Recent Advances in EcoLexicon[1]

Antonio San Martín Melania Cabezas-García
Miriam Buendía Beatriz Sánchez-Cárdenas
Pilar León-Araúz Pamela Faber

asanmartin@universidadviu.com melaniacabezas@ugr.es
miriam.buendia@uclm.es bsc@ugr.es
pleon@ugr.es pfaber@ugr.es

ABSTRACT

EcoLexicon is a multilingual terminological knowledge base concerning the environment. It is the practical application of Frame-based Terminology, a cognitive approach to the representation of specialized knowledge. Recent enhancements include the EcoLexicon English corpus, a phraseological module, and a flexible approach to terminological definitions.

INTRODUCTION

EcoLexicon (http://ecolexicon.ugr.es) (Faber et al. 2011; Faber and Buendía 2014; Faber et al. 2016) is a multilingual terminological knowledge base concerning environmental science; it was developed by the

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LexiCon research group (http://lexicon.ugr.es) at the University of Granada, Spain. Initially designed and implemented in 2003, it contains 3,631 concepts and 20,342 terms in English, Spanish, German, French, Russian, and Modern Greek.

EcoLexicon is the practical application of Frame-based Terminology (FBT) (Faber et al. 2006; Faber 2012, 2015), a theory of specialized knowledge representation that uses certain aspects of Frame Semantics (Fillmore 1982; Fillmore and Atkins 1992) to structure specialized domains and create non-language-specific representations. FBT focuses on the following: (i) conceptual organization; (ii) the multidimensional nature of specialized knowledge units; and (iii) the extraction of semantic and syntactic information through the use of multilingual corpora.

The users targeted by this knowledge base include language specialists, domain experts, and the general public. Its representations are designed to help translators, technical writers, and environmental experts who need to access and better understand specialized environmental concepts with a view to writing or translating specialized and semi-specialized texts.

The rest of this report is organized as follows. The second part provides a short description of the EcoLexicon interface and its various modules. The third part concisely outlines the latest advancements in EcoLexicon, namely, its new English corpus, the revamped phraseological module, and a flexible approach to terminological definition. Finally, the conclusion treats the contributions of EcoLexicon to terminography.

ECOLEXICON INTERFACE

Users interact with EcoLexicon through a visual interface with various modules that provide conceptual, linguistic, and graphical information. Instead of viewing all information simultaneously, users can browse through the windows and select the most relevant data for their needs.

Figure 1 shows the EcoLexicon entry for FAN. When users open the application, three zones appear. The top horizontal bar gives access to the term/concept search engine. The vertical bar on the left of the screen provides information regarding the search concept, namely, its definition, term designations, associated resources, general conceptual role, and phraseology.

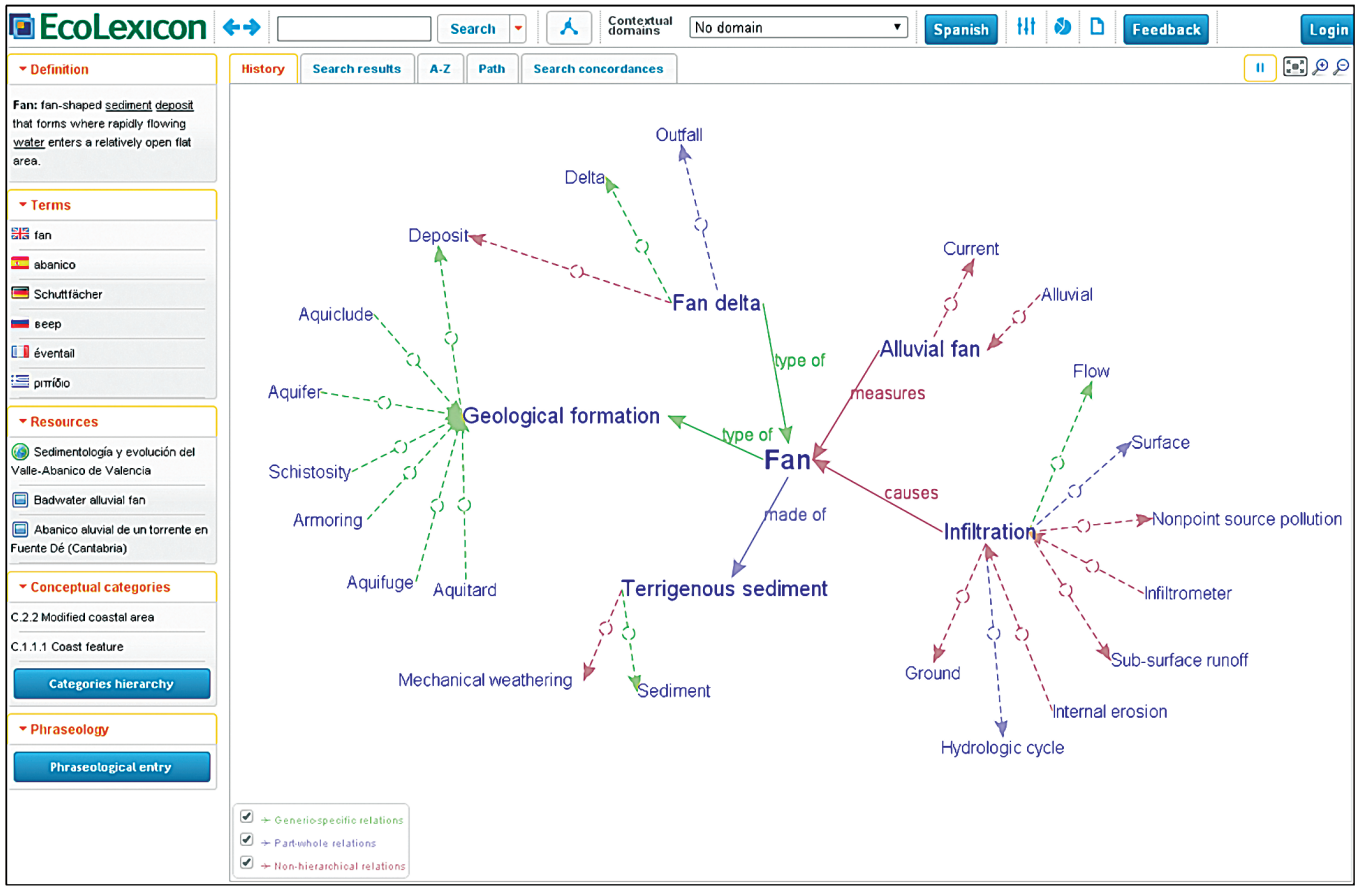

FIGURE 1 User Interface

The topmost box shows the definition of the concept (see the discussion "Flexible terminological definitions," below). The words in each definition also have hyperlinks to their corresponding concept in the knowledge base. The box directly below shows the terms designating the search concept in various languages. The list is organized according to language and term type (main entry term, synonym, variant, acronym, etc.). A click on the term provides further linguistic information regarding language, term type, gender, part of speech, and concordances.

The third box provides resources (images, documents, URLs, audiovisual material, etc.) associated with each concept. The fourth box indicates the very general conceptual role that the concept normally has within the environmental domain.

The phraseology box is currently under construction and shows a list of verbs most commonly used with the term within different phraseological patterns (see the discussion "Phraseology" below). The central area has tabs that access the following: (i) the history of concepts/terms visited; (ii) the results of the most recent query; (iii) an alphabetical list of all of the terms; (iv) the shortest path between two concepts; and (v) concordances for the search term.

At the center of the screen are a conceptual map and icons that permit users to configure and personalize it for their needs. The standard representation mode shows a multi-level semantic network whose concepts are all linked in some way to the search concept at the center. When users click on any of the concepts in the map (e.g., FAN DELTA), the network rearranges itself. In the new map, fan delta is at the center, along with its set of related concepts (see Figure 2).

By right-clicking on a concept in the map, users can access the contextual menu. This menu can be used to perform any of the following actions: (i) centering the concept; (ii) fixing a node by dragging it to a certain position; (iii) visualizing details of the concept (definition, associated terms, resources, etc.) by selection on the sidebar; (iv) generating a URL for direct access to the concept selected; (v) searching Google Images, Google, and Wolfram Alpha; (vi) removing a concept and its related concepts from the map. Any of these actions enhances concept representation by providing a rich quantity of conceptual information, depending on the specific needs of the user.

EcoLexicon also includes icons to personalize concept map visualization such as *Zoom map, Zoom out map,* and *Fullscreen*. *Stop layout*

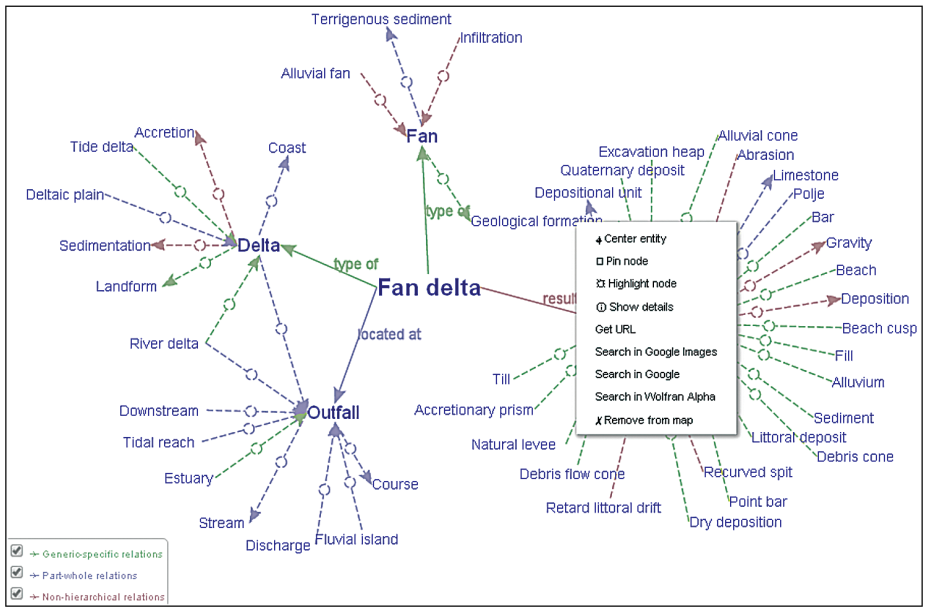

FIGURE 2 Conceptual Map of FAN DELTA and Contextual Menu

deactivates the automatic arrangement of concepts in the network. This allows users to configure the map by dragging concepts to the desired location.

The *Settings* icon further customizes semantic networks by permitting users to establish the depth of the network, namely, its maximum conceptual level. Similarly, they can also decide whether they wish to visualize the names of all semantic relations since, by default, relation labels only appear when the relation includes the central concept.

The scope and multidimensionality of the environmental domain as well as the many conceptual propositions represented in EcoLexicon initially resulted in information overload. This problem has since been solved as follows: (i) by allowing the user to filter overloaded networks by relation type; (ii) by offering a recontextualized view of concepts according to topic-based contextual constraints; and (iii) by providing different access modes to the concept visualization (network mode, tree mode, and path mode).

As can be glimpsed in the lower left-hand corner of the conceptual maps in Figures 1 and 2, a text box allows users to identify the three categories of conceptual relations in EcoLexicon: (i) hyponymic (*type_of*) relations (generic-specific); (ii) meronymic (*part_of*) relations

(part-whole); (iii) non-hierarchical relations (*has_function*, *located_at*, *causes*, *affects*, *result_of*, etc.).

The checkbox at the left of each label can be used to activate or deactivate the visualization of a certain type of relation so that it does not appear on the map. This allows users to filter overloaded networks based on relation types. Recontextualized networks can be visualized by choosing one of the contextual domains from a pull-down menu (upper ribbon in Figure 1).

Recontextualization is a qualitative way to solve the problem of information overload while enhancing the representation of multidimensionality. Recontextualized networks are reshaped depending on how the relational behavior of concepts varies with perspective. Instead of representing all possible dimensions of a concept, conceptual propositions are activated or constrained according to their salience in particular subject fields (León-Araúz et al. 2013).

In Figure 3, WATER appears in a context-free user-unfriendly overloaded network. In contrast, Figure 4 shows the same concept framed in the Civil Engineering domain. The network is substantially reduced because it shows only conceptual relations pertinent to that domain.

Users can also choose between a tree mode and a path mode of representation. The tree mode generates a *type_of* hierarchy for the concept (see Figure 5). In contrast, in the path mode, users choose two concepts, one each at the beginning and end of the path. The application then calculates and shows the shortest distance between them, as exemplified with HURRICANE and SAND in Figure 6.

RECENT ADVANCES IN ECOLEXICON

The English EcoLexicon corpus. The EcoLexicon English corpus (EEC) is a 23.1-million-word corpus of contemporary environmental texts. It was compiled by the LexiCon research group for the development of EcoLexicon and can be queried in the *Search concordances tab* (Figure 1).

Each text in the corpus is tagged according to a set of XML-based metadata (see Figure 7), some of which are based on the Dublin Core Schema, while others have been included to meet needs of the research group.

Corpus metadata permit users to constrain corpus queries based on pragmatic factors, such as contextual domains and target reader. In this

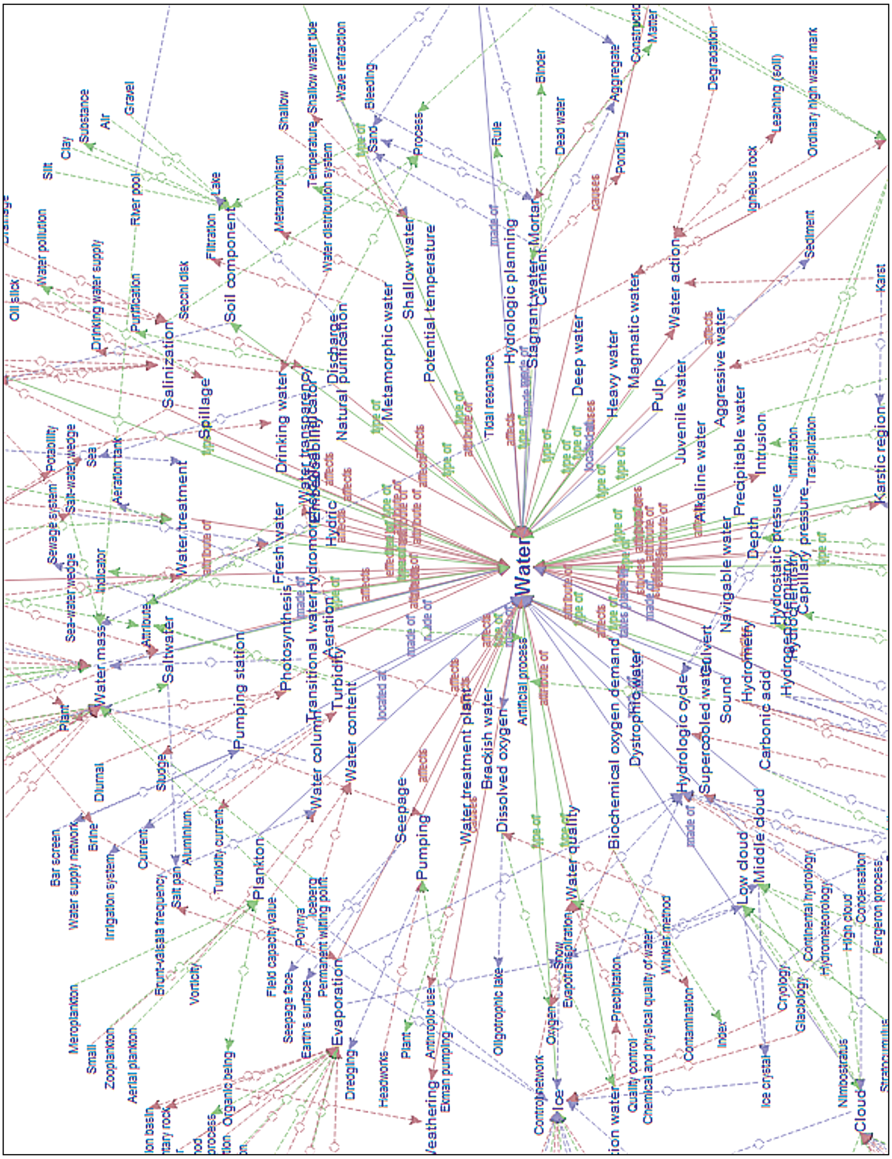

FIGURE 3 Context-free Overloaded Network for WATER

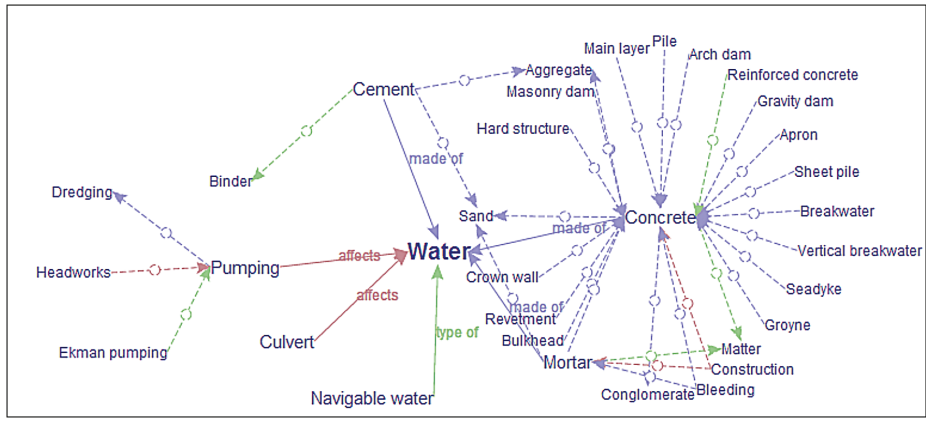

FIGURE 4 Network for WATER in the Civil Engineering Domain

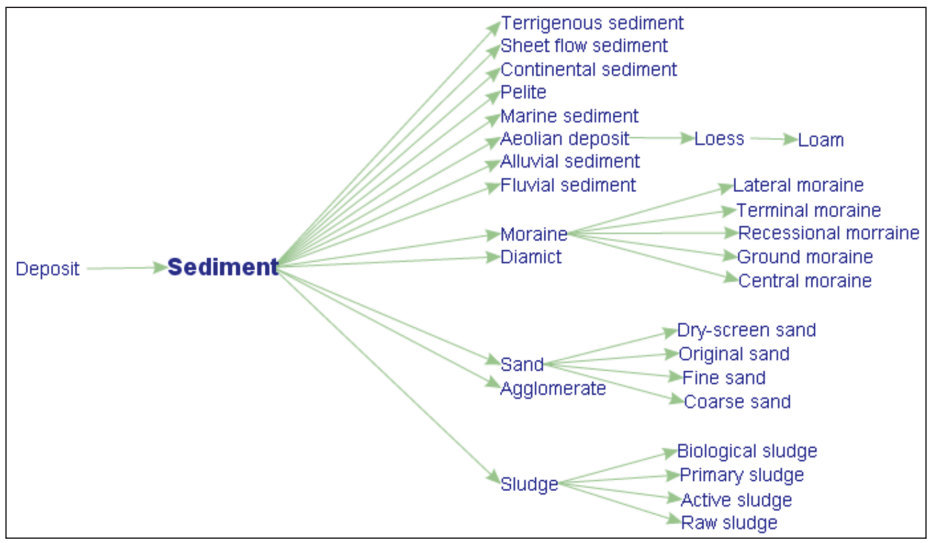

FIGURE 5 Tree Mode for SEDIMENT

way, use of the same term in different contexts can be compared. For instance, Figure 8 shows concordance lines for *methane* in Environmental Engineering texts.

Furthermore, the EEC is now freely available in Sketch Engine Open Corpora (https://the.sketchengine.co.uk/open/). Users interested in querying the corpus have access to all of its features even without a Sketch Engine subscription (Kilgarriff et al. 2014). Tags, which can be used to limit queries, are based on the following parameters:

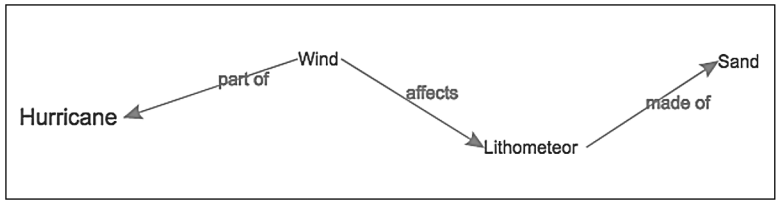

FIGURE 6 Path Mode for HURRICANE and SAND

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<?xml version="1.0" ?>
- <metadata xmlns:xsi="http://www.w3.org/2001/XMLSchema-instanc
    xmlns:eco="http://manila.ugr.es/tags/0.1">
  - <header>
      <dc:title>Coastal Engineering Manual Part 1 Chapter 2 History of
      <dc:creator>US Army Corps of Engineers</dc:creator>
      <eco:respon>adm</eco:respon>
      <dc:date>2002-04-30</dc:date>
      <eco:country>us</eco:country>
      <eco:domain>3.2.3</eco:domain>
      <dc:subject>coastal engineering</dc:subject>
      <dc:subject>history</dc:subject>
      <dc:subject>evolution</dc:subject>
      <dc:subject>military</dc:subject>
      <dc:subject>civil engineering</dc:subject>
      <eco:user>s</eco:user>
      <eco:text>book</eco:text>
      <dc:language>en</dc:language>
      <eco:variant>am</eco:variant>
      <eco:note />
    </header>
    <body>History of Coastal Engineering I-3-i Chapter 3 EM 1110-2-11
```

FIGURE 7 Corpus Metadata

- Domain: the EEC encompasses all the domains and subdomains of environmental studies (e.g., biology, meteorology, ecology, environmental engineering, environmental law).
- User: the EEC includes texts for three types of user (depending on level of expertise): expert, semi-expert, general public.
- Geographical variant: the EEC comprises American, British, and Euro English.
- Genre: the EEC covers a wide variety of text genres—journal articles, books, websites, lexicographical material, etc.
- Editor: the EEC distinguishes texts edited by scholars/researchers, businesses, government bodies, etc.

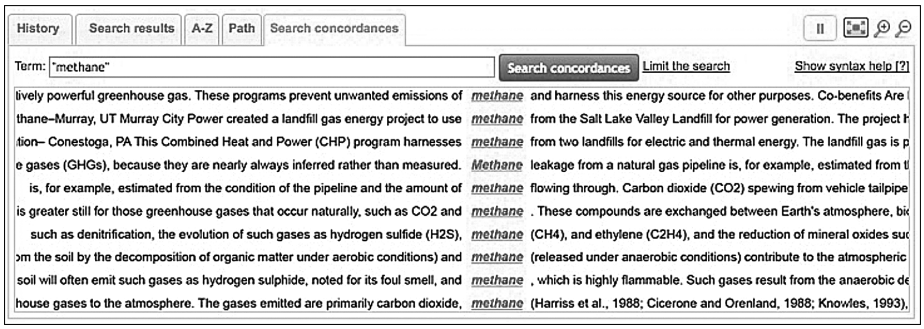

FIGURE 8 Concordances for *methane* in Environmental Engineering

- Year: the EEC includes texts from 1973 to 2016.
- Country: the EEC texts are tagged according to the country of publication.

The EEC is tagged with the Penn Treebank tagset (TreeTagger version 3.3), which permits more fine-grained queries in the Corpus Query Language (CQL) (Schulze and Christ 1996). It also employs the default Sketch Grammars for English in combination with the Sketch Grammars developed by León Araúz et al. (2016). The latter was developed for the extraction of some of the most common semantic relations in terminology: generic-specific, part-whole, location, cause, and function. Thanks to these sketch grammars, users can access ready-made word sketches such as those shown in Figure 9.

Phraseology. EcoLexicon contains a phraseological module that includes verb collocations. The initial focus of this module is on verb phrases for each term because verbs are conceived as the central lexical and syntactic category of language (Fellbaum 1990), and there are currently few terminographic resources that incorporate verbs. Frame-based Terminology and EcoLexicon take a broad approach to the concept of collocation. By *verb collocation*, we mean highly frequent combinations of two or more words in a pattern of noun + verb or verb + noun, where the noun is the *base* and the verb is the *collocate*. The collocate (verb) is constrained by the meaning of the base (noun), but at the same time the collocate constrains the kinds of noun that can combine with it (Buendía 2013, 115). For example, in the collocation "the volcano spits," *volcano* takes a verb designating something being forced out of it (here, *spit*). However, it is also true that *spit* co-occurs only with

"bacterium" is a type of...	1,007	0.12
organism	158	10.00
microorganism	88	10.92
micro-organism	28	9.64
agent	18	8.09
decomposer	15	8.83

"bacterium" is the generic of...	1,028	0.12
coli	17	8.94
plant	14	6.85
Pseudomonas	10	8.24
Escherichia	10	8.22
fungus	9	7.60

"rock" has part...	3,029	0.09
mineral	213	10.54
quartz	65	9.17
fragment	47	8.79
feldspar	45	8.79
plagioclase	41	8.67

“rock" is part of...	2,055	0.06
crust	44	9.09
soil	34	7.97
belt	27	8.52
continent	23	8.30
part	22	7.96

"volcano" is located at...	318	0.04
plate	17	10.11
island	14	9.42
boundary	11	9.38
Pacific	8	8.71
margin	7	8.87

"volcano" is the location of...	71	0.01
cone	7	11.10
ocean	3	8.23
type	3	6.74
area	3	6.59
precursor	2	9.66

"tsunami" is the cause of...	196	0.04
damage	18	7.54
destruction	12	8.74
erosion	7	6.70
devastation	6	9.08
death	6	6.67

"tsunami" caused by...	1,057	0.20
earthquake	177	11.31
landslide	68	10.73
eruption	36	9.34
water	33	7.70
movement	23	8.65

"energy" has function...	2,151	0.03
water	57	8.71
produce	41	8.83
make	33	8.45
process	22	7.99
electricity	21	8.17

"energy" is the function of...	999	0.02
fuel	23	8.96
carbon	14	8.12
biomass	13	8.44
waste	13	8.20
light	12	8.28

FIGURE 9 Word Sketches

noun phrases that activate something being forced out of a mouth or a mouth-like orifice (e.g., *volcano*) (Buendía et al. 2014).

In EcoLexicon, verbs are classified based on meaning. They are thus primarily classified in lexical domains (nuclear meaning) and subdomains (meaning dimension), according to the premises of the Lexical Grammar Model (Faber and Mairal Usón 1999). Figure 10 displays an extract of the phraseological entry for HURRICANE. Specifically, it shows the dimension TO CAUSE TO CHANGE FOR THE WORSE with the nuclear meaning of CHANGE.

In order to arrive at the specification of the dimension (i.e., TO CAUSE TO CHANGE FOR THE WORSE), verb arguments were analyzed and assigned to semantic categories. In our approach, semantic categories are generalizations of a set of terms that are assumed to have a similar semantic

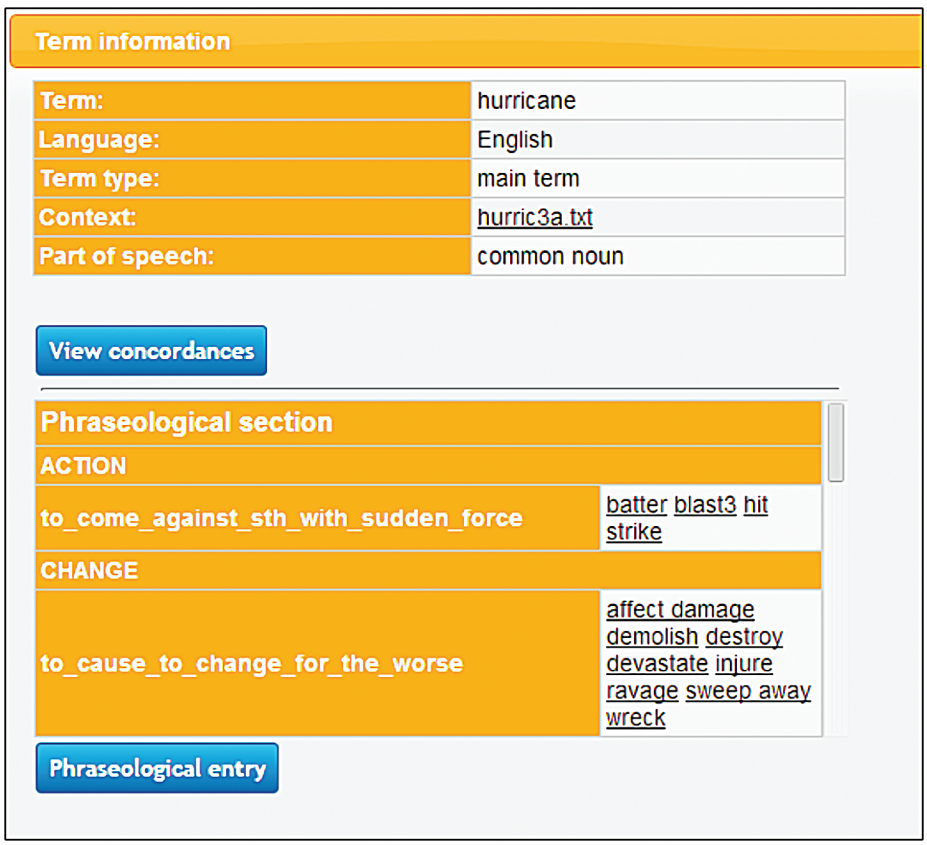

FIGURE 10 Extract of Phraseological Entry for HURRICANE

and syntactic behavior (Buendía 2013, 376). In other words, when various linguistic realizations have the same arguments, they are believed to have a similar meaning, possess the same underlying conceptual structure, and display similar semantic and syntactic behavior. For this reason, they belong to the same semantic category. As such, when different verbs have arguments belonging to the same semantic classes, they will probably activate the same kind of meaning. As shown in Figure 10, the verbs within the dimension to cause to change for the worse are *affect*, *damage*, *demolish*, *destroy*, *devastate*, *injure*, *ravage*, *sweep away*, and *wreck*. All these verbs have as their first argument the semantic category of natural disaster, and as a second argument a CONSTRUCTION, GEOGRAPHIC AREA, or HUMAN BEING. By clicking on each verb, users can access usage examples as well as a note section with information regarding meaning restrictions.

The phraseological module in EcoLexicon is currently being redefined with a view to including complex nominals (CNs) (e.g., *beach erosion control*), that is, expressions with a head noun preceded by a modifying element (nouns or adjectives) (Levi 1978). They are the most frequent units in specialized texts although they are rarely included in terminographic resources.

CNs are characterized by the existence of concealed propositions that can be inferred in the term formation processes highlighted in Levi (1978), involving predicate deletion (e.g., *power plant* instead of *a plant produces power*) and predicate nominalization (e.g., *power generation* instead of *power is generated*). The relation between a predicate and its argument structure is known as its micro-context and is essential in the understanding of these multi-word terms (Cabezas-García and Faber 2017).

Along these lines, one of the main difficulties of CNs is the non-specification of the semantic relation between their constituents as a consequence of noun packing (e.g., *DFIG-based wind turbine*). Thus, different methods are employed for meaning access. Traditionally, inventories of semantic relations (e.g., *cause, effect*) are the preferred option. Furthermore, they can be refined by means of verb paraphrases, such as *carry, transmit,* and *spread* for CNs such as *malaria mosquito*, which further specify the action carried out by the mosquito (Nakov and Hearst 2006; Cabezas-García and Faber 2017).

Our most recent approach combines the use of knowledge patterns, which convey semantic relations in real texts (e.g., *such as, composed of*), paraphrases, and semantic annotation of arguments with conceptual categories. In other words, for *dune erosion*, concordance lines such as *erosion affects the dunes* or *erosion has effects on dunes* are extracted by means of knowledge pattern queries. Access to the concealed semantic relation is then complemented by the use of verb paraphrases (e.g., *dunes are breached by storm wave attack, heavy storm events can destroy the dunes*) and annotation with conceptual categories (e.g., *dune erosion* can be annotated as LANDFORM + PROCESS) (Cabezas-García and San Martín 2017; Cabezas-García and León-Araúz, in press).

Therefore, the new section of the phraseological module of EcoLexicon on CNs will provide information regarding the formation of these multi-word terms, which is essential for accessing micro-contexts (Cabezas-García and Faber 2017). In this part of the module, users can also find solutions to translation problems often posed by multi-word terms. This is especially the case of long CNs (e.g., *stall-regulated horizontal axis wind turbine*). Furthermore, the use of knowledge patterns, paraphrases, and conceptual categories is expected to be helpful in the development of a procedure to infer semantic relations that allows the conceptual organization of CNs, as well as the semi-automatization of the strategies and the elaboration of translation rules (Cabezas-García and León-Araúz, in press). Accordingly, the variability typical of CNs is also considered in this part (Cabezas-García and Faber 2017).

The phraseological module is thus a continuum between the verb submodule and the submodule for CNs, given that many collocations have a noun-phrase equivalent in the form of a CN (e.g., *the volcano erupts* and *volcano eruption*). Both sections will be linked by means of verb paraphrases and the semantic annotation of arguments with conceptual categories (Cabezas-García and San Martín 2017). In addition, this new phraseological module will be visualized in different ways, depending on user needs. For instance, there will be a term view and a phraseme view, as well as a bilingual representation (English and Spanish). Users will thus be able to find linguistic and semantic information about phraseological units that will help them produce idiomatic environmental texts.

Flexible terminological definitions. Defining a term traditionally involves stating the necessary and sufficient characteristics that its meaning comprises. This approach—the Aristotelian definition—presupposes the existence of a stable meaning, independent of the context in which the term is used. In addition, term meaning (or semantic knowledge) is assumed to be independent of world (or encyclopedic) knowledge.

The principles underlying this type of definition have, however, been harshly criticized (Lakoff 1987; Croft and Cruse 2004; Evans and Green 2006). Cognitive linguists claim that it is not possible to determine the necessary and sufficient features of a concept because conceptual boundaries are fuzzy, and no features are shared by all category members. Furthermore, no distinction can be made between semantic and encyclopedic knowledge or between semantic and pragmatic knowledge.

From a cognitive viewpoint, encyclopedic knowledge plays a central role in the study of meaning because concepts are always embedded in frames (Fillmore 1982). Moreover, meaning is not considered a stable entity. It is constructed in each usage event in accordance with the context (Fauconnier 1994). As a consequence, meaning and context are inseparable (Faber and León-Araúz 2016).

As a result, EcoLexicon has adopted the *flexible terminological definition approach* (FTDA) (San Martín and León Araúz 2013; San Martín 2016). The FTDA includes a characterization of the contextual dimension of terminological definitions, which can include linguistic, thematic, cultural, ideological, and diachronic constraints (San Martín 2016, 200–14). Building upon FBT methodology for definition crafting (Faber 2002; León Araúz et al. 2012), the FTDA also includes guidelines on corpus-based knowledge extraction for definition writing and the management of multidimensionality in definitional templates (Table 1).

TABLE 1 Definitional Template for GROIN (León-Araúz et al. 2012, 156)

GROIN	
Hard coastal defense structure made of concrete, wood, steel and/or rock perpendicular to the shoreline built to protect a shore area, littoral drift delay, reduce and prevent prevention longshore transportation beach erosion.	
type-of	hard coastal defense structure
located-at	perpendicular to shoreline
made-of	concrete wood metal rock
has-function	shore protection littoral drift retardation reduction longshore transportation beach erosion prevention

In line with the recontextualization of conceptual networks in EcoLexicon, the contextual constraints currently applied to definitions in EcoLexicon are thematic (implemented in the form of domains, such as Hydrology, Chemistry, Energy Engineering). In fact, the FTDA receives its name from the notion of *flexible definition* as applied in EcoLexicon. More specifically, it consists of a set of definitions of the same concept made up of a general definition (in this case, one encompassing the environmental domain as a whole) along with additional definitions describing the concept from the perspective of the subdomains in which it is relevant. Table 2 shows extracts of the flexible definition for CHLORINE.

TABLE 2 Flexible Definition for CHLORINE

GENERAL ENVIRONMENTAL Non-metallic chemical element that belongs to the halogen family and exists as a greenish-yellow gas at standard temperature and pressure. Because of its high reactivity, it is only found naturally in compounds such as sodium chloride (common salt) in seawater, and halite (rock salt). Since it [. . .].
AIR QUALITY MANAGEMENT Air pollutant emitted mainly as chlorofluorocarbons, hydrochlorofluorocarbons, carbon tetrachloride, and methyl chloroform, which are ozone-depleting substances. When these substances reach the stratosphere, ultraviolet radiation and chemical reactions break them apart, and they are converted into hydrochloric acid and chlorine nitrate. Those two compounds are finally converted into chlorine [. . .].
CHEMISTRY Non-metallic halogen element with atomic number 17 that exists as a greenish-yellow gas at standard temperature and pressure. It is only found naturally in compounds, such as sodium chloride (common salt) in seawater and in halite (rock salt) or potassium chloride in sylvite. Chlorine has an atomic weight of [. . .].
WATER TREATMENT AND SUPPLY Water disinfectant that because of its oxidizing power, is added to water usually in a contact tank to kill or inactivate pathogens as part of wastewater treatment. Chlorine is used in pure form or as sodium hypochlorite (bleach), calcium hypochlorite, chlorine dioxide, or chloramine. Chlorine [. . .].

The FTDA assumes that by eliminating the artificial boundaries between semantic and pragmatic knowledge, the representation of contextual variation in the terminological definition is no longer a mere possibility. Given the ubiquity of context and its effects on cognition and language, the representation of the traits activated by concepts in accordance with the context becomes a necessity if one aspires to meet user needs fully. This also entails the inclusion of prototypical characteristics in the definition, that is, characteristics that are not always

applicable to the concept but are relevant in a given context. Similarly, encyclopedic knowledge in the terminological definition is no longer forbidden. It now forms an integral part of the definition.

CONCLUSIONS

EcoLexicon is a robust terminological resource based on a sound theoretical foundation. Although it will soon be fifteen years old, it continues to grow and acquire new domains, concepts, linguistic information, and even functionalities. Because it is continuously being enhanced with new features, it is a work in progress. Over the years, it has also become a platform for the creation of language products that are the practical application of innovative theoretical advances. This article has described some of the most recent developments in EcoLexicon, which reflect its vitality. Because of its high quality and effectiveness in specialized language acquisition and comprehension tasks, it is a valuable tool for language experts and domain experts, as well as for the general public.

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