

Two years later: the landscape of vocabularies and ontologies in the AgroPortal

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Abstract. Mid 2014, we started the AgroPortal project (<http://agroportal.lirmm.fr>) with the vision of offering a vocabulary & ontology repository for agronomy and related domains such as biodiversity, plant sciences and nutrition. The prototype found a good adoption, and growing interest appeared when presenting it to several interlocutors in the agronomy community (e.g., CGIAR (Bioversity International), INRA, IRD, CIRAD, IRSTEA, FAO, RDA, Planteome, EBI). We have now an advanced prototype platform which latest version (v1.3) was released in March 2017, that currently hosts 64 public ontologies including 38 not present in any such ontology repository (e.g., NCBO BioPortal) and 8 privates. This paper presents a short review of our current use cases and of the ontologies & vocabularies hosted in AgroPortal in Mai 2017. Thanks to a new ontology metadata model, we can now aggregate ontology descriptions to display information about the “landscape of agronomical ontologies” as presented.

Keywords: agronomical ontologies, biological ontologies, knowledge organization sources, vocabularies, ontology repository, ontology metadata, AgroPortal.

1 Introduction

There exists a need of a one-stop-shop for ontologies & vocabularies in agronomy (and close related domains such as plant sciences, biodiversity and nutrition) enabling to identify and select an ontology for a specific task as well as offering generic services to exploit them in search, annotation or other scientific data management processes. The need is also for a community-oriented platform that will enable ontology developers and users to meet and discuss their respective opinions & wishes. This need was clearly expressed by stakeholders of various kinds (application developers, database maintainers, researchers) during multiple important meetings of the community such as: 1st Semantic for Biodiversity workshop in 2013 (<http://semantic-biodiversity.mpl.ird.fr>) [1]; the workshop "Improving Semantics in Agriculture" in 2015 [2]; or more recently the RDA 7th Plenary Meeting, in March 2016 which hosted a pre-meeting of the Agricultural Data

Interest Group (IGAD) that includes three working groups that have expressed such a need; and the Open Harvest, in May 2016 that has established the Chania declaration.¹

This motivated us to build an ontology repository that would address this need. In 2015, we introduced the very first prototype of the AgroPortal project (<http://agroportal.lirmm.fr>) [3], a community effort started by the Montpellier's scientific community to build an ontology repository for the agronomy domain. The main objective of the AgroPortal project is to develop and support a reference vocabulary & ontology repository for the agronomic domain. We reused the openly available NCBO BioPortal technology (<http://bioportal.bioontology.org>) [4] to build our first ontology repository and services platform [5]. Today, AgroPortal offers a robust and reliable service to the community that features ontology hosting, search, versioning, visualization, comment, services for semantically annotating data with the ontologies, as well as storing and exploiting ontology alignments and data annotations. Our vision is to facilitate use of all ontologies coming from different sources together as more extensively described in [6].

Even if the project is still at its very beginning, this paper proposes a brief review of the vocabularies & ontologies currently hosted on the portal. Indeed, we have implemented a new metadata model to support better descriptions of ontologies and their relations with respect of the standards metadata vocabularies used in the semantic web community [7]. Then, we have spent a significant amount of time to edit ourselves ontology descriptions, and we have asked the ontology developers to validate our edits and complete them. This has resulted in our capability to automatically aggregate information about ontologies & vocabularies to facilitate the comprehension of the whole agronomical ontology landscape by displaying diagrams, charts and networks about all the ontologies on the portal (grouping, types of ontologies, average metrics, most frequent licenses, languages or formats, leading contributors & organization, most active ontologies, etc.). We have now a specific page dedicated to visualizing this landscape in AgroPortal: <http://agroportal.lirmm.fr/landscape>.

The rest of the paper is organized as follow: Section 2 briefly lists the current AgroPortal driving use cases which are the major sources of ontologies. Section 3 reviews the landscape of vocabularies and ontologies currently available in the portal. Then Section 4 identifies some of the next ontologies we will be working to include. Finally, Section 5 concludes the paper and lists a few perspectives for the future of the project.

2 AgroPortal use cases

The AgroPortal project was originally driven by five use cases [6] that are the principal sources of ontologies & vocabularies:

1. The *Agronomic Linked Data (AgroLD)* project [8] within the *Computational Biology Institute of Montpellier* (IBC – www.ibc-montpellier.fr), which develops a RDF knowledge base (<http://agrold.org>) that integrates data from a variety of plant resources (e.g., Gramene, SouthGreen, UniProtKB, OryGeneDB).

¹ <http://www.godan.info/news/open-harvest-2016-participants-release-kania-declaration>

2. The RDA *Wheat Data Interoperability* (WDI) working group of the Research Data Alliance and International Wheat Initiative (<http://ist.blogs.inra.fr/wdi>) which goals is to provide a common framework for describing, representing, linking and publishing wheat data with respect to open standards.
3. The *INRA Linked Open Vocabularies* (LovInra) which is an effort to publish vocabularies produced or co-produced by INRA scientists and foster their reuse beyond the original researchers (<http://lovinra.inra.fr>).
4. The Crop Ontology project (www.cropontology.org) [9] of the Integrated Breeding Platform which goals is to publish online fully documented lists of breeding traits; which provides 19 crop-specific trait ontologies in addition to ontologies describing germplasm material and evaluation trials.
5. VEST/AgroPortal global map of agri-food data standards maintained under the umbrella of the GODAN initiative a global map of standards in use for the exchange of data in the field of food and agriculture (<http://vest.agrisemantics.org>).

In addition of these five first driving use cases, other projects or organizations have identified AgroPortal as a relevant application to host, share and serve their ontologies both at the national or international levels:

- New INRA projects such as: (i) the AnAAE Thesaurus for the semantic description of the study of continental ecosystems developed by the AnaEE-France infrastructure; (ii) the OntoBioTope ontology of microorganism habitats used collaboratively in multiple projects such as OpenMinted as well as for the BioNLP shared tasks; (iii) the Agri-Food Experiment Ontology (AFEO) ontology network which cover various viticultural practices, and winemaking products and operations.
- New IRSTEA projects such as: (i) the French Crop Usage thesaurus about crops cultivated in France developed by IRSTEA; (ii) the French Agroecology Knowledge Management ontology for design innovative crop systems.
- The new Global Agricultural Concept Scheme project (GACS - <http://www.agrisemantics.org/gacs>) [11] that will result from the integration of the Agrovoc thesaurus (FAO), the NAL Thesaurus and the CAB Thesaurus.

3 Review of current vocabularies and ontologies in AgroPortal

We have now an advanced prototype platform which latest version v1.3 was released in March 2017:² <http://agroportal.lirmm.fr> – that currently hosts 64 public ontologies (Table 1) including 38 not present in any such ontology repository (e.g., NCBO BioPortal) and 8 privates. We have identified 95 other candidate ontologies (Table 3) and we are working daily to import new ones while involving/informing the original ontology developers. The platform counts already 56 registered users.

Importing ontologies within the portal is quite easy assuming standard formats have been used (OWL, RDFS, OBO, RRF & SKOS). However, small technical issues or customizations are sometimes necessary to enable maximum use of the portal capabilities.

² <https://github.com/agroportal/documentation/wiki/Release-notes>

Table 1. Examples of ontologies uploaded in AgroPortal. Acronyms in parenthesis are the identifiers e.g., <http://agroportal.lirmm.fr/ontologies/AEO>. Size (computed by the OWL-API) is either the number of owl:Class (OWL, OBO) or number of skos:Concept (SKOS).

Title	Format	Groups	Size
IBP Rice Trait Ontology (CO_320)	OWL	CROP, RICE	~2K
IBP Wheat Trait Ontology (CO_321)	OWL	CROP, WHEAT	~1K
IBP Wheat Anatomy Ontology (CO_121)	OBO	CROP, WHEAT	~80
IBP Crop Research (CO_715)	OBO	CROP	~250
Multi-Crop Passport Ontology (CO_020)	OBO	CROP	~90
Biorefinery (BIOREFINERY)	OWL	LOVINRA	~300
Matter Transfer(TRANSMAT)	OWL	LOVINRA	~1.1K
Plant Ontology (PO)	OWL	WHEAT, RICE, OBOF	~2K
Plant Trait Ontology (TO)	OWL	WHEAT, RICE, OBOF	~4.4K
Durum Wheat (DURUM WHEAT)	OWL	LOVINRA	~130
Agricultural Experiments (AEO)	OWL	LOVINRA	~60
Environment Ontology (ENVO)	OWL	WHEAT, OBOF	~6.3K
NCBI Organismal Classification (NCBITAXON)	RRF	WHEAT	~900K
AnaEE Thesaurus (ANAEE)	SKOS	LOVINRA	~3.3K
French Crop Usage (CROPUSAGE)	SKOS	none	~300
Agrovoc (AGROVOC)	SKOS	none	~32K
Food Ontology (FOODON)	OWL	OBOF	~10K
National Agriculture Library Thesaurus (NALT)	SKOS	none	~67K
Global Agricultural Concept Scheme (GACS)	SKOS	none	~585K

For instance, language of labels need to be properly defined to avoid indexing the content of the ontologies in another language than English (for search and annotation). Another example, is the requirement for SKOS vocabularies to define a top-level concept to which the hierarchy can be attached. Not necessarily required by the standards, these are often good ontology development practice that we share with the community when they decide to make their ontology available within an external resource such as AgroPortal.

3.1. Ontology organization and sources

The ontologies are generally uploaded by their developers themselves when they have reached a certain maturity and the developers think that it is relevant to make them publicly available. Sometime, like in the AnaEE thesaurus, or the OntoBioTope the portal is/was used before the ontology goes public. We do not pull any content automatically without looking at it first and interacting (if the initiative comes from our side) and the only authority for the ontologies in the portal are the ontology developers themselves. Because of the features offered by AgroPortal [6] we do think it is reasonable to

incorporate ontologies that are only listed on other platforms (e.g., OBO Foundry, BioSharing, VEST registry, LovInra). However:

- We pay attention every time it is possible to connect to the original source of the ontologies (PURL or other persistent URL) to always (nightly update) keep them in sync with the original ontologies and have the latest version available.
- We always inform (and offer to claim back) the ontology developers of the integration of their ontology if it was not submitted by them directly (mostly ontologies coming from the OBO Foundry). While we often edit ourselves ontology descriptions, we ask the ontology developers to validate our edits and complete them.
- We try to avoid (except if required by a specific use case) to duplicate ontologies already hosted in the NCBO BioPortal. But of course, overlap exists between our domain of interest and biomedicine.

3.2. Organizing the content of the portal in relevant groups and categories

Within AgroPortal we organize the ontologies in relevant group and categories (each time an ontology is uploaded into the portal, it is assigned a group and/or category). The groups allow to bring together ontologies from the same project or organization for better identification of the provenance. We have created a group for each use cases (Fig. 1) except the fifth one that is not a source of ontologies and another one for the OBO Foundry [10] that is a major source of biomedical ontologies. For each group, we have deployed a specific slice³ e.g., <http://wheat.agroportal.lirmm.fr>. The categories (Table 2) are another way to classify ontologies in the portal independently from their groups or provenance. As of now we have defined 20 general categories such as Farms & Farming system, Plant Phenotypes and Traits, Plant Anatomy and Development, Agricultural Research, Technology and Engineering, etc. These categories have been established in cooperation with FAO Agricultural Information Management Standards (AIMS) which maintains since a long time the VEST Registry (that became now the AgroPortal/VEST map of standards) a catalog of around 200 knowledge organization sources related to agronomy.

Groups and categories, along with other metadata can be used on the “Browse” page of AgroPortal to filter out the list of ontologies. Of course, groups and categories are customizable and will adapted in the future to reflect the

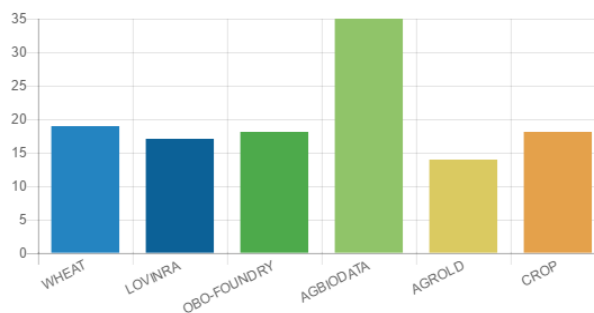


Fig. 1. Distribution of ontologies by Group

³ Slices are a mechanism supported by the platform to allow users to interact (both via API or UI) only with a subset of ontologies in AgroPortal. If browsing the slice, all the portal features will be restricted to a subset enabling users to focus on their specific use cases. On AgroPortal, slices and groups are synchronized.

evolution of the portal’s content and community feedback. Another good aspect of the portal’s architecture is that it provides URIs for any objects in the portal including groups and categories e.g., <http://data.agroportal.lirmm.fr/categories/FARMING> identifies the group “Farms and Farming Systems.” External applications can now use these URIs to organize ontologies or tag them.

Table 2. Distribution of ontologies & vocabularies by Categories.

Category	Number
Plant Phenotypes and Traits	18
Plant Anatomy and Development	3
Natural Resources, Earth and Environment	4
Animal Science and Animal Products	6
Agricultural Research, Technology and Engineering	8
Plant Science and Plant Products	3
Plant Genetic Resources	1
Food and Human Nutrition	4
Taxonomic Classifications of Organisms	2
Farms and Farming Systems	2

3.3. AgroPortal ontologies landscape

We have implemented a new metadata model to better support descriptions of ontologies and their relations with respect to the standards metadata vocabularies used in the semantic web community. We have reviewed the most standard and relevant vocabularies out-there to describe metadata for ontologies (such as: Dublin Core, VoID, Ontology Metadata Vocabulary, Data Catalog Vocabulary, etc.).⁴ We then grouped those properties into a unified and simplified model of 124 properties that includes the 45 properties originally offered by the NCBO BioPortal and describe all the new properties with standard vocabularies [7]. We have now for instance a model to capture which kind of knowledge organization source the file uploaded to the portal is (e.g., thesaurus, ontology, taxonomy, terminology, etc.) that uses values proposed by the DCMI.⁵ We also have property to capture information such as licenses, ontology editor used, syntax, etc. We can also capture how ontologies are related to other resources (web site, publication, wiki, datasets, etc.) and other ontologies. Most of metadata are automatically extracted from the original ontology file if present and/or sometime automatically generated by the portal.

We then have spent a significant amount of time to edit the metadata of the ontologies with the goal to facilitate the comprehension of the agronomical ontology landscape by displaying diagrams and charts about all the ontologies on the portal (average metrics, most used languages, leading contributors & organization, etc.). In this paper, we present some views (figures) automatically created with the content from May 2017.

⁴ <https://github.com/agroportal/documentation/wiki/Ontology-metadata>

⁵ http://wiki.dublincore.org/index.php/NKOS_Vocabularies

Figure 2 shows the number of access/ views per ontology over the last 18 months (since we started logging). Among the most popular ontologies are either reference ontologies widely used (e.g., Plant Ontology, Gene Ontology, NCBI Taxonomy) or ontologies exclusively hosted on AgroPortal, especially the ones from the LovInra (Wheat Phenotype, Biorefinery, Ontobiotope, Transmat) and Crop Ontology use cases (CO_*).

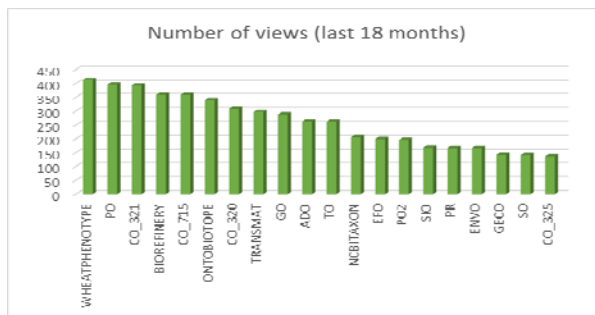


Fig. 2. Number of access/views to ontologies (top 20).

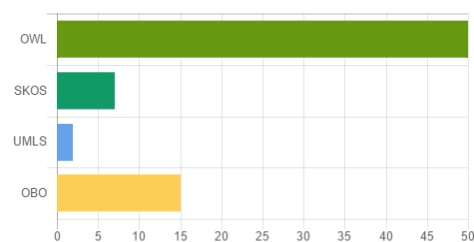


Fig. 3. Ontologies by format.

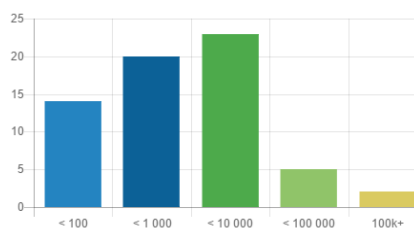


Fig. 4. Ontology sizes.

The most common adopted format is OWL (Fig. 3) which confirms the community has clearly turned to the W3C recommendation for building ontologies. In addition, we already have six vocabularies in SKOS, which shall be a format that will grow in the future. It has been adopted, for instances, by the ANAEE Thesaurus, Agrovoc, NAL Thesaurus and CAB Thesaurus as well as the new GACS project [11]. Figure 4 shows that most of the ontologies are in the range between 100 and 10K classes (or concepts), although a few big resources have been uploaded (Agrovoc, GACS, NCBI taxonomy).

Ontologies are mostly in English (Fig. 5) although we have seven resources that offers French labels (mostly because of our French collaborators). Multilingual resources include Agrovoc and NAL Thesaurus.

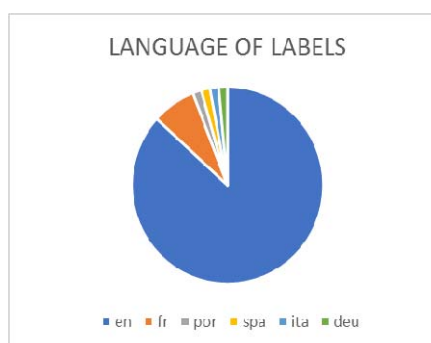


Fig. 5. Available natural languages.

In the context of the SIFR project (Semantic Indexing of French Biomedical Data Resources (SIFR) project - <http://www.lirmm.fr/sifr>) and in collaboration with the Stanford NCBO, we are working on making BioPortal multilingual [12] and properly handle multilingual ontologies (i.e., with labels in multiple languages). For the moment, we have chosen to consider English as the main language of AgroPortal (i.e., the one use to display content as well as used with Search, Annotator & Recommender services). Multilingual ontologies are parsed but only the English content is explicitly used. Non-English monolingual ontologies are attached as “views” of a main ontology that is solely described with metadata (no content). For instance, the Agroecology Knowledge Management ontology, (<http://agroportal.lirmm.fr/ontologies/GECO>) is only described with metadata but has attached a specific view (<http://agroportal.lirmm.fr/ontologies/GECO-FR>) with the real content in French.

The type and formality level of resources are described by Figure 6. The number of upper level ontologies (not specifically dedicated to agriculture) is maintained low and not surprisingly most of the ontologies are domain or application ontologies. Acknowledging the “ambiguity” of these information, as there are no standards definitions of the type and formality level of a knowledge organization system, we do thing that this information is useful and may help selecting the right resources for a given task [13].

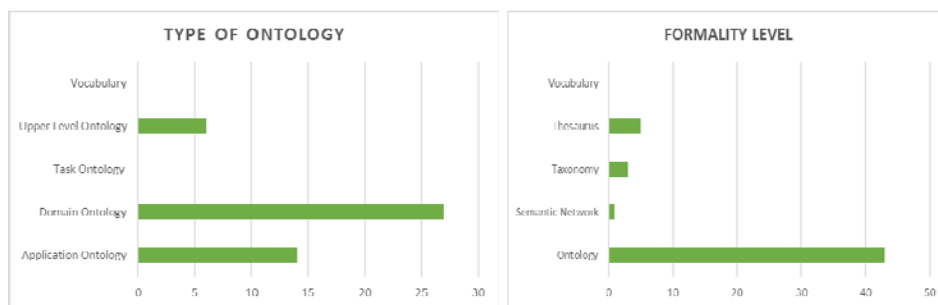


Fig. 7. **Type and formality level of resources in AgroPortal.** The type and level “vocabulary” has not been formally defined yet and will be in the future.

Among the 31 ontologies that have explicitly described their access right information, all of them are openly accessible with different licenses. The other ontologies are also usually publicly accessible, but do not precise under which license. All the 8 private ontologies are private because they are not considered ready for being made public, not because of access restrictions.

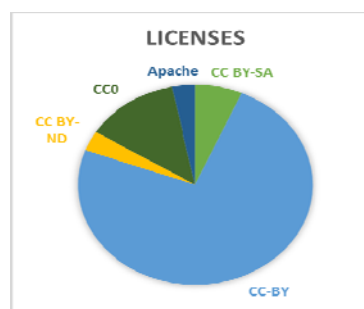


Fig. 6. **Licensing information.**

Figure 8 is an aggregation (term cloud) of several properties that relate ontologies and organizations. Such a view is interesting to identify which organizations are the most involved in funding, adopting or endorsing ontologies. Figure 9 is a similar cloud showing which ontologies are the most actively commented, reviewed or used within research projects. Indeed, AgroPortal provides a project list edited by its users that materialize the ontology-project relation (<http://agroportal.lirmm.fr/projects>).

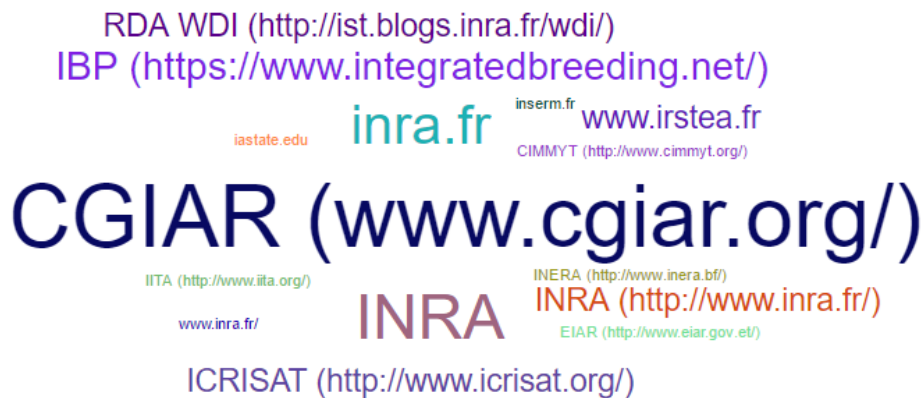


Fig. 8. Most mentioned organizations (aggregation as a tag cloud from the properties rights holder, publisher, funded by, endorsed by).

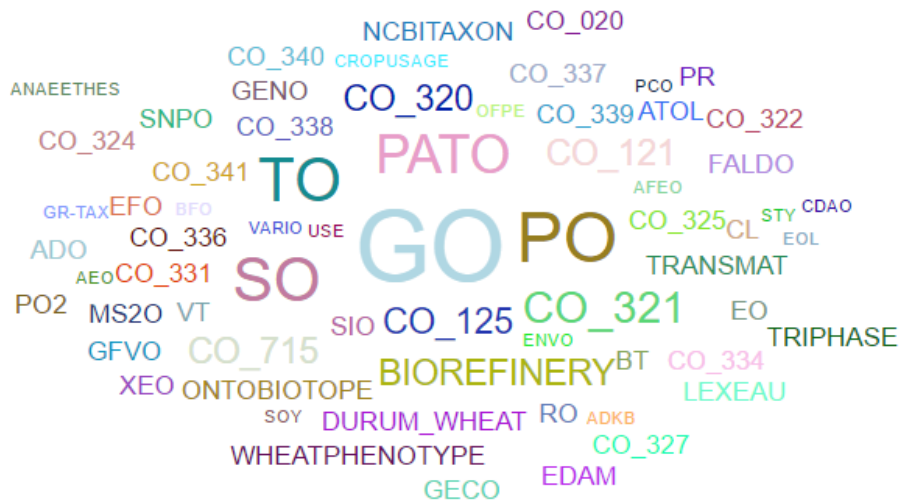


Fig. 9. Most active ontologies (aggregation of numbers of notes, reviews and projects related to an ontology in AgroPortal).

The new metadata model allows to capture 14 possible relations between ontologies or between ontologies and external resources. For instances, relations to capture that an ontology is aligned to another one, represents knowledge from the same domain, is compatible or incompatible with another one, imported or used by another one, translated or more generally related to another one. We can use these relations to represent the agronomy ontology network. For instance, Figure 10 shows the cluster of ontologies made by the alignment of all the Crop Ontologies aligned to the Trait Ontology, itself interconnected to the Plant Ontology and Plant Environment ontology. The Soy Ontology, developed outside of the Crop Ontology project also appears as related to both TO and CO_336 (the Soybean Ontology developed within the Crop Ontology project).

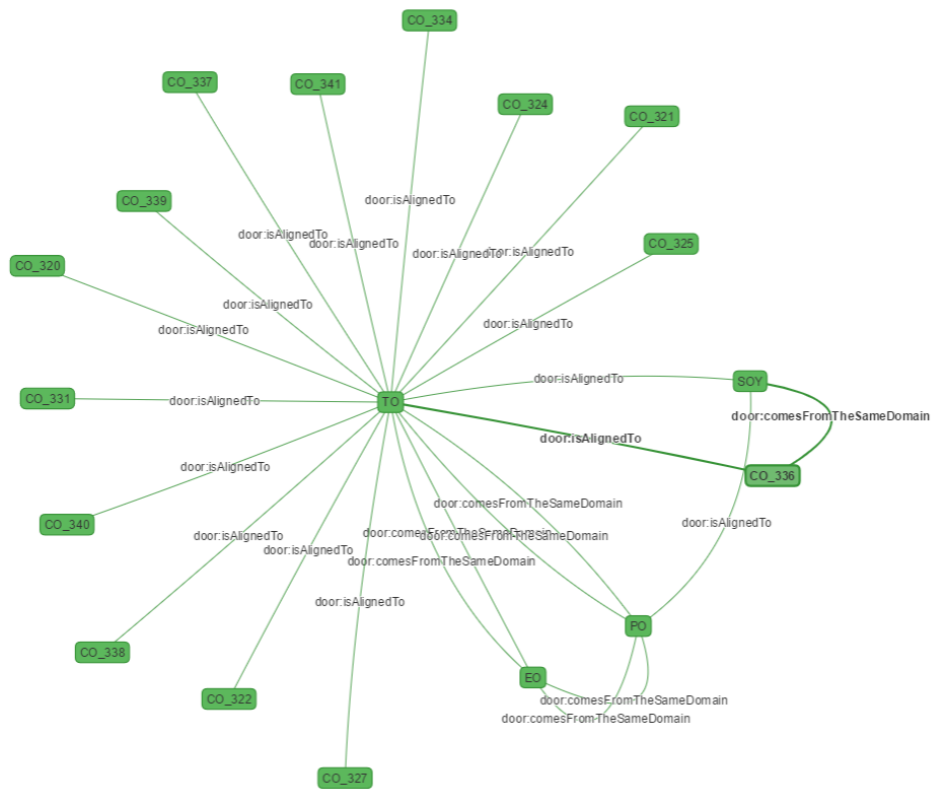


Fig. 10. Subset of the ontology network showing the relations between reference plant ontologies.

4 Future ontologies and analysis

In addition to the analysis done in previous section, in the future we want to be able to describe more the usage of ontologies by defining (i) generic tasks for which ontology are used (annotation, indexing, search, reasoning, etc.) and (ii) small examples of usages of the ontologies. We also plan to use the same metadata analysis approach to suggest development guidelines (based on community practices) by looking at the most used properties to describe ontologies, to define labels and terms.

We are currently wrapping up the development of a new AgroPortal landscape page that displays metadata “by property” (as opposed as “by ontology” as in for instance <http://agroportal.lirmm.fr/ontologies/AGROVOC>) and automatically generates the diagrams and charts presented in previous Section: <http://agroportal.lirmm.fr/landscape> .

Table 3. Selection of candidate ontologies of interest for the agronomic community, not present in the NCBO BioPortal

Title	Organization
CAB Thesaurus	CABI
Wine Ontology	INRA
Oat, Barley, Brachiaria, Potato (etc.) trait ontologies	Crop Ontology
Agronomy Ontology	CGIAR
Plant Disease Ontology	INRA
Agriculture Activity Ontology	CAVOC
IC-FOODS Ontologies (12)	UC Davis
agINFRA Soil Vocabulary	FAO, GFAR
Plant-Pathogen Interactions Ontology	CBGP
Biological Collections Ontology	OBO Foundry
Plant Phenology Ontology	OBO Foundry
Thesaurus Of Plant characteristics	CEFE

5 Conclusion

In this paper, we have briefly reviewed the current content of AgroPortal, an open ontology repository for the agronomy domain. The first two years of the project have been very productive and resulted in a repository that is already playing a significant role for the five use cases already driving the portal. The pace to which ontologies are added to the portal also shows that it is considered by other users besides the first five use cases.

This analysis of the portal content helps to figure out what are some of the main domain of interests as well as common development practices when creating a vocabulary or ontology in agronomy. We believe that information, will be of interest for the community. By being able to capture (thanks to metadata) and automatically represent (thanks to landscape page), shall facilitate the elicitation of which ontology (or group of

ontologies) use, which practices follow, which complementary resources develop. Of course, this information, relies on the metadata extracted from the ontologies or edited on the portal. Such visualizations are also a mean to motivate the ontology developers to document and describe more their ontologies.

In the future, by integrating more relevant ontologies and vocabularies into the portal we hope to offer a unique resource to identify and use knowledge organizations systems in agriculture. We will also continue our metadata edition and curation effort to be sure to provide the community with the best descriptions for ontologies available. We are currently working in generalizing this work on ontology metadata to develop an application profile (as defined by the DCMI) and an ontology for Metadata for Ontology Description and Publication.⁶

Acknowledgements

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References

- [1] P. Larmande, E. Arnaud, I. Mougnot, C. Jonquet, T. Libourel, and M. Ruiz, eds., *Proceedings of the 1st International Workshop on Semantics for Biodiversity*, (Montpellier, France), May 2013.
- [2] T. Baker, C. Caracciolo, and Y. Jaques, eds., *Report on the Workshop "Improving Semantics in Agriculture"*, (Rome, Italy), Food and Agriculture Organization of the UN, July 2015.
- [3] C. Jonquet, E. Dzalé-Yeumo, E. Arnaud, and P. Larmande, “AgroPortal: a proposition for ontology-based services in the agronomic domain,” in *3ème atelier INtégration de sources/masses de données hétérogènes et Ontologies, dans le domaine des sciences du VIVant et de l’Environnement, IN-OVIVE’15*, (Rennes, France), p. 5, June 2015.
- [4] N. F. Noy, N. H. Shah, P. L. Whetzel, B. Dai, M. Dorf, N. B. Griffith, C. Jonquet, D. L. Rubin, M.-A. Storey, C. G. Chute, and M. A. Musen, “BioPortal: ontologies and integrated data resources at the click of a mouse,” *Nucleic Acids Research*, vol. 37, pp. 170–173, May 2009.
- [5] C. Jonquet, A. Toulet, E. Arnaud, S. Aubin, E. Dzalé-Yeumo, V. Emonet, J. Graybeal, M. A. Musen, C. Pommier, and P. Larmande, “Reusing the NCBO BioPortal technology for agronomy to build AgroPortal,” in *7th International Conference on Biomedical Ontologies, ICBO’16, Demo Session* (P. Jaiswal and R. Hoehndorf, eds.), vol. 1747 of *CEUR Workshop Proceedings*, (Corvallis, Oregon, USA), p. 3, August 2016.

⁶ <https://github.com/siffrproject/MOD-Ontology>

- [6] C. Jonquet, A. Toulet, E. Arnaud, S. Aubin, E. D. Yeumo, V. Emonet, J. Graybeal, M.-A. Laporte, M. A. Musen, V. Pesce, and Pierre Larmande, "AgroPortal: an ontology repository for agronomy," *Computers and Electronics in Agriculture*, p. 10, (under review - COMPAG_2016_643). Under review.
- [7] A. Toulet, V. Emonet, and C. Jonquet, "Modèle de métadonnées dans un portail d'ontologies," in *6èmes Journées Francophones sur les Ontologies, JFO'16* (G. Diallo and O. Kazar, eds.), (Bordeaux, France), October 2016. Best paper award.
- [8] A. Venkatesan, G. Tagny, N. E. Hassouni, I. Chentli, V. Guignon, M. Ruiz, P. Valduriez, and P. Larmande, "Agronomic Linked Data: a knowledge system to enable integrative biology in Agronomy," *PLOS One - UNDER REVIEW*, 2017.
- [9] R. Shrestha, E. Arnaud, R. Mauleon, M. Senger, G. F. Davenport, D. Hancock, N. Morrison, R. Bruskewich, and G. McLaren, "Multifunctional crop trait ontology for breeders' data: field book, annotation, data discovery and semantic enrichment of the literature," *AoB Plants*, vol. 2010, May 2010.
- [10] B. Smith, M. Ashburner, C. Rosse, J. Bard, W. Bug, W. Ceusters, L. J. Goldberg, K. Eilbeck, A. Ireland, C. J. Mungall, T. O. Consortium, N. Leontis, P. Rocca-Serra, A. Ruttenberg, S.-A. Sansone, R. H. Scheuermann, N. H. Shah, P. L. Whetzel, and S. Lewis, "The OBO Foundry: coordinated evolution of ontologies to support biomedical data integration," *Nature Biotechnology*, vol. 25, pp. 1251–1255, November 2007.
- [11] T. Baker, C. Caracciolo, and E. Arnaud, "Global Agricultural Concept Scheme (GACS)A Hub for Agricultural Vocabularies," in *7th International Conference on Biomedical Ontologies, ICBO'16, Poster Session* (P. Jaiswal and R. Hoehndorf, eds.), vol. 1747 of *CEUR Workshop Proceedings*, (Corvallis, Oregon, USA), p. 2, August 2016.
- [12] C. Jonquet, V. Emonet, and M. A. Musen, "Roadmap for a multilingual BioPortal," in *4th Workshop on the Multilingual Semantic Web, MSW4'15* (J. Gracia, J. McCrae, and G. Vulcu, eds.), vol. 1532 of *CEUR Workshop Proceedings*, (Portoroz, Slovenia), pp. 15–26, June 2015.
- [13] J. Park, S. Oh, and J. Ahn, "Ontology selection ranking model for knowledge reuse," *Expert Systems with Applications*, vol. 38, no. 5, pp. 5133–5144, 2011.