EducaWood: a Semantic Web Application for Forestry Education

Guillermo Vega-Gorgojo [a,b,*], Juan I. Asensio-Pérez [a], Miguel L. Bote-Lorenzo [a], Pablo García-Zarza [a], José M. Giménez-García [a,b], Felipe Bravo [b] and Irene Ruano [b]

[a] *Group of Intelligent and Cooperative Systems, Universidad de Valladolid, Spain*
E-mails: guiveg@tel.uva.es, juaase@tel.uva.es, migbot@tel.uva.es, pablogz@gsic.uva.es, jm.gimenez.garcia@gsic.uva.es

[b] *SMART Ecosystems research group, iuFOR – Sustainable Forest Management Research Institute, Universidad de Valladolid, Spain*
E-mails: felipe.bravo@uva.es, irene.ruano@uva.es

Abstract. There are few applications available for educational purposes in the forestry domain. These applications have significant limitations, including not exploiting existing biodiversity datasets, lacking flexible and consistent use of domain concepts, and generating annotations that are not easily shareable or reusable by other applications. In this paper, we introduce EducaWood, a novel Semantic Web application designed for forestry education that overcomes these limitations by leveraging Linked Open Data (LOD). Users can easily create tree annotations through a web form that hides the complexity of Semantic Web technologies. These annotations adhere to the Simple Tree Annotation ontology and are saved in a triplestore, facilitating seamless sharing with other users and applications. Moreover, EducaWood offers scalable and efficient visualization of semantic tree data across various zoom levels on a map interface. Access to LOD is handled through a REST API that allows read and write operations over multiple data sources. An implementation of EducaWood has been successfully tested by almost 500 users, including real students and teachers in a pilot educational experience.

Keywords: semantic spatial data, access to LOD, semantic annotation, data visualization, semantic user interfaces, forestry education

1. Introduction

We find ourselves in an increasingly urbanized society, which struggles to distinguish forest or fauna species, and with the generalized idea that a forest is a wild place where no intervention should be made. Therefore, in recent times, forest harvesting has a bad social acceptance, as it is related to deforestation, considered one of the main environmental problems of the planet [1–3]. However, we can be sure that cutting trees is not inherently bad. Forestry operations, including tree harvesting, allow us to obtain significant ecosystem products and services[1] [4], all of them linked to human well-being [5]: provisioning raw materials; supporting biodiversity, soil health and nutrient cycling; mitigating climate change; regulating water flows and pest dynamics; providing cultural value (tourism, spiritual, education, research...). By

*Corresponding author. E-mail: guiveg@tel.uva.es.
[1] https://www.millenniumassessment.org

harvesting trees, we can shape forests for better ecosystem service provision and anticipate potentially catastrophic disturbances. Like any other tool, harvesting can be misapplied or misused, but this does not qualify every operation of this type as problematic. There is no silvicultural alternative capable of simultaneously maximizing the provision of all ecosystem services, as Morán-Ordóñez et al. [6] showed for Mediterranean forests under different global change scenarios.

Thus, there is a need to bring the forestry world closer to society, encompassing both urban and rural communities. Environmental education emerges as an effective approach to accomplish this objective. Multiple researchers argue that a better understanding of environmental sciences is achieved through active learning experiences grounded in real-life settings [7, 8]. For example, field trips can be organized to identify tree species and analyze biodiversity. Therefore, contextualized environmental education activities hold significant promise to better understand Earth's ecosystems and promote more responsible attitudes toward the conservation and sustainable use of our planet.

While a few applications exist such as Integrate Tree Microhabitat[2], Observation.org[3] and iNaturalist[4], they have some limitations for environmental education that can be addressed with Semantic Web technologies. First, they do not exploit existing biodiversity datasets like tree inventories, land cover maps, or taxonomic classifications—note that Linked Open Data (LOD) and knowledge graphs are especially suitable for data integration. Second, they tend to make an inconsistent use of domain concepts (tree species, dead materials, decay stages...), a difficulty that can be alleviated by employing ontologies. Third, they make an intensive use of environmental annotations (i.e., descriptions made by application users about physical entities such as trees, leaves, timber, etc.) that cannot be shared or reused by other applications. In this regard, the publication of environmental annotations as LOD enable their sharing and reuse, facilitating follow-up educational activities using the same or a different environmental education application.

Despite the aforementioned advantages of Semantic Web technologies for applications in environmental education, they bring their own set of challenges:

CHALLENGE #1 Human-computer interaction with the Semantic Web is quite demanding [9–11]. Target users, particularly forestry teachers and students, do not usually know RDF or SPARQL and should be able to easily visualize and author environmental annotations while carrying out educational tasks.

CHALLENGE #2 Access to LOD is complex [12, 13], especially when dealing with read and write operations across multiple sources. Note that this is the expected situation when different forestry datasets need to be exploited.

CHALLENGE #3 Forestry data tends to be very large and is geospatial by nature [14], requiring efficient approaches for visualizing semantic geospatial data.

In response to these challenges, we introduce EducaWood, a Semantic Web application designed for forestry education that showcases: (a) good practices in the design of web applications aimed at hiding the complexity of Semantic Web technologies to end users; (b) an easier approach to dealing with read and write access over multiple LOD endpoints; (c) efficient visualization of large geospatial environmental semantic datasets. More concretely, EducaWood features: (1) a web architecture aimed at supporting the description of physical entities (e.g., trees) by means of user-friendly web forms for authoring various types of annotations (e.g., location, tree status, taxon...) while concealing the complexity of RDF, OWL, and SPARQL; (2) access to LOD through a CRAFTS API. CRAFTS [15] is an API generator for LOD that supports read and write operations across multiple endpoints, largely reducing the development effort when interacting with multiple datasets. Thanks to the CRAFTS API, EducaWood publishes environmental annotations in a triplestore, while consuming data from the Spanish National Forest Inventory[5] (IFN –

[2] http://www.integrateplus.org/m-learning-tools.html
[3] https://observation.org/
[4] https://www.inaturalist.org/
[5] https://www.miteco.gob.es/es/biodiversidad/temas/inventarios-nacionales/inventario-forestal-nacional.html

Inventario Forestal Nacional), Wikidata, and DBpedia; (3) an interactive map for seamless tree browsing and filtering by taxon. Since the application integrates more than one million trees from IFN, smart data management is critical to ensure performance across varying map resolutions and to minimize unnecessary data downloads.

Beyond the educational benefits for the forestry domain brought by EducaWood, the paper presents a set of contributions of special interest for the Semantic Web research community: (a) the Simple Tree Annotation (STA) ontology for structuring environmental annotations (mostly focused on trees);(b) a demonstrator of a web application architecture that hides the complexity of Semantic Web technologies from users, and that streamlines the read and write access to multiple LOD sources; (c) a novel mechanism for the scalable and efficient visualization of semantic tree data on a map.

The rest of the paper is organized as follows. Section 2 reviews interactive annotation applications in forestry education, as well as semantic approaches for the aforementioned challenges. Section 3 provides a technical description of EducaWood, including its requirements, its ontology, its architecture, its main functionalities, and implementation details. Section 4 reports on the impact of EducaWood so far and includes a pilot study with forestry students. The paper ends with a discussion in Section 5.

2. Related work

2.1. Interactive annotation applications in forestry education

Currently, there are few applications available that could potentially be used for forestry education. One of them is the Integrate Tree Microhabitat application,[6] developed by the European Forest Institute[7] to support training exercises for forest managers, inventory personnel, and other groups in identifying and describing tree microhabitats. However, its utility is limited to a series of training and demonstration plots known as "marteloscopes" where all trees are measured and geopositioned and where foresters can conduct virtual tree marking for training. This network of marteloscopes includes 224 sites across 25 European countries and four additional sites in Vietnam. Marteloscopes serve multifaceted purposes, including training for both students and professionals, public outreach, and research endeavors such as human behaviour concerning forests [16] or thinning effects on biodiversity conservation and socio-economic co-benefits [17]. However, a limitation of the Integrate Tree Microhabitat application is its inability to incorporate new data, a restriction imposed to uphold data integrity and facilitate consistent comparisons across different time frames and analyses.

Observation.org[8] is another application that may be used for forestry education. Nowadays, it serves as a global hub for citizen science where naturalists, citizen scientists, and biologists collaborate to gather, verify, and exchange biodiversity data. Users can create their own projects, located anywhere in the world, allowing them to generate biodiversity annotations through the website or the mobile application. Observation.org is more intensively used for animal projects (especially birds and insects) since it only includes a very general section for plants. More specifically, users can only annotate tree species, photos, and locations, but no further information such as dendrometric measures or tree status.

iNaturalist[9] is very similar to Observation.org, allowing users to gather, verify, and collaboratively exchange biodiversity data. iNaturalist has been used as a blended learning framework for biodiversity monitoring [18] and to engage the community in the organism identification in outdoor activities [19]. Again, iNaturalist annotations are limited to tree species, photos, and locations.

[6] See footnote 2.
[7] https://efi.int/
[8] See footnote 3.
[9] See footnote 4.

2.2. Semantic Web challenges for applications in forestry education

As noted in Section 1, there are several challenges with the use of Semantic Web technologies in interactive applications spanning multiple domains, including forestry education. The first challenge entails facilitating human-computer interaction for stakeholders unfamiliar with Semantic Web technologies. Addressing this issue involves offering appropriate user interfaces with familiar conventions, thereby facilitating a transparent utilization of Semantic Web technologies while enabling seamless data analysis [20]. Several examples in the literature adopt this approach, although they are typically limited to LOD consumption without support for write operations. For example, the suite of Sampo portals [21] allows users to query and filter semantic Cultural Heritage data using form interfaces comprising textboxes and selectors, dynamically presenting data in tables, graphs, and maps. LOD4Culture [22] is another Semantic Web application from our previous work that follows this approach; it offers an interactive map and a table-based browser of Cultural Heritage entities sourced from Wikidata and DBpedia. Additionally, Linked Data browsers such as [23] aid users unfamiliar with Semantic technologies in visualizing semantic data.

Expanding upon this challenge, enabling end users to add or modify semantic data poses a significant hurdle. Andrews et al. [24] reviews the different annotation types employed in interactive annotation applications. Interestingly, the type of data to be recorded should influence the user interface design to introduce user input. For example, a clickable map interface may prove effective for capturing the coordinates of a place. In our previous work, we have successfully employed web forms to gather user data; this is the case of CHEST [25], where teachers can easily create spatial objects and learning tasks, which are then transparently saved as LOD. Notably, Wikidata is acknowledged as the leading open knowledge base in the world [26], also leveraging web forms for user inputs.

While the availability of LOD and knowledge graphs has grown across all domains, access to LOD is quite demanding even for knowledge engineers (refer to CHALLENGE #2 in the introduction). Beyond expertise with RDF, OWL, and SPARQL, access to LOD requires familiarity with the ontologies used and domain knowledge. To address this challenge, the Semantic Web community has proposed different approaches. Some define an HTTP interface over Linked Data such as Linked Data Fragments [12] which offers a limited API for efficient consumption of Linked Data, although write access is not supported. Other approaches define new serializations of Linked Data and SPARQL results to JSON like JSON-LD [27] and SPARQL transformer [28]; unfortunately, they do not support SPARQL query formulation, a much more demanding task for web developers than output transformations.

Since web developers typically employ REST APIs and JSON as interchange format, it is therefore desirable to follow these conventions when accessing LOD. As a result, there is a number of proposals that support the creation of REST APIs on top of triplestores: RAMOSE [29], R4R [30], OBA [31], grlc [32], BASIL [33], and CRAFTS [15]. RAMOSE, grlc, and BASIL essentially allow the provision of APIs that encapsulate parametrized SPARQL queries. R4R, OBA, and CRAFTS also allow the exposition of RDF resources over an API. Only OBA and CRAFTS support write operations, although partial updates through HTTP PATCH [34] are only available in CRAFTS. All of these API generators provide one-to-one mappings between API calls and SPARQL queries. CRAFTS, on the other hand, uses one-to-many mappings, offering greater control over data exposure. Lastly, CRAFTS is the only API generator that can work with multiple endpoints from a single API. Vega-Gorgojo [15] includes a thorough comparison of API generators over Linked Data.

Lastly, some application domains like forestry heavily rely on geospatial data, which brings their own set of challenges [14]. Here, we particularly focus on the visualization of semantic geospatial data (CHALLENGE #3), requiring effective interfaces that ease access and analysis. We can find several proposals for visualizing geospatial Linked Data that are targeted to Semantic Web experts. This is the case of GeoYASGUI [35], a GeoSPARQL editor that provides a map visualizer of result sets. Sextant [36] is an advanced visualization application that can combine spatial data from several endpoints, although it still requires knowledge of SPARQL in order to use it.

Visualization of semantic spatial data should not be limited to Semantic Web experts. Given the ubiquitous use of map applications, map-based interfaces seem a suitable approach for lay users. However,

Table 1
Prefixes and namespaces employed in this paper.

Prefix	Namespace
dc	http://purl.org/dc/terms/
diamann	http://educawood.gsic.uva.es/diamann/
foaf	http://xmlns.com/foaf/0.1/
heightann	http://educawood.gsic.uva.es/heightann/
ifn	http://crossforest.eu/ifn/ontology/
ifntx	https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/
img	http://educawood.gsic.uva.es/img/
imgann	http://educawood.gsic.uva.es/imgann/
observann	http://educawood.gsic.uva.es/observann/
posann	http://educawood.gsic.uva.es/posann/
sta	http://educawood.gsic.uva.es/sta/ontology/
tree	http://educawood.gsic.uva.es/tree/
treestann	http://educawood.gsic.uva.es/treestann/
spann	http://educawood.gsic.uva.es/spann/
user	http://educawood.gsic.uva.es/user/
w3cgeo	http://www.w3.org/2003/01/geo/wgs84_pos#

spatial data is inherently complex and tends to be quite large, needing thoughtful design decisions when presenting data directly on the map. In this regard, Gaigg [37] proposes techniques for dealing with large amounts of spatial data, including data filtering, layering, and clustering. Following these principles, our previous work introduced Forest Explorer [38], a forest visualizer tailored for a semantic dataset of Spain and Portugal. At lower zoom levels the application provides aggregated forest information within administrative regions, gradually revealing more detailed data such as land cover maps, national inventory plots, and sampled trees with their measurements as the zoom level increases.

There exist other seldom visualizers of geospatial LOD designed for non-Semantic Web experts, such as LinkedGeoData [39] and Map4rdf [40]. LinkedGeoData is a dedicated visualization tool for OpenStreetMap data (transformed to adhere to Linked Data principles), while Map4rdf is a browsing tool of geospatial RDF datasets that uses a faceted interface to control the information to display. However, the current status of these tools appears uncertain.

3. Design of EducaWood

EducaWood is a novel application devised for environmental education that can also be used to create biodiversity repositories. Its primary objective is to support learning activities based on the social annotation of trees, while also allowing the exploration of forestry information within specific regions of interest. Tree annotations can be of different types and are published as LOD. The application exploits existing semantic datasets from Spain that we have released as LOD in our previous work [38, 41], specifically the Spanish National Forest Inventory (IFN – *Inventario Forestal Nacional*). Moreover, EducaWood also consumes third-party semantic data such as tree species taxonomic data from Wikidata and DBpedia. Along this paper we use the prefixes and namespaces listed in Table 1.

3.1. Requirements

We have carried out a requirement analysis for EducaWood using as sources our own experience in the field, the gaps found in the literature (see Section 2), and the feedback collected from users when

Table 2
Requirements for EducaWood: functional (FRx) and non-functional (NFRx).

ID	Requirement
FR0	Provide comprehensive visualizations of tree annotations
FR1	Allow the creation of tree annotations by registered users hiding RDF and SPARQL querying
FR2	Support different types of annotations (location, tree status, taxon, height, diameter, image, and observation)
FR3	Handle multi-author tree annotations and deletions
FR4	World-wide exploration of trees through an interactive map
FR5	Map view adaptable to different zoom levels
FR6	Allow filtering of trees by taxon
FR7	Include tree data from forest inventories
FR8	Support downloads of tree data (at least in CSV format)
NFR0	Portability (mobile phones, tablets, and desktop computers)
NFR1	Provide mechanisms to keep latency low
NFR2	Localized to English and Spanish

testing early prototypes of the application. Table 2 summarizes the main requirements, organized as functional (FRx) and non-functional (NFRx). The first group of functional requirements (FR0–3) addresses CHALLENGE #1, while the second group (FR4–8) corresponds to CHALLENGE #3. Note that the remaining challenge, CHALLENGE #2, is addressed by the architecture of the application and is not, per se, perceived directly by EducaWood users.

1. Supporting semantic annotations by non Semantic Web experts (FR0–3): EducaWood should provide comprehensive visualizations of the tree annotations available (FR0); tree annotations can be created by registered users in the application (FR1), using an appropriate web form; trees can be described by annotations of different types (FR2), a location is always required, while the rest of annotation types (image, dendrometric measures, tree status, etc.) are optional; annotations can be made incrementally by different users, so the application has to handle multi-author tree annotations and deletions (FR3).
2. Visualizing and managing large geospatial datasets (FR4–8): FR4 refers to one of the main functionalities, the exploration of trees through an interactive map; the scope should be worldwide, while the map view has to be adaptable to different zoom levels (FR5), so as to facilitate the exploration of small areas—showing markers for trees—but also large ones, providing appropriate aggregation mechanisms to avoid cluttering the view with too many markers; as species information is quite relevant in forest education, the application should provide a taxon filtering mechanism (FR6); the map view should also display trees from forest inventories available as LOD (FR7), specifically, EducaWood will integrate IFN data as this source contains reliable and relevant information of native trees (although limited to Spain); tree data should also be downloadable at least in CSV format (FR8) to allow the realization of different types of analysis for forestry education such as allometric equations fitting, tree mingling analysis, or environmental effect on species distributions.

Regarding non-functional requirements, EducaWood should be portable to different devices, especially mobile phones, as well as tablets and desktop computers (NFR0). The application should provide mechanisms for keeping latency low (NFR1), thus trying to limit exchanges with SPARQL endpoints. Finally, the application should be localized to English and Spanish (NFR2).

The following subsections describe in detail how the above requirements have been addressed in the design and implementation of EducaWood.

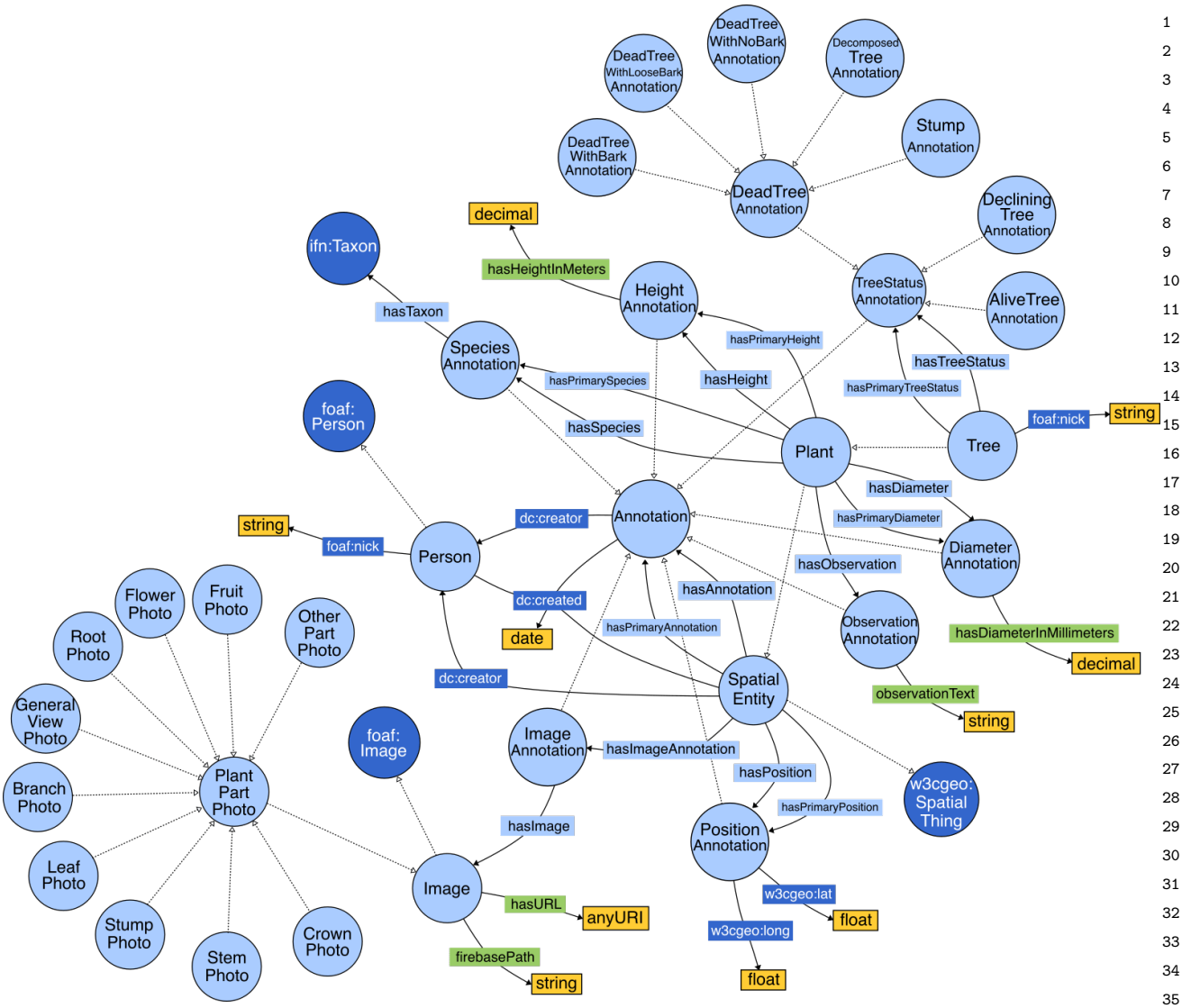

Figure 1. Visualization of the Simple Tree Annotation ontology with VOWL [42].

3.2. Simple Tree Annotation ontology

The Simple Tree Annotation (STA) ontology is the basis for the main functionalities of EducaWood. It has been conceived for describing trees (FR0) and supporting different types of annotations (FR2); it also allows multi-author annotations (FR3), as well as a mechanism for conflict resolution. STA is available in GitHub at https://github.com/guiveg/STA. Fig. 1 graphically depicts STA; its main classes, described below, are `sta:SpatialEntity`, `sta:Annotation`, `sta:Person`, and `sta:Image`.

`sta:SpatialEntity` is a specialization of `w3cgeo:SpatialThing` [43], denoting anything with spatial extent. From `sta:SpatialEntity`, we create subclasses `sta:Plant` and `sta:Tree` for the forestry domain. We borrow `foaf:Person` and `foaf:Image` from the FOAF ontology [44] in order to create our own specialized concepts, `sta:Person` and `sta:Image`. `sta:Annotation` is the main class for annotations, although it is not purposed for direct instantiation; instead, we have created the specializations `sta:PositionAnnotation`, `sta:ImageAnnotation`, `sta:SpeciesAnnotation`, `sta:TreeStatusAnnotation`, `sta:HeightAnnotation`, `sta:DiameterAnnotation`, and `sta:ObservationAnnotation`.

A `sta:Tree` (or more generally a `sta:SpatialEntity`) can have an arbitrary number of annotations. `sta:hasAnnotation` is the object property for linking a `sta:SpatialEntity` (domain) to a `sta:Annotation` (range). Since a tree may have multiple and possibly contradictory annotations of the same type, we also define the object property `sta:hasPrimaryAnnotation` for conflict resolution. A tree should only have a primary annotation of a specific type, e.g. diameter, although it may have multiple diameter annotations (possibly measured at different times and by different people). We then create subproperties of `sta:hasAnnotation` and `sta:hasPrimaryAnnotation` for the different types of annotations, e.g. `sta:hasHeight` and `sta:hasPrimaryHeight`. Note that we have not defined primary annotations for `sta:ImageAnnotation` and `sta:ObservationAnnotation`, as they are naturally multivalued for a single tree.

We have created additional terms in STA to support the different types of annotations: we reuse `w3cgeo:lat` and `w3cgeo:long` to determine the WGS84 coordinates of a `sta:PositionAnnotation` (corresponding to a point); for `sta:ImageAnnotation` we define data properties `sta:firebasePath`[10] and `sta:hasURL` with domain `sta:Image` and we include a taxonomy of part plants for describing tree images (`sta:PlantPartPhoto` and subclasses); in the case of `sta:SpeciesAnnotation` we define the object property `sta:hasTaxon` and then reuse the taxonomy of species employed in IFN (subclasses of `ifn:Taxon`); we create specializations of `sta:TreeStatusAnnotation` such as `sta:AliveTreeAnnotation` or `sta:DeadTreeAnnotation`;[11] `sta:HeightAnnotation` uses the data property `sta:hasHeightInMeters`; `sta:DiameterAnnotation` employs the data property `sta:hasDiameterInMillimeters`; and `sta:ObservationAnnotation` makes use of the data property `sta:observationText`. We use `dc:creator` and `dc:created` metadata annotations to define the creator and the datetime of any instance of `sta:Annotation` or `sta:SpatialEntity`. Finally, we employ `foaf:nick` to give nicknames to people and trees.

In Listing 1 we provide a complete example of a tree annotated with STA and formatted in Turtle. Each annotation type uses the specific terms defined in STA, as described above. Note that this example includes two species annotations and thus `sta:hasPrimarySpecies` serves to identify the primary species annotation. All annotations except the image annotation are produced by the same user. Also, take into account that the image and the observation annotations were created later than the tree creation (check values of `dc:created`).

Listing 1: Sample annotation of a tree with STA.

```
# basic metadata
tree:Neik7P0woiDY a sta:Tree ;
  foaf:nick "Olivo milenario" ;
  dc:creator user:F4TwL5qWuMScby3OU3Pk27ZPOBE3 ;
  dc:created "2023-11-04T21:24:49.606Z"^^xsd:dateTime .

# position annotation
tree:Neik7P0woiDY sta:hasPositionAnnotation posann:Neik7P0woiDY ;
  sta:hasPrimaryPosition posann:Neik7P0woiDY .
posann:Neik7P0woiDY a sta:PositionAnnotation ;
  w3cgeo:lat 37.976725958308535 ;
  w3cgeo:long 23.74917417246512 ;
  dc:creator user:F4TwL5qWuMScby3OU3Pk27ZPOBE3 ;
  dc:created "2023-11-04T21:24:49.606Z"^^xsd:dateTime .

# species annotations
tree:Neik7P0woiDY sta:hasSpeciesAnnotation spann:Neik7P0woiDY, spann:_X-nX5DYwmn8 ;
  sta:hasPrimarySpecies spann:_X-nX5DYwmn8 .
spann:Neik7P0woiDY a sta:SpeciesAnnotation ;
  sta:hasTaxon ifntx:Genus442 ;
  dc:creator user:F4TwL5qWuMScby3OU3Pk27ZPOBE3 ;
```

[10] This property is used to reference the path of an image if using Cloud Storage for Firebase.

[11] Dead trees and down woody materials annotations follow the scale proposed by Maser et al. [45] and consolidated by Hunter [46] for managing forest ecosystems to sustain biodiversity. Dead materials are key resources for many species and act as biodiversity harbors in the forest matrix.

```
  dc:created "2023-11-04T21:24:49.606Z"^^xsd:dateTime .
spann:_X-nX5DYwmn8 a sta:SpeciesAnnotation ;
  sta:hasTaxon ifntx:Species66 ;
  dc:creator user:F4TwL5qWuMScby3OU3Pk27ZPOBE3 ;
  dc:created "2023-11-05T14:50:43.205Z"^^xsd:dateTime .

# tree status annotation
tree:Neik7POwoiDY sta:hasTreeStatusAnnotation treestann:Neik7POwoiDY ;
  sta:hasPrimaryTreeStatus treestann:Neik7POwoiDY .
treestann:Neik7POwoiDY a sta:AliveTreeAnnotation ;
  dc:creator user:F4TwL5qWuMScby3OU3Pk27ZPOBE3 ;
  dc:created "2023-11-04T21:24:49.606Z"^^xsd:dateTime .

# height annotation
tree:Neik7POwoiDY sta:hasHeightAnnotation heightann:Neik7POwoiDY ;
  sta:hasPrimaryHeight heightann:Neik7POwoiDY .
heightann:Neik7POwoiDY a sta:HeightAnnotation ;
  sta:hasHeightInMeters 6.5 ;
  dc:creator user:F4TwL5qWuMScby3OU3Pk27ZPOBE3 ;
  dc:created "2023-11-04T21:24:49.606Z"^^xsd:dateTime .

# diameter annotation
tree:Neik7POwoiDY sta:hasDiameterAnnotation diamann:Neik7POwoiDY ;
  sta:hasPrimaryDiameter diamann:Neik7POwoiDY .
diamann:Neik7POwoiDY a sta:DiameterAnnotation ;
  sta:hasDiameterInMillimeters 70 ;
  dc:creator user:F4TwL5qWuMScby3OU3Pk27ZPOBE3 ;
  dc:created "2023-11-04T21:24:49.606Z"^^xsd:dateTime .

# image annotation
tree:Neik7POwoiDY sta:hasImageAnnotation imgann:3GryiBuMbxHK .
imgann:3GryiBuMbxHK a sta:ImageAnnotation ;
  sta:hasImage img:3GryiBuMbxHK ;
  dc:creator user:osUzXSTSTzbjd50RsTvAGla8ngH3 ;
  dc:created "2023-11-04T22:12:20.200Z"^^xsd:dateTime .
img:3GryiBuMbxHK a sta:Image ;
  sta:firebasePath "images/osUzXSTSTzbjd50RsTvAGla8ngH3/3GryiBuMbxHK.png" ;
  sta:imageURL <https://firebasestorage.googleapis.com/v0/b/educawood-fbaf4.appspot.com/o/images%2
       FosUzXSTSTzbjd50RsTvAGla8ngH3%2F3GryiBuMbxHK.png?alt=media&token=21b44d3f-2a58-4b16-a6a3-cdcde8da7166> .

# observation annotation
tree:Neik7POwoiDY sta:hasObservationAnnotation observann:l1Uoalgz7hJb .
observann:l1Uoalgz7hJb a sta:ObservationAnnotation ;
  sta:observationText "Arbol creado en la ISWC2023"@es ;
  dc:creator user:F4TwL5qWuMScby3OU3Pk27ZPOBE3 ;
  dc:created "2023-12-19T05:49:30.710Z"^^xsd:dateTime .
```

3.3. Application architecture

EducaWood is designed as a web application with an architecture aimed at facilitating its users to visualize and carry out semantic annotations without needing technical expertise on Semantic Web technologies (refer to CHALLENGE #1 in the introduction). The web architecture of EducaWood can be described by the routes shown in Table 3.

R0 is a landing page that presents the application and includes a link to route R1, corresponding to the interactive map functionality that will be described in detail in Section 3.4. R1 includes a required query parameter, `loc`, that defines a specific position and zoom level with the format `LAT,LONG,ZOOMz`;[12] `taxon` can be set to filter the trees shown in the map (FR6), e.g. `ifntx:Species23` is the IRI of *Pinus pinea* in the IFN dataset; `esri` is a boolean query parameter for using the satellite base map provided by Esri;[13] and `ifn` can be activated to show the trees from the IFN dataset (FR7). In this way, R1 can be used to specify the location of any place in the world, with a specific zoom level, and with optional taxon filter,

[12] `LAT` and `LONG` assume the WGS 84 datum. `ZOOM` represents the zoom level in powers of two, typically ranging from 0 (the whole world is entirely represented in a tile) to 20 (∼1 trillion tiles are needed to show the entire world).

[13] https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9

Table 3
Routes exposed in EducaWood. Query parameters marked with * are required.

ID	Path	Query parameters	Description
R0	`/`	—	Landing page of EducaWood
R1	`/map`	`loc`*, `taxon`, `ifn`, `esri`	Map centered in `loc` with optional `taxon` filter, optional `esri` satellite layer, and optional display of `ifn` trees
R2	`/newtree`	`loc`*	Creation form of a new tree positioned in `loc`
R3	`/tree/{treeId}`	—	Page of tree `treeId`
R4	`/lasttrees`	`pe`, `showann`, `pae`	Last created trees in EducaWood paginated with optional `pe` parameter, or last annotations if `showann` is `true`, paginated with optional `pae` parameter
R5	`/user/{userId}`	`pe`, `showann`, `pae`	Page of user `userId` with their last created trees paginated with optional `pe` parameter, or their last annotations if `showann` is `true`, paginated with optional `pae` parameter

satellite base map, and display of IFN data, such as the route /map?loc=41.751849,-4.585419,10z&ifn=true&esri=true&taxon=ifntx:Species23.[14]

New trees are created with a web form available at route R2 (FR1); query parameter `loc` has the same format as in route R1. Route R3 is used to provide functionalities FR0 and FR2, allowing the visualization of the annotations of a tree `treeId` and providing controls for creating and removing annotations. Note that the management of trees and their annotations involve write operations that are restricted to registered users (FR3), as we will explain in Section 3.5. Route R4 is used to display the last created trees in EducaWood; the optional query parameters are employed to switch from tree creations to annotations (`showann`), while `pe` and `pae` are used for pagination. Route R5 defines user pages employing the path parameter `userId` for identifying the user; tree creations and annotations are also displayed in user pages and for this purpose we use the same query parameters as in route R4.

Regarding data sources, EducaWood stores tree data in our own triplestore, henceforth named *EducaWood*.[15] This dataset is continuously updated with tree annotations, thus requiring write access through SPARQL Update [47]. We read IFN data from *CrossForest*, a SPARQL endpoint that we set up as part of our work in the European project CrossForest.[16] Additionally, we obtain tree taxonomic information (descriptions, images, links to other repositories, etc.) from *Wikidata* and *DBpedia*, two well-known sources by the Semantic Web community.

In order to satisfy the non functional requirements of portability (NFR0) and low latency (NFR1), EducaWood has been designed as a single-page application (SPA). SPAs are web applications that initially load a single web document and then update their body content with data from the server, thus avoiding full-page reloads. SPAs tend to provide performance gains and a more dynamic experience [48].

The architecture of EducaWood is graphically depicted in Figure 2. The *Router* component is in charge of performing client-side routing; if the browser URL changes, the *Router* detects it and checks its validity. A valid URL has to follow one of the routes in Table 3. The *Router* dispatches R1-compliant URLs to the *Map handler*, R2-compliant URLs to the *Tree handler*, R3-compliant URLs to the *Tree creation handler*, R4-compliant URLs to the *Last trees handler*, and R5-compliant URLs to the *User handler*. A *Handler* updates the view according to the incoming request, i.e. the refreshed URL, and provides appropriate controls for user interaction. The *Handlers* will make requests to the *Data manager* to carry out their tasks. This latter component centralizes data access by making calls to the *EducaWood API*. Responses from the API are locally stored in the *Data cache* to minimize future exchanges; indeed, the *Data manager* first checks the *Data cache* and in case of a miss will make a call to the API.

In order to address the CHALLENGE #2 described in the introduction (dealing with complexity associated with the access to multiple LOD sources), the *EducaWood API* is built with Configurable REST APIs For Triple Stores (CRAFTS) [15]. The case of EducaWood is quite suitable for using CRAFTS given

[14] The rendering of this route in EducaWood is shown in Fig. 3(c).
[15] Endpoint URL https://crossforest.gsic.uva.es/pruebas/sparql and graph IRI http://educawood.gsic.uva.es.
[16] https://crossforest.eu/

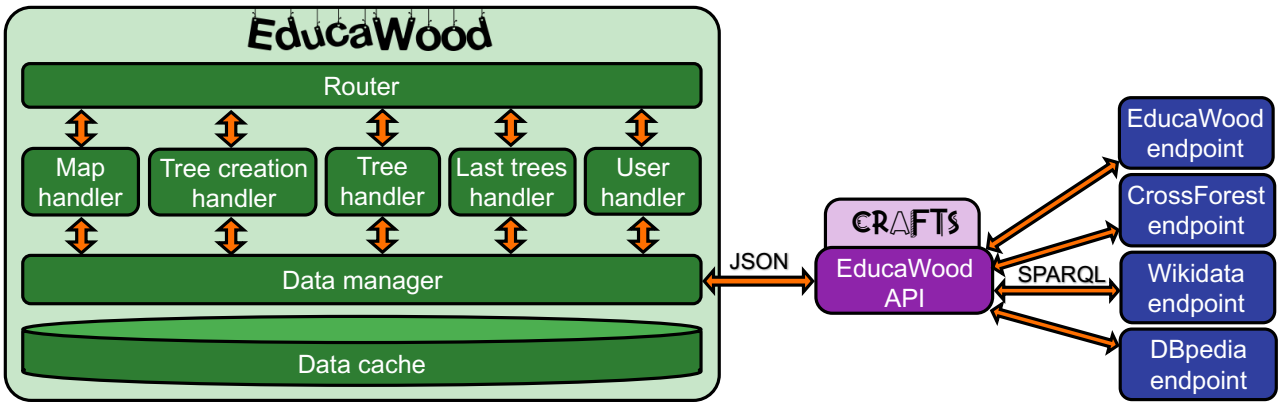

Figure 2. Architecture of EducaWood.

the need of a highly flexible data access with read and write operations over four different endpoints. CRAFTS provides a simple REST API exposing RDF resources and parametrized SPARQL queries, using JSON as interchange format, and caching SPARQL queries from the source endpoints. In other words, the use of a CRAFTS-based API serves to reduce the complexity of creating a LOD-based application such as EducaWood. This complexity is transferred to the creation of a configuration file that is used in a CRAFTS site to translate REST calls into SPARQL queries. Vega-Gorgojo [15] describes the elements of a CRAFTS configuration file, while the OpenAPI specification of CRAFTS is browsable (and actionable) at https://crafts.gsic.uva.es/docs/.

Appendix A depicts the configuration file of the *EducaWood API*—essentially a JSON object with a collection of keys and values. `apiId` contains the identifier of the API, `educawood`. `endpoints` includes the information for accessing the four endpoints in EducaWood.[17] `model` contains an array of the different RDF resources exposed by the API; each one defines mappings of RDF data to JSON by referring to datatype properties (`dprops`), object properties (`oprops`), and class membership (`types`). `queryTemplates` list a number of parametrized SPARQL queries. Table 4 includes a sample of the API calls used in EducaWood.

3.4. Rendering maps

EducaWood addresses CHALLENGE #3 (efficient visualization of large geospatial semantic datasets) using a novel approach for rendering maps. At launch time, the *Data manager* prepares the taxonomy of tree species in a bootstrapping routine by sending several C0 and C1 calls (see Table 4). C0 serves to obtain the hierarchy of taxons that derive from the ancestor class *Gymnospermae* (`ifntx:Class2`) by using the `subclasses` template query included in the *EducaWood API*; a trivial replacement of `ifntx:Class2` with `ifntx:Class1` serves to gather the hierarchy of taxons that derive from the ancestor class *Angiospermae*.[18] C1 is then used to retrieve representations of the different taxons found, using the RDF resource `Species` from the `model` in Appendix A;[19] while C1 includes three taxons for illustration, the *Data manager* will make C1-like calls packing a larger number of taxons so as to limit exchanges with the *EducaWood API*.

The *Map handler* is in charge of supporting the map navigation functionality (FR4), showing the trees on the map view using LOD as source (*EducaWood* and *CrossForest* endpoints). An interactive map is used for this purpose, supporting typical panning and zooming operations that are naturally supported for both point-and-click and touchscreen interfaces. The *Map handler* carries out this task by handling

[17] Note that the *EducaWood* endpoint includes credentials for using SPARQL Update, although not shown in Appendix A

[18] Trees are seed plants belonging to either the *Gymnospermae* clade, predominantly composed of conifers, or the *Angiospermae* clade, which consists of flowering plants.

[19] Note that the RDF resource `Species` in Appendix A combines data from *EducaWood*, *Wikidata*, and *DBpedia* endpoints. This is illustrated in the visualization of *Pinus pinea* in Fig. 4(b).

Table 4
Sample calls to the EducaWood API.

ID	Op.	Route	Description
Bootstrapping			
C0	`GET`	/apis/educawood/query?id=subclasses&ancestor=https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/Class2	Retrieve the subclass relations between pairs of classes derived from the ancestor class *Gymnospermae* (`ifntx:Class2`)
C1	`GET`	/apis/educawood/resources?id=Species&ns=https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/&nspref=ifntx&iris=ifntx:Class2&iris=ifntx:Genus211&iris=ifntx:Species23	Retrieve the representations of class *Gymnospermae* (`ifntx:Class2`), genus *Pinus* (`ifntx:Genus211`), and species *Pinus Pinea* (`ifntx:Species23`)
Map exploration			
C2	`GET`	/apis/educawood/query?id=educatreesinbox&lngwest=-4.6875&lngeast=-4.5&latnorth=42&latsouth=41.8125&limit=1&offset=1000	Retrieve tree #1001 within a specified map cell
C3	`GET`	/apis/educawood/query?id=counteducatreesinbox&lngwest=-4.6875&lngeast=-4.5&latnorth=42&latsouth=41.8125	Count the number of trees within a specified map cell
C4	`GET`	/apis/educawood/query?id=educatreesinbox&species=https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/Species23&lngwest=-4.6875&lngeast=-4.5&latnorth=42&latsouth=41.8125	Retrieve the trees of species *Pinus Pinea* (`ifntx:Species23`) within a specified map cell
C5	`GET`	/apis/educawood/resources?id=BasicEducaTree&ns=http://educawood.gsic.uva.es/tree/&nspref=tree&iris=tree:x3tbrTrWLn1C&iris=tree:9bq9FeHxsgfS	Retrieve the basic representations of trees `tree:x3tbrTrWLn1C` and `tree:9bq9FeHxsgfS`
Tree view			
C6	`GET`	/apis/educawood/resource?id=EducaTree&iri=http://educawood.gsic.uva.es/tree/Neik7P0woiDY	Retrieve the representation of `tree:Neik7P0woiDY`
Tree management			
C7	`PUT`	/apis/educawood/resource?id=EducaTree&iri=http://educawood.gsic.uva.es/tree/yUhX0LzFP-57	Create `tree:yUhX0LzFP-57` with the tree representation enclosed to this call
C8	`PATCH`	/apis/educawood/resource?id=EducaTree&iri=http://educawood.gsic.uva.es/tree/yUhX0LzFP-57	Update `tree:yUhX0LzFP-57` with the patch representation enclosed to this call
C9	`DELETE`	/apis/educawood/resource?id=SpeciesAnnotation&iri=http://educawood.gsic.uva.es/spann/JXbiTiPApexo	Delete species annotation `spann:JXbiTiPApexo`
C10	`DELETE`	/apis/educawood/resource?id=EducaTree&iri=http://educawood.gsic.uva.es/tree/yUhX0LzFP-57	Delete `tree:yUhX0LzFP-57`

R1-compliant routes. Upon an incoming request, the map view is centered in the location extracted from the browser URL, and with the indicated zoom level. Then, a rectangular grid, centered in point `LAT=0, LONG=0`, is employed to fill the map view; cell side is configured to 12º for zoom level 4 and scaled to other zoom levels.[20] In this way, a cell in unambiguously identified by its x and y indexes at zoom level z, independently of the device. Screen size and resolution will determine which cells are required to fill the map view; a mobile phone will typically use 20–30 cells, while a desktop computer with a 21" screen can easily employ 90–120. Nonetheless, a location at a given zoom level will always correspond to the same grid cell.

A grid cell is the unit of work to display trees on the map. The *Map handler* begins by identifying the cells corresponding to the map view and subsequently sends individual data request for each of these cells to the *Data manager*. When a cell request is received, the *Data manager* gathers only the **essential** data required for display, rather than retrieving **all** available data (FR5). This is particularly relevant at low zoom levels, where a single cell may encompass numerous trees, potentially reaching into the tens or even hundreds of thousands.[21] Thus, the *Data manager* will follow the following procedure for cell requests:

1. Request tree #1001 of the map cell (call C2 in Table 4)

[20] We use powers of two for scaling: a cell at zoom level z corresponds to four cells at zoom level $z+1$.

[21] This scenario is highly plausible with the IFN dataset, considering it contains approximately 1.4 million trees within the Spanish territory.

(finish if tree #1001 exists, otherwise continue)

2. Count the number of trees within the map cell (C3)

(finish if the count is 0 or greater than 100, otherwise continue)

3. Discover the trees within the map cell (C4)
4. Obtain basic representations of the trees found in step #3 (C5)

Step #1 serves to assess whether there is a large number of trees within a cell, i.e. more than one thousand, without requiring to count them all (an expensive operation in SPARQL). If this is not the case, the actual count is obtained in step #2. In the range of 1–100 trees, it makes sense to display individual markers, so step #3 serves to discover the IRIs of the trees and then step #4 to retrieve their basic representations. Note that this procedure illustrates the case of the *EducaWood* endpoint; if the IFN dataset is selected (parameter `ifn` in route R1), a similar procedure will be carried out with the *CrossForest* endpoint using alternative query templates and RDF resources, e.g. `treesinbox` instead of `educatreesinbox` (check Appendix A for more details). Taxon filtering (FR6) is also supported in cell requests: the sample C4 call in Table 4 contains a *Pinus pinea* filter, while all the query templates employed for map exploration include an optional taxon filter parameter. It is also relevant that responses from the *EducaWood API* are always cached, thus allowing to reuse previous cell results when requested again. Moreover, the *Data manager* exploits the *Data cache* to derive new information without making further API calls, as in the following cases:

- If cell C_i has more than 1K trees and cell C_j contains cell $C_i \Rightarrow$ cell C_j has more than 1K trees.
- If cell C_i has 0 trees and cell C_j is contained in cell $C_i \Rightarrow$ cell C_j has 0 trees.
- If cell C_i has a taxon filter Tx_i and more than 1K trees, and cell C_j contains cell C_i and has no taxon filter $\Rightarrow$ cell C_j has more than 1K trees.
- If cell C_i includes a list of tree representations Lt_i and cell C_j is contained in cell $C_i \Rightarrow$ the subset of tree representations of cell C_j can be derived from Lt_i.
- Etc.

Once cell data is retrieved, the *Map handler* can proceed with rendering, as graphically depicted in Fig. 3. Snapshot (a) spans a vast area (zoom level six) in South-West Europe; there is a large cluster with label '430', as well as numerous tree markers in South Spain, North Spain, South France, and North Italy. Snapshot (b) covers a medium size area (zoom level 10) in the northern Spanish plateau; the IFN dataset is activated (`ifn` query parameter), so tree clusters proliferate with labels from '101' to '+1K'; some areas include tree markers in a distinctive pale green color to represent IFN trees. Snapshot (c) is positioned in the same area as (b), although the route now includes the `esri` query parameter and the taxon filter `ifntx:Species23` (*Pinus pinea*); as a result, the satellite base map from Esri is activated; only *Pinus pinea* trees are displayed, so there are fewer clusters and more tree markers, predominantly in pale indigo (representing IFN trees) and a few in solid indigo (obtained from the *EducaWood* endpoint). Snapshot (d) narrows down to a tiny area (zoom level 18) at the Yutera campus of Universidad de Valladolid, with the `esri` query parameter set to true; the map view shows university buildings surrounded by numerous tree markers, all in solid green, corresponding to the *EducaWood* endpoint; one of these markers has a popup with essential tree details: a photo, a nickname, tree status, height, diameter, creator, and creation date.

The map controls in Fig. 3 include a download button in the right panel. Upon clicking it, the user can draw a polygon on the map with the area of interest. Next, the user can choose the level of detail (summarized tree reports or full tree annotations) and the desired data format (GeoJSON, CSV, or KML). The *Map handler* will obtain the set of trees within the polygon and proceed with the download. In this way, functionality FR8 in Table 2 is fulfilled.

3.5. Viewing and creating tree annotations

Here we focus on CHALLENGE #1 (support of semantic annotations by non-experts on Semantic Web technologies) by providing a holistic view of how the EducaWood components work together in a typical

Figure 3. Snapshots of the map interface of EducaWood. (a) Route /map?loc=41.843949,0.548121,6z, corresponding to a large area in South-West Europe. (b) Route /map?loc=41.752276,-4.585411,10z&ifn=true, focused on a mid–size area in North Spain. (c) Route /map?loc=41.751849,-4.585419,10z&ifn=true&esri=true&taxon=ifntx:Species23; this is the same area as (b), but restricted to *Pinus pinea* species and using the Esri satellite base map. (d) Route /map?loc=41.986754,-4.516886,18z&esri=true, showing a tiny urban area with numerous tree markers.

use case. This entails a detailed examination of user interactions with the application when viewing and creating tree annotations. We outline the sequence of significant API calls and data exchanges step by step, also illustrating how the requirements in Section 3.1 are satisfied.

During a session with EducaWood, a user can initiate the creation of a new tree (FR1) by pushing the tree icon button[22] (see Fig. 3) and subsequently selecting the desired position on the map. This action triggers a URL update to an R2 route; the *Router* detects this change and activates the *Tree creation handler*. This component is responsible for rendering a tree creation form with various fields, each corresponding to different types of annotations in the STA ontology (see Section 3.2). Fig. 4(a) shows the tree creation form; it employs different widgets to facilitate content authoring. The route enforces the inclusion of a valid position for the tree; it can be changed by dragging the red marker on the map. The remaining form elements are optional. A tree taxon can be selected either by browsing the species taxonomy or by typing some text. The user can easily check taxon information, as illustrated in Fig. 4(b). Note that taxon information is obtained from DBpedia (providing descriptive text) and Wikidata (including images, and link buttons to GBIF, Wikidata, Wikipedia, and Wikispecies websites) in the bootstrapping routine outlined in Section 3.4.

Once the user pushes the 'Create tree' button, the *Tree creation handler* generates a unique ID for the tree and uses the creation form to prepare a JSON object that follows model `educatree` in Appendix A. Listing 2 shows a sample JSON object that corresponds to the form in Fig. 4(a). The *Tree creation handler* will transfer this object to the *Data manager* to actually create the tree in the dataset. This will be simply achieved by making call C7 in Table 4 to the *EducaWood API* with Listing 2 as request body. The API will validate this call and will then map Listing 2 to an `INSERT DATA` operation with the triples to be inserted into the *EducaWood* endpoint.

Listing 2: Request body for creating `tree:yUhX0LzFP-57` with the form values in Fig. 4(a).

```
{
  "iri": "http://educawood.gsic.uva.es/tree/yUhX0LzFP-57",
  "created": "2024-01-12T08:08:06.445Z",
  "creator": "http://educawood.gsic.uva.es/user/F4TwL5qWuMScby3OU3Pk27ZPOBE3",
  "position": {
    "iri": "http://educawood.gsic.uva.es/posann/yUhX0LzFP-57",
    "latWGS84": 41.611668,
    "lngWGS84": -4.777814,
    "types": "http://educawood.gsic.uva.es/sta/ontology/PositionAnnotation",
    "created": "2024-01-12T08:08:06.445Z",
    "creator": "http://educawood.gsic.uva.es/user/F4TwL5qWuMScby3OU3Pk27ZPOBE3"
  },
  "positionAnnotations": "http://educawood.gsic.uva.es/posann/yUhX0LzFP-57",
  "species": {
    "iri": "http://educawood.gsic.uva.es/spann/yUhX0LzFP-57",
    "species": "https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/Species23",
    "types": "http://educawood.gsic.uva.es/sta/ontology/SpeciesAnnotation",
    "created": "2024-01-12T08:08:06.445Z",
    "creator": "http://educawood.gsic.uva.es/user/F4TwL5qWuMScby3OU3Pk27ZPOBE3"
  },
  "speciesAnnotations": "http://educawood.gsic.uva.es/spann/yUhX0LzFP-57",
  "types": "http://educawood.gsic.uva.es/sta/ontology/Tree"
}
```

Created trees can be browsed in the map view, as described in Section 3.4. Tree markers show essential data and a 'More information' button (Fig. 3(d)). Pushing one of these buttons triggers a URL update to an R3 route. The *Router* will detect a change in the URL and transfer control to the *Tree handler* in order to provide a comprehensive visualization of the requested tree (FR0). Upon this request, the *Tree handler* will ask the *Data manager* to obtain the tree record. If it is not cached, the *Data manager* will make a C6-like call to the *EducaWood API*. In our running example, the *Data manager* will return a JSON object similar to the one employed in the creation, i.e. Listing 2. The *Tree handler* will prepare a webpage that adequately presents data to users. This is illustrated in Fig. 4(c) for the case of `tree:Neik7POwoiDY` whose source data corresponds to the RDF snippet in Listing 1.

[22] This button is only enabled under two conditions: (1) the user has logged in, and (2) the zoom level is 16 or higher (at lower levels locations are too imprecise).

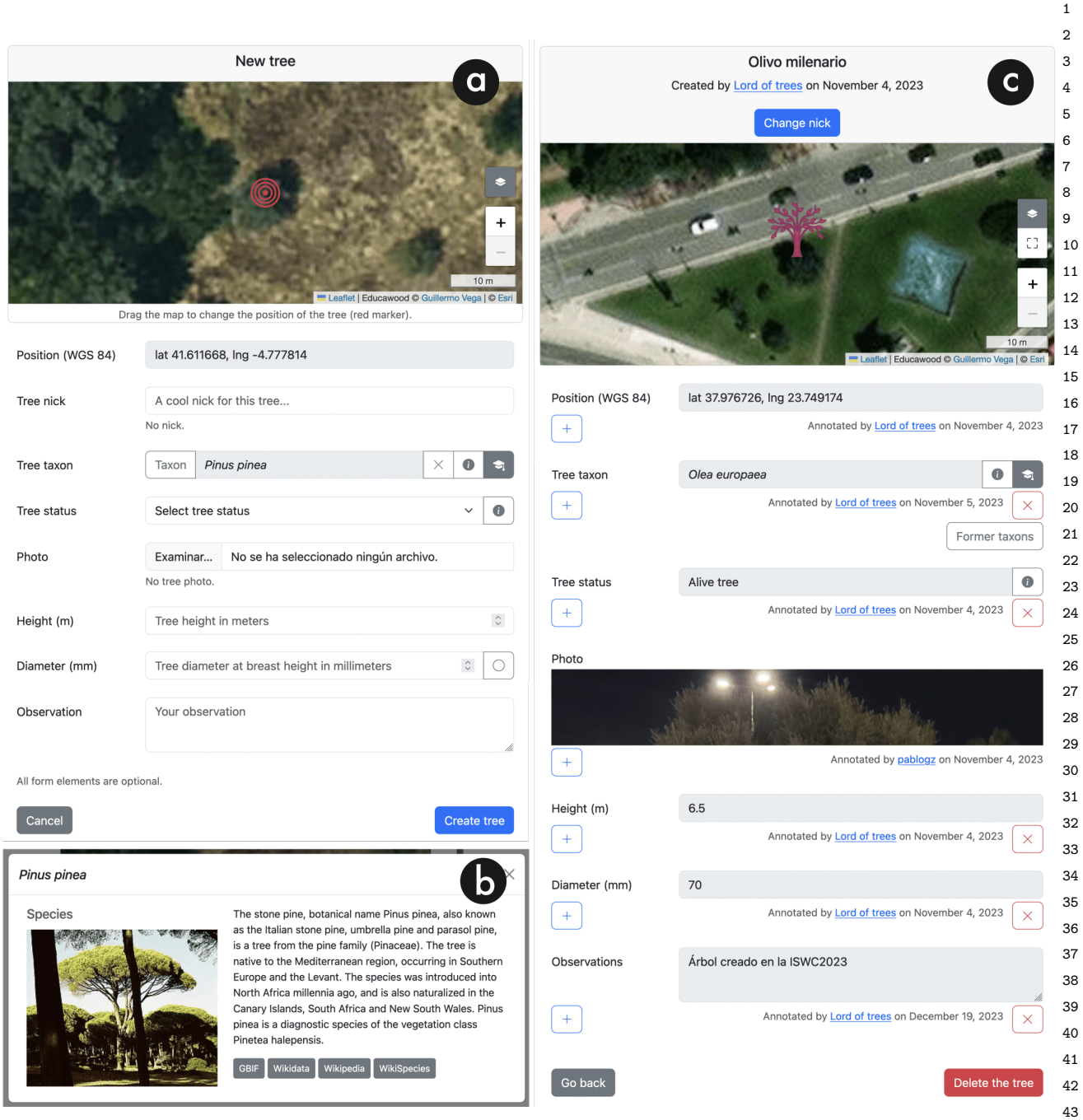

Figure 4. Snapshots of the tree creation and tree view pages of EducaWood. (a) Form for creating a tree associated with route /newtree?loc=41.611668,-4.777814,20z; the position is extracted from the route, while the user has set *Pinus pinea* in the tree taxon field; the remaining fields are currently blank. (b) View of a modal window that appears upon selecting the information button for a tree taxon (*Pinus pinea* in this case). (c) Visualization of the tree at route /tree/Neik7P0woiDY; source data corresponds to the RDF snippet in Listing 1; this view belongs to the creator of the tree, so there are controls for deleting the tree, creating new annotations, and removing existing annotations (with the exception of the photo, which was contributed by another user).

The *Tree handler* may include controls to make tree annotations and delete the tree depending on the user identity (FR2 and FR3). If the user has not logged in, all tree data is accessible, but no edition controls are included. Any registered user can make new annotations (check blue '+' buttons in Fig. 4(c)) and delete their own annotations (red 'x' buttons), but cannot delete other users' annotations. The creator of a tree is also allowed to delete it (red 'Delete the tree' button in Fig. 4(c)). New annotations are supported for each annotation type with appropriate widgets to easily include new values. The *Tree handler* will gather the value introduced by the user and prepare a JSON PATCH [49] referred to the model `educatree` in Appendix A. Listing 3 shows an example JSON PATCH for creating a new taxon annotation (`spann:JXbiTiPApexo`) that will be the primary species annotation of the tree (`replace` operation of the PATCH) and will be also added to the list of species annotations (`add` operation of the PATCH). The *Tree handler* will request the *Data manager* to update `tree:yUhX0LzFP-57` with the patch in Listing 3. As a result, the *Data manager* will make call C8 with Listing 3 in the body request to the *EducaWood API*. The latter component will validate the call and then map Listing 3 to a `DELETE DATA` operation to remove the previous primary species of the tree (`spann:yUhX0LzFP-57`) and an `INSERT DATA` operation with the new triples to be inserted in the *EducaWood* endpoint.

Listing 3: JSON PATCH for updating `tree:yUhX0LzFP-57` with a new taxon annotation `spann:JXbiTiPApexo` (value `ifntx:Species26`, *Pinus pinaster*).

```
[
  {
    "op": "replace",
    "path": "/species",
    "value": {
      "iri": "http://educawood.gsic.uva.es/spann/JXbiTiPApexo",
      "species": "https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/Species26",
      "types": "http://educawood.gsic.uva.es/sta/ontology/SpeciesAnnotation",
      "created": "2024-01-12T08:19:58.868Z",
      "creator": "http://educawood.gsic.uva.es/user/F4TwL5qWuMScby3OU3Pk27ZPOBE3"
    }
  },
  {
    "op": "add",
    "path": "/speciesAnnotations/-",
    "value": "http://educawood.gsic.uva.es/spann/JXbiTiPApexo"
  }
]
```

Deletion of tree annotations is handled very similarly to annotation creations. Once the user has confirmed the deletion of an annotation, the tree has to be updated with a PATCH to reflect changes. Listing 4 shows the PATCH for removing taxon annotation `spann:JXbiTiPApexo`; the `remove` operation serves to filter out `spann:JXbiTiPApexo` from the list of taxon annotations of `tree:yUhX0LzFP-57`, while the `replace` operation restores `spann:yUhX0LzFP-57` as primary species. The *Data manager* will make call C8 with Listing 4 in the body request to the *EducaWood API*. Additionally, it will send call C9 to delete the dangling annotation `spann:JXbiTiPApexo` from the *EducaWood* endpoint. As for tree deletion, this case requires call C10 to remove `tree:yUhX0LzFP-57`; the *Data manager* will also make explicit C9-like deletion calls to each associated annotation (`spann:yUhX0LzFP-57` and `posann:yUhX0LzFP-57` in this case). This is because CRAFTS does not propagate deletions to other RDF resources by design [15].

Listing 4: JSON PATCH for updating `tree:yUhX0LzFP-57` to remove taxon annotation `spann:JXbiTiPApexo`.

```
[
  {
    "op": "remove",
    "path": "/speciesAnnotations/0"
  },
  {
    "op": "replace",
```

```
    "path": "/species",
    "value": "http://educawood.gsic.uva.es/spann/yUhX0LzFP-57"
  }
]
```

Regarding *Last trees handler* and *User handler* in Fig. 2, these components are simpler than the previous handlers as they only provide visualizations and do not deal with data updates. *Last trees handler* is purposed for displaying the latest trees and annotations produced in the application. As always, the *Data manager* obtains the content by using query templates `mostRecentEducatrees` and `mostRecentAnnotations` of the API (check details in Appendix A). Unsurprisingly, the *User handler* prepares webpages of users in EducaWood. The *Data manager* employs the model `Person` to retrieve essential information such as nick or creation date (see Appendix A). As user webpages also contain their latest trees and annotations, query templates `mostRecentEducatrees` and `mostRecentAnnotations` are reused for this purpose, in this case setting parameter `user` to only obtain their created trees and annotations.

3.6. Implementation details

EducaWood is coded in JavaScript; this programming language is the natural choice for developing web applications. We use the JavaScript module syntax,[23] the recommended way for developing modern web applications, Node Package Manager (npm)[24] as package manager, and Parcel[25] as build tool. Notably, the *Map handler* relies on Leaflet[26] for the interactive map through the use of markers, popups, map controls, and interaction capabilities. As base maps we employ OpenStreetMap[27] and Esri World Imagery.[28]

We use Bootstrap[29] as a front-end framework to easily accommodate different browsers and screen sizes in a responsive way. The top-left bar of the map view in Fig. 3 uses Bootstrap components. Web pages for tree creation (Fig. 4(a)), tree visualizations (Fig. 4(c)), last trees, and users are entirely based on the Bootstrap framework. We use Mustache[30] templates in the creation of HTML pages, greatly simplifying the rendering of tree and user pages. We also employ the utility functions of Underscore[31] for handling collections along the code.

We use several modules of the Firebase suite[32] for different purposes. We employ Firebase Authentication with Google Sign-in as identity provider; we extract the user's unique ID from this service to assign user IDs in EducaWood.[33] Tree images are stored in Cloud Storage for Firebase. We employ Google Analytics for Firebase to track user activity on EducaWood.

The *EducaWood API* is deployed on a test site of CRAFTS, accessible at https://crafts.gsic.uva.es/apis/educawood/. EducaWood includes a configuration file with the URL of this API along with a token for accessing CRAFTS through Bearer authentication [50]. This configuration file also contains access data to a Solr[34] text search server for looking up world-wide places; this can be seen in the text search box in Fig. 3.

Since EducaWood needs to be localized to English and Spanish (requirement NFR2), *EducaWood API* is configured to extract all labels and descriptions in these two languages. Moreover, the application includes a multilingual strings file with all the labels employed in the user interface. Users can choose their language preferences in the application menu (*hamburger* button in Fig. 3).

---

[23] https://developer.mozilla.org/en-US/docs/Web/JavaScript/Guide/Modules
[24] https://www.npmjs.com/
[25] https://parceljs.org/
[26] https://leafletjs.com/
[27] https://www.openstreetmap.org
[28] https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9
[29] https://getbootstrap.com/
[30] https://mustache.github.io/
[31] https://underscorejs.org/
[32] https://firebase.google.com/
[33] This solution has the advantage that user IDs will not change, even if we include additional identity providers.
[34] https://solr.apache.org/

The source code of EducaWood is available on GitHub.[35] A live version of the application[36] is openly available for anybody who wants to use it.

4. EducaWood in practice

In Section 4.1, we present evidence regarding the impact of EducaWood thus far. Additionally, we report a pilot in an urban tree management activity with forestry engineering students in Section 4.2.

4.1. Preliminary impact

In 2021, we presented an early demonstrator of EducaWood in the 16th European Conference on Technology Enhanced Learning (EC-TEL 2021) [51]. Although the functionality of this demonstrator was limited, it allowed testing key system components, particularly the creation of trees through a CRAFTS API. Following this, EducaWood received the third award in the "*III Desafío Aporta*",[37] a Spanish open data challenge sponsored by the Spanish Ministry of Digital Transformation.

Encouraged by this early success, we worked on a new version of EducaWood that meets the requirements outlined in Section 3.1. In July 2023, we released a new prototype,[38] aimed at supporting forestry education scenarios. We tested the application with a selected group of forestry experts, who provided very positive feedback and valuable suggestions, leading to the incorporation of features such as a tutorial, satellite base map, drawing tool for defining data download areas, support for tree nicks and text observations, and tree form improvements to facility data entering. More recently, we expanded the outreach of EducaWood by sharing it with academic contacts and running a pilot with forestry students which is summarized in Section 4.2.

Since traffic on the EducaWood website is tracked with Google Analytics, we can report some figures in the period from July 2023 to June 2024. Table 5 summarizes the collected data; 489 active users have employed EducaWood in 789 engaged sessions[39] with an average duration of 2 minutes and 41 seconds. Most users are from Spain (62.2%), while the rest come from Italy (10.6%), Sweden (7.8%), the Netherlands (3.5%), Finland (3.1%), Greece (2.5%), and other countries (10.4%). Devices employed include mobiles (58.6%), desktop computers (41.0%), and tablets (0.4%). We also tracked page views (26.3K in total), finding that the map interface route is the most intensively used (80.7% of all page views); activity in the remaining routes range from 5.4% to 1.3% (see Table 5).

We have also analyzed the annotations created in the EducaWood dataset. As of June 2024, the dataset contains 36K triples, corresponding to 659 trees and 3.5K tree annotations. Notably, 51 users contributed to content generation, constituting 10.4% of the application user base.

4.2. Pilot study

We have carried out a pilot study of EducaWood within the context of a "*Reforestation, Nurseries, and Gardening*" course in the third year of the Forestry and Environmental Engineering degree at Universidad de Valladolid. The course has two teachers and 20 enrolled students. The teachers have prepared the educational design of an urban tree management activity that comprises three stages: first, a two-hour training session in November 2023 familiarized students with EducaWood through a classroom demonstration, followed by a practical tree annotation session in the campus gardens, and a subsequent verification of the accuracy of tree labeling in the classroom.

[35] https://github.com/guiveg/educawood
[36] https://educawood.gsic.uva.es/
[37] https://datos.gob.es/es/noticia/universidata-lab-proyecto-mip-y-educawood-ganan-el-iii-desafio-aporta
[38] See footnote 36.
[39] According to Google Analytics, an engaged session is one that lasted longer than 10 seconds, or had a key event, or had two or more screen or page views.

Table 5
Uptake of the test site of EducaWood.

Item	Value
# of active users	489
# of engaged sessions	789
Average time per session	2m 41s
# of page views	26.3K
% of landing page views (route R0)	4.4%
% of map page views (route R1)	80.7%
% of tree creation page views (route R2)	4.8%
% of tree page views (route R3)	5.4%
% of last created trees page views (route R4)	1.3%
% of user page views (route R5)	3.4%

Second, the students were tasked to collaboratively create a tree inventory at the Yutera Campus throughout November and December 2023. Each student had to annotate a minimum of 20 trees, recording positions, species identification, images, dendrometric measures, tree status, and text observations using EducaWood. Third, students had to prepare an urban forestry management plan for the Yutera Campus, utilizing the collaboratively created tree inventory. This involves downloading tree data with the application and calculating various variables such as quality indexes (number of trees per inhabitant or per hectare), biodiversity indicators (number of species, percentage of the most abundant species), dimension indicators (abundance of trees by diameter classes or height ranges), and condition indicators.

The resulting tree inventory can be accessed and verified using EducaWood—Fig. 3(d) provides an overview at the target location. We asked the course students and teachers to fill the standardized System Usability Score (SUS) questionnaire [52]. We received 16 responses, obtaining an average SUS score of 75.2, with a standard deviation of 11.5. This figure is good, given that SUS scores range from 0 to 100. According to the grading scale interpretation of SUS scores in [53, ch. 8], EducaWood was graded with a B. This indicates a good level of usability.

Overall, the pilot was carried out smoothly, with no major issues. Participants noted a few minor bugs which were quickly resolved. The educational design supported by EducaWood effectively replaced a similar paper-and-pencil activity of previous editions of the course. The collaborative effort to generate the tree inventory at Yutera Campus was faster and well-received by students. It also allowed teachers to monitor progress and provide feedback before the activity concluded. Students successfully collected the tree inventory, delivering detailed urban forestry management plans.

5. Discussion

EducaWood is a LOD-based application designed for forestry education that meets all the requirements in Table 2. The application functionality is considerable, encompassing multiauthor tree management and visualization of geospatial data coming from diverse sources. Tree annotation relies on the STA ontology, offering a flexible model for annotating trees and including a conflict resolution mechanism via primary annotations—Section 3 gives multiple examples of the use of this ontology for annotating trees. STA can be extended in different ways and we have already received suggestions from foresters, including: new annotation types like microhabitats (cavities, excrescences, exudates, epiphytics, nests, etc.)—see [54]; additional spatial entities such as down deadwood [45]; and, specialized terminology for urban tree management (e.g. tree pits and pruning).

In order to address CHALLENGE #1, the user interface of EducaWood provides an interactive map to visualize tree data at various zoom levels, complemented by form-based interfaces for both viewing

and authoring trees. Page URLs are designed to encapsulate all application state—check the routes in Table 3—ensuring that a URL will produce the same view regardless of the device employed and allowing users to safely bookmark and share EducaWood URLs. Findings from the pilot indicate that this user interface design effectively addresses two key objectives: (1) concealing the intricacies of Semantic Web technologies, and (2) facilitating user tasks. This is supported by the good SUS score and the successful creation of a tree inventory with EducaWood—see Section 4.2. It is noteworthy that neither pilot students nor teachers have a background in Semantic Web or databases, highlighting the challenge of user interaction with Semantic Web technologies [9–11]. The use of form interfaces for semantic annotation thus seems an adequate approach, as exemplified in EducaWood and other systems such as Wikidata.

Accessing data in EducaWood can be demanding due to the mixture of write and read operations across multiple data sources (CHALLENGE #2). Nevertheless, the utilization of a CRAFTS API significantly streamlines this process by providing a centralized access point for all data operations. This required a thorough authoring of the configuration file in Appendix A to support the different features of EducaWood—Table 4 gives a good overview of the API calls used in the application. Template queries are primarily employed during the bootstrapping routine and map exploration, with careful attention given to meeting latency requirements, as elaborated in Section 3. In this regard, we employ client-side caching along a user session to avoid duplicated requests to the API, as well as exploiting geospatial relations among cells to derive new information without making further API calls. Tree management essentially involves the use of model `educatree` with the appropriate HTTP methods (GET, PUT, PATCH, DELETE) for retrieving, creating, updating, and deleting trees. All in all, the application only sees JSON data and REST API calls; CRAFTS automatically makes the translation of API requests into SPARQL queries.

When addressing CHALLENGE #3, EducaWood employs various techniques to efficiently handle semantic geospatial data. Our grid of cells for requesting tree data is inspired by tiled web maps [55], a prevalent strategy for enhancing the cacheability of web maps. By dividing a map into a grid, EducaWood ensures that identical API calls are made for data within the same cell by different users, optimizing server caching at CRAFTS. To manage cells with varying tree densities, EducaWood uses a procedure that limits data requests when numerous trees are present. Moreover, EducaWood also exploits geospatial relations among cells to reduce the number of API calls (see Section 3.4). These techniques hold broader applicability to scenarios involving semantic geospatial data. In fact, we are currently refining Forest Explorer [38], aligning its design with that of EducaWood. This new iteration will integrate features such as a CRAFTS API, a grid of cells, exploitation of geospatial cell relationships, and URL redesign to facilitate their sharing.

Thus far, EducaWood has been tested by almost 500 users, with 10.4% of them actively contributing content. This creator-to-consumer ratio surpasses the 1% rule of thumb often observed in Internet communities [56], although collected data in EducaWood is still limited. To moderate its emerging community, we have defined several roles within the application: normal users can create trees and annotations, with the ability to delete their own contributions only; superusers can delete any content and ban normal users; while banned users are restricted from authoring. Each annotation includes its creator, facilitating swift action against vandalism.

EducaWood emerges as a versatile educational tool poised to enhance environmental education across various educational levels, spanning from secondary to university master's programs. The learning objectives of EducaWood can encompass a broad spectrum, aiming to cultivate various skills and knowledge among students, depending on the activity designed by teachers. Simpler activities may allow, for example, the differentiation of main groups of forest species, fostering a deeper understanding of ecosystem diversity, and igniting a greater interest in nature among learners. Also, interdisciplinary learning can be favored by incorporating mathematical concepts such as calculating structural diversity indices and carbon sequestration rates, thereby enhancing students' quantitative reasoning skills. So EducaWood promotes collaborative learning experiences, nurturing teamwork and communication skills essential for effective problem solving and group dynamics.

By bridging classroom learning with real-world experiences, EducaWood extends the educational landscape beyond traditional confines, fostering active and contextualized learning. Moreover, it amplifies eco-

logical awareness by spotlighting forests' pivotal role in climate change mitigation and biodiversity conservation. Its innovative features, such as collaborative annotation functionalities, not only facilitate remote learning but also enable students from diverse backgrounds to engage with forest ecosystems regardless of geographical constraints. This adaptability is very valuable, especially in navigating challenges such as those posed by the COVID-19 pandemic, where traditional in-person educational activities may be impractical. Our future work includes new pilots in forestry education to gather feedback and further improve EducaWood, thereby bolstering its utility for environmental education.

Acknowledgements

This work has been partially funded by the European Commission through "Small4Good" (069/230331), by the Spanish Research Agency through "LOD. For.Trees" (TED2021-130667B-I00) and "H2O" (PID2020-112584RB-C32) projects, by the Junta de Castilla y León through project "iuFOR Institute Unit of Excellence" (CLU-2019-01) of Universidad de Valladolid and co-financed by the European Regional Development Fund (ERDF "Europe drives our growth"). The authors also want to thank the participants in the pilot study.

Appendix A. CRAFTS API configuration of EducaWood

We include here the CRAFTS API configuration file employed in EducaWood. For further information on the use of CRAFTS, refer to [15].

```
{
  "apiId": "educawood",
  "endpoints": [
    {
      "id": "crossforest",
      "sparqlURI": "https://crossforest.gsic.uva.es/sparql/",
      "graphURI": "http://crossforest.eu",
      "httpMethod": "GET"
    },
    {
      "id": "educawood",
      "sparqlURI": "https://crossforest.gsic.uva.es/pruebas/sparql",
      "graphURI": "http://educawood.gsic.uva.es",
      "httpMethod": "GET",
      "sparqlUpdate": {
        "sparqlURI": "https://crossforest.gsic.uva.es/pruebas/sparql-auth",
        "authInfo": {
          "user": "NOT SHOWN",
          "password": "NOT SHOWN",
          "type": "digest"
        }
      }
    },
    {
      "id": "dbpedia",
      "sparqlURI": "http://dbpedia.org/sparql",
      "graphURI": "http://dbpedia.org",
      "httpMethod": "GET"
    },
    {
      "id": "wikidata",
      "sparqlURI": "https://query.wikidata.org/sparql",
      "httpMethod": "GET"
    }
  ],
  "model": [
    {
      "id": "Tree",
      "oprops": [ ],
      "dprops": [
```

```
      {
        "label": "dbh1mm",
        "iri": "https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/hasDBH1InMillimeters",
        "endpoint": "crossforest"
      },
      {
        "label": "dbh2mm",
        "iri": "https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/hasDBH2InMillimeters",
        "endpoint": "crossforest"
      },
      {
        "label": "heightM",
        "iri": "https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/hasTotalHeightInMeters",
        "endpoint": "crossforest"
      }
    ],
    "types": [
      {
        "label": "species",
        "targetId": "Species",
        "restrictions": [
          "?type a/rdfs:subClassOf <https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/Taxon> ."
        ],
        "embed": true,
        "endpoint": "crossforest"
      }
    ]
  },
  {
    "id": "Person",
    "oprops": [
    ],
    "dprops": [
      {
        "label": "created",
        "iri": "http://purl.org/dc/terms/creator>/<http://purl.org/dc/terms/created",
        "inv": true,
        "orderBy": "?value",
        "limit": 1,
        "endpoint": "educawood"
      },
      {
        "label": "nick",
        "iri": "http://xmlns.com/foaf/0.1/nick",
        "endpoint": "educawood"
      },
      {
        "label": "isMasterAnnotator",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/isMasterAnnotator",
        "endpoint": "educawood"
      },
      {
        "label": "cannotAnnotate",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/cannotAnnotate",
        "endpoint": "educawood"
      },
      {
        "label": "numberOfAnnotations",
        "iri": "http://purl.org/dc/terms/creator",
        "inv": true,
        "altResult": "count(distinct ?value) as ?nanns",
        "altVariable": "nanns",
        "endpoint": "educawood"
      },
      {
        "label": "numberOfEducatrees",
        "iri": "http://purl.org/dc/terms/creator",
        "inv": true,
        "restrictions": [ "?value a <http://educawood.gsic.uva.es/sta/ontology/Tree> ." ],
        "altResult": "count(distinct ?value) as ?nets",
        "altVariable": "nets",
        "endpoint": "educawood"
      }
    ],
    "types": [
      {
```

```
            "label": "types",
            "endpoint": "educawood",
            "writeonly": true
          }
        ]
      },
      {
        "id": "BasicEducaTree",
        "oprops": [
          {
            "label": "creator",
            "targetId": "Person",
            "iri": "http://purl.org/dc/terms/creator",
            "embed": true,
            "endpoint": "educawood"
          },
          {
            "label": "species",
            "targetId": "Species",
            "iri": "http://educawood.gsic.uva.es/sta/ontology/hasPrimarySpecies>/<http://educawood.gsic.uva.es/sta/ontology/
                hasTaxon",
            "embed": false,
            "endpoint": "educawood"
          },
          {
            "label": "images",
            "iri": "http://educawood.gsic.uva.es/sta/ontology/hasImageAnnotation>/<http://educawood.gsic.uva.es/sta/ontology/
                hasImage>/<http://educawood.gsic.uva.es/sta/ontology/imageURL",
            "endpoint": "educawood"
          },
          {
            "label": "treeStatus",
            "iri": "http://educawood.gsic.uva.es/sta/ontology/hasPrimaryTreeStatus>/<http://www.w3.org/1999/02/22-rdf-syntax-
                ns#type",
            "endpoint": "educawood"
          }
        ],
        "dprops": [
          {
            "label": "created",
            "iri": "http://purl.org/dc/terms/created",
            "endpoint": "educawood"
          },
          {
            "label": "nick",
            "iri": "http://xmlns.com/foaf/0.1/nick",
            "endpoint": "educawood"
          },
          {
            "label": "lat",
            "iri": "http://educawood.gsic.uva.es/sta/ontology/hasPrimaryPosition>/<http://www.w3.org/2003/01/geo/wgs84_pos#
                lat",
            "endpoint": "educawood"
          },
          {
            "label": "lng",
            "iri": "http://educawood.gsic.uva.es/sta/ontology/hasPrimaryPosition>/<http://www.w3.org/2003/01/geo/wgs84_pos#
                long",
            "endpoint": "educawood"
          },
          {
            "label": "dbh",
            "iri": "http://educawood.gsic.uva.es/sta/ontology/hasPrimaryDiameter>/<http://educawood.gsic.uva.es/sta/ontology/
                hasDiameterInMillimeters",
            "endpoint": "educawood"
          },
          {
            "label": "height",
            "iri": "http://educawood.gsic.uva.es/sta/ontology/hasPrimaryHeight>/<http://educawood.gsic.uva.es/sta/ontology/
                hasHeightInMeters",
            "endpoint": "educawood"
          },
          {
            "label": "observations",
            "iri": "http://educawood.gsic.uva.es/sta/ontology/hasObservationAnnotation>/<http://educawood.gsic.uva.es/sta/
                ontology/observationText",
```

```
        "endpoint": "educawood"
      }
    ],
    "types": [ ]
  },
  {
    "id": "EducaTree",
    "oprops": [
      {
        "label": "creator",
        "targetId": "Person",
        "iri": "http://purl.org/dc/terms/creator",
        "embed": true,
        "endpoint": "educawood"
      },
      {
        "label": "position",
        "targetId": "PositionAnnotation",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/hasPrimaryPosition",
        "embed": true,
        "endpoint": "educawood"
      },
      {
        "label": "positionAnnotations",
        "targetId": "PositionAnnotation",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/hasPositionAnnotation",
        "embed": true,
        "endpoint": "educawood"
      },
      {
        "label": "species",
        "targetId": "SpeciesAnnotation",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/hasPrimarySpecies",
        "embed": true,
        "endpoint": "educawood"
      },
      {
        "label": "speciesAnnotations",
        "targetId": "SpeciesAnnotation",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/hasSpeciesAnnotation",
        "embed": true,
        "endpoint": "educawood"
      },
      {
        "label": "diameter",
        "targetId": "DiameterAnnotation",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/hasPrimaryDiameter",
        "embed": true,
        "endpoint": "educawood"
      },
      {
        "label": "diameterAnnotations",
        "targetId": "DiameterAnnotation",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/hasDiameterAnnotation",
        "embed": true,
        "endpoint": "educawood"
      },
      {
        "label": "height",
        "targetId": "HeightAnnotation",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/hasPrimaryHeight",
        "embed": true,
        "endpoint": "educawood"
      },
      {
        "label": "heightAnnotations",
        "targetId": "HeightAnnotation",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/hasHeightAnnotation",
        "embed": true,
        "endpoint": "educawood"
      },
      {
        "label": "observations",
        "targetId": "ObservationAnnotation",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/hasObservationAnnotation",
        "embed": true,
```

```
      "endpoint": "educawood"
    },
    {
      "label": "treeStatus",
      "targetId": "TreeStatusAnnotation",
      "iri": "http://educawood.gsic.uva.es/sta/ontology/hasPrimaryTreeStatus",
      "embed": true,
      "endpoint": "educawood"
    },
    {
      "label": "treeStatusAnnotations",
      "targetId": "TreeStatusAnnotation",
      "iri": "http://educawood.gsic.uva.es/sta/ontology/hasTreeStatusAnnotation",
      "embed": true,
      "endpoint": "educawood"
    },
    {
      "label": "imageAnnotations",
      "targetId": "ImageAnnotation",
      "iri": "http://educawood.gsic.uva.es/sta/ontology/hasImageAnnotation",
      "embed": true,
      "endpoint": "educawood"
    }
  ],
  "dprops": [
    {
      "label": "created",
      "iri": "http://purl.org/dc/terms/created",
      "endpoint": "educawood"
    },
    {
      "label": "nick",
      "iri": "http://xmlns.com/foaf/0.1/nick",
      "endpoint": "educawood"
    }
  ],
  "types": [
    {
      "label": "types",
      "endpoint": "educawood",
      "writeonly": true
    }
  ]
},
{
  "id": "PositionAnnotation",
  "oprops": [
    {
      "label": "creator",
      "targetId": "Person",
      "iri": "http://purl.org/dc/terms/creator",
      "embed": true,
      "endpoint": "educawood"
    }
  ],
  "dprops": [
    {
      "label": "created",
      "iri": "http://purl.org/dc/terms/created",
      "endpoint": "educawood"
    },
    {
      "label": "latWGS84",
      "iri": "http://www.w3.org/2003/01/geo/wgs84_pos#lat",
      "endpoint": "educawood"
    },
    {
      "label": "lngWGS84",
      "iri": "http://www.w3.org/2003/01/geo/wgs84_pos#long",
      "endpoint": "educawood"
    }
  ],
  "types": [
    {
      "label": "types",
      "endpoint": "educawood",
```

```
            "writeonly": true
          }
        ]
      },
      {
        "id": "DiameterAnnotation",
        "oprops": [
          {
            "label": "creator",
            "targetId": "Person",
            "iri": "http://purl.org/dc/terms/creator",
            "embed": true,
            "endpoint": "educawood"
          }
        ],
        "dprops": [
          {
            "label": "created",
            "iri": "http://purl.org/dc/terms/created",
            "endpoint": "educawood"
          },
          {
            "label": "millimeters",
            "iri": "http://educawood.gsic.uva.es/sta/ontology/hasDiameterInMillimeters",
            "endpoint": "educawood"
          }
        ],
        "types": [
          {
            "label": "types",
            "endpoint": "educawood",
            "writeonly": true
          }
        ]
      },
      {
        "id": "HeightAnnotation",
        "oprops": [
          {
            "label": "creator",
            "targetId": "Person",
            "iri": "http://purl.org/dc/terms/creator",
            "embed": true,
            "endpoint": "educawood"
          }
        ],
        "dprops": [
          {
            "label": "created",
            "iri": "http://purl.org/dc/terms/created",
            "endpoint": "educawood"
          },
          {
            "label": "meters",
            "iri": "http://educawood.gsic.uva.es/sta/ontology/hasHeightInMeters",
            "endpoint": "educawood"
          }
        ],
        "types": [
          {
            "label": "types",
            "endpoint": "educawood",
            "writeonly": true
          }
        ]
      },
      {
        "id": "ObservationAnnotation",
        "oprops": [
          {
            "label": "creator",
            "targetId": "Person",
            "iri": "http://purl.org/dc/terms/creator",
            "embed": true,
            "endpoint": "educawood"
          }
```

```
      ],
      "dprops": [
        {
          "label": "created",
          "iri": "http://purl.org/dc/terms/created",
          "endpoint": "educawood"
        },
        {
          "label": "text",
          "iri": "http://educawood.gsic.uva.es/sta/ontology/observationText",
          "endpoint": "educawood"
        }
      ],
      "types": [
        {
          "label": "types",
          "endpoint": "educawood",
          "writeonly": true
        }
      ]
    },
    {
      "id": "TreeStatusAnnotation",
      "oprops": [
        {
          "label": "creator",
          "targetId": "Person",
          "iri": "http://purl.org/dc/terms/creator",
          "embed": true,
          "endpoint": "educawood"
        }
      ],
      "dprops": [
        {
          "label": "created",
          "iri": "http://purl.org/dc/terms/created",
          "endpoint": "educawood"
        }
      ],
      "types": [
        {
          "label": "treeStatus",
          "endpoint": "educawood"
        }
      ]
    },
    {
      "id": "ImageAnnotation",
      "oprops": [
        {
          "label": "creator",
          "targetId": "Person",
          "iri": "http://purl.org/dc/terms/creator",
          "embed": true,
          "endpoint": "educawood"
        },
        {
          "label": "image",
          "targetId": "Image",
          "iri": "http://educawood.gsic.uva.es/sta/ontology/hasImage",
          "embed": true,
          "endpoint": "educawood"
        }
      ],
      "dprops": [
        {
          "label": "created",
          "iri": "http://purl.org/dc/terms/created",
          "endpoint": "educawood"
        }
      ],
      "types": [
        {
          "label": "types",
          "endpoint": "educawood",
          "writeonly": true
```

```
      }
    ]
  },
  {
    "id": "Image",
    "oprops": [
      {
        "label": "imageURL",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/imageURL",
        "endpoint": "educawood"
      }
    ],
    "dprops": [
      {
        "label": "firebasePath",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/firebasePath",
        "endpoint": "educawood"
      }
    ],
    "types": [
      {
        "label": "plantPart",
        "restrictions": [
          "FILTER (?type NOT IN ( <http://educawood.gsic.uva.es/sta/ontology/Image> ))"
        ],
        "endpoint": "educawood"
      },
      {
        "label": "types",
        "endpoint": "educawood",
        "writeonly": true
      }
    ]
  },
  {
    "id": "SpeciesAnnotation",
    "oprops": [
      {
        "label": "creator",
        "targetId": "Person",
        "iri": "http://purl.org/dc/terms/creator",
        "embed": true,
        "endpoint": "educawood"
      },
      {
        "label": "species",
        "targetId": "Species",
        "iri": "http://educawood.gsic.uva.es/sta/ontology/hasTaxon",
        "embed": true,
        "endpoint": "educawood"
      }
    ],
    "dprops": [
      {
        "label": "created",
        "iri": "http://purl.org/dc/terms/created",
        "endpoint": "educawood"
      }
    ],
    "types": [
      {
        "label": "types",
        "endpoint": "educawood",
        "writeonly": true
      }
    ]
  },
  {
    "id": "Species",
    "oprops": [
      {
        "label": "wikidata",
        "targetId": "WikidataTaxonBasic",
        "iri": "http://www.w3.org/2000/01/rdf-schema#subClassOf",
        "restrictions": [
          "FILTER strstarts(str(?value), \"http://www.wikidata.org/entity/\" )"
```

```
            ],
            "embed": true,
            "endpoint": "educawood"
          },
          {
            "label": "subclasses",
            "iri": "http://www.w3.org/2000/01/rdf-schema#subClassOf",
            "endpoint": "educawood",
            "writeonly": true
          },
          {
            "label": "creator",
            "targetId": "Person",
            "iri": "http://purl.org/dc/terms/creator",
            "endpoint": "educawood",
            "writeonly": true
          }
        ],
        "dprops": [
          {
            "label": "scientificName",
            "iri": "https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/acceptedNameWithoutAuthor",
            "endpoint": "educawood"
          },
          {
            "label": "vulgarName",
            "iri": "https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/vulgarName",
            "restrictions": [
              "FILTER(LANG(?value) = 'en' || LANG(?value) = 'es')"
            ],
            "endpoint": "educawood"
          },
          {
            "label": "wikipediaPage",
            "iri": "https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/hasWikipediaPage",
            "endpoint": "educawood"
          },
          {
            "label": "wikispeciesPage",
            "iri": "https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/hasWikispeciesPage",
            "endpoint": "educawood"
          },
          {
            "label": "created",
            "iri": "http://purl.org/dc/terms/created",
            "endpoint": "educawood",
            "writeonly": true
          }
        ],
        "types": [
          {
            "label": "types",
            "endpoint": "educawood",
            "writeonly": true
          }
        ]
      },
      {
        "id": "WikidataTaxonBasic",
        "oprops": [
          {
            "label": "image",
            "iri": "http://www.wikidata.org/prop/P18>/<http://www.wikidata.org/prop/statement/P18",
            "endpoint": "wikidata"
          },
          {
            "label": "gbifPage",
            "iri": "http://www.wikidata.org/prop/direct/P846",
            "restrictions": [ "BIND(URI(CONCAT(\"https://www.gbif.org/species/\", ?value)) AS ?gbif)" ],
            "altResult": "?gbif",
            "altVariable": "gbif",
            "endpoint": "wikidata"
          }
        ],
        "dprops": [
          {
```

```
            "label": "sitelinks",
            "iri": "http://wikiba.se/ontology#sitelinks",
            "restrictions": [ "hint:Query hint:optimizer \"None\"." ],
            "endpoint": "wikidata"
          },
          {
            "label": "statements",
            "iri": "http://wikiba.se/ontology#statements",
            "restrictions": [ "hint:Query hint:optimizer \"None\"." ],
            "endpoint": "wikidata"
          },
          {
            "label": "comment",
            "iri": "http://www.w3.org/2002/07/owl#sameAs>/<http://www.w3.org/2000/01/rdf-schema#comment",
            "inv": true,
            "restrictions": [
              "FILTER(LANG(?value) = 'en' || LANG(?value) = 'es')"
            ],
            "endpoint": "dbpedia"
          }
        ],
        "types": []
      },
      {
        "id": "WikidataTaxon",
        "oprops": [
          {
            "label": "genus",
            "targetId": "WikidataTaxon",
            "iri": "http://www.wikidata.org/prop/direct/P171",
            "altResult": "?genus",
            "altVariable": "genus",
            "restrictions": [
                  "?iri <http://www.wikidata.org/prop/direct/P171>+ ?genus .",
                  "?genus <http://www.wikidata.org/prop/direct/P105> <http://www.wikidata.org/entity/Q34740> ."
            ],
            "embed": false,
            "endpoint": "wikidata"
          },
          {
            "label": "family",
            "targetId": "WikidataTaxon",
            "iri": "http://www.wikidata.org/prop/direct/P171",
            "altResult": "?family",
            "altVariable": "family",
            "restrictions": [
                  "?iri <http://www.wikidata.org/prop/direct/P171>+ ?family .",
                  "?family <http://www.wikidata.org/prop/direct/P105> <http://www.wikidata.org/entity/Q35409> ."
            ],
            "embed": false,
            "endpoint": "wikidata"
          },
          {
            "label": "image",
            "iri": "http://www.wikidata.org/prop/P18>/<http://www.wikidata.org/prop/statement/P18",
            "endpoint": "wikidata"
          },
          {
            "label": "wikipediaPage",
            "iri": "http://schema.org/about",
            "inv": true,
            "restrictions": [
              "?value <http://schema.org/inLanguage> \"en\" ;\n  <http://schema.org/isPartOf> <https://en.wikipedia.org/> ."
            ],
            "endpoint": "wikidata"
          },
          {
            "label": "wikispeciesPage",
            "iri": "http://schema.org/about",
            "inv": true,
            "restrictions": [
              "?value  <http://schema.org/inLanguage> \"en\" ;\n  <http://schema.org/isPartOf> <https://species.wikimedia.org
                  /> ."
            ],
            "endpoint": "wikidata"
          },
```

```
        {
          "label": "gbifPage",
          "iri": "http://www.wikidata.org/prop/direct/P846",
          "restrictions": [ "BIND(URI(CONCAT(\"https://www.gbif.org/species/\", ?value)) AS ?gbif)" ],
          "altResult": "?gbif",
          "altVariable": "gbif",
          "endpoint": "wikidata"
        }
      ],
      "dprops": [
        {
          "label": "scientificName",
          "iri": "http://www.wikidata.org/prop/direct/P225",
          "endpoint": "wikidata"
        },
        {
          "label": "vulgarName",
          "iri": "http://www.wikidata.org/prop/P1843>/<http://www.wikidata.org/prop/statement/P1843",
          "restrictions": [
            "FILTER(LANG(?value) = 'en' || LANG(?value) = 'es')"
          ],
          "endpoint": "wikidata"
        },
        {
          "label": "comment",
          "iri": "http://www.w3.org/2002/07/owl#sameAs>/<http://www.w3.org/2000/01/rdf-schema#comment",
          "inv": true,
          "restrictions": [
            "FILTER(LANG(?value) = 'en' || LANG(?value) = 'es')"
          ],
          "endpoint": "dbpedia"
        },
        {
          "label": "isSpecies",
          "iri": "http://www.wikidata.org/prop/direct/P105",
          "altResult": "?isSpecies",
          "altVariable": "isSpecies",
          "restrictions": [
            "BIND ( sameTerm(?value, <http://www.wikidata.org/entity/Q7432>) as ?isSpecies )"
          ],
          "endpoint": "wikidata"
        },
        {
          "label": "isConifer",
          "iri": "http://www.wikidata.org/prop/direct/P171",
          "altResult": "(true as ?isConifer)",
          "altVariable": "isConifer",
          "restrictions": [
            "?value <http://www.wikidata.org/prop/direct/P171>+ <http://www.wikidata.org/entity/Q133712> ."
          ],
          "endpoint": "wikidata"
        }
      ],
      "types": []
    }
  ],
  "queryTemplates": [
    {
      "id": "subclasses",
      "description": "Obtain subclass relations between pairs of clases (variables \"sup\" and \"sub\") from an ancestor
          class (parameter \"ancestor\")",
      "template": "SELECT DISTINCT ?sup ?sub WHERE {
          ?sup rdfs:subClassOf* <{{{ancestor}}}> .
          ?sub rdfs:subClassOf ?sup . }",
      "variables": [
        "sup",
        "sub"
      ],
      "parameters": [
        {
          "label": "ancestor",
          "type": "iri"
        }
      ],
      "endpoint": "educawood"
    },
```

```
{
  "id": "infoClasses",
  "description": "Obtain info about all the classes (variable \"class\") from an ancestor class (parameter \"ancestor
      \")",
  "template": "SELECT DISTINCT ?class ?parent ?labes ?laben ?comes ?comen WHERE {
     ?class rdfs:subClassOf* <{{{ancestor}}}> ;
       rdfs:subClassOf ?parent .
      OPTIONAL {
        ?class rdfs:label ?labes .
       FILTER (lang(?labes) = \"es\")
      }
      OPTIONAL {
        ?class rdfs:label ?laben .
       FILTER (lang(?laben) = \"en\")
      }
      OPTIONAL {
        ?class rdfs:comment ?comes .
       FILTER (lang(?comes) = \"es\")
      }
      OPTIONAL {
        ?class rdfs:comment ?comen
       FILTER (lang(?comen) = \"en\")
      } }",
  "variables": [
    "class",
    "parent",
    "labes",
    "laben",
    "comes",
    "comen"
  ],
  "parameters": [
    {
      "label": "ancestor",
      "type": "iri"
    }
  ],
  "endpoint": "educawood"
},
{
  "id": "counttreesinbox",
  "description": "Count the number of trees (variable \"count\") of an optional species (variable \"species\") in a
      bounding box with GPS coordinates \"latsouth\", \"latsouth\", \"latsouth\", and \"latsouth\"",
  "template": "SELECT COUNT(distinct ?tree) AS ?count WHERE {
    ?tree a <https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/Tree> ;
        <http://crossforest.eu/position/ontology/hasPosition> ?pos .
    {{#species}}?tree a/rdfs:subClassOf*<{{{species}}}> .{{/species}}
    ?pos <http://crossforest.eu/position/ontology/hasCoordinateReferenceSystem> <http://epsg.w3id.org/data/crs/4326> ;
        <http://epsg.w3id.org/ontology/axis/106> ?lat ;
        <http://epsg.w3id.org/ontology/axis/107> ?lng .
     {{#latnorth}}  FILTER (?lat <= {{latnorth}}) .{{/latnorth}}
     {{^latnorth}}  FILTER (?lat <= 0) .{{/latnorth}}
     {{#latsouth}}  FILTER (?lat > {{latsouth}}) .{{/latsouth}}
     {{^latsouth}}  FILTER (?lat > 0) .{{/latsouth}}
     {{#lngeast}}  FILTER (?lng <= {{lngeast}}) .{{/lngeast}}
     {{^lngeast}}  FILTER (?lng <= 0) .{{/lngeast}}
     {{#lngwest}}  FILTER (?lng > {{lngwest}}) .{{/lngwest}}
     {{^lngwest}}  FILTER (?lng > 0) .{{/lngwest}} }",
  "variables": [
    "count"
  ],
  "parameters": [
    {
      "label": "lngwest",
      "type": "number",
      "optional": true
    },
    {
      "label": "lngeast",
      "type": "number",
      "optional": true
    },
    {
      "label": "latnorth",
      "type": "number",
      "optional": true
```

```
      },
      {
        "label": "latsouth",
        "type": "number",
        "optional": true
      },
      {
        "label": "species",
        "type": "iri",
        "optional": true
      }
    ],
    "endpoint": "crossforest"
  },
  {
    "id": "treesinbox",
    "description": "Obtain trees (variable \"tree\") of an optional species (parameter \"species\") along with their GPS
         coordinates (variables \"lat\" and \"lng\"), diameters (\"dbh1mm\" and \"dbh2mm\"), height (\"heightM\") and
         species (\"type\") a in a bounding box with GPS coordinates \"latsouth\", \"latsouth\", \"latsouth\", and \"
         latsouth\". This template query can be paginated with the optional parameters \"limit\" and \"offset\"",
    "template": "SELECT DISTINCT ?tree ?lat ?lng ?dbh1mm ?dbh2mm ?heightM ?type WHERE {
       ?tree a <https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/Tree> ;
           <https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/hasDBH1InMillimeters> ?dbh1mm ;
           <https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/hasDBH2InMillimeters> ?dbh2mm ;
           <https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/hasTotalHeightInMeters> ?heightM ;
            <http://crossforest.eu/position/ontology/hasPosition> ?pos .
       {{#species}} ?tree a/rdfs:subClassOf* <{{{species}}}> . {{/species}}
       OPTIONAL {
           ?tree a ?type .
           ?type a/rdfs:subClassOf <https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/Taxon> .
        }
        ?pos <http://crossforest.eu/position/ontology/hasCoordinateReferenceSystem> <http://epsg.w3id.org/data/crs/4326>
             ;
            <http://epsg.w3id.org/ontology/axis/106> ?lat ;
            <http://epsg.w3id.org/ontology/axis/107> ?lng .
       {{#latnorth}}  FILTER (?lat <= {{latnorth}}) .{{/latnorth}}
       {{^latnorth}}  FILTER (?lat <= 0) .{{/latnorth}}
       {{#latsouth}}  FILTER (?lat > {{latsouth}}) .{{/latsouth}}
       {{^latsouth}}  FILTER (?lat > 0) .{{/latsouth}}
       {{#lngeast}}  FILTER (?lng <= {{lngeast}}) .{{/lngeast}}
       {{^lngeast}}  FILTER (?lng <= 0) .{{/lngeast}}
       {{#lngwest}}  FILTER (?lng > {{lngwest}}) .{{/lngwest}}
       {{^lngwest}}  FILTER (?lng > 0) .{{/lngwest}}
     }
     {{#limit}}LIMIT {{limit}}{{/limit}}{{^limit}}LIMIT 100{{/limit}}
     {{#offset}}OFFSET {{offset}}{{/offset}}",
    "variables": [
      "tree",
      "lat",
      "lng",
      "dbh1mm",
      "dbh2mm",
      "heightM",
      "type"
    ],
    "parameters": [
      {
        "label": "species",
        "type": "iri",
        "optional": true
      },
      {
        "label": "lngwest",
        "type": "number",
        "optional": true
      },
      {
        "label": "lngeast",
        "type": "number",
        "optional": true
      },
      {
        "label": "latnorth",
        "type": "number",
        "optional": true
      },
```

```
      {
        "label": "latsouth",
        "type": "number",
        "optional": true
      },
      {
        "label": "limit",
        "type": "integer",
        "optional": true
      },
      {
        "label": "offset",
        "type": "integer",
        "optional": true
      }
    ],
    "endpoint": "crossforest"
  },
  {
    "id": "treesinboxbasico",
    "description": "Obtain trees (variable \"tree\") of an optional species (parameter \"species\") and their GPS
         coordinates (variables \"lat\" and \"lng\") in a bounding box with GPS coordinates \"latsouth\", \"latsouth\",
         \"latsouth\", and \"latsouth\". This template query can be paginated with the optional parameters \"limit\" and
         \"offset\"",
    "template": "SELECT DISTINCT ?tree ?lat ?lng WHERE {
      ?tree a <https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/Tree> ;
          <http://crossforest.eu/position/ontology/hasPosition> ?pos .
      {{#species}} ?tree a/rdfs:subClassOf* <{{{species}}}> .{{/species}}
      ?pos <http://crossforest.eu/position/ontology/hasCoordinateReferenceSystem> <http://epsg.w3id.org/data/crs/4326> ;
          <http://epsg.w3id.org/ontology/axis/106> ?lat ;
          <http://epsg.w3id.org/ontology/axis/107> ?lng .
       {{#latnorth}}  FILTER (?lat <= {{latnorth}}) .{{/latnorth}}
       {{^latnorth}}  FILTER (?lat <= 0) .{{/latnorth}}
       {{#latsouth}}  FILTER (?lat > {{latsouth}}) .{{/latsouth}}
       {{^latsouth}}  FILTER (?lat > 0) .{{/latsouth}}
       {{#lngeast}}  FILTER (?lng <= {{lngeast}}) .{{/lngeast}}
       {{^lngeast}}  FILTER (?lng <= 0) .{{/lngeast}}
       {{#lngwest}}  FILTER (?lng > {{lngwest}}) .{{/lngwest}}
       {{^lngwest}}  FILTER (?lng > 0) .{{/lngwest}}
      }
      {{#limit}}LIMIT {{limit}}{{/limit}}{{^limit}}LIMIT 100{{/limit}}
      {{#offset}}OFFSET {{offset}}{{/offset}}",
    "variables": [
      "tree",
      "lat",
      "lng"
    ],
    "parameters": [
      {
        "label": "species",
        "type": "iri",
        "optional": true
      },
      {
        "label": "lngwest",
        "type": "number",
        "optional": true
      },
      {
        "label": "lngeast",
        "type": "number",
        "optional": true
      },
      {
        "label": "latnorth",
        "type": "number",
        "optional": true
      },
      {
        "label": "latsouth",
        "type": "number",
        "optional": true
      },
      {
        "label": "limit",
        "type": "integer",
```

```
            "optional": true
          },
          {
            "label": "offset",
            "type": "integer",
            "optional": true
          }
        ],
        "endpoint": "crossforest"
      },
      {
        "id": "counteducatreesinbox",
        "description": "Count the number of educatreestrees (variable \"count\") of an optional species (variable \"species
            \") in a bounding box with GPS coordinates \"latsouth\", \"latsouth\", \"latsouth\", and \"latsouth\"",
        "template": "SELECT COUNT(distinct ?tree) AS ?count WHERE {
          ?tree a <http://educawood.gsic.uva.es/sta/ontology/Tree> ;
              <http://educawood.gsic.uva.es/sta/ontology/hasPrimaryPosition> ?pos .
          {{#species}}
            ?tree <http://educawood.gsic.uva.es/sta/ontology/hasPrimarySpecies> ?ps .
            ?ps <http://educawood.gsic.uva.es/sta/ontology/hasTaxon>/rdfs:subClassOf* <{{{species}}}> .
          {{/species}}
          ?pos  <http://www.w3.org/2003/01/geo/wgs84_pos#lat> ?lat ;
             <http://www.w3.org/2003/01/geo/wgs84_pos#long> ?lng .
           {{#latnorth}}  FILTER (?lat <= {{latnorth}}) .{{/latnorth}}
           {{^latnorth}}  FILTER (?lat <= 0) .{{/latnorth}}
           {{#latsouth}}  FILTER (?lat > {{latsouth}}) .{{/latsouth}}
           {{^latsouth}}  FILTER (?lat > 0) .{{/latsouth}}
           {{#lngeast}}  FILTER (?lng <= {{lngeast}}) .{{/lngeast}}
           {{^lngeast}}  FILTER (?lng <= 0) .{{/lngeast}}
           {{#lngwest}}  FILTER (?lng > {{lngwest}}) .{{/lngwest}}
           {{^lngwest}}  FILTER (?lng > 0) .{{/lngwest}} }",
        "variables": [
          "count"
        ],
        "parameters": [
          {
            "label": "lngwest",
            "type": "number",
            "optional": true
          },
          {
            "label": "lngeast",
            "type": "number",
            "optional": true
          },
          {
            "label": "latnorth",
            "type": "number",
            "optional": true
          },
          {
            "label": "latsouth",
            "type": "number",
            "optional": true
          },
          {
            "label": "species",
            "type": "iri",
            "optional": true
          }
        ],
        "endpoint": "educawood"
      },
      {
        "id": "educatreesinbox",
        "description": "Obtain educatrees (variable \"tree\") of an optional primary species (parameter \"species\") and
            their GPS coordinates corresponding to their primary location (variables \"lat\" and \"lng\") in a bounding box
            with GPS coordinates \"latsouth\", \"latsouth\", \"latsouth\", and \"latsouth\". This template query can be
            paginated with the optional parameters \"limit\" and \"offset\"",
        "template": "SELECT DISTINCT ?tree ?lat ?lng WHERE {
          ?tree a <http://educawood.gsic.uva.es/sta/ontology/Tree> ;
              <http://educawood.gsic.uva.es/sta/ontology/hasPrimaryPosition> ?pos .
          {{#species}}
            ?tree <http://educawood.gsic.uva.es/sta/ontology/hasPrimarySpecies> ?ps .
            ?ps <http://educawood.gsic.uva.es/sta/ontology/hasTaxon>/rdfs:subClassOf* <{{{species}}}> .
          {{/species}}
```

```
      ?pos  <http://www.w3.org/2003/01/geo/wgs84_pos#lat> ?lat ;
         <http://www.w3.org/2003/01/geo/wgs84_pos#long> ?lng .
       {{#latnorth}}  FILTER (?lat <= {{latnorth}}) .{{/latnorth}}
       {{^latnorth}}  FILTER (?lat <= 0) .{{/latnorth}}
       {{#latsouth}}  FILTER (?lat > {{latsouth}}) .{{/latsouth}}
       {{^latsouth}}  FILTER (?lat > 0) .{{/latsouth}}
       {{#lngeast}}  FILTER (?lng <= {{lngeast}}) .{{/lngeast}}
       {{^lngeast}}  FILTER (?lng <= 0) .{{/lngeast}}
       {{#lngwest}}  FILTER (?lng > {{lngwest}}) .{{/lngwest}}
       {{^lngwest}}  FILTER (?lng > 0) .{{/lngwest}}
      }
      {{#limit}}LIMIT {{limit}}{{/limit}}{{^limit}}LIMIT 100{{/limit}}
      {{#offset}}OFFSET {{offset}}{{/offset}}",
    "variables": [
      "tree",
      "lat",
      "lng"
    ],
    "parameters": [
      {
        "label": "species",
        "type": "iri",
        "optional": true
      },
      {
        "label": "lngwest",
        "type": "number",
        "optional": true
      },
      {
        "label": "lngeast",
        "type": "number",
        "optional": true
      },
      {
        "label": "latnorth",
        "type": "number",
        "optional": true
      },
      {
        "label": "latsouth",
        "type": "number",
        "optional": true
      },
      {
        "label": "limit",
        "type": "integer",
        "optional": true
      },
      {
        "label": "offset",
        "type": "integer",
        "optional": true
      }
    ],
    "endpoint": "educawood"
  },
  {
    "id": "usernick",
    "description": "Obtain the user (variable \"user\") with a specific nick (parameter \"nick\")",
    "template": "SELECT DISTINCT ?user WHERE {
        ?user <http://xmlns.com/foaf/0.1/nick> \"{{nick}}\" }",
    "variables": [
      "user"
    ],
    "parameters": [
      {
        "label": "nick",
        "type": "string",
        "optional": false
      }
    ],
    "endpoint": "educawood"
  },
  {
    "id": "mostRecentEducatrees",
```

```
    "description": "Obtain the most recent educatrees (variable \"tree\") with their creation date (variable \"date\"),
         tree nick (if exists with variable \"tnick\"), creator (variable \"creator\"), and nick (if exists with variable
          \"unick\"), that have been optionally created by a user (parameter \"user\"). This template query can be
         paginated with the optional parameters \"limit\" and \"offset\"",
    "template": "SELECT DISTINCT ?tree ?date ?tnick ?creator ?unick WHERE {
       {{#user}}  VALUES ?creator { <{{{.}}}> }{{/user}}
       ?tree a <http://educawood.gsic.uva.es/sta/ontology/Tree> ;
           <http://purl.org/dc/terms/creator> ?creator ;
           <http://purl.org/dc/terms/created> ?date .
        OPTIONAL { ?tree <http://xmlns.com/foaf/0.1/nick> ?tnick }
        OPTIONAL {?creator <http://xmlns.com/foaf/0.1/nick> ?unick}
      }
      ORDER BY DESC(?date)
      {{#limit}}LIMIT {{.}}{{/limit}}{{^limit}}LIMIT 10{{/limit}}
      {{#offset}}OFFSET {{.}}{{/offset}}",
    "variables": [
      "tree",
      "date",
      "tnick",
      "creator",
      "unick"
    ],
    "parameters": [
      {
        "label": "user",
        "type": "iri",
        "optional": true
      },
      {
        "label": "limit",
        "type": "integer",
        "optional": true
      },
      {
        "label": "offset",
        "type": "integer",
        "optional": true
      }
    ],
    "endpoint": "educawood"
  },
  {
    "id": "mostRecentAnnotations",
    "description": "Obtain the most recently annotated educatrees (variable \"tree\") with their annotation type (
         variable \"annType\"), date (variable \"date\"), tree nick (if exists with variable \"tnick\"), annotator (
         variable \"annotator\") and nick (if exists with variable \"unick\"), that have been optionally annotated by a
         user (parameter \"user\"). This template query can be paginated with the optional parameters \"limit\" and \"
         offset\"",
    "template": "SELECT DISTINCT ?tree ?annType ?date ?tnick ?annotator ?unick WHERE {
        {{#user}} VALUES ?annotator { <{{{.}}}> }{{/user}}
        ?tree a <http://educawood.gsic.uva.es/sta/ontology/Tree> ;
            ?pr ?ann .
        ?pr rdfs:subPropertyOf <http://educawood.gsic.uva.es/sta/ontology/hasAnnotation> .
        ?ann a ?annType ;
            <http://purl.org/dc/terms/creator> ?annotator ;
            <http://purl.org/dc/terms/created> ?date .
         OPTIONAL {?tree <http://xmlns.com/foaf/0.1/nick> ?tnick}
         OPTIONAL {?annotator <http://xmlns.com/foaf/0.1/nick> ?unick}
       }
       ORDER BY DESC(?date)
       {{#limit}}LIMIT {{.}}{{/limit}}{{^limit}}LIMIT 10{{/limit}}
       {{#offset}}OFFSET {{.}}{{/offset}}",
    "variables": [
      "tree",
      "annType",
      "date",
      "tnick",
      "annotator",
      "unick"
    ],
    "parameters": [
      {
        "label": "user",
        "type": "iri",
        "optional": true
      },
```

```
        {
          "label": "limit",
          "type": "integer",
          "optional": true
        },
        {
          "label": "offset",
          "type": "integer",
          "optional": true
        }
      ],
      "endpoint": "educawood"
    },
    {
      "id": "validTaxons",
      "description": "Obtain the subset of the Wikidata entities (parameter \"eiri\") which are valid tree species, genera
           or families. Additionally, the sitelinks (variable \"sitelinks\") and statements (variable \"statements\") of
           the valid taxons are extracted.",
      "template": "SELECT ?taxon ?sitelinks ?statements WHERE {
         VALUES ?taxon { {{#eiri}} <{{{.}}}>{{/eiri}} }
         VALUES ?ranks {<http://www.wikidata.org/entity/Q7432> <http://www.wikidata.org/entity/Q34740> <http://www.wikidata
              .org/entity/Q35409>}
         VALUES ?plantclasses { <http://www.wikidata.org/entity/Q25314> <http://www.wikidata.org/entity/Q133712>}
         ?taxon wdt:P31 <http://www.wikidata.org/entity/Q16521> ;
             wdt:P105 ?ranks ;
             wdt:P171+ ?plantclasses ;
          <http://wikiba.se/ontology#sitelinks> ?sitelinks ;
          <http://wikiba.se/ontology#statements> ?statements .}",
      "variables": [
        "taxon",
        "sitelinks",
        "statements"
      ],
      "parameters": [
        {
          "label": "eiri",
          "type": "iri[]"
        }
      ],
      "endpoint": "wikidata"
    },
    {
      "id": "existingWikidataTaxons",
      "description": "Obtain the subset of the Wikidata taxons (parameter and variable \"wdiri\") with a corresponding
           taxon (variable \"txiri\") in the dataset. This is for checking if a taxon is already imported.",
      "template": "SELECT DISTINCT ?wdiri ?txiri WHERE {
        VALUES ?wdiri { {{#wdiri}} <{{{.}}}>{{/wdiri}} }
        VALUES ?plantclasses { <https://datos.iepnb.es/def/sector-publico/medio-ambiente/ifn/Class2> <https://datos.iepnb.
             es/def/sector-publico/medio-ambiente/ifn/Class1> }
        ?txiri rdfs:subClassOf* ?plantclasses .
        ?txiri rdfs:subClassOf ?wdiri . }",
      "variables": [
        "txiri",
        "wdiri"
      ],
      "parameters": [
        {
          "label": "wdiri",
          "type": "iri[]"
        }
      ],
      "endpoint": "educawood"
    }
  ]
}
```

References

[1] F. Ayuga Téllez, *Gestión sostenible de paisajes rurales – Técnicas e ingeniería*, Fundación Alfonso Martín Escudero, 2002.

[2] R. Hansis, The social acceptability of clearcutting in the Pacific Northwest, *Human Organization* **54** (1995), 95–101. doi:10.17730/HUMO.54.1.YJ5338V42768002R.

[3] J.M. Western, A.S. Cheng, N.M. Anderson and P. Motley, Examining the social acceptability of forest biomass harvesting and utilization from collaborative forest landscape restoration: A case study from western Colorado, USA, Vol. 115, 2017, pp. 530–539. ISSN 19383746. doi:10.5849/JOF-2016-086.

[4] W. Reid, T. Wilbanks, D. Capistrano and F. Berkes (eds), *Bridging Scales and Knowledge Systems Concepts and Applications in Ecosystem Assessment*, World Resources Institute and Millennium Ecosystem Assessment, 2006.

[5] E. Pramova, B. Locatelli, M. Brockhaus and S. Fohlmeister, Ecosystem services in the National Adaptation Programmes of Action, *Climate Policy* **12**(4) (2012), 393–409. doi:10.1080/14693062.2011.647848.

[6] A. Morán-Ordóñez, A. Ameztegui, M. De Cáceres, S. de-Miguel, F. Lefevre, L. Brotons and L. Coll, Future trade-offs and synergies among ecosystem services in Mediterranean forests under global change scenarios, *Ecosystem Services* **45** (2020), 101174. doi:10.1016/j.ecoser.2020.101174.

[7] O. Derevenskaia, Active Learning Methods in Environmental Education of Students, *Procedia - Social and Behavioral Sciences* **131** (2014). doi:10.1016/j.sbspro.2014.04.086.

[8] S.C. Cheng, G.J. Hwang and C.H. Chen, From reflective observation to active learning: A mobile experiential learning approach for environmental science education, *British Journal of Educational Technology* **50** (2019). doi:10.1111/bjet.12845.

[9] C.C. Charalampidis and E.A. Keramopoulos, Semantic Web user interfaces – A model and a review, *Data & Knowledge Engineering* **115** (2018), 214–227. doi:10.1016/j.datak.2018.04.003.

[10] A.-S. Dadzie and M. Rowe, Approaches to visualising Linked Data: a survey, *Semantic Web* **2**(2) (2011), 89–124. doi:10.3233/SW-2011-0037.

[11] T. Heath, J. Domingue and P. Shabajee, User interaction and uptake challenges to successfully deploying Semantic Web technologies, in: *Proceedings of the 3rd International Semantic Web User Interaction Workshop (SWUI2006), co-located with the 5th International Semantic Web Conference*, Athens, GA, USA, 2006.

[12] R. Verborgh, M. Vander Sande, O. Hartig, J. Van Herwegen, L. De Vocht, B. De Meester, G. Haesendonck and P. Colpaert, Triple Pattern Fragments: a Low-cost Knowledge Graph Interface for the Web, *Journal of Web Semantics* **37–38** (2016), 184–206. doi:10.1016/j.websem.2016.03.003.

[13] A.-S. Dadzie and E. Pietriga, Visualisation of Linked Data – Reprise, *Semantic Web* **8**(1) (2017), 1–21. doi:10.3233/SW-160249.

[14] L.V.D. Brink, P. Barnaghi, J. Tandy, G. Atemezing, R. Atkinson, B. Cochrane, Y. Fathy, R. García Castro, A. Haller, A. Harth, K. Janowicz, S. Kolozali, B.V. Leeuwen, M. Lefrançois, J. Lieberman, A. Perego, D. Le-Phuoc, B. Roberts, K. Taylor and R. Troncy, Best Practices for Publishing, Retrieving, and Using Spatial Data on the Web, *Semantic Web* **10** (2019), 95–114. doi:10.3233/SW-180305.

[15] G. Vega-Gorgojo, CRAFTS: Configurable REST APIs for triple stores, *IEEE Access* **10** (2022), 32426–32441. doi:10.1109/ACCESS.2022.3160610.

[16] A. Bravo-Oviedo, M. Marchi, D. Travaglini, F. Pelleri, M.C. Manetti, P. Corona, F. Cruz, F. Bravo and S. Nocentini, Adoption of new silvicultural methods in Mediterranean forests: the influence of educational background and sociodemographic factors on marker decisions, *Annals of Forest Science* **77** (2020), 48, DOI: 10.1007/s13595-020-00947-z.

[17] G. Segalina, C. Dang and R. Grado, thinning scenarios to reconcile biodiversity conservation and socio-economic cobenefits in protected forest of Vietnam: effects on habitat value and timber yield, *Asian Journal of Forestry* **4** (2020), 22–35. doi:10.13057/asianjfor/r040105.

[18] C. Herodotou, N. Ismail, A.I. Benavides-Lahnstein, M. Aristeidou, A.N. Young, R.F. Johnson, L.M. Higgins, M. Ghadiri-Khanaposhtani, L.D. Robinson and H.L. Ballard, Young people in iNaturalist: a blended learning framework for biodiversity monitoring, *International Journal of Science Education, Part B* **0**(0) (2023), 1–28. doi:10.1080/21548455.2023.2217472.

[19] S. Unger, M. Rollins, A. Tietz and H. Dumais, iNaturalist as an engaging tool for identifying organisms in outdoor activities, *Journal of Biological Education* **55**(5) (2021), 537–547. doi:10.1080/00219266.2020.1739114.

[20] V. Ivanova, P. Lambrix, S. Lohmann and C. Pesquita, Visualization and interaction for ontologies and linked data?Editorial, *Journal of Web Semantics* **55** (2019), 145–149. doi:10.1016/j.websem.2018.10.001.

[21] E. Hyvönen, Digital humanities on the semantic web: Sampo model and portal series, *Semantic Web* **14**(4) (2023), 729–744. doi:10.3233/SW-223034.

[22] G. Vega-Gorgojo, LOD4Culture: Easy exploration of cultural heritage linked open data, *Semantic Web* **Pre-press** (2023), 1–30. doi:10.3233/SW-233358.

[23] T. Berners-Lee, Y. Chen, L. Chilton, D. Connolly, R. Dhanaraj, J. Hollenbach, A. Lerer and D. Sheets, Tabulator: Exploring and analyzing Linked Data on the Semantic Web, in: *Proceedings of the 3rd International Semantic Web User Interaction Workshop*, Athens, Georgia, 2006.

[24] P. Andrews, I. Zaihrayeu and J. Pane, A Classification of Semantic Annotation Systems, *Semantic Web* **3**(3) (2012), 223–248. doi:10.3233/SW-2011-0056.

[25] P. García-Zarza, M.L. Bote-Lorenzo, G. Vega-Gorgojo and J.I. Asensio-Pérez, CHEST: A Linked Open Data-based Application to Annotate and Carry Out Learning Tasks About Cultural Heritage, in: *Educating for a New Future: Making Sense of Technology-Enhanced Learning Adoption*, I. Hilliger, P.J. Muñoz-Merino, T.D. Laet, A. Ortega-Arranz and T. Farrell, eds, Springer International Publishing, 2022, pp. 441–447. ISBN 978-3-031-16290-9. doi:10.1007/978-3-031-16290-9_34.

[26] E. Koutsiana, G.M.R. Amaral, N. Reeves, A. Meroño-Peñuela and E. Simperl, An analysis of discussions in collaborative knowledge engineering through the lens of Wikidata, *Journal of Web Semantics* **78** (2023). doi:10.1016/j.websem.2023.100799.

[27] G. Kellogg, P.A. Champin and D. Longley, JSON-LD 1.1: A JSON-based Serialization for Linked Data, Recommendation, W3C, 2020, URL: https://www.w3.org/TR/2020/REC-json-ld11-20200716/, last visited July 2024.

[28] P. Lisena, A. Meroño-Peñuela, T. Kuhn and R. Troncy, Easy Web API Development with SPARQL Transformer, in: *Proceedings of the 18th International Semantic Web Conference (ISWC 2019)*, C. Ghidini, O. Hartig, M. Maleshkova, V. Svátek, I. Cruz, A. Hogan, J. Song, M. Lefrançois and F. Gandon, eds, LNCS, Vol. 11779, Springer, Cham, Switzerland, 2019, pp. 454–470.

[29] M. Daquino, I. Heibi, S. Peroni and D. Shotton, Creating Restful APIs over SPARQL endpoints with RAMOSE, *Semantic Web* **13**(2) (2022), 195–213. doi:10.3233/SW-210439.

[30] C. Badenes-Olmedo, P. Espinoza-Arias and O. Corcho, RESTful-API for RDF data (R4R), in: *Proceedings of the ISWC 2021 Posters & Demonstrations and Industry Tracks co-located with 20th International Semantic Web Conference (ISWC 2021)*, O. Seneviratne, C. Pesquita, J. Sequeda and L. Etcheverry, eds, CEUR Workshop Proceedings, Vol. 2980, Aachen, Germany, 2021.

[31] D. Garijo and M. Osorio, OBA: An Ontology-Based Framework for Creating REST APIs for Knowledge Graphs, in: *Proceedings of the 19th International Semantic Web Conference (ISWC 2020)*, J.Z. Pan, V. Tamma, C. d'Amato, K. Janowicz, B. Fu, A. Polleres, O. Seneviratne and L. Kagal, eds, LNCS, Vol. 12507, Springer, Cham, Switzerland, 2020, pp. 48–64.

[32] A. Meroño-Peñuela and R. Hoekstra, grlc makes GitHub taste like linked data APIs, in: *Proceedings of the 13th European Semantic Web Conference (ESWC 2016)*, H. Sack, G. Rizzo, N. Steinmetz, D. Mladenić, S. Auer and C. Lange, eds, LNCS, Vol. 9989, Springer, Cham, Switzerland, 2016, pp. 342–353.

[33] E. Daga, L. Panziera and C. Pedrinaci, A BASILar approach for building web APIs on top of SPARQL endpoints, in: *Proceedings of the Third Workshop on Services and Applications over Linked APIs and Data (SALAD2015)*, Vol. 1359, Portoroz, Slovenia, 2015, pp. 22–32, co-located with the 12th European Semantic Web Conference (ESWC 2015).

[34] L. Dusseault, L. Lab and J. Snell, PATCH Method for HTTP, Standards Track, RFC 5789, Internet Engineering Task Force (IETF), 2010, URL: https://datatracker.ietf.org/doc/html/rfc5789, last visited July 2024.

[35] W. Beek, E. Folmer, L. Rietveld and J. Walker, GeoYASGUI: The GeoSPARQL query editor and result set visualizer, *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences* **42** (2017), 39–42. doi:10.5194/isprs-archives-XLII-4-W2-39-2017.

[36] C. Nikolaou, K. Dogani, K. Bereta, G. Garbis, M. Karpathiotakis, K. Kyzirakos and M. Koubarakis, Sextant: Visualizing time-evolving linked geospatial data, *Journal of Web Semantics* **35** (2015), 35–52. doi:10.1016/j.websem.2015.09.004.

[37] M. Gaigg, *Designing Map Interfaces: Patterns for Building Effective Map Apps*, Esri Press, 2023.

[38] G. Vega-Gorgojo, J.M. Giménez-García, C. Ordóñez and F. Bravo, Pioneering easy-to-use forestry data with Forest Explorer, *Semantic Web* **13**(2) (2022), 147–162. doi:10.3233/SW-210430.

[39] C. Stadler, J. Lehmann, K. Höffner and S. Auer, LinkedGeoData: A core for a web of spatial open data, *Semantic Web* **3**(4) (2012), 333–354. doi:10.3233/SW-2011-0052.

[40] A. de León, F. Wisniewki, B. Villazón-Terrazas and O. Corcho, Map4rdf – Faceted browser for geospatial datasets, in: *Proceedings of the First International Workshop on Open Data (WOD-2012)*, Nantes, France, 2012.

[41] J.M. Giménez-García, G. Vega-Gorgojo, C. Ordóñez, N. Crespo-Lera and F. Bravo, Transnational Land Use and Forest Inventories Using Linked Open Data, *Frontiers in Forests and Global Change* (2024), Under review.

[42] S. Lohmann, S. Negru, F. Haag and T. Ertl, Visualizing ontologies with VOWL, *Semantic Web* **7**(4) (2016), 399–419. doi:10.3233/SW-150200.

[43] D. Brickley, Basic Geo (WGS84 lat/long) Vocabulary, Technical Report, W3C Semantic Web Interest Group, 2006, URL: https://www.w3.org/2003/01/geo/, last visited July 2024.

[44] D. Brickley and L. Miller, FOAF Vocabulary Specification, Technical Report, 2014, Paddington Edition. URL: http://xmlns.com/foaf/spec/20140114.html, last visited July 2024.

[45] C. Maser, R.G. Anderson, K. Cromack, J.T. Williams and R.E. Martin, Dead and Down Woody Material, in: *Wildlife Habitats in Managed Forests the Blue Mountains of Oregon and Washington*, J.W. Thomas, ed., Agriculture Handbook, Vol. 553, U.S. Department of Agriculture, Forest Service., Washington, USA, 1979.

[46] M.L. Hunter (ed.), *Maintaning biodiversity in Forest Ecosystems*, Cambridge University Press, 2006.

[47] P. Gearon, A. Passant and A. Polleres, SPARQL 1.1 Update, Recommendation, W3C, 2013, URL: http://www.w3.org/TR/2013/REC-sparql11-update-20130321/, last visited July 2024.

[48] E.A. Scott, *SPA Design and Architecture: Understanding single-page web applications*, Manning Publications, 2015.

[49] P. Bryan, JavaScript Object Notation (JSON) Patch, Standards Track, RFC 6902, Internet Engineering Task Force (IETF), 2013, URL: https://datatracker.ietf.org/doc/html/rfc6902, last visited July 2024.

[50] M. Jones and D. Hardt, The OAuth 2.0 Authorization Framework: Bearer Token Usage, Standards Track, RFC 6750, Internet Engineering Task Force (IETF), 2012, URL: https://datatracker.ietf.org/doc/html/rfc6750, last visited July 2024.
[51] J. Andrade-Hoz, G. Vega-Gorgojo, I. Ruano-Benito, M.L. Bote-Lorenzo, J.I. Asensio-Pérez, F. Bravo and C. Ordóñez, EducaWood: a Socio-Semantic Annotation System for Environmental Education, in: *Proceedings of the 16th European Conference on Technology Enhanced Learning (EC-TEL 2021)*, LNCS, Springer, Cham, Switzerland, 2021, pp. 368–372. doi:10.1007/978-3-030-86436-1_37.
[52] J. Brooke, SUS – A quick and dirty usability scale, in: *Usability evaluation in industry*, P.W. Jordan, B. Thomas, I.L. McClelland and B. Weerdmeester, eds, Taylor & Francis, London, UK, 1996.
[53] J. Sauro and J.R. Lewis, *Quantifying the user experience: Practical statistics for user research*, Morgan-Kaufmann, Amsterdam, Netherlands, 2012.
[54] L. Larrieu, Y. Paillet, S. Winter, R. Bütler, D. Kraus, F. Krumm, T. Lachat, A.K. Michel, B. Regnery and K. Vandekerkhove, Tree related microhabitats in temperate and Mediterranean European forests: A hierarchical typology for inventory standardization, *Ecological Indicators* **84** (2018), 194–207. doi:10.1016/j.ecolind.2017.08.051.
[55] J.T. Sample and E. Ioup, *Tile-based geospatial information systems: principles and practices*, Springer, 2010.
[56] C. Arthur, What is the 1% rule?, 2006, URL: https://www.theguardian.com/technology/2006/jul/20/guardianweeklytechnologysection2, last visited July 2024.