeling technique. This is to solve the complexity issues associated with agricultural concepts in order to achieve an improved information retrieval method.

III. THE ONTOLOGY ENGINEERING PROCESS

Ontology may be created from scratch or reuse of an existing one. However, ontology development demands a great deal of time and efforts by both ontology's developers and domain experts. Indeed, creating ontology manually is tasking but it is said to be more accurate [14]. Irrespective of the approaches, ontology is expected to be sharable and reusable. That is, it has to be evolved. Similarly, since ontology is a data technique for modeling complex knowledge representation, it means it has the capacity to transforms the models into intelligent systems. Following the review of ontology development methodologies, the proposed methodology for developing the domain ontology is a hybridization of Fox-Gruninger, Methontology and FAO-Based methodologies which is described as an iterative ontology engineering process that consists of six activities, [27] in press. We emphasis on this hybridization because of its interoperability capacity between models and systems; also the weakness of one is complimented by the strength of the other. For instance, ontology evolution activity is not stated in Gruninger-Fox while, setting out competency questions to determine the intelligence level of the ontological system does not equally form part of FAO-based methodology's activities. Thus, the proposed iterative ontology engineering process shown by Fig.1 is summarized as follows. The bidirectional arrows of Fig.1 indicate that the whole activities of the process are iterative.

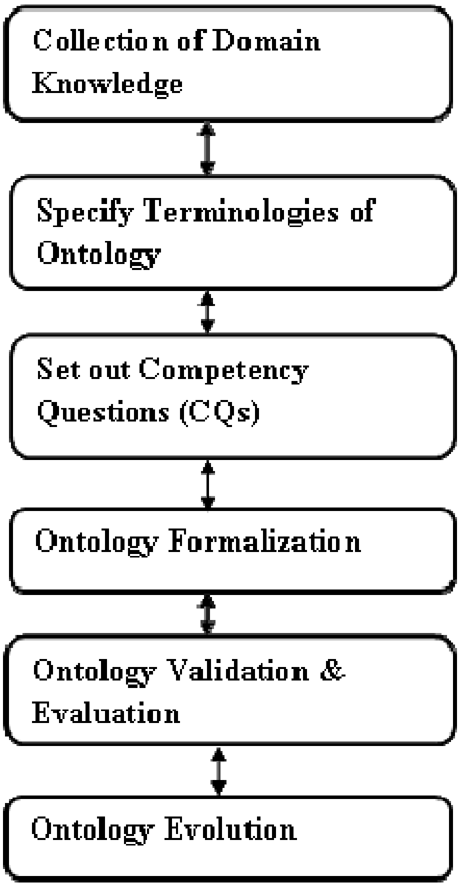

Fig. 1. Ontology Engineering Process

A. Collection and Analysis of Domain Knowledge

At this first activity, domain specific knowledge such as maize along with its synonyms, its relationships with crop or plant, maize varieties, fertilizers and its methods (such as primarynutrient,micronutrients,urea,ammoniumSulphate,ammoniumChloride,ammoniumNitrate,ammoniumPhosphate, , muriateOfPotash, compoundFertilizers, fertilizerApplication, fertilizerApplicationMethods: banding method, broadcasting method), soil conditions or soil fertility (clay, loam, sandy), slope (slope flat land, mildly slope) were collected in conjunction with domain experts and other agro-allied stakeholders. The knowledge was collected via different reliable information sources. Such as research articles and books, published authoritative online data sources, and institutions for instance, CMMYT, IITA, The Institute for Agricultural Research (IAR), Zaria.

B. Specification of Ontology's Terminologies

At this level of activity of the process, the required terms that forms the domain concepts as analyzed and presented by the previous activity are specified according to the OWL's components of classes, properties (object and data) and instances or individuals using the middle-out-approach.

C. Set out Competency Questions (CQs) to Determine Ontology's Purpose and Scope

Considering the goal of this project, the underlying activity is very crucial and important. In the first place, it creates a platform for the domain ontology to be validated and ascertained whether we need to proceed to the next activity or move back to the previous activity. With the validation, we were able to define the purpose and scope of the ontology. Secondly, the activity enables the design of task ontology with the sole aim of making the ontology a decision based application. Some of the competency questions formulated by the experts are shown by Table I and were modeled using First-Order-Logic (FOL) based axioms.

TABLE I. COMPETENCY QUESTIONS

Competency Questions
• Can maize be grown in any soil? • Who can grow maize? • If recommended fertilizer rate for a given plot of land to grow maize is 72-30-30kg of N, P_2O_5 and K_2O per ha respectively and you have a Compound Fertilizer 15-15-15 and Urea. How a decision would be made on what would be the rate of Basal application of N, P_2O_5 and K_2O per ha? • At what growth stage of maize can fertilizer be applied?/When is fertilizer can be applied to maize crop? • What type of fertilizer (materials) can be applied to maize?

D. Ontology Formalization

Considering this project, decidability is an essential factor owing to the fact that maize knowledge based on soils and fertilizations have to be retrieved in context. As a result, OWL2-DL approach of RDF/XML syntax is considered in order to formalize the ontology. The domain terms specified in activity B and the CQs being modeled in FOL of activity C of the engineering process are implemented using the protégé editor of version 5.5.0. This version has advantages of some plug-ins files such as VOWL.

E. Ontology Validation & Evaluation

This is another essential activity that was performed in the course of this project. In order to ensure the correctness of the developed ontology both in terms of its construction and content, a validation process is duly carried out. The probable errors or defects associated with the construction correctness of ontology is far mitigated when activity B (that is, terms specification) is meticulously and cohesively dealt with. The domain experts were duly involved in defining the domain's concepts along with their synonyms, appropriate hierarchical structure of concepts in terms of super or sub concepts and instances, relations (object properties) that exist between concepts along with relations synonyms, data types properties and constraints to ensure axioms and rules. General concepts axioms were also taken into consideration. Proper specification and classification of all these terms ensure correctness of ontology construction. The domain specialists validated the content of the ontology against user's requirement. This is also very important because it validate the purpose and scope of the ontology design. The consistency of the ontology is also validated via the use of HermiT 1.4.3.456, Pellet 2.2.0 and ELK Reasoner (a java based reasoner) of protégé 5.5.0 edition.

Similarly, wrong synonyms concept of hyponymy, hypernymy and that of relations holonymy and meronymy were tested to ascertain further the evaluation of the ontology. It is important to mention that this project is still in progress. At the point of completion, further evaluation would be carried out by conducting the syntactic queries using the existing system and semantic query using the SPARQL tab of the protégé. The competency questions would serve as the queries.

F. Ontology Evolution

One of the primary goals of developing ontology is reusability. Therefore, for ontology to be gainfully reused, its growth needs to be sustained especially for dynamic data component of the ontology. The ontology in this paper would be evolved via an open source technology such as Semantic Web Best Practices and Development under W3C.

IV. MODELING THE ONTOLOGY

Ontology modeling requires a lot of considerations which are strictly depends on the type, purpose and scope of ontology to design. In this project, the ontology design goes beyond mere classification of classes and its relationships that is, domain ontology. The proposed application based ontology is designed to address some topical issues in other words, competency questions from group of experts and users considering soils and fertilizers knowledge. The framework of the proposed ontology design is presented by Fig2. However, it is important to mention that the framework is generic. That is, it can serves for any ontology design in any domain.

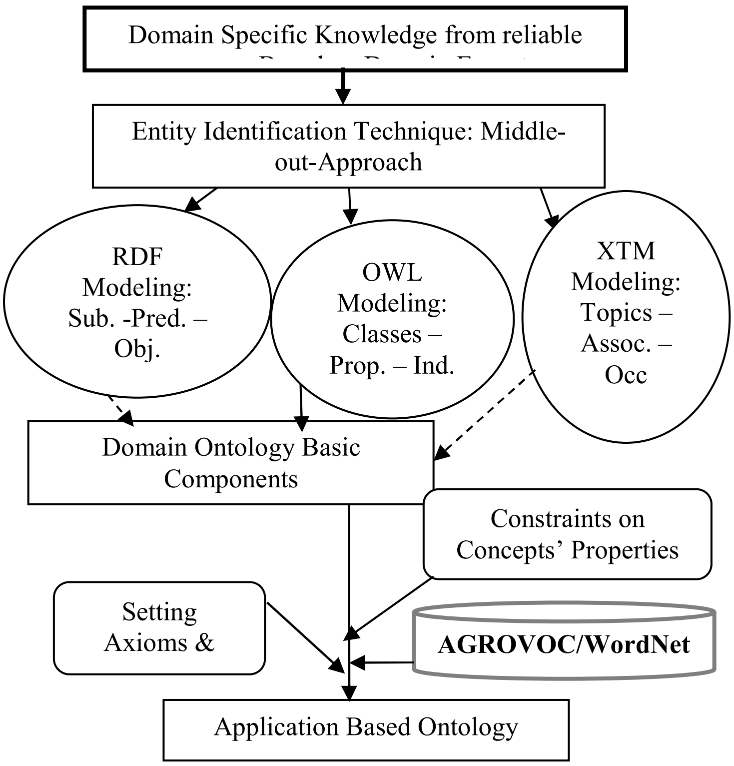

Fig. 2. Conceptual Framework of Ontology Design

In order to avoid what is described as ontology hacking, ontology design must ensure adherence to the principle of ontology engineering process. In modeling ontology for any domain, it is expected to gather knowledge from reliable or trusted information sources and validated by domain experts; which have been duly followed as stated in the previous section of this paper. Also, to mitigate the errors of construction correctness of ontology; middle-out-approach is implored in this work as concept identifying technique. It possesses the ability to first identified the most important concepts and then generalized and specialized into other concepts. Similarly, Table II presents the modeling of some entities as relations (object properties) with their inverse properties between concepts as domain and range.

TABLE II. PROPERTIES' INVERSE AND CHARACTERISTICS

Object Property	Characteristics	inverseOf	Classes	
			Domains	***Ranges***
madeUp	Symmetric	Composes	SoilParticles	Soil
isEssential	Transitive	Requires	Fertilizer, Soil	Soil, Crop
affectsYieldsOf	Functional	isAffectedBy	Fertilizer	Maize

For instance, relation isEssential is modeled as transitive in that, if Fertilizer isEssential for Soil and Soil isEssential for Crop, it implies that Fertilizer isEssential for Crop. Same axiom holds for inverse requires (such as Crop requires Fertilizer). Also, Individuals as the third component of OWL were modeled taking cognizance of relationship that exist between them and their root classes.

A unique idea that shows the novelty of this framework is that once concepts are properly generalized and specialized with the aid of specialists into appropriate concepts, it can be modeled into any of the knowledge representation languages and standardization formats. For instance, World Wide Web Consortium (W3C) standard which includes RDF/S [28][29] and XTM [15][30] of Standardization of International Organization (ISO). Regardless of the standards, they all have three basic components in common for example, subject, predicate and objects denoted in Fig.2 as ***sub, pred and obj*** respectively for RDF. Topics, association and occurrences denoted as ***topics, assoc and occ*** respectively for XML Topic Maps (XTM). While OWL the most expressivity and used in this work has classes, properties and individuals denoted as ***classes, prop and ind*** respectively.

We defined and encoded object property *plants* as a relation between *Farmer and MaizeSeeds* classes along with *length* as data property of class Farm as follows:

```
<owl:ObjectProperty rdf:ID="plants">
  <rdfs:domain rdf:resource="#Farmer"/>
  <rdfs:range rdf:resource="#MaizeSeeds"/>
</owl:ObjectProperty>
<owl:DatatypeProperty rdf:ID="length">
  <rdfs:domain rdf:resource="#Farm"/>
  <rdfs:range
rdf:resource="http://www.w3.org/2001/XMLSchema#nonNegativeInteger"/>
</owl:DatatypeProperty>
```

owl:inverseOf which is a symmetric property is also used to encodes the object properties as follows:

```
:plants a owl:ObjectProperty;
 owl:inverseOf     :isPlantedBy.
```

Thus, currently the metrics for the proposed maize farming domain ontology in general consists of 1785 axioms, 217 classes include the root class of owl:Thing. Soils have 31 classes with 32 individuals and overall usage of 437. This includes *soil* as a class and its other related or sub classes. Fertilizers have 40 classes with 27 instances and a total usage of 933 that is, the overall usage of the class *fertilizers* and other fertilizers' classes or components. Maize related classes are 56 with 48 instances and a total usage of over 523.

In this project, as earlier stated; it goes beyond the development of domain ontology. We extended it to design application based ontology, making it tasking and supportive for intelligent systems. That is, we used First-Order-Logic (FOL) to model axioms and rules and enforce high-level constraints on concepts properties based on the competency questions formulated earlier in Table I. Therefore, Table III modeled some of the CQs of Table I using the FOL.

TABLE III. MODELING COMPETENCY QUESTIONS

Probable Information Required (Informal CQs)	**Information Required in Context**
Can maize be grown in any soil?	• Nutrients available in soils • Soil fertility, appropriate soil texture, enrich soil nutrient • Availability of suitable fertilizer/Water • Expected maize yields
If recommended fertilizer rate for a given plot of land to grow maize is 72-30-30kg of N, P2O5 and K2O per ha respectively and you have a Compound Fertilizer 15-15-15 and Urea. How a decision would be made on what would be the rate of Basal application of N, P2O5 and K2O per ha?	• Fertilizer nutrients content • Products available as fertilizer source materials • Crop to be grown and the recommended fertilizer rate • Determine the area of the plot

The Table presented a fragment of the possible questions in the first column along with their respective contextual information in the second column that likely defines the level of intelligence of the ontology. Therefore, the respective questions are formally modeled as follows:

i. $$\forall X \forall Y : Soil(Y) \wedge Maize(X) \Rightarrow Crop(X) \Rightarrow can\_be\_grown\_in\_any(X, Y) \wedge (\exists X)(\exists Y)(Maize\_Yields(X)) \wedge Soil\_Types(Y) \Rightarrow depends(X, Y) \vee (\exists Y)(Maize\_Crop(Y)) \wedge (\forall X)(Soils(X)) \wedge (\exists X)(High\ soil\ fertility \wedge Appropriate\ soil\ texture \wedge Enriches\ soil\ nutrients\ (X)) \Leftrightarrow Loamy\_Soil \Rightarrow guaranteeMoreYields(X, Y) \vee (\exists X)(AppropriateFertilizer) \Rightarrow guaranteeMoreYields(X, Y)$$

ii. $$\exists X (MaizeSeed(X)) \Rightarrow (\exists Y)(LandPlot(Y)) \wedge (\forall F)(FertilizerInformation(F)) \exists F (RecommendedFertilizer \wedge SourceMaterial \wedge NutrientContent(F)) \wedge (\forall P)(Broadcasting\_Method(P)) \wedge \exists P (Basal\_Application(P)) \Rightarrow dependsOnAvailable(P, SourceMaterial)$$

More so, in order to ensure credible ontology design we take into account to a large extent how to mitigate the issues of word mismatch or terms ambiguities (for instance, synonyms) associated with the natural languages. This research issue inadvertently normally affects the recall and precision of user's query results. The issue will be address in this project through the use of AGROVOC which is similar to that of wordNet lexical database. It is a database for agricultural vocabularies. Examples of some concepts' synonyms are as follows:

- plants ≡ grows ≡ sows : this is a relation (object property)
- Maize ≡ Corn ≡ *Zea may*: this is a class
- Soils ≡ Soil_Conditions ≡ Edaphic_Requirements: this is a class
- Fertilizers ≡ Manures ⊆ owl:Thing: this is a class that fertilizer is equivalent to manure but subclass of top class owl:Thing.

Similarly, general class axiom of protégé editor was equally implored to address the issue of polysemy. The axiom assists to take care of general characteristics of concepts beyond synonyms as shown by the following examples.

((plantProducesCobsLike some Crop) and (grassProducesSilkingLike some Crop)) SubClassOf Crop

What this axiom means is that, apart from maize being also known as corn or *zea may*, any information repositories of plant or grass with keywords such as cobs or ears, silk may highly be considered as maize crop. Thus, considering all these processes in our framework, we are able to model application based ontology that is geared towards developing intelligent systems.

V. RESULTS AND DISCUSSION

In this paper, ontology has been designed taken the advantage of protégé 5.5.0 editor. The ontology developed is premised on the proposed hybridized ontology development methodology along with the conceptual model of the ontology presented in this work. Core domain concepts such as maize, soils and fertilizers along with their related classes as either super classes or sub classes were considered via middle-out technique. It is important to note that all user defined classes are sub classes to the default super class owl:Thing. Fig.3 presented a graphical view of some of the classes via a tab known as OntoGraf.

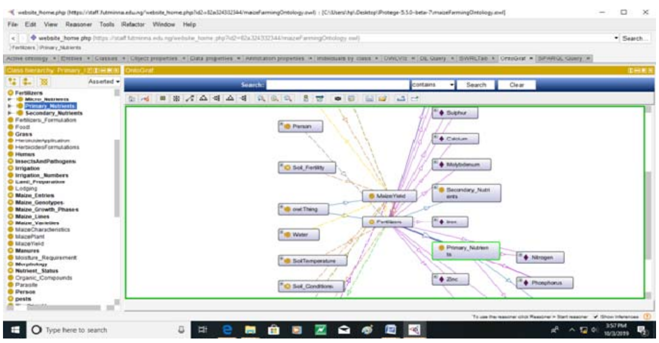

Fig. 3. Ontology's Core Concepts

Fragment of the classes are presented by Fig3. For instance, class *SoilFertility* related to class *MaizeYield* and also related to class *Fertilizer*. The concept *MaizeYield* is synonymous to another concept encoded as *CornYield* which are subclasses to class *Crop.* Fertilizer has *PrimaryNutrient, SecondaryNutrient* and *MicroNutirent* as subclasses. Also, there exist some instances of class Fertilizer such as *Nitrogen, Phosphorus, Potassium, Manganese, Magnesium, Zinc, Boron* and *Calcium.* Concepts *MaizePlant* establishes a relationship to concepts *Soils* and *SoilPreparation* via an object property ***requires*** with an inverse property ***enriches***. This assertion is characterized as transitive in that:

If *MaizePlant* requires *Soils* and *Soils* requires *SoilPreparation* it then implies that *MaizePlant* requires *SoilPreparation*.

Similarly, *Fertilizer, Soil/Farm* and *Crop* concepts equally forms an assertion using object property called ***isEssential*** with inverse property ***requires*** which is also described as transitive. That is,

If *Fertilizer* isEssential for *Soil* and *Soil* isEssential for *Crop* it then implies that *Fertilizer* isEssential for *Crop*.

Some other axioms that have been defined in the ontology are: *Soil_Nutrient* ***influences*** *MaizeYields* with an inverse of ***isAffectedBy***. In the future work, class Irrigation will be considered. For example, *Irrigation_Number* ***isDeterminedBy*** *Maize_Growth_Phase and SoilsType*. The concept irrigation will be regarded as *Precise_Irrigations* as a class.

More so, data properties such as float, integer, and literal were modeled for the appropriate concepts. For instance, length and breadth of Farm were encoded as floats. Fertilization_Numbers (that is, frequency of applying fertilizer) were encoded in Integer as 1, 2 or 3 depends on the phase of maize growth and soil types.

Also considered in this work is the General Class Axioms (GCA) as part of the results or implemented task in this project. GCA of protégé gives room for modeling further assertions for concepts in order to improve on the recall metric of information. Aside from modeling Concepts with their synonyms such as *Soils* concept with its equivalent as *Soil_Conditions* and *Edaphic_Requirement*, we model generic axioms that further describe the concept. For example;**(*CompositionOfOrganicMatter some Soils*) *and* (*MixtureOfSandClaySilt* some *Soils*) *SubClassOf Soils***. It means that when user search for information regarding soils; knowledge repositories with keywords or phrases such as sand, clay, silt or composition of organic matter in their documents base should be intelligent to connect any of those related term(s) that characterized the search query term and retrieve them as part of relevant information required.

VI. Conclusions and Future work

The research work focuses to model soils and fertilizers management for maize crop farming. The maize farming ontology is developed using hybridization of three ontology development methodologies. Namely: 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 that is based on First Order Logic. In the quest to design application based ontology in this project, the domain ontology is progressively developed into task ontology capable of answering competent questions using the SPARQL. 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 development is based on the novelty conceptual framework of ontology design proposed in this work that can generally use as prototype for any ontology design.

The framework depicts that the domain ontology can be developed across different knowledge representations and formats based on concepts identification approach for a vital goal of system's interoperability. However, such aim has not been achieved in this work as only one (OWL) knowledge representation is considered. In the future work, we hope to achieve that of XTM which is different standard from OWL and RDF and implement an interoperability system for them. In this work, the OWL-Based domain ontology is developed to the capacity of task ontology by way of enforcing constraints on concepts properties and setting axioms and rules based on competency questions. The questions were formulated and validated by the domain experts and were modeled into ontology design using first-order-logics. 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 encode into the ontology some maize growth and development factors such as Irrigation for efficiency and more accuracy of Information Retrieval (Intelligent) Systems. More so, we proposed 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.

Acknowledgements

This research work was performed as part of a PhD Thesis at the Federal University of Technology Minna Nigeria, and funded through the Award of TETFUND Institution-Based Research Intervention (IBRI) Fund with Grant TETFUND/FUTMINNA/2016-2017/6th BRP/04.

References

[1] B. Ghimire, and D. Timsina, "Analysis of Yield and Yield Attributing Traits of Maize Genotypes in Chitwan, Nepal". *World Journal of Agricultural Research, 2015, Vol. 3, No. 5, 153-162*

[2] M. A. Badmus, and O. S. Ariyo, "Forecasting Cultivated Areas and Production of Maize in Nigerian using ARIMA Model". Asian Journal of Agricultural Sciences 3(3): 171-176, 2011

[3] N. Alexandratos, and J. Bruinsma. *World agriculture towards 2030/2050: the 2012 revision.* ESA Working paper No. 12-03. Rome, FAO.

[4] D. K. Ray, N. D. Mueller, P. C. West, and J. A. Foley, "Yield Trends Are Insufficient to Double Global Crop Production by 2050". PLoS ONE 2013, 8(6): e66428. doi:10.1371/journal.pone.0066428

[5] P. Suresh, A. S. Mohamed, and L. Jens, "Ontology Based Data Access and Integration for Improving the Effectiveness of Farming in Nepal". International Joint Conference on Web Intelligence (WI) and Intelligent Agent Technologies (IAI), 2014 – Vol. 02 Pages 319 – 326

[6] R. N. Roy, A. Finck, G. J. Blair, and H. L. S. Tandon, "Plant nutrition for food security". *A guide for integrated nutrient management. FAO Fertilizer and Plant Nutrition Bulletin*, 2006, *16*, 368.

[7] W. Ding, H. Yu, Z. Cai, F. Han, and Z. Xu, "Responses of soil respiration to N fertilization in a loamy soil under maize cultivation". *Geoderma* 155 (2010) 381–389.

[8] R. Bonanci, O. F. Nabuco and I. P. Junior, "Ontology models of the impacts of agriculture and climate changes on water resources: Scenarios on interoperability and information recovery". Future Generation Computer Systems 54 (2016) 423 – 434

[9] N. Kaushik, and N. Chatterjee, A Practical Approach for Term and Relationship Extraction for Automatic Ontology Creation from Agricultural Text. 2016 International Conference on Information Technology

[10] D. Li, L. Kang, X. Cheng, D. Li, L. Ji, K. Wang, and Y. Chen, "An ontology-based knowledge representation and implement method for crop cultivation standard". Mathematical and Computer Modelling 58 (2013) 466–473

[11] Y. Wang, and Y. Wang, "Citrus ontology development based on the eight-point charter of agriculture". *Computers and electronics in agriculture*, 2018, *155*, 359-370.

[12] M. Uschold, and M. Grüninger, "Ontologies: principles methods and applications" *KnowledgEngineeringReview , 1996,* Vol. 11(2)93–137.

[13] H. Park, A. Yoon, and H. C. Kwon, "Task model and task ontology for intelligent tourist information service". *International Journal of u-and e-Service, Science and Technology*, 2012, *5*(2), 43-58.

[14] N. Malik, A. Sharan, and J. Shrivastav, "Natural Language Interface for Ontology in Agriculture Domain. In Smart Trends in Systems, Security and Sustainability" (pp. 259-268). Springer, Singapore, 2018.

[15] E. F. Aminu. and O. S. Adewale, 'A Mechanism for Detecting Dead URLs in XTM-Based Ontology Repository' International Journal of Computer Applications (0975 – 8887) Volume111 – No 12, 2015

[16] F. Gong, X. Wu, H. Zhang, Y. Chen and W. Wang. " Making better maize plants for sustainable grain production in a changing climate". Front. Plant Sci. 6:835, 2015.

[17] G. X. Cai., D. L. Chen, H. Ding, A. Pacholski, X. H. Fan, and Z. L. Zhu, "Nitrogen losses from fertilizers applied to maize, wheat and rice in the North China Plain". *Nutrient Cycling in Agroecosystems*, *63*(2-3), 187-195, 2002.

[18] B. Vanlauwe, J. Wendt, K. E. Giller, M. Corbeels, B. Gerard, and C. Nolte, "A fourth principle is required to define conservation agriculture in sub-Saharan Africa: the appropriate use of fertilizer to enhance crop productivity". *Field Crops Research*, *155*, 10-13, 2014.

[19] N. Panawong, and C. S. Namahoot, "Cultivation of plants harnessing an ontology-based expert system and a wireless sensor network". *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, *9*(2-3), 109-113, 2017.

[20] K. Agyapong-Kodua, L. Niels, D. Robert, and R. Svetan. "Review of semantic modelling technologies in support of virtual factory design". International Journal of Production Research, Vol. 51, No. 14, 4388–4404, 2013.

[21] N. Malik, A. Sharan, and D. Hijam, Ontology development for agriculture domain. In *2015 2nd International Conference on Computing for Sustainable Global Development (INDIACom)* (pp. 738-742). IEEE.

[22] Y. Wang, Y. Wang, J. Wang, Y. Yuan, and Z. Zhang, "An ontology-based approach to integration of hilly citrus production knowledge". *Computers and electronics in agriculture*, *113*, 24-43, 2015.

[23] A. Chougule, V. K. Jha, and D. Mukhopadhyay, "Crop Suitability and Fertilizers Recommendation Using Data Mining Techniques". In Progress in Advanced Computing and Intelligent Engineering, 2019(pp. 205-213). Springer, Singapore

[24] R. Iqbal, A. M. Mustapha, and Z. Yusoff, ,"An experience of developing Quran ontology with contextual information support", Multicultural Education & Technology Journal, 2013, Vol. 7 Iss 4 pp. 333 - 343

[25] T. Heeptaisong, and A Shivihok, Soil knowledge-based systems using ontology. In *Proceedings of the International MultiConference of Engineers and Computer Scientists* (Vol.1), 2012.

[26] G. Song, M. Wang, X. Ying, R. Yang, and B. Zhang,. Study on precision agriculture knowledge presentation with ontology. *AASRI Procedia*, *3*, 732-738, 2012.

[27] E. F. Aminu, I.O Oyefolahan, M.B. Abdullahi, & M. T. Salaudeen "A Review on Ontology Development Methodologies for Developing Ontological Knowledge Representation for various Domains". In Press , 2019, IJIEEB

[28] M. Arenas, B. C. Grau, E. Kharlamov, S, Marciuška, and D. Zheleznyakov, "Faceted search over RDF-based knowledge graphs". Journal of Web Semantics, 37, 55-74, 2016

[29] J. Cardoso, and A. M. Pinto, The Web Ontology Language (OWL) and its Applications. In Encyclopedia of Information Science and Technology, Third Edition (pp. 7662-7673). IGI Global, 2015

[30] L M. Garshol, "Metadata? Thesauri? Taxonomies? Topic maps! Making sense of it all" Journal of Information Science, 30(4), 378–391, 2004.