FlexWood

Flexible Wood Supply Chain

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Description of Standards

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SEVENTH FRAMEWOR PROGRAMME

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Website: www.FlexWood-eu.org

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Abbreviations

CTL	Cut to length
DBMS	Database Management System
GIS	Geographic Information System
GML	Geographic Markup Language
GNU GPL	GNU is not Unix General Public License
HTML	Hyptertext Markup Language
ISO	International Organization for Standardization
KWF	Kuratorium für Wald- und Forstwirtschaft
OGC	Open Geospatial Consortium
PC	Personal Computer
RMSE	Root Mean Spare Error
SI	International System of Units (Système International d'Unités)
SME	Small and Medium Entrepreneurs
SOA	Service Orientated Architecture
SQL	Standard Query Language
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Service
XML	Extensible Markup Language
XSLT	Extensible Stylesheet Language Transformation

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1. Executive Summary

The deliverable 7.1 “Description of standards” reflects the results of an intensive collaboration between different Work packages. We give an overview of the relevant standards and their adaptions for the FlexWood system. There have been several standards and organisations identified. The main focus at this stage lies on the development of a GML-Application Profile suitable for forest inventory data derived from remote sensing data, such as Lidar, spectral and radar. GML is an XML dialect developed by the OGC and widely spread throughout the GIS-community. Other standards (e.g. StandForD and PapiNet) relevant for FlexWood in the area of timber measurement and harvesting are also described. The proposed application profile consists of two entities: stands and single trees. Both have the same structure in terms of the data model; however they include different types of parameters. The application profile is designed to meet future demands and developments. It can be modified with just changing the parameter lists without changing the schema itself. The schema is incorporated in an OGC conform Web Feature Service. This leads to a high interoperability and connectivity. A Web Feature Service is suitable for connecting to the proposed service oriented architecture of FlexWood and further more, bridging the gap between the use of aggregated results (e.g. break out, logistic analysis) through the FlexWood portal and the use of the raw data with a client GIS-Software for further analyses or processing. The data can be queried against the WFS with an open filtering language specified by the OGC.

The architecture is implemented as WFS java-servlet and Postgresql (with Postgis extension) as a backend storing the data. The system is connected to the FlexWood Integrated Controller.

2. Introduction

2.1 Objectives of the Deliverable

This report gives an overview of existing standards and their adoption to forestry applications with particular focus on the FlexWood-Project. In addition, we describe an exchange format for forest inventory data derived from new technology methods namely from the field of remote sensing. Special focus lies on utilisation of Lidar (Light detection and Ranging) data, both airborne and terrestrial acquisition. For more details see Deliverable 4.1 "Description of tree and wood resources in the forest based on novel technologies".
For development of a data format for a specific domain, we agreed on three major requirements for the new exchange format:

Reflection of forestry specific demands:
The domain of forestry deals with two different geometric forms: points and polygons. Points represent single tree related data whereas polygons relate to stand and site specific data. There are overlapping parameters for both groups, for example trees and stands can have a height attribute. However, there are significant differences too: stands are heterogeneous constructs which have often averaged and accumulated data like "dominant species".

Consideration of existing standards:
The data format must conform to all relevant standards in geomatics and computer science namely Extensible Markup Language (XML) 1.0 W3C Recommendation, OpenGIS Geography Markup Language (GML) Encoding Standard, OpenGIS Web Feature Service (WFS) Implementation Specification and ISO TC 211 family. Conforming to those standards guarantees interoperability to existing software and platforms.

Flexible and easy to implement:
The exchange format must be extensible and open. Situations and scenarios will change in future and the sector of forestry is constantly optimizing its workflows and structure. History taught us that a standard developed now has to be adapted to meet future requirements. Therefore we took care about an open structure that allows users to change parameters without losing its conformity to the mentioned standards and recommendations.

2.2 Work Package Task Status

Work Package 7000 is about designing and implementing an architecture around the support of multiple information and decision webservices along the wood product supply chain. Where possible, the architecture will be open to allow future expansion and update. It will also use current graphical display capabilities to show the results of forest measurement, harvesting and sawing.

Task 7100 Specification of geodata formats and standards
Task 7100 concerns the standards associated with Geo-information and information transfer. This is on target and has been incorporated within task 7200. The deliverable coming from this task is the present document.

Task 7200 Implementation of interfaces into wood industry existing standards
Task 7200 is the main task in designing and bringing all the component modules together. The main controller to the FlexWood portal is hosted at UCC and through web services communicates to other models representing WP4000 (measurement), WP5000 (harvesting

and logistics) and WP6000 (sawmill and post cutting analysis). The controller has been built and full interaction via XML is happeneing to the WP4000 measurement web service.
We are therefore on schedule here. Some progress at the controller side has been made towards scenario creating to set up the parameters for simulated harvesting/logistics (WP5000). Work is currently underway with WP3000 on the online negotiation aspect of WP7000.

Task 7300 Design and implementation of system architechture including information viewers and decision support interfaces
Task 7300 concerns the adherence to standards within the forest industry. The main ones here are StanforD and PapiNet which relate to our interactions with WP5000 and WP6000. Since this part of task 7200 has not been established fully their adherence has not been made.

WP 7000 Deliverables

Del. no.	Deliverable name	Delivery date	Status
7.1	Description of standards	Month 12	Current report
7.2	Design of the overall architecture	Month 24	
7.3	Connecting interfaces and viewer software package	Month 29	

3. Overview on existing standards relevant to FlexWood

In this part we would like to give an overview about the relevant standards and the institutions behind them. There are mainly three standardisation bodies relevant for the FlexWood IT-infrastructure:

3.1 W3C

"W3C's primary activity is to developing protocols and guidelines that ensure long-term growth for the Web. W3C's standards define key parts of what makes the World Wide Web work." (http://www.w3.org/Help/#activity) One can say that this institution designs the overall framework for all internet or web related developments. In FlexWood we make use of W3C specifications about XML, HTML and of course just because we use the internet.

3.2 ISO

"ISO (International Organization for Standardization) is a global network that identifies what International Standards are required by business, government and society, develops them in partnership with the sectors that will put them to use, adopts them by transparent procedures based on national input and delivers them to be implemented worldwide." (http://www.iso.org/iso/isoinbrief_2008.pdf) Almost every process and product worldwide is related to the ISO. There are overlaps with other standardization bodies, e.g. OGC standards and ISO standards. The FlexWood-system implements the ISO 19125-1 - Geographic information -- Simple feature access, ISO 19125-2 - Geographic information -- Simple feature access – SQL options, the ISO 19136 Geographic information -- Geography Markup Language (GML) and the ISO 19107 Geographic information -- Spatial schema.

3.3 OGC

"The Open Geospatial Consortium, Inc.® (OGC) is a non-profit, international, voluntary consensus standards organization that is leading the development of standards for geospatial and location based services." (http://www.opengeospatial.org). The OGC formerly known as OpenGIS consortium is working together with the ISO TC211 Geographic Information/Geomatics. FlexWood implements several OGC standards and recom-mendations:

- Web Feature Service
- Web Map Service
- Filter Encoding

Within FlexWood the focus concerning geo-standards lies on GML-Profiles and Web Feature Services in a Service Oriented Architecture (for more details see deliverable 7.2-"Design of the overall architecture"). Next, we give a detailed overview on geographic standards developed by the OGC. Parts of this section are based on earlier works from the authors in different projects like in the EC funded projects NATURNET-REDIME and GEOBENE.

4. Geographic Standards by OGC

OGC does not only publish approved standards, but also serves as a communication- and discussion platform within the geospatial community. OGC's "technical baseline document" holds links to > 140 documents describing Implementation specifications, Discussion papers, Abstract specifications, recommendation papers etc.

Therefore and due to the highly dynamic process of publishing standards, we do not only focus on approved well known standards like for instance the Web Map Service, but also on Services currently in discussion and not yet approved as standards.

4.1 OGC Reference Model

The OGC Reference Model (ORM) provides an architecture framework for the ongoing work of the OGC. Further, the ORM provides a framework for the OGC Technical Baseline. The OGC Technical Baseline consists of the currently approved OGC Specifications as well as for a number of candidate specifications that are currently in progress.

The ORM has the following purposes:
Provides a foundation for coordination and understanding (both internal and external to OGC) of ongoing OGC activities and the Technical Baseline; Update/Replacement of parts of the 1998 OpenGIS Guide; Describes the OGC requirements baseline for geospatial interoperability; Describes the OGC architecture framework through a series of non-overlapping viewpoints: including existing and future elements; Regularize the development of domain-specific interoperability architectures by providing examples.
The ORM is a living document that will be revised on a regular basis to continually and accurately reflect the ongoing work of the Consortium.
Background information for this chapter can be found at (Percivall, 2008).

Figure 1 illustrates an informative value chain for geospatial information within an enterprise or an information community. The value chain starts with geospatial information sources entering an interoperable environment, which then passes through geo-processing chains, creating intermediate value-add geospatial-based products along the way. Figure 1 shows several examples of such value-add products including fusion (combining, correlating, annotating, and interrelating geospatial information from many sources into a single structure) and analysis (operating on geospatial information for the purpose of deriving new information, extracting results or understanding its nature and significance). The last step in the value chain involves creating finished products that contain geospatial information, or are derived from geospatial information, for both internal customers and external customers. Typical products provide functions such as visualization and portrayal, reporting, analysis or information transfer and dissemination. The FlexWood system follows this chain: The first two steps are mainly performed in WP4000. Here we derive and model forests based on multi-source geospatial data. The Collaboration & Sharing tier is of great importance for the project since here the wood supply chain is accessible and modifiable by all stakeholders in the system. For example, the analysis of wood supply and demand in certain areas with respect to infrastructure and supply quality is allowed. The last tier is the products which come out of the FlexWood system. These can be detailed maps of forests of interest as well as lists of possible breakouts (products). In each tier the information dealt with has a spatial context which makes it perfect suitable for spatial data infrastructure.

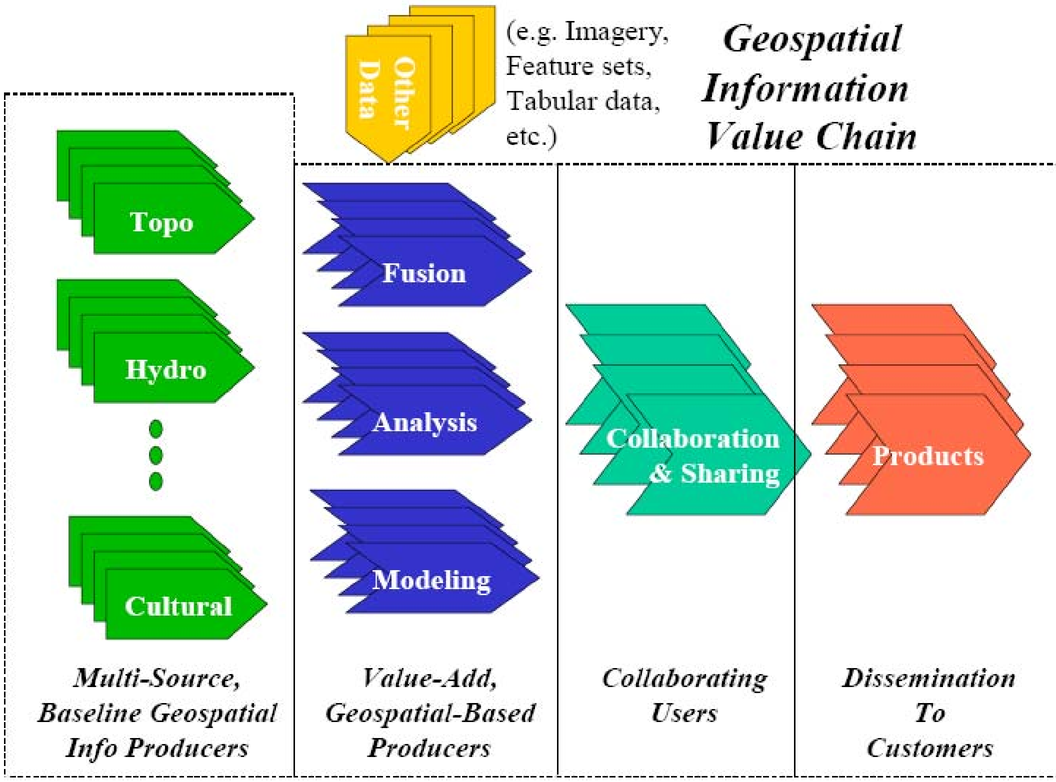


Figure 1 Geospatial Value Chain (OGC Reference Model Version 0.1.3)

4.1.1 Geographic services taxonomy

The OGC-reference modell can be found in (Percivall, 2008). For the FlexWood system we picked the well accepted geospatial services (e.g. WFS) and geospatial information models (e.g. GML) and designed an infrastrucure according to the wood sector's needs.

4.1.2 Geographic human interaction services

Geographic human interaction services shall be a category in the geographic service taxonomy. One example of a human interaction service for working with geographic data and services in FlexWood is the Geographic viewer. It is a client service that allows a user to view one or more feature collections or coverages.This viewer allows a user to interact with map data, e.g., displaying, overlaying and querying. The viewer is a main entity in our human interface concept and will be descriped in detail the upcoming deliverable 7.3 – „Connecting interface and viewer software package" due in month 29. A preview of the current work is given in Figure 2.

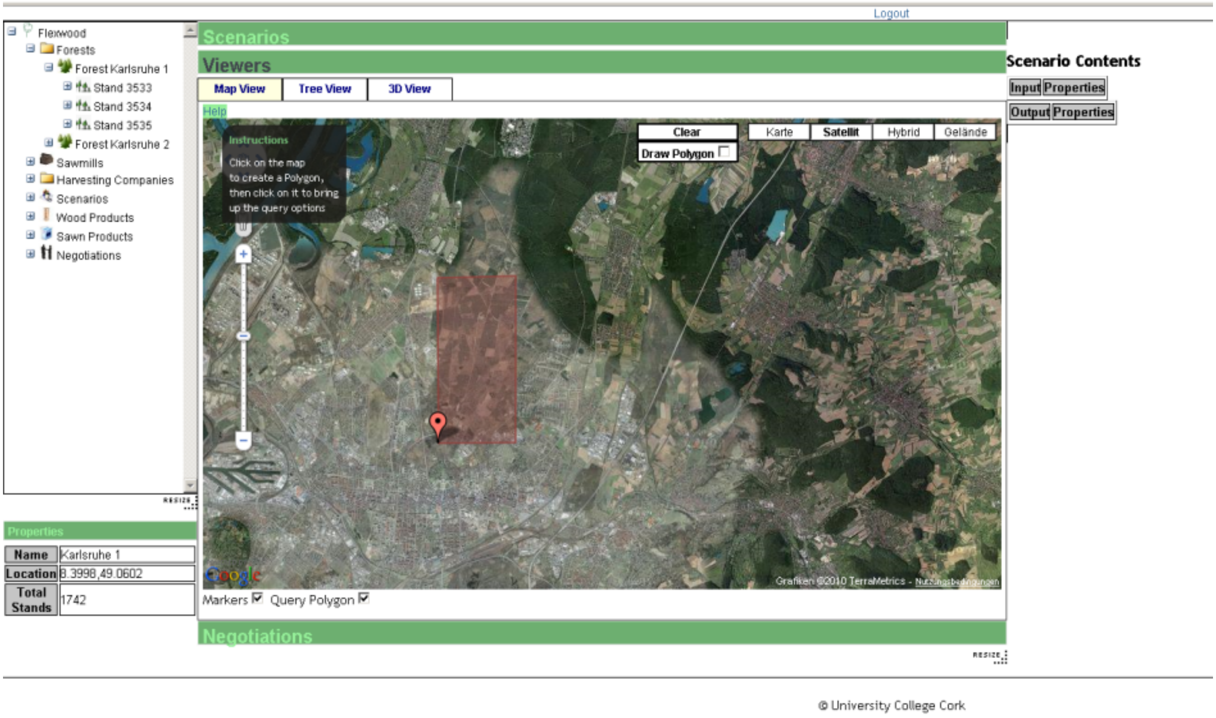


Figure 2 Preview on the FlexWood viewer. It allows interaction between web services defined by the OGC and web services from other domains.

4.1.3 Portrayal and human interface

Portrayal is the presentation of information to humans, e.g., a map. A map is a two-dimensional visual portrayal of geospatial data; a map is not the data itself. Two or more maps with the same geographic extent and coordinate reference system can be accurately layered to produce a composite map. Information types associated with geospatial data visualization are shown in the context of the portrayal process

1. Image or picture of the data, e.g., a map to be displayed.
2. Display elements, e.g., lexical description of graphics to be drawn onto the target display.

4.2 The Web Map Service (WMS)

From (de la Beaujardiere, 2006): “A Web Map Service (WMS) produces maps of spatially referenced data dynamically from geographic information. This International Standard defines a "map" to be a portrayal of geographic information as a digital image file suitable for display on a computer screen. A map is not the data itself. WMS-produced maps are generally rendered in a pictorial format such as PNG, GIF or JPEG, or occasionally as vector-based graphical elements in Scalable Vector Graphics (SVG) or interactive formats such as Openlayers. This International Standard defines three operations: one returns service-level metadata; another returns a map whose geographic and dimensional parameters are well-defined; and an optional third operation returns information about particular features shown on a map.
Web Map Service operations can be invoked using a standard web browser by submitting requests in the form of Uniform Resource Locators (URLs).

An example request regarding stands in FlexWood looks like this:

http://172.30.116.79:8080/geoserver/wms?service=WMS&version=1.1.0&request=GetMap&layers=flw:stands&bbox=8.401,49.021,8.43,49.061&width=371&height=512&srs=EPSG:4326&format=image/jpeg

The web service returnes an image of type jpge which covers a bounding box and has the designated dimensions.

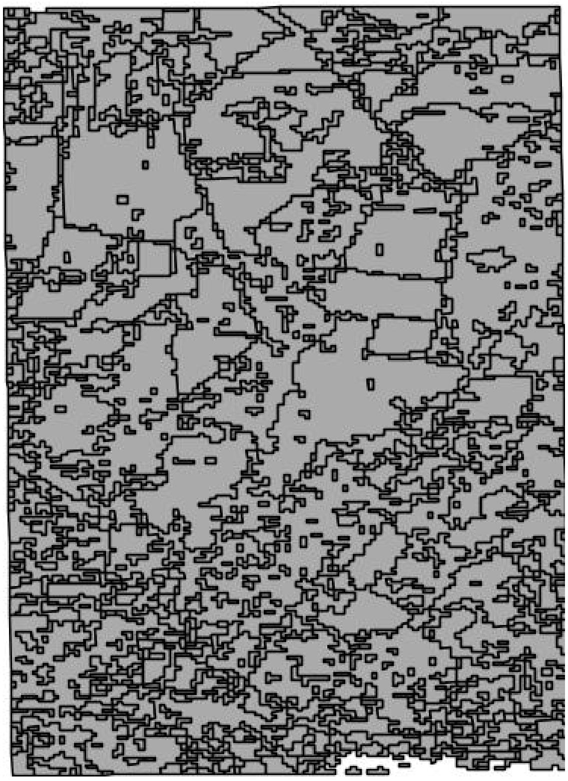


Figure 3 Return of a standard GetMap request in the FlexWood system. The pictures stands in a specific area.

4.3 Web Coverage Service (WCS)

"The Web Coverage Service (WCS) supports electronic retrieval of geospatial data as "coverages" – that is, digital geospatial information representing space-varying phenomena. A WCS provides access to potentially detailed and rich sets of geospatial information, in forms that are useful for client-side rendering, multi-valued coverages, and input into scientific models and other clients. The WCS may be compared to the OGC Web Map Service (WMS) and the Web Feature Service (WFS); like them it allows clients to choose portions of a server's information holdings based on spatial constraints and other criteria. Unlike the WMS, which portrays spatial data to return static maps (rendered as pictures by the server), the Web Coverage Service provides available data together with their detailed descriptions; defines a rich syntax for requests against these data; and returns data with its original semantics (instead of pictures) which may be interpreted, extrapolated, etc. – and not just portrayed.
FlexWood makes use of a WCS for integrating digital terrain models in the system. Terrain models are of importance when it comes to 3-D visualisation, logistics and harvesting planning.

4.4 Web Feature Service (WFS)

From (Vretanos, 2005) OGC WFS implementation specification:
"The OGC Web Map Service allows a client to overlay map images for display served from multiple Web Map Services on the Internet. In a similar fashion, the OGC Web Feature Service allows a client to retrieve and update geospatial data encoded in Geography Markup Language (GML) from multiple Web Feature Services. The requirements for a Web Feature Service are:

1. The interfaces must be defined in XML.
2. GML must be used to express features within the interface.
3. At a minimum a WFS must be able to present features using GML.
4. The predicate or filter language will be defined in XML and be derived from CQL as defined in the OpenGIS Catalogue Interface Implementation Specification.
5. The datastore used to store geographic features should be opaque to client applications and their only view of the data should be through the WFS interface.
6. The use of a subset of XPath expressions for referencing properties.

The exchange format between WFS client and server is based on the Geographic Markup Language GML."

Due to its significant relevance to the FlexWood-Project the WFS is described more in detail in this section.

Web Feature Services (WFS) and Geographic Markup Language (GML) are associated to each other but can exist independently. A WFS can be seen as a black-box which serves geographic vector data from various sources as GML (or other formats, but GML is the mandatory output format) over the web. The OGC has published several related implementation Specifications. For FlexWood the relevant documents are listed in Table 1.

Table 1 Relevant OGC specification documents

Document	Comment
OpenGIS Geography Markup Language (GML) Encoding Standard	Describes the structure and elements of gml-documents.
OpenGIS Web Feature Service (WFS) Implementation Specification	Explains the implementation of a common Web Feature Service
OpenGIS Filter Encoding Implementation Specification	Describes the syntax and parameters of filter requests in general (valid for e.g WMS, WFS, WCS)

4.4.1 Web Feature Service principles

According to the OGC specification, a standard conform WFS must be capable of handling three basic requests. These requests are the foundation of the OGC service architecture and can be found (modified) in almost all OGC web services such as Web Map Service and Web Coverage Service.

GetCapabilities

Every OGC web service must have implemented a GetCapabilities-document as an answer to a request concerning its service metadata and capabilities. The general key value pair (KVP) request looks in the FlexWood case like this:

http://FlexWood.felis.uni-freiburg.de:8080/deegree-wfs/services?service=WFS&version=1.1.0&request=GetCapabilities

Table 2 explains the parameters of the request.

Table 2 KVP encoded WFS GetCapabilities-request parameters

KVP	Description
service=WFS&	Specifies the type of service, eg. WFS, WMS, WCS
version=1.1.0&	Set the version of the service according to OGC specifications
request=GetCapabilities	Specifies the kind of request, eg. GetCapabilities, GetFeature

The WFS sends back a xml-document which follows the specification described in (Whiteside & Greenwood, OGC Web Services Common Standard, 2010). The GetCapabilities-document is separated into four sections:

```
<?xml version="1.0" encoding="UTF-8"?>
<WFS_Capabilities>
        <ServiceIdentification>
                …
        </ServiceIdentification>
        <ServiceProvider>
                ..
        </ServiceProvider>
        <OperationsMetadata>
                …
        </OperationsMetadata>
        <FeatureTypeList>
                …
        </FeatureTypeList>
        <Filter_Capabilities>
                …
        </Filter_Capabilities>
</WFS_Capabilities>
```

- ServiceIdentification:
  states the title, abstract, service type and fees along with other general information.
- ServiceProvider:
  gives detailed information about the point of contact related to the service including email-address and name of the responsible person.
- OperationsMetadata:
  provides information of the WFS´s offered operations such as “DescribeFeatureType”.
- Filter_Capabilities:
  states all filters separated in comparison and spatial filters.

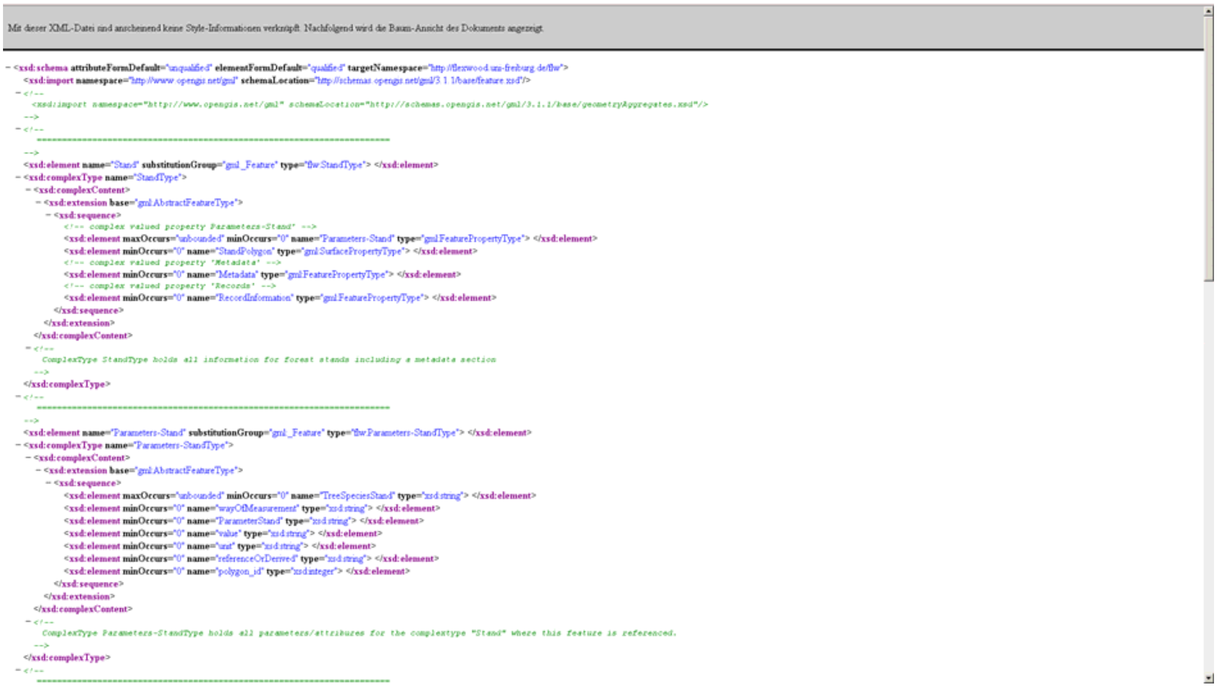
The GetCapabilites document is of importance for every client dealing with the WFS. It is the starting point of the communication between the web-service and a client.

DescribeFeatureType

The DescribeFeatureType-request returns a description of the features offered by a WFS. The response is an xml-schema document describing the structure of every feature served by the WFS. The following is an example for FlexWood,

http://FlexWood.felis.uni-freiburg.de:8080/deegree-wfs/services?service=WFS&version=1.1.0&request=DescribeFeatureType

The response of the DescribeFeatureType request will be presented in detail in section 8.1, however Figure 4 gives an impression of the response.


Mit dieser XML-Datei sind anscheinend keine Style-Informationen verknüpft. Nachfolgend wird die Baum-Ansicht des Dokuments angezeigt.


```
- <xsd:schema attributeFormDefault="unqualified" elementFormDefault="qualified" targetNamespace="http://flexwood.uni-freiburg.de/flw">
    <xsd:import namespace="http://www.opengis.net/gml" schemaLocation="http://schemas.opengis.net/gml/3.1.1/base/feature.xsd"/>
  - <!--
      <xsd:import namespace="http://www.opengis.net/gml" schemaLocation="http://schemas.opengis.net/gml/3.1.1/base/geometryAggregates.xsd"/>
    -->
  - <!--
      ======================================================================
    -->
    <xsd:element name="Stand" substitutionGroup="gml:_Feature" type="flw:StandType"> </xsd:element>
  - <xsd:complexType name="StandType">
    - <xsd:complexContent>
      - <xsd:extension base="gml:AbstractFeatureType">
        - <xsd:sequence>
            <!-- complex valued property Parameters-Stand' -->
            <xsd:element maxOccurs="unbounded" minOccurs="0" name="Parameters-Stand" type="gml:FeaturePropertyType"> </xsd:element>
            <xsd:element minOccurs="0" name="StandPolygon" type="gml:SurfacePropertyType"> </xsd:element>
            <!-- complex valued property 'Metadata' -->
            <xsd:element minOccurs="0" name="Metadata" type="gml:FeaturePropertyType"> </xsd:element>
            <!-- complex valued property 'Records' -->
            <xsd:element minOccurs="0" name="RecordInformation" type="gml:FeaturePropertyType"> </xsd:element>
          </xsd:sequence>
        </xsd:extension>
      </xsd:complexContent>
    - <!--
        ComplexType StandType holds all information for forest stands including a metadata section
      -->
    </xsd:complexType>
  - <!--
      ======================================================================
    -->
    <xsd:element name="Parameters-Stand" substitutionGroup="gml:_Feature" type="flw:Parameters-StandType"> </xsd:element>
  - <xsd:complexType name="Parameters-StandType">
    - <xsd:complexContent>
      - <xsd:extension base="gml:AbstractFeatureType">
        - <xsd:sequence>
            <xsd:element maxOccurs="unbounded" minOccurs="0" name="TreeSpeciesStand" type="xsd:string"> </xsd:element>
            <xsd:element minOccurs="0" name="wayOfMeasurement" type="xsd:string"> </xsd:element>
            <xsd:element minOccurs="0" name="ParameterStand" type="xsd:string"> </xsd:element>
            <xsd:element minOccurs="0" name="value" type="xsd:string"> </xsd:element>
            <xsd:element minOccurs="0" name="unit" type="xsd:string"> </xsd:element>
            <xsd:element minOccurs="0" name="referenceOrDerived" type="xsd:string"> </xsd:element>
            <xsd:element minOccurs="0" name="polygon_id" type="xsd:integer"> </xsd:element>
          </xsd:sequence>
        </xsd:extension>
      </xsd:complexContent>
    - <!--
        ComplexType Parameters-StandType holds all parameters/attributes for the complextype "Stand" where this feature is referenced.
      -->
    </xsd:complexType>
  - <!--
      ======================================================================
```


Figure 4 Screenshot of the DescribeFeatureType response for the FlexWood WFS.

GetFeature

A GetFeature-operation returns data according to the schema stated with a DescribeFeatureType-request. There are many restrictions possible, such as the limitation to a certain number of returned features and filtering of features. To query a feature one has to specify its name (e.g. Flw:SingleTree) and namespace (e.g. NAMESPACE=xmlns(app=http://www.FlexWood.felis.uni-freiburg.de/flw)). Again an example relevant to FlexWood is as follows,

http://FlexWood.felis.uni-freiburg.de:8080/deegree-wfs/services?service=WFS&version=1.1.0&request=GetFeature&typename=flw:SingleTree&NAMESPACE=xmlns(app=http://www.FlexWood.felis.uni-freiburg.de/flw

"Typename" can be extracted from either the GetCapabilites-document or the DescribeFeatureType-response. GetFeature returns an instance of the schema-document created by the DescribeFeatureType request. A complete return can be found in section 8.5 Full gml-output for stands and trees.

4.4.2 WFS-Implementations suitable for the FlexWood-system architecture

WFS-Implementations differ in terms of the version they support and their licensing. The OGC currently (2010) lists 108 products which conform to the WFS Implementation Specification 1.1.0. Thereof are 32 clients, 50 are servers and 26 are server and client. Our focus lies on open-source implementations with a significant large community which provides documentations and tutorials. Two major pieces of software are on the market meeting our requirements:

- geoserver[1] – a java servlet based on GeoTools. Major contributors are OpenGeo, GeoSolutions and Refraction Research.
- deegree-WFS[2] – a framework written in java. The company lat/lon is the most important contributor.

Our need to develop a dynamic and flexible application profile including nested features led to the deegree-framework since it supports GML 3-Application profiles as default. Geoserver is capable of GML 3 as well; however the implementation of application profiles seems much more cumbersome and are not a routine procedure.

4.4.3 Data-Stores

Relevant data generated within the different tasks of WP4000 –"Integrated Forest Inventory Design for Optimised Quality and Quantity Assessment of Wood Resources" need to be stored consistently and accessible for a WFS. In general, WFS accept different types of so called backends (data-stores). It is distinguished between file based stores and databases. To serve static data, e.g. administrative boarders, a file based backend, e.g. shape-files are acceptable. However, FlexWood deals with dynamic data of different quality, size and geometric composition therefore a data-base with spatial capabilities is required. The most common database management systems (DBMS) are Oracle spatial, Microsoft SQL server, IBM DB2, MySQL and Postgresql.
The open source database Postgresql with its spatial extension Postgis has been choosen as backend for the FlexWood WFS. The main reasons were its great performance and strict complaints to the SQL standard and Simple Feature Access - Part 2: SQL Option.

The database schema was developed with focus on its extendibility and flexibility for futures demands. In annex 8.2 the complete schema is shown.

[1] www.geoserver.org
[2] www.deegree.org

4.5 Extendibility

Since the complete spatial data infrastructure (SDI) of FlexWood relies on open standards it is self-evident to stress its extendibility. Project partners use the web-service to parse the GML and extract relevant information for further actions like cutting simulation or logistic optimisation. Another scenario is that forest administration or NGO´s access the database via the WFS to generate new content or use the provided information for decision support. Sticking to existing standards provides a flexible environment for upcoming changes and demands. It is easy to connect with a desktop GIS system or rendering the WFSs vector data online with the use of a Web Map Service and present a map of interest.

5. Forestry related standards incorporated in FlexWood

Within FlexWood, all information is represented in XML. Although some standards have their own format, they are moving towards XML. Therefore in FlexWood we are working with the XML format, but considering other older format standards for their content description. FlexWood does not require all the information contained within standards such as StanForD ((http://www.skogforsk.se/en/About-skogforsk/Collaboration-groups/StanForD/StanForD-2010/)) or papiNET (www.papinet.org/), instead it takes into account areas of overlap.
PapiNet is very much oriented towards the business negotiation, while StanForD is oriented towards the operational aspect of harvesting – neither of which covers the FlexWood requirements completely. In particular, FlexWood will not go into so much detail around the harvester operations (StanForD). Instead we will provide a harvest simulator to predict the wood products without cutting the trees. Business negotiation (Papinet) plays some part in the FlexWood interface by providing the environment for different parties to view the forests and use tools to simulate harvesting and sawmill cutting. However the actual transaction and monitoring the shipping of products is not part of the FlexWood remit and so PapiNet is not completely relevant. The current status of the FlexWood project means that the interaction with these standards is not fully realised. However, the intention as with the measurement data is to adhere as much as possible while at the same time influencing any standard for future versions. Our immediate adoption of XML has in a sense put us ahead of many standards.

Standards in harvesting
In FlexWood we pass descriptions about a set of tree stems or a stand description to a harvest simulator along with harvesting instructions. We receive back a set of wood products, typically logs. The concepts of stems and logs are both present in StanForD. However, much of the standard refers to products from the actual harvesting machine. At that stage, when the tree has been cut, we know much more about the output products. FlexWood simulates this process and so the level of detail is not so great. StanForD describes the output in a thp file (total harvested production) and this contains a subset of attributes we require in FlexWood – but represented in XML. The input in FlexWood is first the diameter classes which appears in StanForD within the Production Instruction file. Demand is the second input and this is represented indirectly in StanForD through the APT file format which is instructions for the harvester towards that type of demand. FlexWood also passes APT files for the simulator to use. APT files are then current standard way of describing to a harvester (or harvest simulator) how it should behave in the way it chooses to cut each stem.
In the following subchapters the two above mentioned standards (StandForD and Stand) are described.
The following section describes briefly the most relevant standards regarding forestry.

5.1.1 StanForD – Standard for Forest Data and Communication

Abstract of the standard
StanForD, Standard for Forest Data and Communication, is a de-facto standard implemented by all manufacturers of cut-to-length harvesting machines. The standard was originally developed to handle communication with bucking computers in harvesters in a standardized way. Today, StanForD covers data communication as well as a set of standardized file types and variables that are used for bucking instructions, production reporting and follow-up in harvesters and forwarders. Skogforsk, the Forestry Research Institute of Sweden, is coordinating the administration and development of the standard.

History and Development

In the mid 1980s, manufacturers of cut-to-length harvesters started introducing bucking computers to assist in optimizing the bucking procedure. In order to facilitate communication with bucking computers independent of computer model, standardized communication protocols were developed as the first parts of StanForD in 1987-88. The next step in developing the standard was the creation of apt-files, i.e., bucking instructions used to control the bucking computer. A third step was to create a standardized model for production reporting, which was obtained by prd-files that summarize production. Today, StanForD consists of approximately 800 variables, 20 different file types, and a communication protocol based on Kermit. All data are stored and transferred in ASCII format.

StanForD was built upon a few basic principles: small-size files to allow data communication even when there are limited possibilities to transfer data, a high degree of flexibility so that new variables could be added when needed and full compatibility backwards so that no variables can be removed. These principles have lead to a rapidly increasing size of the standard.

In May 2008, the StanForD members decided to upgrade the standard to meet the demands of modern computer communication as well as getting a possibility to remove unutilized parts of the old standard. The new version, StanForD 2010, is built on the XML format and is to be introduced in 2011.

Field of Standardization

StanForD was developed as a standardized way of communicating with the computer of a forest machine, mainly for production control and follow-up. However, some of the information included in the standard can be used as a basis for business transactions, e.g., for paying the forest owner or the machine owner.

Standardization Body

The standard is coordinated by Skogforsk since the beginning in 1987 with participation from all major machine manufacturers in northern Europe as well as Swedish and Finnish forest companies. Two official open work meetings are arranged each year where decisions are taken concerning updates and changes of the standard. The working language today is English and all documents can be found at www.skogforsk.se.

The administrative costs for the standard are covered by the machine manufacturers together with the Swedish forest companies. The manufacturers that financially contribute are called member companies. These companies are Komatsu Forest (Valmet), John Deere, Ponsse, Rottne, Dasa, Parker (Motomit), LogMax and SDC. The Finnish forestry sector and forest industry contribute financially to StanForD through the work done by Finnish R&D company Metsäteho.

Short Demonstration Example

StanForD is a standard under continuous development, deeply influenced by the users of forest machines. An illustration of that is the addition of a new file type – Geographic Harvesting Data – that is used to standardize presentation of harvesting directives in a GIS environment.

Forest companies have traditionally produced a harvesting directive including maps printed on paper and sent to the machine operators or owners by mail. Today nearly all CTL-machines in Scandinavia are equipped with PC and GPS when delivered from the factory. An initiative was therefore taken by some of the Swedish forest companies to develop a standard for transferring these directives in an electronic format directly to the forest machines. The standard was therefore updated with a new file type called ghd (Geographic Harvesting Data). The ghd-file includes references to all relevant GIS-files (for example shp, dbf, shx, jpg, jgw), that are needed in the GIS application. The file also describes how the different GIS layers should be presented regarding for example color, symbols, orders etc.

The standard thus makes it possible to present the maps in a uniform way independently of what GIS application/machine is used.

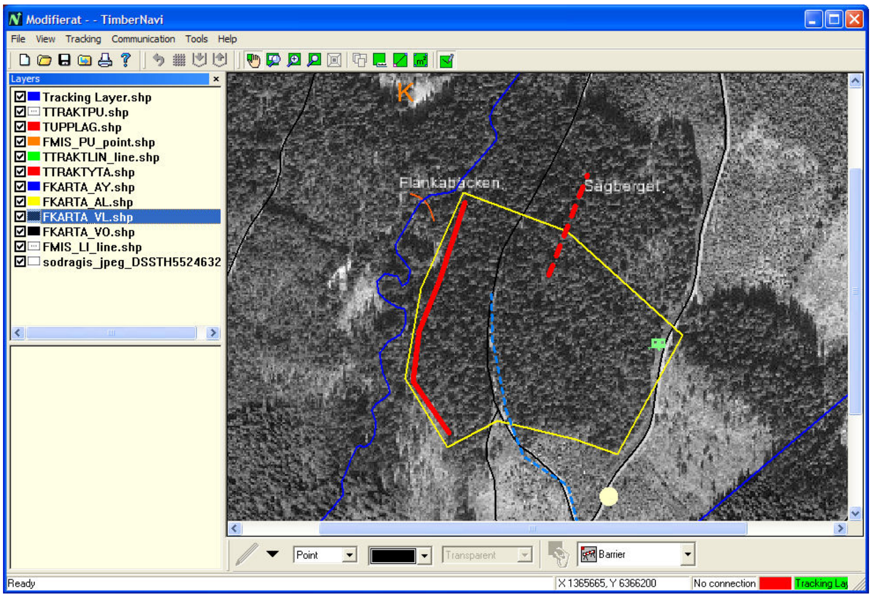


Figure 5 Example of standardized geographical harvesting directive

Distribution and Acceptance
StanForD is today a de-facto standard in the cut-to-length harvesting system, implemented by all manufacturers of harvesting machinery.

5.1.2 Stand

Standards in forest Measurement
The Swedish Forest Measurement Initiative (acronym “Stand”) from the Swedish Standard Institute (www.sis.se) is work in progress. Their plan is to have a proposal of the standard out in January 2012, but already in spring 2011 they expect to have the fundamental parts in place. The standard will consider inventory data, forestry treatments and other forest information required in forest planning such biodiversity, recreational values, etc. Inventory data is of particular interest for FlexWood and in particular its inclusion of different field inventories and methods for remote sensing. However, without a published standard, we in FlexWood, through Andreas Barth of Skogforsk, are sharing our experiences with SIS in how we represent the various inventory data from aerial and terrestrial information.

Abstract of the standard
The use of digital data and information has increased in forestry applications as well as in other parts of society. Data are used for planning and modeling in data systems, often tailor-made for a specific organization. When data need to be transferred to another system, e.g., when wood or land is traded or when compartment descriptions are updated with new inventory measurements, problems arise if two systems cannot easily communicate. In response to this problem, a common Swedish data standard for forest data is under development. The work is coordinated by SIS, Swedish Standards Institute, and a technical committee is outlining the details of the coming standard. The Swedish forestry sector is represented by Skogforsk, the Forestry Research Institute of Sweden, who also holds the chairman position of the technical committee.

History and Development

In order to investigate the need for a common data standard for forest data and information, a group of four companies and organizations – Sveaskog, Skogssällskapet, the Swedish Forest Agency and LRF Skogsägarna (The Swedish Federation of Forest Owners) – contracted Skogforsk to lead a feasibility study on the topic. The study showed that there is a large support and need for a national standard for forest data among stakeholders. It was concluded that the standardization work was best done with the support of SIS, Swedish Standards Institute. Therefore, in February 2010, a technical committee was constituted to work out the details of a standard for forest data and information. The work is in progress and is planned to last for three years, i.e., the standard is to be ready for publication in February 2013.

Field of Standardization

The degree of digitalization of forest inventory data is increasing, and so is the need to facilitate transfer of such digital data between different users and software systems. Today, data must be converted and often manually treated to be transferred between two different types of systems, since there is no common data standard in use.

The aim of the standardization initiative for forest data is to facilitate information exchange between Swedish organizations in order to increase efficiency and competitiveness. The goal is to obtain a system where digital forest data can be handled automatically and without loss of information.

Standardization Body

The Standard for forest data and information is administrated by SIS, Swedish Standards Institute. SIS holds extensive experience from other work with both national and international geographical data standards. The standard for forest data and information is open for anyone to join, and paying members of the standard are organized in a steering committee and a technical committee. The Swedish forestry sector is represented by Skogforsk, who also holds the chairman position of the technical committee.

Standard documents can be found at www.sis.se/stanli.

Distribution and Acceptance

All major software manufacturers and user groups within the field of forest inventory data in Sweden have been asked to take part in the standardization process to ensure a strong basis for the coming standard. The standard is primarily intended to be a Swedish national standard.

The next Section describes in Details the Web Feature Service and the Application Profile used in the Project.

6. Schema implementation

This section shows the actual implementation of the schema described in section 2. We will present the xml-schema code with an instance of the feature.

6.1 Namespaces and schema import

The application profile is in the target namespace http://FlexWood.felis.uni-freiburg.de/flw" with the prefix “flw”. An instance fragment looks like this:

```
<flw:ParameterSingleTree>total heights</flw:ParameterSingleTree>
```

GML3 is dependent on several schemas describing the functionality, data types and structure of a GML3 instances. The relevant schema is imported in the application schema.

```
<xsd:import namespace="http://www.opengis.net/gml" schemaLocation="http://schemas.opengis.net/gml/3.1.1/-base/feature.xsd"/>
```

feature.xsd defines the gml-feature structure. It includes among others the references to geometry properties (e.g. PointPropertyType) and abstract super types (e.g. AbstractFeatureType). All other dependent schemata will be imported from here automatically.

6.2 Feature definitions

The FlexWood gml-application profile is made up of six features:

- Stand
- Parameter-Strand
- SingleTree
- Parameter-SingleTree
- Metadata
- RecordInformation

Their xml-representation is shown in the next sections. The complete schema can be found in annex 8.3 Full GML-Application Schema.

6.2.1 Stand

```
<xsd:element name="Stand" substitutionGroup="gml:_Feature" type="flw:StandType">
</xsd:element>
<xsd:complexType name="StandType">
		<xsd:complexContent>
			<xsd:extension base="gml:AbstractFeatureType">
				<xsd:sequence>
					<xsd:element maxOccurs="unbounded" minOccurs="0" name="Parameters-Stand"
type="gml:FeaturePropertyType">
					</xsd:element>
					<xsd:element minOccurs="1" name="StandPolygon" type="gml:SurfacePropertyType">
					</xsd:element>
					<!-- complex valued property 'Metadata' -->
					<xsd:element minOccurs="0" name="Metadata" type="gml:FeaturePropertyType">
					</xsd:element>
					<!-- complex valued property 'Records' -->
					<xsd:element minOccurs="0" name="RecordInformation" type="gml:FeaturePropertyType">
					</xsd:element>
				</xsd:sequence>
			</xsd:extension>
		</xsd:complexContent>
</xsd:complexType>
```

The first line declares the feature Stand as a type flw:StandType. Within in the subsequent complex element “StandType” the feature is defined. The “xsd:extension” declares the feature as derived from AbstractFeatureType. The elements within the sequence refer to the actual visible instances.

The first element “Parameters-Stand” is directly a nested feature. The type gml:FeaturePropertyType makes clear that this element is refers to another feature. MaxOccurs=unbounded and minOccurs=0 specify the multiplicity. “Parameters-Stand” must not be instantiated but can be instantiated unlimited times. One can represent just a stand-geometry without further parameters or attach a set of unlimited parameters.

The geometry element “StandPolygon” is of type “SurfaceGeometryType”. It is further described in section 2.1 Structure of GML.

The next two elements are technically identical to the “Parameters-Stand” feature. They are both nested features and must be instantiated once.

6.2.2 Parameters-Stand

```
<xsd:element name="Parameters-Stand" type="flw:Parameters-StandType" substitutionGroup="gml:_Feature"/>
<xsd:complexType name="Parameters-StandType">
		<xsd:complexContent>
			<xsd:extension base="gml:AbstractFeatureType">
				<xsd:sequence>
					<xsd:element name="TreeSpeciesStand" type="xsd:string" minOccurs="0"
maxOccurs="unbounded"/>
					<xsd:element name="wayOfMeasurement" type="xsd:string" minOccurs="0"/>
					<xsd:element name="ParameterStand" type="xsd:string" minOccurs="0"/>
					<xsd:element name="value" type="xsd:string" minOccurs="0"/>
					<xsd:element name="unit" type="xsd:string" minOccurs="0"/>
					<xsd:element name="referenceOrDerived" type="xsd:string" minOccurs="0"/>
					<xsd:element name="polygon_id" type="xsd:integer" minOccurs="0"/>
				</xsd:sequence>
			</xsd:extension>
		</xsd:complexContent>
</xsd:complexType>
```

Parameters-Stand describe the parameters related to the feature Stand. It follows the same principle as in “Stands”, expect it doesn´t contain nested features.

6.2.3 SingleTree

```
<xsd:element name="SingleTree" type="flw:SingleTreeType" substitutionGroup="gml:_Feature"/>
<xsd:complexType name="SingleTreeType">
		<xsd:complexContent>
				<xsd:extension base="gml:AbstractFeatureType">
						<xsd:sequence>
								<xsd:element name="Parameters-SingleTree" type="gml:FeaturePropertyType" minOccurs="0"
maxOccurs="unbounded"/>
								<xsd:element name="SingleTree_Stem_Position" type="gml:PointPropertyType" minOccurs="0"/>
								<xsd:element name="SingleTree_CrownTop_Position" type="gml:PointPropertyType" minOccurs="0"/>
								<xsd:element name="SingleTree_Optional_Position" type="gml:PointPropertyType" minOccurs="0"/>
								<xsd:element name="CrownPolygon" type="gml:SurfacePropertyType" minOccurs="0"/>
								<!-- complex valued property 'Metadata' -->
								<xsd:element name="Metadata" type="gml:FeaturePropertyType" minOccurs="0"/>
								<!-- complex valued property 'Records' -->
								<xsd:element name="RecordInformation" type="gml:FeaturePropertyType" minOccurs="0"/>
						</xsd:sequence>
				</xsd:extension>
		</xsd:complexContent>
</xsd:complexType>
```

The feature SingleTree is identically built than the Stand-feature however the geographic elements such as tree and crown position are of PointPropertyType and the CrownPolygon is of SurfacePropertyType.

6.2.4 Parameters-SingleTree

```
<xsd:element name="Parameters-SingleTree" type="flw:Parameters-SingleTreeType" substitutionGroup="gml:_Feature"/>
<xsd:complexType name="Parameters-SingleTreeType">
		<xsd:complexContent>
				<xsd:extension base="gml:AbstractFeatureType">
						<xsd:sequence>
								<xsd:element name="TreeSpeciesSingleTree" type="xsd:string" minOccurs="0" maxOccurs="unbounded"/>
								<xsd:element name="wayOfMeasurement" type="xsd:string" minOccurs="0"/>
								<xsd:element name="ParameterSingleTree" type="xsd:string" minOccurs="0"/>
								<xsd:element name="value" type="xsd:string" minOccurs="0"/>
								<xsd:element name="unit" type="xsd:string" minOccurs="0"/>
								<xsd:element name="referenceOrDerived" type="xsd:string" minOccurs="0"/>
						</xsd:sequence>
				</xsd:extension>
		</xsd:complexContent>
</xsd:complexType>
```

Parameters-SingleTree is differs only in terms of its relation to single trees from the feature Parameters-Stand.

6.2.5 Metadata

```
<xsd:element name="Metadata" type="flw:MetadataType" substitutionGroup="gml:_Feature"/>
<xsd:complexType name="MetadataType">
		<xsd:complexContent>
				<xsd:extension base="gml:AbstractFeatureType">
						<xsd:sequence>
								<xsd:element name="metadata_id" type="xsd:integer" minOccurs="0"/>
								<xsd:element name="AccuracyLlevel" type="xsd:decimal" minOccurs="0"/>
								<xsd:element name="Methods" type="xsd:string" minOccurs="0"/>
								<xsd:element name="Publication" type="xsd:string" minOccurs="0"/>
								<xsd:element name="Notes" type="xsd:string" minOccurs="0"/>
						</xsd:sequence>
				</xsd:extension>
		</xsd:complexContent>
</xsd:complexType>
```

The metadata-feature is similar structured than the other features mentioned above.

6.2.6 RecordInformation

```
<xsd:element name="RecordInformation" type="flw:RecordInformationType" substitutionGroup="gml:_Feature"/>
<xsd:complexType name="RecordInformationType">
		<xsd:complexContent>
			<xsd:extension base="gml:AbstractFeatureType">
				<xsd:sequence>
					<xsd:element name="NameOfUploader" type="xsd:string" minOccurs="0"/>
					<xsd:element name="NameOfUpload" type="xsd:string" minOccurs="0"/>
				</xsd:sequence>
			</xsd:extension>
		</xsd:complexContent>
</xsd:complexType>
```

Recordinformation consists of just two elements of type string.

6.3 Software Implementation

The Web Feature Service used in FlexWood is based on deegree for the reasons described in section 1.4.3. The specific implementation is set up in a Tomcat6 servlet container with a Postgresql 8.4 – Postgis 1.4 backend solution. The running degree release is 2.3.

6.3.1 deegree

To run our application profile with degree it is a prerequisite to work with a database backend instead of a file based backend, which would be in general possible.
The degree configuration is done in two files: wfs.xml and yourapplicationprofile.xsd. Wfs.xml holds general configuration parameters such as timeout limits and maximal number of features served by the wfs as well as ogc specific parameters. The latter are basically related to the GetCapabilites-operation which gives information such as contact person and operation hours.
The yourapplicationprofile.xsd document designs the schema returned by a DescribeFeature-operation. It is structured in two sections: 1. Configuration of the backend and 2. Configuration of the elements.

To give a short impression how an application profile can map a database schema an example is presented.

We look at two tables: tbl_stands and lut_parameter_stands. In the stand-table we have a column parameter_stand which holds a foreign-key to table lut_parameter_stands. This relationship can be expressed in the yourapplicationprofile.xsd with the following xml-fragment.

```
<xsd:element name="ParameterStand" type="xsd:string" minOccurs="0">
		<xsd:annotation>
			<xsd:appinfo>
				<deegreewfs:Content>
					<deegreewfs:MappingField field="parameter_stand" type="VARCHAR"/>
						<deegreewfs:Relation>
						<deegreewfs:From>
						<deegreewfs:MappingField field="parameter_stand_id" type="INTEGER"/>
						</deegreewfs:From>
						<deegreewfs:To fk="true">
						<deegreewfs:MappingField field="parameter_stand_id" type="INTEGER"
table="lut_parameter_stands"/>
						</deegreewfs:To>
						</deegreewfs:Relation>
				</deegreewfs:Content>
			</xsd:appinfo>
		</xsd:annotation>
</xsd:element>
```

The deegreewfs-namespace indicates that here vendor specific configuration parameters are set. We set a relation between to tables in which the “from-table” is set in the Parameters-

Stand element (tbl_stands). The MappingField element sets the column, type of data and table in its attributes. With this structure one can reflect arbitrary relations between elements and tables in a database. For more information on setting up deegree please refer to the user manual available at www.deegree.org.

6.3.2 Database

For a flexible and future-oriented data-storage design we applied normalization on the database structure. The normalization level reached is the 3. Normal Form. This ensures the data integrity and prevents data anomalies, however to load data into the database becomes a bit more complex. To overcome this constraint we developed a python command-line tool to load ESRI-shape-files of type point and polygon into the backend. The FlexWood-database schema can be found in annex 8.2 Database schema.

7. Conclusions

In this section we want to discuss some points which came up during the development process and the running system. We want to address among others performance issues, interoperability capabilities and the flexible design.

7.1 Performance

We experienced problems in parsing the data in a browser and GIS-desktop-client when it comes to a large number of single trees. The Problem here is the large data overhead which is naturally to xml. The below example illustrates the effect. The first box represents the information of one single tree in plain text.

Information:
ID=SINGLETREE_151918
Position=8.410309171282528 49.05796233872338
CRS=EPSG:4326
WayOfMeasurement=indirect
ParameterSingleTree=heights
Value=17.21
Unit=m
referenceOrDerived=derived
metadataID=8
AccuracyLevel=80
Method=Watershed
Publication=Heinzel, et al.
Notes=none
Name of uploader = Andreas Fritz
Upload name = single tree demonstration

The second box shows the same information in valid GML. One can see right away the enourmus data overhead. To overcome this difficulty there are two possibilities. On one hand it is possible to check before requesting a set of features how many of them to expect. To achieve this behaviour one has to add the MaxFeature="hits" keyword to the KVP. The complete respond looks like this (without GML-specific headers):

```
<wfs:FeatureCollection timeStamp="2010-11-02T20:18:09.776" numberOfFeatures="151918"/>
```

The second option is to use filter expression to limit the output to a reasonable amount of information. Filter expressions are a powerful toolset to query the data a WFS contains. Possible filters are comparison operators like "greater than", "equal" or "like". The most remarkable operators are spatial filters which enable the user to perform spatial queries as "overlap", "intersect" or "within". The FlexWood portal described in deliverable 7.2 makes heavy use of filter operations.

```
<gml:featureMember>
	<app:SingleTree gml:id="SINGLETREE_151918">
		<gml:boundedBy>
			<gml:Envelope srsName='EPSG:4326'>
				<gml:lowerCorner>8.410309171282528 49.05796233872338</gml:lowerCorner>
				<gml:upperCorner>8.410309171282528 49.05796233872338</gml:upperCorner>
			</gml:Envelope>
		</gml:boundedBy>
		<app:Parameters-SingleTree>
			<!-- xlink:href="#PARAMETER-SINGLETREE_154967" -->
			<app:Parameters-SingleTree gml:id="PARAMETER-SINGLETREE_154967">
				<app:wayOfMeasurement>indirect</app:wayOfMeasurement>
				<app:ParameterSingleTree>heights</app:ParameterSingleTree>
				<app:value>17,21</app:value>
				<app:unit>cm</app:unit>
				<app:referenceOrDerived>derived</app:referenceOrDerived>
			</app:Parameters-SingleTree>
		</app:Parameters-SingleTree>
		<app:SingleTree_Stem_Position>
			<gml:Point srsName="EPSG:4326">
				<gml:pos>8.410309171282528 49.05796233872338</gml:pos>
			</gml:Point>
		</app:SingleTree_Stem_Position>
		<app:Metadata>
			<!-- xlink:href="#METADATA_8" -->
			<app:Metadata gml:id="METADATA_8">
				<app:metadata_id>8</app:metadata_id>
				<app:AccuracyLlevel>80</app:AccuracyLlevel>
				<app:Methods>watershed</app:Methods>
				<app:Publication>Heinzel, et al.</app:Publication>
				<app:Notes>none</app:Notes>
			</app:Metadata>
		</app:Metadata>
		<app:RecordInformation>
			<!-- xlink:href="#RECORD_8" -->
			<app:RecordInformation gml:id="RECORD_8">
				<app:NameOfUploader>Andreas Fritz</app:NameOfUploader>
				<app:NameOfUpload>single tree demonstration</app:NameOfUpload>
			</app:RecordInformation>
		</app:RecordInformation>
	</app:SingleTree>
</gml:featureMember>
```


7.2 Interoperability

Interoperability was a main goal to achieve within task 7100. With GML we are a great step closer to overcome the digital wall of different formats and data types. We showed that GML is an adequate format to meet future demands in information technology and due to its XML character it can be integrated in any piece of software or web application regardless if it supports GML natively or not by parsing it externally.

We have chosen two common open-source GIS desktop clients to test the WFS and its application profile against interoperability. The first candidate is gvSIG[3], which is maintained by the gvSIG Association. Its origin lies in Spain where it was developed in cooperation of public authorities and SMEs. The second candidate is OpenJUMP[4]. It is published under GNU GPL and widely spread through the GIS community due to its extensibility with plugins (e.g. WFS-plugin) and good support for GML.
Both, OpenJump and gvSIG can handle WFS version 1.1.0 services. This makes them one of the most innovative desktop applications available on market at the moment.

We successfully displayed the two features Stand and SingleTree in both of them, however we were facing some inconveniences. The problems mentioned in the previous section (6.1) are manifesting here in a sensible manner. Just adding the complete feature SingleTree results in a breakdown of the client since the file to parse is way too big. Both clients allow

[3] http://www.gvsig.org/web/
[4] http://www.openjump.org/

filtering the results before loading in them from the web service. In addition one can set the maximum number features requested from the WFS.
The other problem which came up when testing the clients was, that they were both not capable of handling nested features. gvSIG displayed instead the plain GML-code. OpenJUMP just returned the name of the nested feature but didn´t show its instances. At least the developers of OpenJump are working according to mailing lists on this feature, so in future this limitation might be abonded.

7.3 Flexibility

In month 12 this deliverable is describing the geographic standards used in FlexWood so far. We are aware of the fact that the parameters and even the application profile itself will go through changes since the project has just passed a third of its duration. One characteristic of the application profile is its openness. We intentional avoided constructs similar to

<flw:tree_height_in_meter>17.21</flw:tree_height_in_meter>

since they are extremely definite. To change the unit of the parameter height would have the consequence of changing the whole profile. All partners within the FlexWood SOA would need to change their communication settings (e.g. modify the parser). With the presented design this change would not be a problem at all.

When starting to develop this schema we were far from knowing the exact parameters FlexWood will incorporate within the projects duration. This automatically led us to an open and flexible design. Incorporating new or dumping existing parameters doesn't has a change in the XML in consequence. It will be changed just on the backend in adding or deleting entries in the lookup tables.

7.4 Outlook

For the last 12 month we were utilizing various standards from the field of computer science and forestry. The Deliverable 7.2 – "Design of the overall architecture" and 7.3 – "Connecting Interfaces and viewer software packages" are going to describe how and what standards we incorporate. So far StandForD, Eldat or the WMS and WCS Implementations Specifications were not regarded with respect to their full capabilities. Further work need to be done in optimizing the application-schema and visualisation of inventory data.

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9. Appendix

9.1 Description of the schema

The previous section gives a short overview of the Geographic Markup Language. In this section the use of such a language is described with the background of the project. We propose a schema meeting the demands identified within work package 3000, 4000 and 7000.

9.1.1 Structure of GML

In GML features represent a real world phenomenon. Features can have properties of geographic content and not. Objects within features can be nested. Figure 3 demonstrates a feature and its possible content. A feature can consist of several simple, complex features and geometries (A). In (B) a Stand feature and its property children are described where the parameters-property consists of a parameter feature.

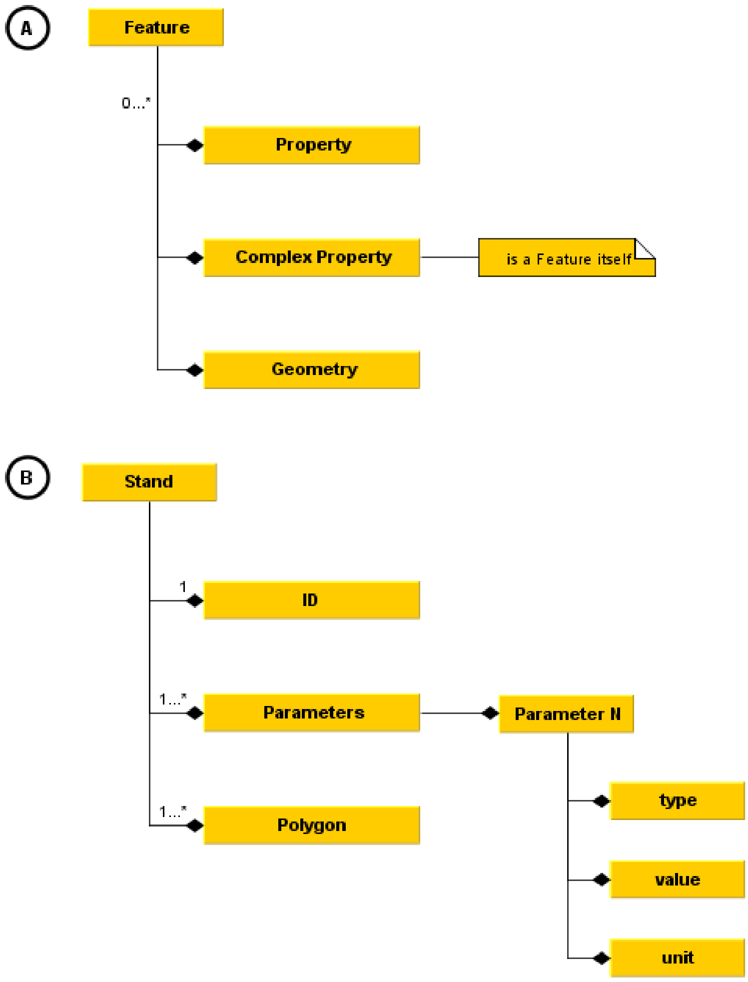


Figure 6 GML feature schema. A Feature can consists of serveral properties and other features (nested features). The cardinality is arbritary.

In GML-schema representation such a construct looks like the xml-code below.

```
<xsd:element name="Stand" type="flw:StandType" substitutionGroup="gml:_Feature"/>
<xsd:complexType name="StandType">
	<xsd:complexContent>
		<xsd:extension base="gml:AbstractFeatureType">
			<xsd:sequence>
				<xsd:element name="ID" type="xsd:integer"/>
				<!-- complex valued property Parameters-->
				<xsd:element name="Parameters" type="gml:FeaturePropertyType" minOccurs="0" maxOccurs="unbounded"/>
				<xsd:element name="Polygon" type="gml:SurfacePropertyType" minOccurs="0"/>
			</xsd:sequence>
		</xsd:extension>
	</xsd:complexContent>
</xsd:complexType>
<!-- =================================================================== -->
<xsd:element name="Parameters-Stand" type="flw:Parameters-StandType" substitutionGroup="gml:_Feature"/>
<xsd:complexType name="Parameters-StandType">
	<xsd:complexContent>
		<xsd:extension base="gml:AbstractFeatureType">
			<xsd:sequence>
				<xsd:element name="ParameterStand" type="xsd:string" minOccurs="0"/>
				<xsd:element name="value" type="xsd:string" minOccurs="0"/>
				<xsd:element name="unit" type="xsd:string" minOccurs="0"/>
			</xsd:sequence>
		</xsd:extension>
	</xsd:complexContent>
</xsd:complexType>
```

It shows two elements: “Stand” and “Parameters-Stand”. Each are of type “flw:StandType” and “flw:Parameters-StandType”. The prefix “flw:” specifies the namespace of the elements. The types of the elements are defined in complexTypes. With this xml-technique one can generate arbitrary reusable types for elements.

Lets have a closer look at the StandType. The substitution group is set to “gml:_Feature” which just means that the element is a feature. gml:_Feature is part of the abstract data type gml:AbstractFeatureType. xsd:sequence holds the elements of the type in the strict order as they appear in the schema. The first element has the name “ID” and is of type xsd:integer. The namespace shows that this element has a xml-schema standard data type such as xsd:string, xsd:Boolean or xsd:anURI. The next element “Parameters” is of type “gml:FeaturePropertyType”. It declares the element to a container for another feature. “minOccurs” and “maxOccurs” are standard xml tags and define how often this element must be instantiated.

The last element “Polygon” is a gml:SurfacePropertyTye type. The name already gives a hint what to expect from such a type. The SurfacePropertyType specifies the element in terms of its geometry, in detail its surface. This type defines among others how polygons will be instantiated. We use PointPropertyType to represent single tree positions.

The element “Parameters-Stand” is of type “flw:Parameters-StandType” defined as complexType. It is the same principle as in the “flw:StandType”. One has to be aware of the fact that GML makes excessive use of defining derived types in its schema definitions.

For more details see (Cox, Daisey, Lake, Portele, & Whiteside, 2004) and (Burggraf, 2003).

The next section explains the FlexWood data-model in detail. Features and Relationships are described with corresponding examples.

9.1.2 FlexWood data-model for forest inventory data derived from remote sensing

Literature shows that various stand and single tree based parameters can be derived from remote sensing data. Great improvements have been made in this field introducing Lidar technology for measuring trees and stands concerning their three-dimensional charateristics. A state of the art survey and current research are presented in deliverable 4.1 “Description of tree and wood resources in the forest based on novel technologies” due to month 24 of the project. The FlexWood architecture is based on a service oriented architecture (SOA) (for details see deliverable 7.3 month 24). Therefore the communication between services is based on xml. Forest inventory data does always have a geographic component. Tree positions, stand polygons, roads lines are major geographic properties in forest inventory. The previous described GML satisfies our need to reflect this geo-attributes in inventory data. Stands and trees are modelled with respect to their spatial dimension. Figure 4 shows a tree and stand with their spatial attributes in the FlexWood-System and their correspondence at a tree.

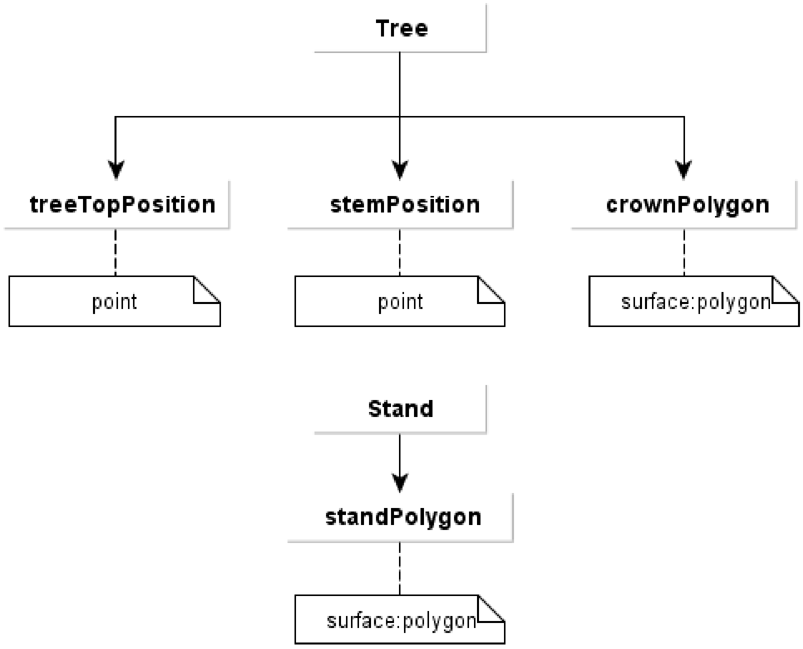


Figure 7 The two entities tree and stand with their spatial attributes.

Apart the spatial attributes the two entities have non spatial attributes. The next section describes in detail all attributes optional or mandatory for trees and stands.

9.1.2.1 Parameters single tree

A single tree feature consist of several attributes and features in a hierarchic structure. Figure 5 gives an overview of the tree model in FlexWood. A tree is a two-tier approach. The spatial information is on the top level. Aggregated parameters, metadata and record information are “boxed” in separate features. These features have a depth of one, so they hold the second level. The knowledge of this structure becomes relevant for using filter expressions against the WFS. The following section goes in detail through all features and parameters.

Parameters

SingleTree-Parameters is a feature itself. It consists of six non-spatial attributes:

species
the element species holds the information about species. It is of type string, but uses a list of values which are allowed when instantiated. The list is hold in a separate lookup-table in the

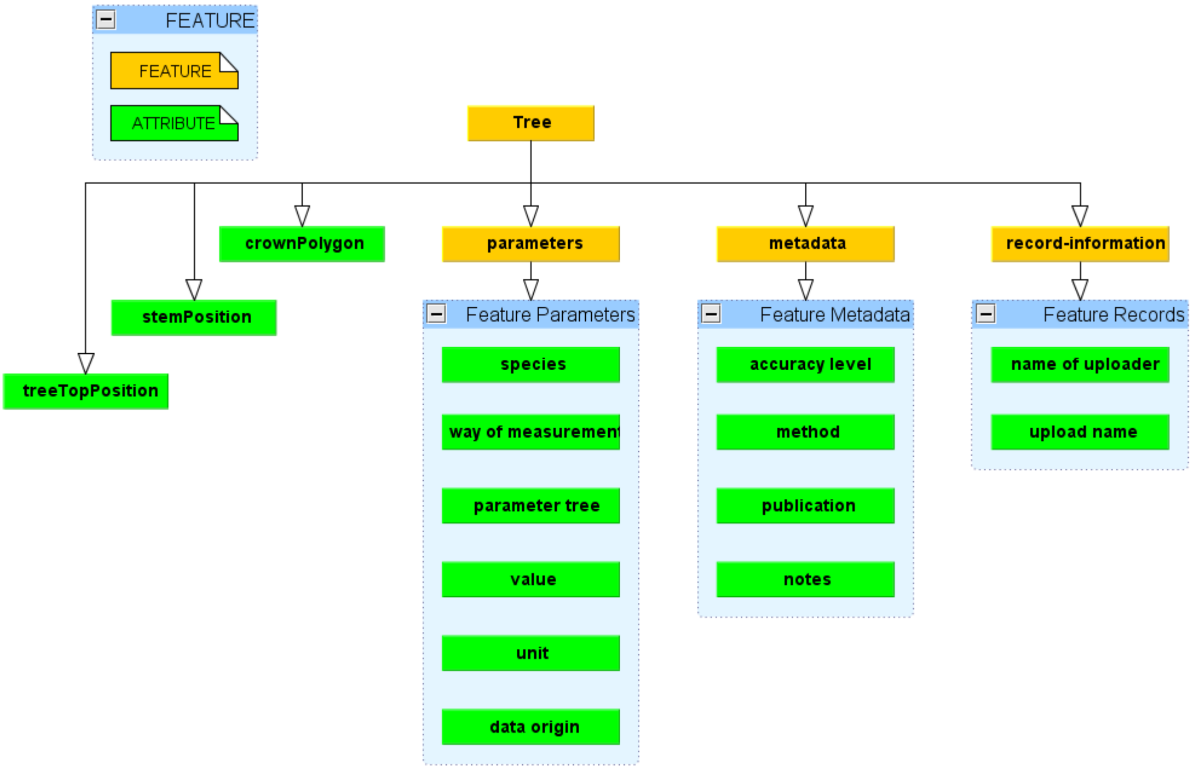


Figure 8 Hierarchical structure of a tree feature in FlexWood. Yellow boxes indicate features and green boxes attributes. Blue frames indicate features and their attributes.

backend. Within WP5000 we made a survey to ask for relevant species which are encoded according to the standard EN13556.

way of measurement
this element indicates the way of measurement. It can have three values:

value	examples
Direct	e.g. laser point values for height
Indirect	e.g. crown volume
Unknown	

The most often used value will be “indirect”, however laser-raw data can be used without further modelling.

parameter tree
The parameter tree element holds the actual parameter described in the feature “parameter”. It determines the succeeding element “unit”. This element is of type string. The value is restricted to a list of values kept in a lookup-table in the database. According to WP3000 and WP4000 we conducted a list of values suitable for singletrees.

"species"	"total heights"
"dbh"	"total biomass volume"
"crown diameter"	"crown volume"
"age"	"stem volume"
"height of lowest green branch"	"height at crown base"
"d7"	"defects"
"bow"	"solid volume (>7cm)"
"taper curve"	"crown ratio"
"stem ratio"	"timber assortments"
"crown cover"	

The list is likely to change throughout the project. Due to the open structure of the schema this doesn't result in changing the schema itself.

value
This element actually holds the value of the the parameter specified in the element parameter tree. There is one exception regarding the tree species. Tree species are presented in a special element due to type-restrictions. Decimal values are stored in a specific column of type decimal and species is stored in a column of type string. An element can only be related to one column in a database.

unit
The values of the element unit are specified in a lookup-table. Units relevant to the FlexWood system and its potential users were specified in a literature analyses within WP4000. The list contains not only SI-units but also derived units suitable for forestry applications. A list of the current units is presented below.

"mm"	"cm"	"m"
"m2"	"ha"	"m3"
"kg"	"years"	"degrees"
"percent"	"no unit"	"unknown"

reference or derived
Element referenceOrDerived just indicates whether the data is reference data or derived data. This becomes relevant for calibrating algorithms with ground truth data. Partners can access easy through the WFS such data and can test and develop their delineation programs. Possible values are "reference", "ALS", "TLS", "Spectral", "Radar" or "unknown".

Metadata

The feature metadata is of high importance for the project. Metadata describes among others data quality and used methods for deriving the data. The feature consists of so far four elements describing data for FlexWood.

accuracy level
The accuracy level of the modelled or derived data is expressed trough the RMSE. Range of the values is 0...100. The elements data type is decimal. Deliverable 4.1 – "Description of tree and wood resources in the forest based on novel technologies" and 8.2 – "Evaluation of the FlexWood Concept" might specify accuracy more precise in future.

method
The data requested by users is generated with a variety of methods and approaches. The element denotes the methodology with a describing string. A Possible entry can look like this:

“dbh estimated with linear regression”. The element method is meant as an informal tag which lets the user get a better idea on how the data has been generated.

publication
The method mentioned in the previous element can here be linked to a publication describing the procedure in detail. The type is of string as well. The content in that element should be in line with accepted citation styles such as APA, however it must include the standard information autor, title, journal, volume and year.

notes
The element notes is a string type and is meant to hold information which is seen as important and doesn´t fit in one of the other´s elements.

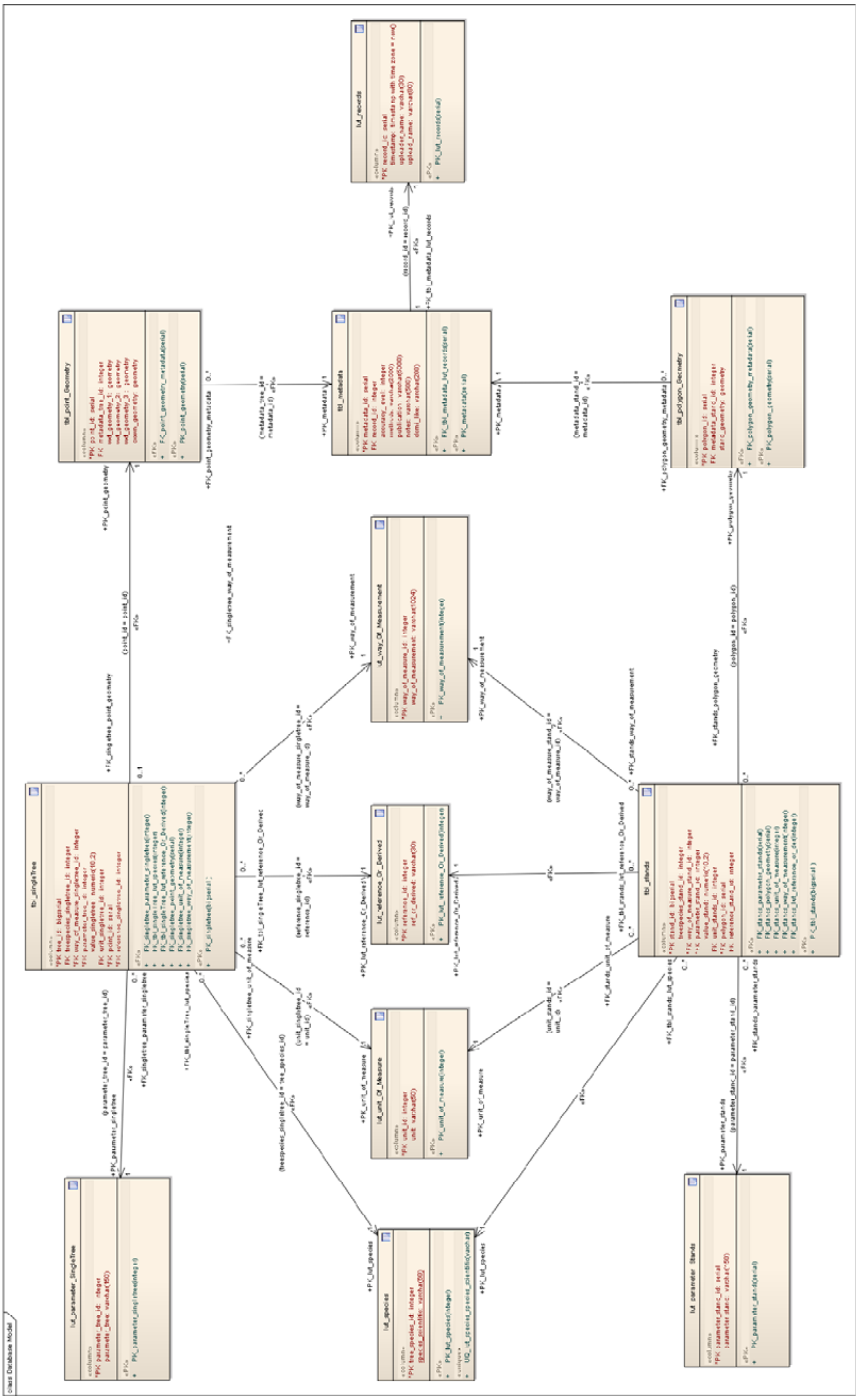
9.1.2.2 Record Information

The record-information feature allows the user to get information about the upload. It helps to track the activity of the FlexWood data provider community namely WP4000. The feature consists of two elements:

Name of uploader
The string element denotes the name of the uploader.

Upload name
The upload name describes the name of the set of data uploaded. E.g. “Test site Poland complete”.

9.2 Database schema



9.3 Full GML-Application Schema

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:deegreewfs="http://www.deegree.org/wfs" xmlns:flw="http://FlexWood.uni-freiburg.de/flw"
xmlns:gml="http://www.opengis.net/gml" xmlns:ogc="http://www.opengis.net/ogc"
attributeFormDefault="unqualified" elementFormDefault="qualified"
targetNamespace="http://FlexWood.uni-freiburg.de/flw">
  <xsd:import namespace="http://www.opengis.net/gml"
schemaLocation="http://schemas.opengis.net/gml/3.1.1/base/feature.xsd"/>
  <xsd:import namespace="http://www.opengis.net/gml"
schemaLocation="http://schemas.opengis.net/gml/3.1.1/base/geometryAggregates.xsd"/>
  <!-- ==================================================================== -->
  <xsd:element name="Stand" substitutionGroup="gml:_Feature" type="flw:StandType">

  </xsd:element>
  <xsd:complexType name="StandType">
    <xsd:complexContent>
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <xsd:element maxOccurs="unbounded" minOccurs="0" name="Parameters-Stand"
type="gml:FeaturePropertyType">
          </xsd:element>
          <xsd:element minOccurs="0" name="StandPolygon" type="gml:SurfacePropertyType">
          </xsd:element>
          <xsd:element minOccurs="0" name="Metadata" type="gml:FeaturePropertyType">
          </xsd:element>
          <xsd:element minOccurs="0" name="RecordInformation" type="gml:FeaturePropertyType">
          </xsd:element>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
  <!-- ==================================================================== -->
  <xsd:element name="Parameters-Stand" substitutionGroup="gml:_Feature" type="flw:Parameters-
StandType">

  </xsd:element>
  <xsd:complexType name="Parameters-StandType">
    <xsd:complexContent>
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <xsd:element maxOccurs="unbounded" minOccurs="0" name="TreeSpeciesStand"
type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="wayOfMeasurement" type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="ParameterStand" type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="value" type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="unit" type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="referenceOrDerived" type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="polygon_id" type="xsd:integer">
          </xsd:element>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
  <!-- ==================================================================== -->
  <xsd:element name="SingleTree" substitutionGroup="gml:_Feature" type="flw:SingleTreeType">

  </xsd:element>
  <xsd:complexType name="SingleTreeType">
    <xsd:complexContent>
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <xsd:element maxOccurs="unbounded" minOccurs="0" name="Parameters-SingleTree"
type="gml:FeaturePropertyType">
          </xsd:element>
          <xsd:element minOccurs="0" name="SingleTree_Stem_Position"
type="gml:PointPropertyType">
          </xsd:element>
          <xsd:element minOccurs="0" name="SingleTree_CrownTop_Position"
type="gml:PointPropertyType">
          </xsd:element>
          <xsd:element minOccurs="0" name="SingleTree_Optional_Position"
type="gml:PointPropertyType">
          </xsd:element>
          <xsd:element minOccurs="0" name="CrownPolygon" type="gml:SurfacePropertyType">
          </xsd:element>
          <xsd:element minOccurs="0" name="Metadata" type="gml:FeaturePropertyType">
          </xsd:element>
          <xsd:element minOccurs="0" name="RecordInformation" type="gml:FeaturePropertyType">
          </xsd:element>
```

```
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
  <!-- ================================================================ -->
  <xsd:element name="Parameters-SingleTree" substitutionGroup="gml:_Feature"
type="flw:Parameters-SingleTreeType">

  </xsd:element>
  <xsd:complexType name="Parameters-SingleTreeType">
    <xsd:complexContent>
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <xsd:element maxOccurs="unbounded" minOccurs="0" name="TreeSpeciesSingleTree"
type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="wayOfMeasurement" type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="ParameterSingleTree" type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="value" type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="unit" type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="referenceOrDerived" type="xsd:string">
          </xsd:element>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
  <!-- ================================================================ -->
  <xsd:element name="Metadata" substitutionGroup="gml:_Feature" type="flw:MetadataType">

  </xsd:element>
  <xsd:complexType name="MetadataType">
    <xsd:complexContent>
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <xsd:element minOccurs="0" name="metadata_id" type="xsd:integer">
          </xsd:element>
          <xsd:element minOccurs="0" name="AccuracyLlevel" type="xsd:decimal">
          </xsd:element>
          <xsd:element minOccurs="0" name="Methods" type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="Publication" type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="Notes" type="xsd:string">
          </xsd:element>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
  <!-- ================================================================ -->
  <xsd:element name="RecordInformation" substitutionGroup="gml:_Feature"
type="flw:RecordInformationType">

  </xsd:element>
  <xsd:complexType name="RecordInformationType">
    <xsd:complexContent>
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <xsd:element minOccurs="0" name="NameOfUploader" type="xsd:string">
          </xsd:element>
          <xsd:element minOccurs="0" name="NameOfUpload" type="xsd:string">
          </xsd:element>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
</xsd:schema>
```

9.4 Full degree configuration - schema (vendor specific implementation)

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:flw="http://FlexWood.uni-
freiburg.de/flw" xmlns:deegreewfs="http://www.deegree.org/wfs"
xmlns:gml="http://www.opengis.net/gml" xmlns:ogc="http://www.opengis.net/ogc"
targetNamespace="http://FlexWood.uni-freiburg.de/flw" elementFormDefault="qualified"
attributeFormDefault="unqualified">
  <xsd:import namespace="http://www.opengis.net/gml"
schemaLocation="http://schemas.opengis.net/gml/3.1.1/base/feature.xsd"/>

  <xsd:annotation>
    <xsd:appinfo>
      <deegreewfs:Prefix>flw</deegreewfs:Prefix>
      <deegreewfs:Backend>POSTGIS</deegreewfs:Backend>
      <deegreewfs:DefaultSRS>EPSG:4326</deegreewfs:DefaultSRS>
      <JDBCConnection xmlns="http://www.deegree.org/jdbc">
        <Driver>org.postgresql.Driver</Driver>
        <Url>jdbc:postgresql://172.30.111.7:5432/FlexWood</Url>
        <User>FlexWooduser</User>
        <Password>topsecret</Password>
        <SecurityConstraints/>
        <Encoding>iso-8859-1</Encoding>
      </JDBCConnection>
    </xsd:appinfo>
  </xsd:annotation>
  <!-- ====================================================================== -->
  <xsd:element name="Stand" type="flw:StandType" substitutionGroup="gml:_Feature">
    <xsd:annotation>
      <xsd:appinfo>
        <deegreewfs:table>tbl_stands</deegreewfs:table>
        <deegreewfs:gmlId prefix="STAND_">
          <deegreewfs:MappingField field="polygon_id" type="INTEGER"/>
          <deegreewfs:IdGenerator type="DB_SEQ">
            <deegreewfs:param name="sequence">FID_seq</deegreewfs:param>
          </deegreewfs:IdGenerator>
          <deegreewfs:IdentityPart>false</deegreewfs:IdentityPart>
        </deegreewfs:gmlId>
        <deegreewfs:visible>true</deegreewfs:visible>
        <deegreewfs:transaction update="true" delete="true" insert="true"/>
        <deegreewfs:DefaultSRS>EPSG:4326</deegreewfs:DefaultSRS>
      </xsd:appinfo>
    </xsd:annotation>
  </xsd:element>
  <xsd:complexType name="StandType">
    <xsd:complexContent>
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <!-- complex valued property Parameters-Stand' -->
          <xsd:element name="Parameters-Stand" type="gml:FeaturePropertyType" minOccurs="0"
maxOccurs="unbounded">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:IdentityPart>false</deegreewfs:IdentityPart>
                <deegreewfs:Content type="flw:Parameters-Stand">
                  <deegreewfs:MappingField field="stand_id" type="INTEGER"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="polygon_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="false">
                      <deegreewfs:MappingField field="polygon_id" type="INTEGER"
table="tbl_stands"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="StandPolygon" type="gml:SurfacePropertyType" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="stand_geometry" type="GEOMETRY" srs="4326"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="polygon_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="polygon_id" type="INTEGER"
table="tbl_polygon_geometry"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
```

```
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <!-- complex valued property 'Metadata' -->
          <xsd:element name="Metadata" type="gml:FeaturePropertyType" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:IdentityPart>false</deegreewfs:IdentityPart>
                <deegreewfs:Content type="flw:Metadata">
                  <deegreewfs:Relation>
                    <!--Points from tbl_stands-->
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="polygon_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="polygon_id" type="INTEGER"
table="tbl_polygon_geometry"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                  <deegreewfs:Relation>
                    <!--Metadata from tbl_polygon_geometry-->
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="metadata_stand_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="metadata_id" type="INTEGER"
table="tbl_metadata"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <!-- complex valued property 'Records' -->
          <xsd:element name="RecordInformation" type="gml:FeaturePropertyType" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:IdentityPart>false</deegreewfs:IdentityPart>
                <deegreewfs:Content type="flw:RecordInformation">
                  <deegreewfs:Relation>
                    <!--Points from tbl_stands-->
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="polygon_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="polygon_id" type="INTEGER"
table="tbl_polygon_geometry"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                  <deegreewfs:Relation>
                    <!--Metadata from tbl_polygon_geometry-->
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="metadata_stand_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="metadata_id" type="INTEGER"
table="tbl_metadata"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                  <deegreewfs:Relation>
                    <!--Records from lut_records-->
                    <deegreewfs:From fk="true">
                      <deegreewfs:MappingField field="record_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To>
                      <deegreewfs:MappingField field="record_id" type="INTEGER"
table="lut_records"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
    <!--ComplexType StandType holds all information for forest stands including a metadata
section-->
  </xsd:complexType>
  <!-- =============================================================== -->
  <xsd:element name="Parameters-Stand" type="flw:Parameters-StandType"
substitutionGroup="gml:_Feature">
    <xsd:annotation>
      <xsd:appinfo>
        <deegreewfs:table>tbl_stands</deegreewfs:table>
        <deegreewfs:gmlId prefix="PARAMETER-STAND_">
```

```
          <deegreewfs:MappingField field="stand_id" type="INTEGER"/>
          <deegreewfs:IdGenerator type="DB_SEQ">
            <deegreewfs:param name="sequence">FID_seq</deegreewfs:param>
          </deegreewfs:IdGenerator>
          <deegreewfs:IdentityPart>false</deegreewfs:IdentityPart>
        </deegreewfs:gmlId>
        <deegreewfs:visible>false</deegreewfs:visible>
        <deegreewfs:transaction update="true" delete="true" insert="true"/>
        <deegreewfs:DefaultSRS>EPSG:4326</deegreewfs:DefaultSRS>
      </xsd:appinfo>
    </xsd:annotation>
  </xsd:element>
  <xsd:complexType name="Parameters-StandType">
    <xsd:complexContent>
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <xsd:element name="TreeSpeciesStand" type="xsd:string" minOccurs="0"
maxOccurs="unbounded">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="species_scientific" type="VARCHAR"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="treespecies_stand_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="tree_species_id" type="INTEGER"
table="lut_species"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="wayOfMeasurement" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="way_of_measurement" type="VARCHAR"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="way_of_measure_stand_id"
type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="way_of_measure_id" type="INTEGER"
table="lut_way_of_measurement"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="ParameterStand" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="parameter_stand" type="VARCHAR"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="parameter_stand_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="parameter_stand_id" type="INTEGER"
table="lut_parameter_stands"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="value" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="value_stand" type="NUMERIC"/>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="unit" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="unit" type="VARCHAR"/>
                  <deegreewfs:Relation>
```

```
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="unit_stands_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="unit_id" type="INTEGER"
table="lut_unit_of_measure"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="referenceOrDerived" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="ref_or_derived" type="VARCHAR"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="reference_stand_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="reference_id" type="INTEGER"
table="lut_reference_or_derived"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="polygon_id" type="xsd:integer" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="polygon_id" type="INTEGER"/>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
    <!--ComplexType Parameters-StandType holds all parameters/attribures for the complextype
"Stand" where this feature is referenced. -->
  </xsd:complexType>
  <!-- ================================================================== -->
  <xsd:element name="SingleTree" type="flw:SingleTreeType" substitutionGroup="gml:_Feature">
    <xsd:annotation>
      <xsd:appinfo>
        <deegreewfs:table>tbl_singletree</deegreewfs:table>
        <deegreewfs:gmlId prefix="SINGLETREE_">
          <deegreewfs:MappingField field="point_id" type="INTEGER"/>
          <deegreewfs:IdGenerator type="DB_SEQ">
            <deegreewfs:param name="sequence">FID_seq</deegreewfs:param>
          </deegreewfs:IdGenerator>
          <deegreewfs:IdentityPart>false</deegreewfs:IdentityPart>
        </deegreewfs:gmlId>
        <deegreewfs:visible>true</deegreewfs:visible>
        <deegreewfs:transaction update="true" delete="true" insert="true"/>
        <deegreewfs:DefaultSRS>EPSG:4326</deegreewfs:DefaultSRS>
      </xsd:appinfo>
    </xsd:annotation>
  </xsd:element>
  <xsd:complexType name="SingleTreeType">
    <xsd:complexContent>
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <!-- complex valued property 'Parameters-SingleTree' -->
          <xsd:element name="Parameters-SingleTree" type="gml:FeaturePropertyType"
minOccurs="0" maxOccurs="unbounded">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:IdentityPart>false</deegreewfs:IdentityPart>
                <deegreewfs:Content type="flw:Parameters-SingleTree">
                  <deegreewfs:MappingField field="tree_id" type="INTEGER"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="point_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="false">
                      <deegreewfs:MappingField field="point_id" type="INTEGER"
table="tbl_singletree"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
```

```
          </xsd:element>
          <xsd:element name="SingleTree_Stem_Position" type="gml:PointPropertyType"
minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="wkt_geometry_1" type="GEOMETRY" srs="4326"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="point_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="point_id" type="INTEGER"
table="tbl_point_geometry"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="SingleTree_CrownTop_Position" type="gml:PointPropertyType"
minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="wkt_geometry_2" type="GEOMETRY" srs="4326"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="point_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="point_id" type="INTEGER"
table="tbl_point_geometry"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="SingleTree_Optional_Position" type="gml:PointPropertyType"
minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="wkt_geometry_2" type="GEOMETRY" srs="4326"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="point_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="point_id" type="INTEGER"
table="tbl_point_geometry"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="CrownPolygon" type="gml:SurfacePropertyType" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="crown_geometry" type="GEOMETRY" srs="4326"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="point_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="point_id" type="INTEGER"
table="tbl_point_geometry"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <!-- complex valued property 'Metadata' -->
          <xsd:element name="Metadata" type="gml:FeaturePropertyType" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:IdentityPart>false</deegreewfs:IdentityPart>
                <deegreewfs:Content type="flw:Metadata">
                  <deegreewfs:Relation>
                    <!--Points from tbl_singleTree-->
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="point_id" type="INTEGER"/>
                    </deegreewfs:From>
```

```
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="point_id" type="INTEGER"
table="tbl_point_geometry"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                  <deegreewfs:Relation>
                    <!--Metadata from tbl_point_geometry-->
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="metadata_tree_id" type="INTEGER"
table="tbl_point_geometry"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="metadata_id" type="INTEGER"
table="tbl_metadata"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <!-- complex valued property 'Records' -->
          <xsd:element name="RecordInformation" type="gml:FeaturePropertyType" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:IdentityPart>false</deegreewfs:IdentityPart>
                <deegreewfs:Content type="flw:RecordInformation">
                  <deegreewfs:Relation>
                    <!--Points from tbl_singleTree-->
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="point_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="point_id" type="INTEGER"
table="tbl_point_geometry"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                  <deegreewfs:Relation>
                    <!--Metadata from tbl_point_geometry-->
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="metadata_tree_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="metadata_id" type="INTEGER"
table="tbl_metadata"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                  <deegreewfs:Relation>
                    <!--Records from lut_records-->
                    <deegreewfs:From fk="true">
                      <deegreewfs:MappingField field="record_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To>
                      <deegreewfs:MappingField field="record_id" type="INTEGER"
table="lut_records"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
    <!--ComplexType SingleTreeType holds all information for individual trees including a
metadata section-->
  </xsd:complexType>
  <!-- ====================================================================== -->
  <xsd:element name="Parameters-SingleTree" type="flw:Parameters-SingleTreeType"
substitutionGroup="gml:_Feature">
    <xsd:annotation>
      <xsd:appinfo>
        <deegreewfs:table>tbl_singletree</deegreewfs:table>
        <deegreewfs:gmlId prefix="PARAMETER-SINGLETREE_">
          <deegreewfs:MappingField field="tree_id" type="INTEGER"/>
          <deegreewfs:IdGenerator type="DB_SEQ">
            <deegreewfs:param name="sequence">FID_seq</deegreewfs:param>
          </deegreewfs:IdGenerator>
          <deegreewfs:IdentityPart>false</deegreewfs:IdentityPart>
        </deegreewfs:gmlId>
        <deegreewfs:visible>false</deegreewfs:visible>
        <deegreewfs:transaction update="true" delete="true" insert="true"/>
        <deegreewfs:DefaultSRS>EPSG:4326</deegreewfs:DefaultSRS>
      </xsd:appinfo>
    </xsd:annotation>
  </xsd:element>
  <xsd:complexType name="Parameters-SingleTreeType">
    <xsd:complexContent>
```

```
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <xsd:element name="TreeSpeciesSingleTree" type="xsd:string" minOccurs="0"
maxOccurs="unbounded">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="species_scientific" type="VARCHAR"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="treespecies_singletree_id"
type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="tree_species_id" type="INTEGER"
table="lut_species"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="wayOfMeasurement" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="way_of_measurement" type="VARCHAR"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="way_of_measure_singletree_id"
type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="way_of_measure_id" type="INTEGER"
table="lut_way_of_measurement"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="ParameterSingleTree" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="parameter_tree" type="VARCHAR"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="parameter_tree_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="parameter_tree_id" type="INTEGER"
table="lut_parameter_singletree"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="value" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="value_singletree" type="NUMERIC"/>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="unit" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="unit" type="VARCHAR"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="unit_singletree_id" type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="unit_id" type="INTEGER"
table="lut_unit_of_measure"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="referenceOrDerived" type="xsd:string" minOccurs="0">
```

```
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="ref_or_derived" type="VARCHAR"/>
                  <deegreewfs:Relation>
                    <deegreewfs:From>
                      <deegreewfs:MappingField field="reference_singletree_id"
type="INTEGER"/>
                    </deegreewfs:From>
                    <deegreewfs:To fk="true">
                      <deegreewfs:MappingField field="reference_id" type="INTEGER"
table="lut_reference_or_derived"/>
                    </deegreewfs:To>
                  </deegreewfs:Relation>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
    <!--ComplexType Parameters-SingleTreeType holds all parameters/attribures for the
complextype "SingleTreeType" where this feature is referenced. -->
  </xsd:complexType>
  <!-- ================================================================== -->
  <xsd:element name="Metadata" type="flw:MetadataType" substitutionGroup="gml:_Feature">
    <xsd:annotation>
      <xsd:appinfo>
        <deegreewfs:table>tbl_metadata</deegreewfs:table>
        <deegreewfs:gmlId prefix="METADATA_">
          <deegreewfs:MappingField field="metadata_id" type="INTEGER"/>
          <deegreewfs:IdGenerator type="DB_SEQ">
            <deegreewfs:param name="sequence">FID_seq</deegreewfs:param>
          </deegreewfs:IdGenerator>
          <deegreewfs:IdentityPart>false</deegreewfs:IdentityPart>
        </deegreewfs:gmlId>
        <deegreewfs:visible>true</deegreewfs:visible>
        <deegreewfs:transaction update="true" delete="true" insert="true"/>
      </xsd:appinfo>
    </xsd:annotation>
  </xsd:element>
  <xsd:complexType name="MetadataType">
    <xsd:complexContent>
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <xsd:element name="metadata_id" type="xsd:integer" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:IdentityPart>true</deegreewfs:IdentityPart>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="metadata_id" type="INTEGER"/>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="AccuracyLlevel" type="xsd:decimal" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:IdentityPart>true</deegreewfs:IdentityPart>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="accuracy_level" type="INTEGER"/>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="Methods" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:IdentityPart>true</deegreewfs:IdentityPart>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="methods" type="VARCHAR"/>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="Publication" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:IdentityPart>true</deegreewfs:IdentityPart>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="publication" type="VARCHAR"/>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="Notes" type="xsd:string" minOccurs="0">
            <xsd:annotation>
```

```
              <xsd:appinfo>
                <deegreewfs:IdentityPart>true</deegreewfs:IdentityPart>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="notes" type="VARCHAR"/>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
    <!--ComplexType MetadataType holds all metadata for the complextype "SingleTreeType" and
"StandType" where this feature is referenced. -->
  </xsd:complexType>
  <!-- ====================================================================== -->
  <xsd:element name="RecordInformation" type="flw:RecordInformationType"
substitutionGroup="gml:_Feature">
    <xsd:annotation>
      <xsd:appinfo>
        <deegreewfs:table>lut_records</deegreewfs:table>
        <deegreewfs:gmlId prefix="RECORD_">
          <deegreewfs:MappingField field="record_id" type="INTEGER"/>
          <deegreewfs:IdGenerator type="DB_SEQ">
            <deegreewfs:param name="sequence">FID_seq</deegreewfs:param>
          </deegreewfs:IdGenerator>
          <deegreewfs:IdentityPart>false</deegreewfs:IdentityPart>
        </deegreewfs:gmlId>
        <deegreewfs:visible>true</deegreewfs:visible>
        <deegreewfs:transaction update="true" delete="true" insert="true"/>
      </xsd:appinfo>
    </xsd:annotation>
  </xsd:element>
  <xsd:complexType name="RecordInformationType">
    <xsd:complexContent>
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <xsd:element name="NameOfUploader" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="uploader_name" type="VARCHAR"/>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
          <xsd:element name="NameOfUpload" type="xsd:string" minOccurs="0">
            <xsd:annotation>
              <xsd:appinfo>
                <deegreewfs:Content>
                  <deegreewfs:MappingField field="upload_name" type="VARCHAR"/>
                </deegreewfs:Content>
              </xsd:appinfo>
            </xsd:annotation>
          </xsd:element>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
</xsd:schema>
```

9.5 Full gml-output for stands and trees

Two trees represented in the proposed GML-schema.


```xml
<?xml version="1.0" encoding="UTF-8"?>

<wfs:FeatureCollection numberOfFeatures='2' xmlns:wfs="http://www.opengis.net/wfs"
xmlns:flw="http://FlexWood.uni-freiburg.de/flw" xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:gml="http://www.opengis.net/gml" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://FlexWood.uni-freiburg.de/flw http://FlexWood.felis.uni-
freiburg.de:8080/deegree-
wfs/services?SERVICE=WFS&amp;VERSION=1.1.0&amp;REQUEST=DescribeFeatureType&amp;TYPENAME=flw:Si
ngleTree&amp;NAMESPACE=xmlns(flw=http://FlexWood.uni-freiburg.de/flw)
http://www.opengis.net/wfs http://schemas.opengis.net/wfs/1.1.0/wfs.xsd">

  <gml:boundedBy>

    <gml:Envelope srsName='EPSG:4326'>

      <gml:lowerCorner>8.410309171282528 49.057774544257306</gml:lowerCorner>

      <gml:upperCorner>8.41059989074865 49.05796233872338</gml:upperCorner>

    </gml:Envelope>

  </gml:boundedBy>

  <gml:featureMember>

    <flw:SingleTree gml:id="SINGLETREE_151918">

      <gml:boundedBy>

        <gml:Envelope srsName='EPSG:4326'>

          <gml:lowerCorner>8.410309171282528 49.05796233872338</gml:lowerCorner>

          <gml:upperCorner>8.410309171282528 49.05796233872338</gml:upperCorner>

        </gml:Envelope>

      </gml:boundedBy>

      <flw:Parameters-SingleTree>

        <!-- xlink:href="#PARAMETER-SINGLETREE_154968" -->

        <flw:Parameters-SingleTree gml:id="PARAMETER-SINGLETREE_154968">

          <flw:wayOfMeasurement>direct</flw:wayOfMeasurement>

          <flw:ParameterSingleTree>total heights</flw:ParameterSingleTree>

          <flw:value>15.20</flw:value>

          <flw:unit>m</flw:unit>

          <flw:referenceOrDerived>reference</flw:referenceOrDerived>

        </flw:Parameters-SingleTree>

      </flw:Parameters-SingleTree>

      <flw:Parameters-SingleTree>

        <!-- xlink:href="#PARAMETER-SINGLETREE_154967" -->

        <flw:Parameters-SingleTree gml:id="PARAMETER-SINGLETREE_154967">

          <flw:wayOfMeasurement>direct</flw:wayOfMeasurement>

          <flw:ParameterSingleTree>dbh</flw:ParameterSingleTree>

          <flw:value>22</flw:value>
```

```
        &lt;flw:unit&gt;cm&lt;/flw:unit&gt;
        &lt;flw:referenceOrDerived&gt;reference&lt;/flw:referenceOrDerived&gt;
      &lt;/flw:Parameters-SingleTree&gt;
    &lt;/flw:Parameters-SingleTree&gt;
    &lt;flw:SingleTree_Stem_Position&gt;
      &lt;gml:Point srsName="EPSG:4326"&gt;
        &lt;gml:pos&gt;8.410309171282528 49.05796233872338&lt;/gml:pos&gt;
      &lt;/gml:Point&gt;
    &lt;/flw:SingleTree_Stem_Position&gt;
    &lt;flw:Metadata&gt;
      &lt;!-- xlink:href="#METADATA_8" --&gt;
      &lt;flw:Metadata gml:id="METADATA_8"&gt;
        &lt;flw:metadata_id&gt;8&lt;/flw:metadata_id&gt;
        &lt;flw:AccuracyLlevel&gt;0&lt;/flw:AccuracyLlevel&gt;
        &lt;flw:Methods&gt;field work&lt;/flw:Methods&gt;
        &lt;flw:Publication&gt;none&lt;/flw:Publication&gt;
        &lt;flw:Notes&gt;reference data measured in summer 2010&lt;/flw:Notes&gt;
      &lt;/flw:Metadata&gt;
    &lt;/flw:Metadata&gt;
    &lt;flw:RecordInformation&gt;
      &lt;!-- xlink:href="#RECORD_8" --&gt;
      &lt;flw:RecordInformation gml:id="RECORD_8"&gt;
        &lt;flw:NameOfUploader&gt;Andreas Fritz&lt;/flw:NameOfUploader&gt;
        &lt;flw:NameOfUpload&gt;Demonstration&lt;/flw:NameOfUpload&gt;
      &lt;/flw:RecordInformation&gt;
    &lt;/flw:RecordInformation&gt;
  &lt;/flw:SingleTree&gt;
&lt;/gml:featureMember&gt;
&lt;gml:featureMember&gt;
  &lt;flw:SingleTree gml:id="SINGLETREE_151917"&gt;
    &lt;gml:boundedBy&gt;
      &lt;gml:Envelope srsName='EPSG:4326'&gt;
        &lt;gml:lowerCorner&gt;8.41059989074865 49.057774544257306&lt;/gml:lowerCorner&gt;
        &lt;gml:upperCorner&gt;8.41059989074865 49.057774544257306&lt;/gml:upperCorner&gt;
      &lt;/gml:Envelope&gt;
    &lt;/gml:boundedBy&gt;
    &lt;flw:Parameters-SingleTree&gt;
      &lt;!-- xlink:href="#PARAMETER-SINGLETREE_154966" --&gt;
      &lt;flw:Parameters-SingleTree gml:id="PARAMETER-SINGLETREE_154966"&gt;
```

```
          <flw:wayOfMeasurement>direct</flw:wayOfMeasurement>

          <flw:ParameterSingleTree>total heights</flw:ParameterSingleTree>

          <flw:value>28</flw:value>

          <flw:unit>m</flw:unit>

          <flw:referenceOrDerived>reference</flw:referenceOrDerived>

        </flw:Parameters-SingleTree>

      </flw:Parameters-SingleTree>

      <flw:Parameters-SingleTree>

        <!-- xlink:href="#PARAMETER-SINGLETREE_154965" -->

        <flw:Parameters-SingleTree gml:id="PARAMETER-SINGLETREE_154965">

          <flw:wayOfMeasurement>direct</flw:wayOfMeasurement>

          <flw:ParameterSingleTree>dbh</flw:ParameterSingleTree>

          <flw:value>35</flw:value>

          <flw:unit>cm</flw:unit>

          <flw:referenceOrDerived>reference</flw:referenceOrDerived>

        </flw:Parameters-SingleTree>

      </flw:Parameters-SingleTree>

      <flw:SingleTree_Stem_Position>

        <gml:Point srsName="EPSG:4326">

          <gml:pos>8.41059989074865 49.057774544257306</gml:pos>

        </gml:Point>

      </flw:SingleTree_Stem_Position>

      <!-- xlink:href="#METADATA_8" -->

      <flw:Metadata xlink:href="#METADATA_8"/>

      <!-- xlink:href="#RECORD_8" -->

      <flw:RecordInformation xlink:href="#RECORD_8"/>

    </flw:SingleTree>

  </gml:featureMember>

</wfs:FeatureCollection>
```


Two stands represented in the proposed GML-schema.


```
<?xml version="1.0" encoding="UTF-8"?>

<wfs:FeatureCollection numberOfFeatures='2' xmlns:wfs="http://www.opengis.net/wfs"
xmlns:flw="http://FlexWood.uni-freiburg.de/flw" xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:gml="http://www.opengis.net/gml" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://FlexWood.uni-freiburg.de/flw http://FlexWood.felis.uni-
freiburg.de:8080/deegree-
wfs/services?SERVICE=WFS&amp;VERSION=1.1.0&amp;REQUEST=DescribeFeatureType&amp;TYPENAME=flw:St
and&amp;NAMESPACE=xmlns(flw=http://FlexWood.uni-freiburg.de/flw) http://www.opengis.net/wfs
http://schemas.opengis.net/wfs/1.1.0/wfs.xsd">

  <gml:boundedBy>
```

```
    <gml:Envelope srsName='EPSG:4326'>
      <gml:lowerCorner>8.40675801142806 49.06027343178789</gml:lowerCorner>
      <gml:upperCorner>8.410589074995006 49.0606527146396</gml:upperCorner>
    </gml:Envelope>
  </gml:boundedBy>
  <gml:featureMember>
    <flw:Stand gml:id="STAND_1769">
      <gml:boundedBy>
        <gml:Envelope srsName='EPSG:4326'>
          <gml:lowerCorner>8.40675801142806 49.06027343178789</gml:lowerCorner>
          <gml:upperCorner>8.407307443939125 49.0604560724636</gml:upperCorner>
        </gml:Envelope>
      </gml:boundedBy>
      <flw:Parameters-Stand>
        <!-- xlink:href="#PARAMETER-STAND_1767" -->
        <flw:Parameters-Stand gml:id="PARAMETER-STAND_1767">
          <flw:TreeSpeciesStand>Conifer</flw:TreeSpeciesStand>
          <flw:wayOfMeasurement>indirect</flw:wayOfMeasurement>
          <flw:ParameterStand>dominant species</flw:ParameterStand>
          <flw:unit>no unit</flw:unit>
          <flw:referenceOrDerived>derived</flw:referenceOrDerived>
          <flw:polygon_id>1769</flw:polygon_id>
        </flw:Parameters-Stand>
      </flw:Parameters-Stand>
      <flw:StandPolygon>
        <gml:Surface srsName='EPSG:4326'>
          <gml:patches>
            <gml:PolygonPatch>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList srsDimension='2' count='5'>8.406760151372842 49.06027343178789
8.40675801142806 49.060453261285254 8.40730530596895 49.0604560724636 8.407307443939125
49.06027624294913 8.406760151372842 49.06027343178789</gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:PolygonPatch>
          </gml:patches>
```

```
        </gml:Surface>

      </flw:StandPolygon>

      <flw:Metadata>

        <!-- xlink:href="#METADATA_4" -->

        <flw:Metadata gml:id="METADATA_4">

          <flw:metadata_id>4</flw:metadata_id>

          <flw:AccuracyLlevel>0</flw:AccuracyLlevel>

          <flw:Methods>unknown</flw:Methods>

          <flw:Publication>Straub, C., Weinacker, H., Koch, B. 2010. A Comparison of Different
Methods for Forest Resource Estimation using Information from Airborne Laser Scanning and CIR
Orthophotos, European Journal of Forest Research (Published online: 26 May
2010).</flw:Publication>

          <flw:Notes>prelimany results</flw:Notes>

        </flw:Metadata>

      </flw:Metadata>

      <flw:RecordInformation>

        <!-- xlink:href="#RECORD_4" -->

        <flw:RecordInformation gml:id="RECORD_4">

          <flw:NameOfUploader>Andreas Fritz</flw:NameOfUploader>

          <flw:NameOfUpload>Demonstration of stands</flw:NameOfUpload>

        </flw:RecordInformation>

      </flw:RecordInformation>

    </flw:Stand>

  </gml:featureMember>

  <gml:featureMember>

    <flw:Stand gml:id="STAND_1770">

      <gml:boundedBy>

        <gml:Envelope srsName='EPSG:4326'>

          <gml:lowerCorner>8.40921870645016 49.06046589114838</gml:lowerCorner>

          <gml:upperCorner>8.410589074995006 49.0606527146396</gml:upperCorner>

        </gml:Envelope>

      </gml:boundedBy>

      <flw:Parameters-Stand>

        <!-- xlink:href="#PARAMETER-STAND_1768" -->

        <flw:Parameters-Stand gml:id="PARAMETER-STAND_1768">

          <flw:TreeSpeciesStand>Mixed</flw:TreeSpeciesStand>

          <flw:wayOfMeasurement>indirect</flw:wayOfMeasurement>

          <flw:ParameterStand>dominant species</flw:ParameterStand>
```

```
          <flw:unit>no unit</flw:unit>
          <flw:referenceOrDerived>derived</flw:referenceOrDerived>
          <flw:polygon_id>1770</flw:polygon_id>
        </flw:Parameters-Stand>
      </flw:Parameters-Stand>
      <flw:StandPolygon>
        <gml:Surface srsName='EPSG:4326'>
          <gml:patches>
            <gml:PolygonPatch>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList srsDimension='2' count='5'>8.40922083753035 49.06046589114838
8.40921870645016 49.06064572071691 8.410586948851401 49.0606527146396 8.410589074995006
49.06047288502854 8.40922083753035 49.06046589114838</gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:PolygonPatch>
          </gml:patches>
        </gml:Surface>
      </flw:StandPolygon>
      <!-- xlink:href="#METADATA_4" -->
      <flw:Metadata xlink:href="#METADATA_4"/>
      <!-- xlink:href="#RECORD_4" -->
      <flw:RecordInformation xlink:href="#RECORD_4"/>
    </flw:Stand>
  </gml:featureMember>
</wfs:FeatureCollection>
```