

# EARTH: an Environmental Application Reference Thesaurus in the Linked Open Data Cloud

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**Abstract.** The paper aims at providing a description of EARTH, the Environmental Application Reference Thesaurus. It represents a common general thesaurus for the environment, which has been published as a SKOS dataset in the Linked Open Data cloud. It promises to become a core tool for indexing and discovery environmental resources by refining and extending GEMET, which is considered the de facto standard when speaking of general-purpose thesaurus for the environment in Europe, besides it has been interlinked to popular LOD datasets as AGROVOC, EUROVOC, DBPEDIA and UMTHER. The paper illustrates the main characteristics of EARTH as a guide to its usage. It clarifies (i) the methodology adopted to define the EARTH content; (ii) the design and technological choices made when publishing EARTH as Linked Data; (iii) the information pertaining to its access and maintenance. Descriptions of EARTH applications and future relevance are highlighted.

Keywords: SKOS, Linked Data, EARTH, Thesaurus, Environment

## 1. Introduction

Although different directives (e.g. INSPIRE [1]) and policy communications (e.g. SEIS [2]) have been launched at European-scale with the objective of improving the management of heterogeneous environmental data sources, an effective sharing of these resources is still part of the desiderata due to the intrinsic multicultural and multilingual nature of the environmental domain.

Thesauri are widely employed as common ground enabling communication among the different communities working in environment-related domains: they allow users to share and agree upon scientific/technical terms in the target domain and to express them in multiple languages. In the recent years several controlled vocabularies (thesauri) have been deployed by different communities having a large

spectrum of competencies. They have been created embodying different points of view and based on different ways of conceptualization. Their development reflects different scopes and implies quite a range of levels of abstraction and detail.

Nowadays networked information access to heterogeneous environmental data sources requires interoperability of these controlled vocabularies [3]. The Linked Data publishing paradigm [4] jointly with Simple Knowledge Organization System [5] provides a promising framework to face with the aforementioned problems: it allows to represent and publish distinct thesauri and their interlinks as a whole enabling to switch among them.

This paper presents the latest release of EARTH, the Environmental Application Reference Thesaurus (ver. Linked Data 1.3) that takes advantage of this framework providing a SKOS dataset recently in-

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cluded in the Linked Open Data (LOD) Cloud. Compared to other environmental thesauri available as Linked Data as AGROVOC<sup>2</sup>, EUNIS<sup>3</sup>, Geological Survey of Austria (GBA) Thesaurus<sup>4</sup>, EARTH provides a more general purpose and thematically neutral terminological support. Compared to the GEMET<sup>5</sup>, namely the *de facto* general purpose thesaurus standard, EARTH provides a minor multilingual support, but it extends GEMET with more than 9000 concepts and revises the GEMET concept hierarchy. Being one of the largest general purpose and structured environmental terminological resources available in the LOD cloud, EARTH<sup>6</sup> is expected in close future to become a good linking point serving like a kind of bridge in the integration of other terminological resources dealing with environmental topics. Currently, EARTH already includes more than 12000 links towards thesauri such as GEMET, AGROVOC, EUROVOC and UMLTHES enabling in the traditional thesaurus-based indexing of digital resources, as well as the use of digital resources across multi-thesauri applications and platforms.

The remainder of this paper is organized as follows: Section 2 describes EARTH in terms of its content, the methodology followed and extension of GEMET. Section 3 describes how EARTH has been published in the LOD cloud. Section 4 describes the dataset applications. Future steps and conclusions are drawn in Section 5.

## 2. EARTH thesaurus

EARTH is a project run since 2001 by CNR-IIA-EKOLab aiming at creating a new thesaurus for the environment. It extends the GEMET content and revises its categorical and thematic structure.

### 2.1. From GEMET to EARTH

Originally GEMET, developed by CNR-IIA-EKOLab and by German Federal Environmental Agency within an international consortium, was intended to be used as an indexing, retrieval and control tool for the European Topic Centre on Catalogue

of Data Sources (ETC/CDS) and the European Environment Agency (EEA). The basic idea for the development of GEMET was to use the best of the presently available excellent multilingual thesauri, in order to save time, energy and funds. GEMET was conceived as a “general” thesaurus, aimed to define a common general language, a core of general terminology for the environment. Specific thesauri and descriptor systems (e.g. on Nature Conservation, on Wastes, on Energy, etc.) have been excluded from the first step of development of the thesaurus and have been taken into account only for their structure and upper level terminology.

Since 2001, CNR-IIA-EKOLab has been performing an overall checking of GEMET in order to improve both its content and its structure. In particular the following activities have been undertaken:

- Quality assessment of GEMET structure and content towards ISO standards on mono- and multilingual thesauri. During GEMET development it was mandatory to take into account some decisions adopted by the consortium and this caused some divergences from standards;
- Assessment of English concept representation vs. source language(s);
- Deletion of incorrect terms and removal of about 1000 terms potentially useful for specific lists, such as name of plants, animals, minerals, etc.;
- Updating the content with new terms (e.g., land management strategies, pigmy forest, cryodiversity) and extension of the system of non-descriptors;
- Management of the correspondence of the terms in British and American English (e.g. sulphur hexafluoride/sulfur hexafluoride);
- Revision of the thematic structure and development of a new categorical/hierarchical setup (e.g., Entities, Attributes, Dynamic Aspects, Dimensions) to emphasize the different functions of hierarchy in comparison to themes;
- Extension of the horizontal and the vertical relations system;
- Representation of the accessory elements: singular and plural forms (e.g., biological index/biological indexes); alternate terms (e.g., deoxyribonucleic acid/desoxyribonucleic acid), etc.

Besides from GEMET, EARTH terminological content is derived from various mono and multi-lingual sources of controlled environmental terminologies such as UN Environment and Development [6], Italian Thesaurus of Earth Sciences [7], Inland Water terminology (derived from EDEN-IW project),

<sup>2</sup> <http://aims.fao.org/website/AGROVOC-Thesaurus/sub>

<sup>3</sup> <http://eunis.eea.europa.eu/>

<sup>4</sup> <http://thedatahub.org/dataset/geological-survey-of-austria-thesaurus>

<sup>5</sup> <http://www.eionet.europa.eu/gemet>

<sup>6</sup> <http://thedatahub.org/dataset/environmental-applications-reference-thesaurus>

Emergency Management Terms Thesaurus<sup>7</sup> and other terminology collected from reference documents in specific fields or coming from the daily research activity. EARTH currently contains more than 15.000 terms in English and Italian. Its content includes terms related to earth structure (lithosphere, hydrosphere and atmosphere) and to natural sciences (biosphere), terms dealing with the human society, activities and products (anthroposphere, built environment). In addition the terminology covers physical, chemical, natural and social processes, properties, effects, events, health and safety, productive sectors, data, parameters, methods and techniques. The content is constantly updated following the evolution of environmental terminology.

## 2.2. EARTH semantic model

EARTH is based on a multidimensional classificatory and semantic model [8].

The “vertical structure” of the thesaurus is built through a deductive (top-down)–inductive (bottom-up) approach. It is basically mono-hierarchical. It is developed according to a tree semantic model and is based on a system of categories. The first level of categories corresponds to entities, attributes, dynamic aspects, and dimensions. The vertical structure analyses the primary meaning of the terms and places them in the classificatory-hierarchical tree aiming to orientate the users towards the most “essential” characteristics of terms' semantics.

A thematic organization of terms is elaborated. A theme or a subject is here conceived as a sector of interest that reassembles the terms linked to it. The system of themes as it was conceived is developed according to the specific needs of the applicative context like the classification of terms for the management of environmental information.

"Traditional" thesauri typically provide a poorly differentiated set of relationships between terms, distinguishing only among hierarchical relationships, associative relationships and equivalence relationships. In EARTH the standard relationships are being arranged into richer subtypes, whose semantic content is specified. This work is particularly useful dealing with the associative relations (RTs). Typically RTs include a heterogeneous and undifferentiated set of relations, expressing many kinds of association between terms that are not hierarchically based. In EARTH RTs are differentiated into subtypes, thus strengthening the transversal relational structure.

The enrichment of thesaurus relationships and the increased semantic clarification of the relations could enable a better semantic description of web resources and guide users in meaningful information discovery on the web [9].

## 3. Publishing EARTH as Linked Data

From the technological point of view, D2R Server<sup>8</sup> has been adopted to map EARTH into the SKOS RDF vocabulary and to make EARTH available as Linked Data. This technological choice has been made considering the following requirements: (i) limited efforts and economical resources were allocated to EARTH publication as Linked Data; (ii) the employment of technologies exhibiting a very low competency barriers was recommendable to show how easily Linked Data can be deployed to environmental community; (iii) EARTH must be managed and updated via SuperThes [10], a tool which relies on a relational database to store the thesaurus content.

D2R perfectly matches the above requirements. It allows to deploy data from relational databases as SPARQL end points and HTTP dereferenceable linked datasets. It is open source and free, and users can deploy D2R servers just relying on basic linked data concepts and D2RQ mapping language.

In order to publish EARTH as Linked Data we have adopted the following Linked Data patterns [11]:

- Natural Key for identifier: the internal identifiers for EARTH concepts are assumed as Natural Keys in order to keep coherence with EARTH's previous (not linked data) releases and usages;
- Label Everything: every concept has its English human-readable name expressed as `rdfs:label`. So human-readable names can be exploited debugging queries and exploring EARTH;
- Preferred Label: every concept has its preferred label expressed as `skos:prefLabel`. Both English and Italian lexical representations are provided;
- Materialize Inferences: some of RDF and SKOS entailments have been materialized to support clients with limited processing power. For example, `rdfs:labels` are obtained as materialized inferences of English `skos:prefLabel`. Further materializations can be deployed [12];
- Equivalence Links: more than 4000 `skos:exactMatch` are provided to indicate equiv-

<sup>7</sup> <http://library.ema.gov.au/emathesaurus/>

<sup>8</sup> <http://d2rq.org/d2r-server>

alent URIs between EARTH and GEMET. That has been possible because EARTH is a significant extension of GEMET [13] and explicit references to the GEMET ID were maintained for the concepts shared with GEMET. Further equivalences have been created by working out the transitive closure on GEMET's `skos:exactMatch`. So that, we have been able to import the GEMET's outgoing links to AGROVOC, EUROVOC, DBpedia and UMLTHES in EARTH. Unfortunately, links obtained by this procedure only pertain to the subset of concepts that EARTH shares with GEMET. In order to complement that set and find out a more complete connection among EARTH and GEMET's linked datasets, a two-steps process has been put in place: firstly, SILK has been applied to discover new links, then the SILK results have been validated by the expert members of CNR-IIA-EKOLab in order to verify the accuracy of the links and to identify the most suitable types of interlinking property (i.e., `skos:exactMatch` or `skos:closeMatch`). The joint exploitation of `skos:exactMatch` transitive closure and manually validated SILK link discovery have almost a triplicated the number of outgoing links available with respect to the previous EARTH release. This new release paves the way for a combined exploitation of EARTH with GEMET, AGROVOC, EUROVOC, DBpedia and UMLTHES, enabling EARTH adopters in taking advantage of their respective strengths and complementarities.

### 3.1. EARTH in the LOD cloud

In the late 2011, EARTH has been included in the Linked Open Data (LOD) Cloud. EARTH content is accessible through (i) HTTP dereferenceable URIs<sup>9</sup>; (ii) RDF/XML dump<sup>10</sup>; (iii) SPARQL end point<sup>11</sup>. EARTH is part of a framework that includes other SKOS linked datasets [13], so accessing EARTH concepts via SPARQL end point requires to make a good use of either (i) the SKOS scheme<sup>12</sup> under which EARTH concepts are grouped, or (ii) the specific URI pattern<sup>13</sup> the EARTH concepts follow. Two

<sup>9</sup> <http://linkeddata.ge.imati.cnr.it:2020/directory/EARTH>

<sup>10</sup> <http://purl.oclc.org/net/DumpEarthRDF>

<sup>11</sup> <http://linkeddata.ge.imati.cnr.it:2020/sparql>

<sup>12</sup> <http://linkeddata.ge.imati.cnr.it:2020/resource/SkosConceptScheme/1>

<sup>13</sup> [http://linkeddata.ge.imati.cnr.it:2020/resource/EARTH/.](http://linkeddata.ge.imati.cnr.it:2020/resource/EARTH/)

examples of simple SPARQL making use of SKOS concept scheme and URI pattern are shown below:

Query 1: SPARQL making use of `skos:scheme`

```
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX skosScheme: <http://linkeddata.ge.imati.cnr.it:2020/resource/SkosConceptScheme/>
SELECT DISTINCT * WHERE {
  ?s skos:prefLabel ?o.
  ?s skos:inScheme skosScheme:1
} LIMIT 100
```

Query 2: URI pattern

```
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
SELECT DISTINCT * WHERE {
  ?s skos:prefLabel ?o.
  FILTER (REGEX(STR(?s),
"http://linkeddata.ge.imati.cnr.it:2020/ resource/EARTH/"))
} LIMIT 100
```

It is worth noting that EARTH concepts can work as a bridge between different thesauri. For example, Query 3 retrieves some EARTH concepts pertaining to “meteorological station”. As it is illustrated in Fig. 1 and depicted in Fig. 2, EARTH “meteorological station” and its related concepts connect DBPEDIA and AGROVOC to GEMET and UMLTHES.

Query 3: Meteorological station's linked entities

```
PREFIX EARTH: <http://linkeddata.ge.imati.cnr.it:2020/resource/EARTH/>
PREFIX DBPEDIA: <http://dbpedia.org/resource/Category:>
PREFIX GEMET: <http://www.eionet.europa.eu/gemet/concept/>
PREFIX AGROVOC: <http://aims.fao.org/aos/agrovoc/>
PREFIX UMLTHES: <http://data.uba.de/umt/>
SELECT DISTINCT * WHERE {
  EARTH:46920 ?property ?hasValue
  OPTIONAL {
    {?hasValue skos:exactMatch ?RConceptMatches } UNION
    {?hasValue skos:closeMatch ?RConceptMatches }
  }
}
```

property	hasValue	RConceptMatches
<code>rdf:type</code>	<code>skos:Concept</code>	
<code>rdfs:label</code>	"meteorological station"@en	
<code>skos:broader</code>	EARTH:32890	
<code>skos:exactMatch</code>	DBPEDIA:Meteorological_stations	
<code>skos:exactMatch</code>	AGROVOC:c_4781	
<code>skos:inScheme</code>	<code>skosScheme:1</code>	
<code>skos:prefLabel</code>	"meteorological station"@en	
<code>skos:prefLabel</code>	"stazioni meteorologiche"@it	
<code>skos:related</code>	EARTH:96090	GEMET:5194
<code>skos:related</code>	EARTH:93100	
<code>skos:related</code>	EARTH:85200	GEMET:9276
<code>skos:related</code>	EARTH:85200	UMLTHES:_00051497

Fig. 1. Results of Query 3: EARTH concepts pertaining to “meteorological station”.

Statistics pertaining to the number of SKOS concepts and the availability of properties for those concepts are provided in Table 1. The first column of the table provides information about the number of `skos:Concept` and those having at least one occurrence of the indicated SKOS relations.

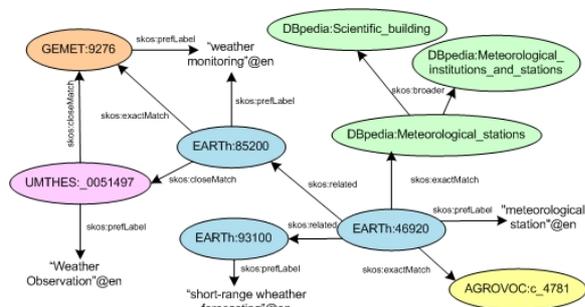


Fig. 2. Meteorological station's linked entities.

For example, the first row indicates that 14351 skos:Concept are available, the second row indicates that 14350 concepts have a skos:inScheme property. The second column shows their SKOS lexical representations. For example, the first row shows that 14350 of them have a skos:prefLabel in English and 14002 in Italian. Table 2 shows statistics about EARTH outgoing interlinks respectively towards GEMET and AGROVOC, UMTHESES, etc.

Table 1

Statistics about the EARTH: SKOS concepts and their properties availability

Property	#	Property	#
skos:concept	14351	skos:prefLabel	14350 (en) 14002 (it)
skos:inScheme	14350	rdfs:label	14350 (en)
skos:broader & skos:narrower	11664	skos:definition	6332 (en) 5883 (it)
skos:related	4083	skos:altLabel	1198 (en) 853 (it)

Table 2

Statistics about EARTH outgoing interlinks

Interlinks	#	Interlinks	#
skos:exactMatch to GEMET	4365	skos:exactMatch to eurovoc	1346
skos:exactMatch to AGROVOC	1458	skos:exactMatch and skos:closeMatch to DBpedia	1862
skos:exactMatch to UMTHESES	2970		

Further details pertaining to linkset and accessibility are available in VOID description<sup>14</sup> and dataHub<sup>15</sup>.

EARTH is available under by-nc-nd creative commons licence<sup>16</sup>, which grants the right to copy, distribute and transmit it for non-commercial purposes,

<sup>14</sup> <http://purl.org/NET/Earth.ttl>

<sup>15</sup> <http://thedatahub.org/dataset/environmental-applications-reference-thesaurus>

<sup>16</sup> <http://creativecommons.org/licenses/by-nc-nd/3.0/>

but implies explicit attribution of work and forbids derived works.

#### 4. EARTH application/relevance

Being able (i) to combine the search of stable logical and conceptual basis with flexibility towards different applications, (ii) to ensure a wide conceptual coverage, (iii) to recognise the cultural dimension of knowledge organization and (iv) to allow different levels of comprehensibility and applicability for users with different expertise, EARTH can be utilized for different purposes. Table 3 summarises EARTH applications at national and international level distinguishing among the different strands in which EARTH is adopted: LOD, RDF or other depending if the applications use EARTH exploiting its published linked data version, its SKOS/RDF dump, or an old fashion access to its relational database version.

At national level, EARTH is deployed by the Italian Environmental Agency (ISPRA) in its portal for Indexing and Networking of Documents on Environmental Knowledge Sharing (INDEKS)<sup>17</sup>.

At international level, EARTH is object of a continuous collaborative exchange with FAO Term Portal<sup>18</sup>. EARTH SKOS/RDF dump is often employed in combination with Geonetwork as a terminological source to compile ISO 19115 metadata, for example, it is employed in Geonetwork SDI on Mercury emissions and Geonetwork SDI KnowSeas.

EARTH availability as linked dataset has raised its relevance at international level, especially in EU funded projects where common controlled vocabularies are created for specific environmental data themes as the base for semantic integration of the data within the Spatial Data Infrastructures. In particular in:

- NatureSDIplus<sup>19</sup>, EARTH has been employed as backbone thesaurus for a common thesaurus framework for Nature Conservation [13].
- GS-SOIL project<sup>20</sup>, the thesaurus for Soil SoilThes has been created with a domain specific thesaurus with direct outgoing skos:exactMatch links to EARTH.
- EnvEurope<sup>21</sup> and ExpeER projects, the common controlled vocabulary EnvThes for long term eco-

<sup>17</sup> <http://www.indeks.isprambiente.it/INDEKS/public/welcome.do>

<sup>18</sup> <http://www.fao.org/termportal/partnerships1/en/>

<sup>19</sup> <http://www.nature-sdi.eu/>

<sup>20</sup> <http://gssoil-portal.eu/ingrid-portal/>

<sup>21</sup> <http://www.enveurope.eu/>

logical research and monitoring data themes provides explicit outgoing links to EARTH. The new release of EARTH has empowered its “bridging” nature with respect to other well-known thesauri, and then we expect that EARTH will be even more often used, not only to support finding and understanding environmental data/metadata, but to enable semantic interoperability of data and metadata within the data infrastructure and its services

Table 3  
EARTH applications at national and international

Applications	LOD	RDF Dump	Other
ISPRA INDEKS		X	
FAO Term Portal (FAOTERM)			X
SDI Geonetwork on Mercury emissions		X	
SDI Geonetwork KnowSeas		X	
Nature-SDI (EU Project)	X		
GS-Soil (EU Project)	X		
EnvEurope (EU Project)	X		
ExpeER (EU Project)	X		

## 5. Conclusion and future work

The paper illustrates the main characteristics of the linked dataset EARTH, an environmental thesaurus that promises to become pivotal for data sharing in the environmental domain. EARTH content continuously evolves as a result of CNR-IIA-EKOLab’s research activity, whilst EARTH Linked Data releases are provided once a year by CNR-IMATI.

Future activity will include improvement in terms of EARTH content as well as its Linked Data publication. Concerning the content, an overall revision of the thesaurus structure and content is currently undergoing as consequence the recent publication of ISO 25964-1:2011 [14]. The number of concepts and lexical correspondents of EARTH are expected to increase also as a consequence of a larger adoption by environmental communities. Concerning the Linked Data publication, novel releases are expected to overcome current limitations: (i) further materializations (e.g., entailments of skos:semanticRelation) will be made available in the future releases; (ii) RT properties, which have been indistinctly mapped into skos:related in order to avoid the adoption of user-defined RDF vocabularies, will be differentiated as in the original version of EARTH; (iii) EARTH connection with other environment-related thesauri will be

strengthened providing links to other thesauri (e.g., NALT Agricultural Thesaurus).

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