

Semantic Interoperability of Volunteered Geographic Information based on Contextual Knowledge



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Research on VGI at IREA - CNR

- **VGI & SDI interoperable management:**
 - **VGI acquisition by development of Smart Apps;**
 - **Applications of VGI for citizen science: agriculture, ecology and biodiversity (LTER) , glaciers monitoring, s-low tourism, emergencies;**
 - **S4A smart App: <https://www.youtube.com/watch?v=M3GYIsQAUWc>**
 - **“I cammini” <http://www.lteritalia.it/it/cammini>**
- **VGI quality assessment methods**
 - **G Bordogna, P Carrara, L Criscuolo, M Pepe, A Rampini, A linguistic decision making approach to assess the quality of volunteer Geographic information for citizen science Information Sciences 258, 312-327**
- **Spatio-temporal analysis of social networks (Tweeter)**
 - **P Arcaini, G Bordogna, D Ienco, S Sterlacchini, User-driven geo-temporal density-based exploration of periodic and not periodic events reported in social networks, Information Sciences, 2016**
- **Sensor Web Enablement**

Open Problem

Interoperable
Spatial Data
Infrastructures



Filling the gap for VGI
interoperable
management



Volunteered Geographic
Information (VGI)
created by distinct
applications



Need to create a bridge for each VGI application

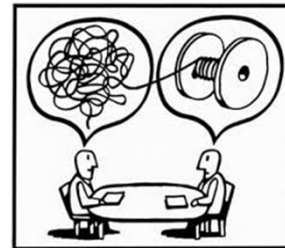


Main Cornerstones for full Interoperable VGI

- OGC services for VGI deploy



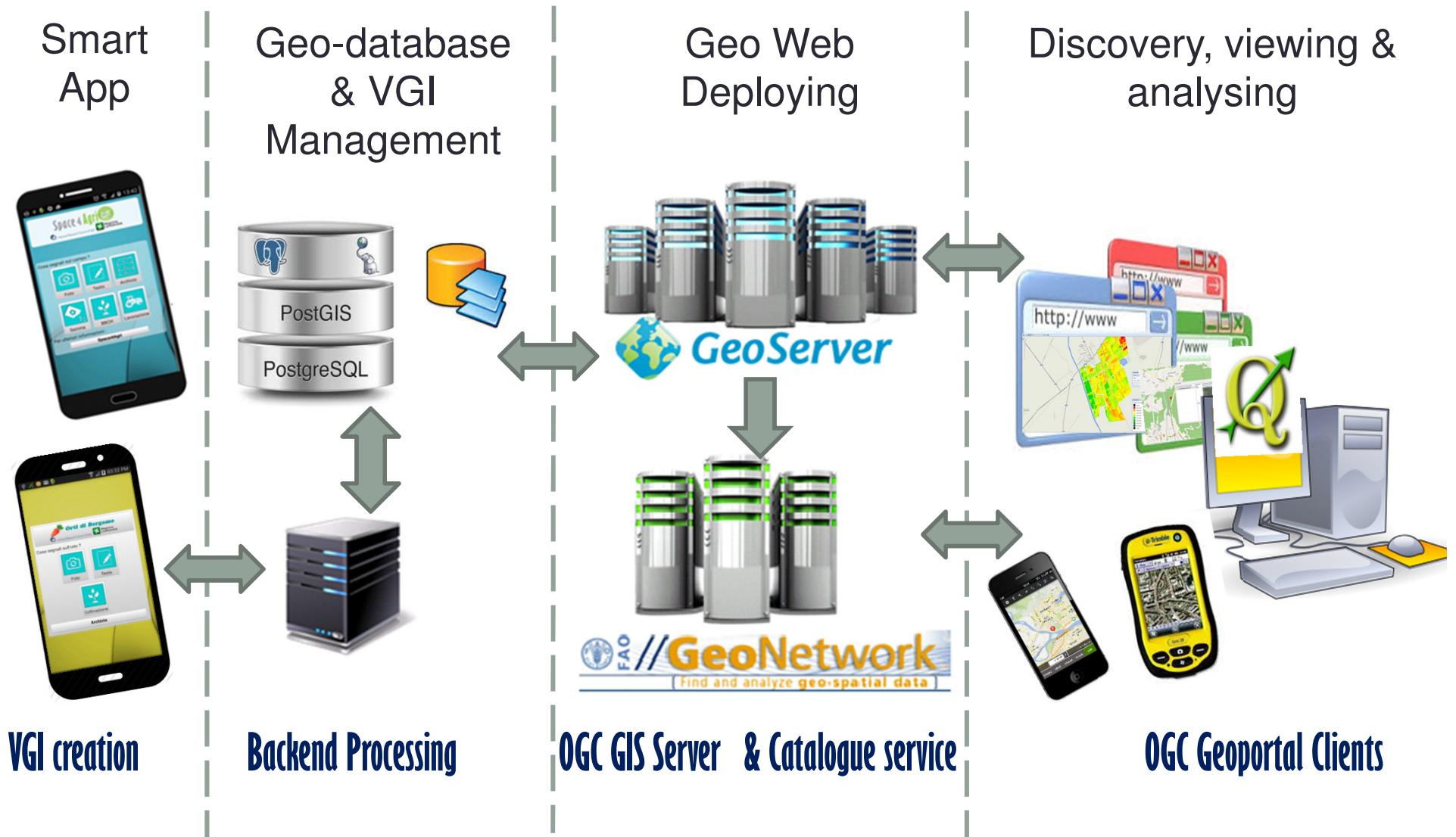
- Ontologies for Data Normalization and semantic interoperability



- Uncertainty management by Data conflation to resolve co-references (data associated with the same geographic object)



Syntactic interoperability of VGI within an SDI



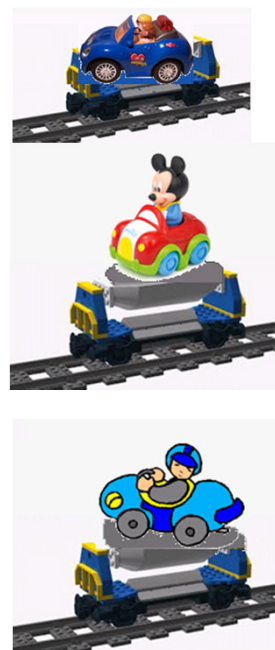
Adopted Solution to support semantic interoperability

SDI managing semantically interoperable VGI created by a Smart App for citizen science projects

Interoperable
Spatial Data
Infrastructures



Semantically annotated
VGI



Semantically
interoperable
Smart App



Smart App for semantically interoperable VGI creation within citizen science projects

Target projects:

- Volunteers contributions about georeferenced features (POIs, entities of interest, etc)

Requirements of the Smart App:

- It must work off-line;
- It must guide the Volunteer;
- It must resolve ambiguities and imprecision in geolocalization of target entities
- It must use a domain language;
- it should allow creation of semantically annotated Free text and pictures;



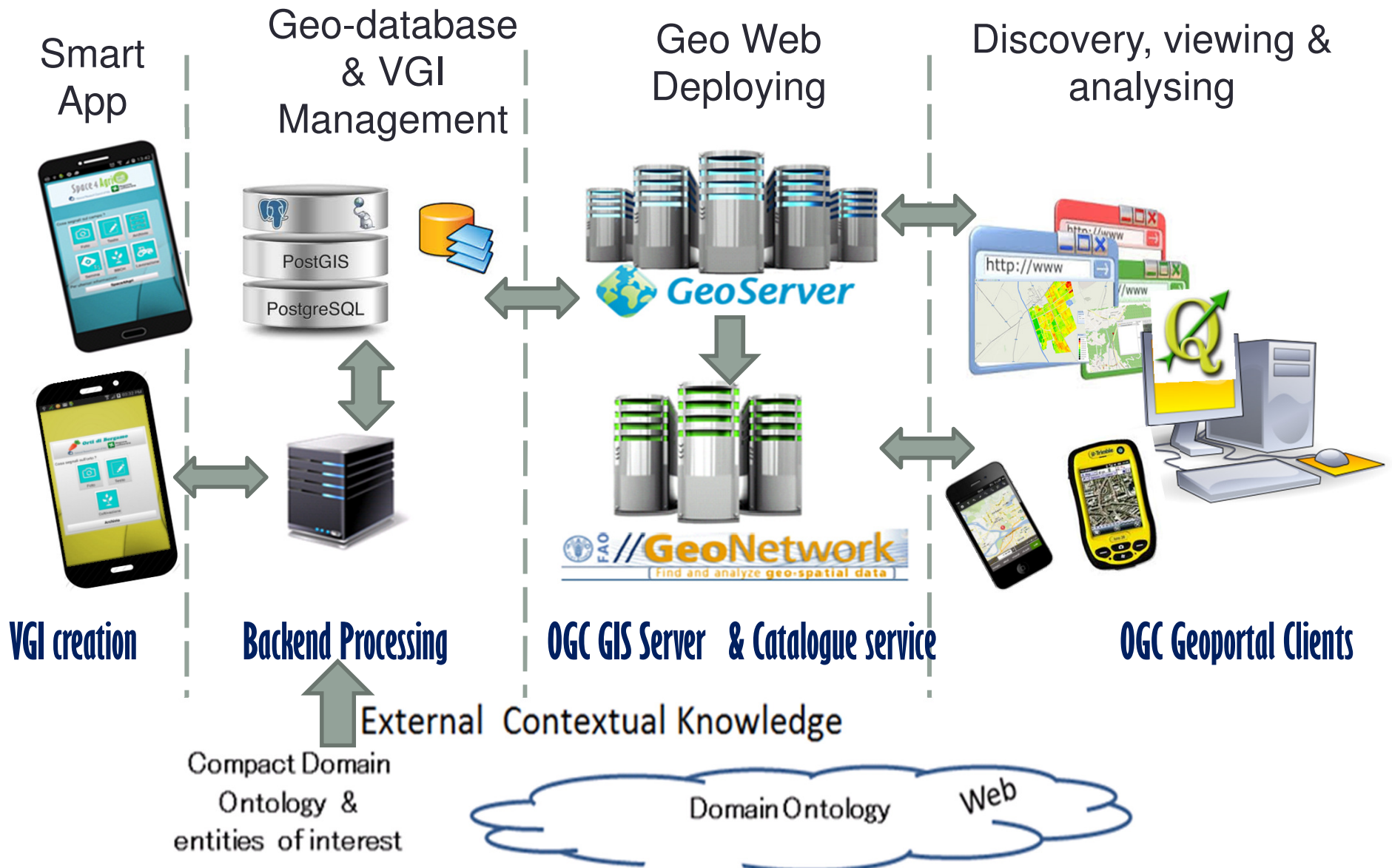
Smart App for semantically interoperable VGI creation within a citizen science project

Proposed solution:

use of contextual knowledge for VGI creation, management, and analysis

- manual repositioning of automatically detected GPS location when creating VGI (to correct possible imprecisions)
- conflation of VGI footprint by the support of a **conflation geospatial data layer** representing the boundaries (or centroids) of entities of interest (to resolve ambiguities)
- **compact domain ontology** stored on the SD card of the device to support creation of categorical VGI
- **extended domain ontology** to support analysis of VGI

Semantic & Syntactic interoperability of VGI within an SDI

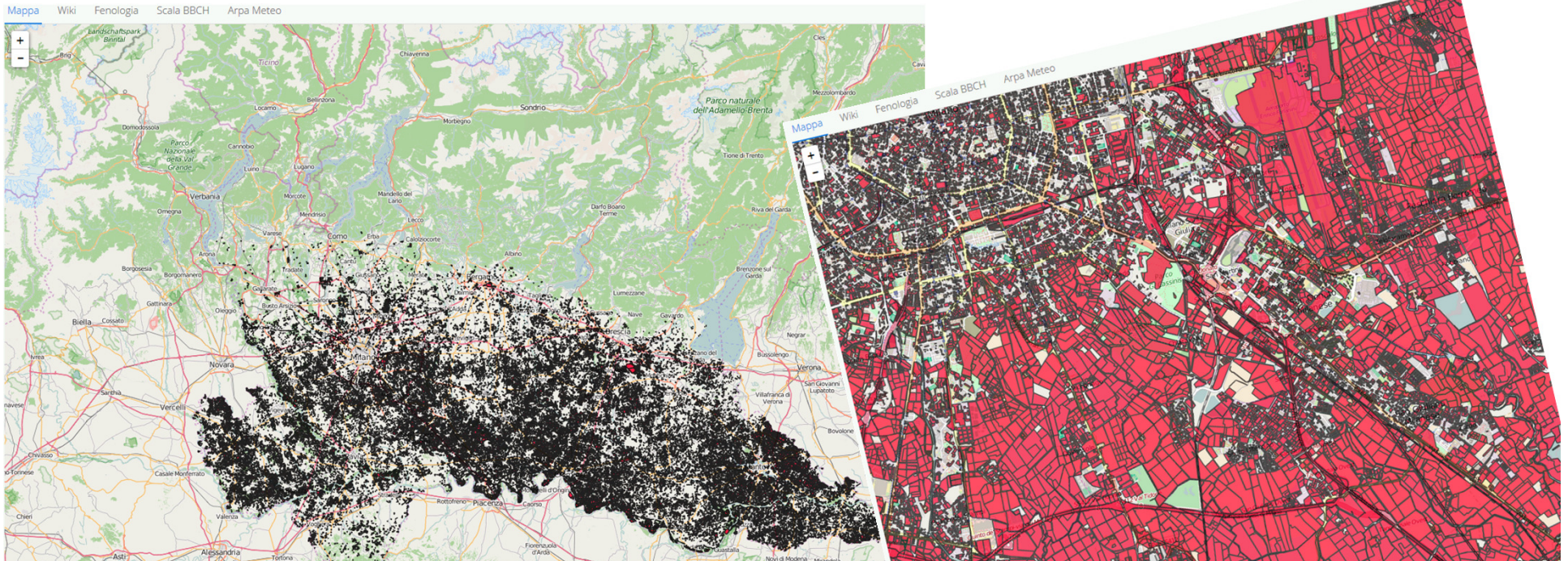


Space4Agri case study: Contextual Knowledge

G Bordogna, T Kliment, L Frigerio, PA Brivio, A Crema, D Stroppiana, ...

[A Spatial Data Infrastructure Integrating Multisource Heterogeneous Geospatial Data and Time Series: A Study Case in Agriculture](#), ISPRS International Journal of Geo-Information 5 (5), 73

- Geospatial data layer of EoI:
 - in vector format stored in the geo-database
 - in Space4Agri :agronomic cadastral parcels within Lombardy Region



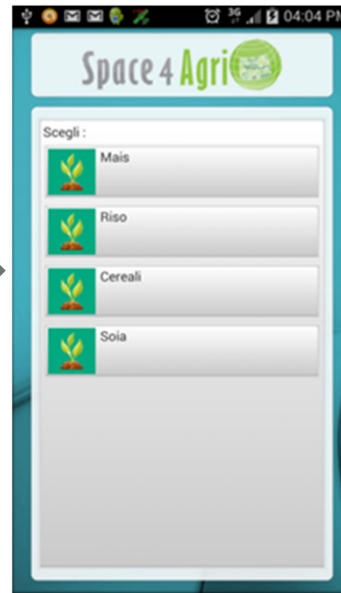
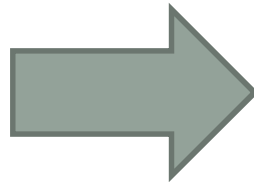
Space4Agri case study: Domain Ontology for VGI creation

- Identification of the domain ontology with the help of citizen science project leaders
 - <https://en.wikipedia.org/wiki/BBCH-scale>
 - <https://www.politicheagricole.it/flex/AppData/WebLive/Agrometeo/MIEPFY800/BBCHengl2001.pdf>
- Identification of a useful compact synthesis from the domain ontology
 - **Selection of concepts:**
 - only BBCH for rice, maize, soybean, cereals, vegetable crops
 - Codification of the compact ontology in the form of a **hierarchy of concepts**

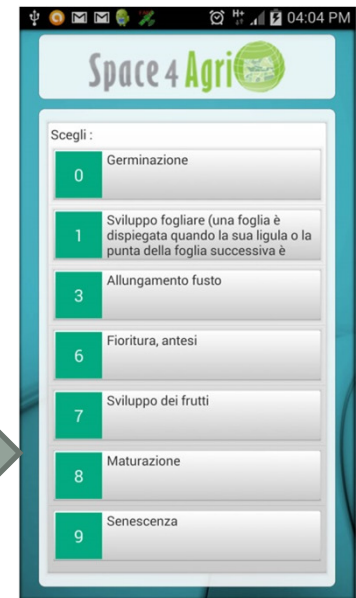
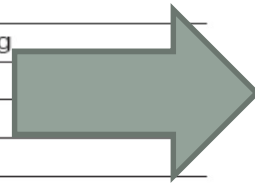
Space4Agri case study: Codification of the compact ontology in the form of a hierarchy of concepts

General Scale

Cereals, Rice, Maize
Oilseed rape, Faba bean, Sunflower
Beta beets
Potato
Fruits
Citrus, Olive, Coffee, Banana
Grapevine
Soybean, Cotton, Peanuts



	Stage	Description
	0	Germination / sprouting / bud development
Hop	1	Leaf development (main shoot)
	2	Formation of side shoots / tillering
	3	Stem elongation or rosette growth / shoot development (main shoot)
Vegetable crops I	4	Development of harvestable vegetative plant parts or vegetatively propagated organs / booting (main shoot)
Vegetable crops II	5	Inflorescence emergence (main shoot) / heading
Weeds	6	Flowering (main shoot)
	7	Development of fruit
	8	Ripening or maturity of fruit and seed
	9	Senescence, beginning of dormancy



Space4Agri case study: Codification of the compact ontology in the form of a hierarchy of concepts

Rice Lancashire et al., 1991

Phenological growth stages and BBCH-identification keys of rice (*Oryza sativa* L.)

Code	Description
------	-------------

Principal growth stage 0: Germination

00	Dry seed (caryopsis)
01	Beginning of seed imbibition
03	Seed imbibition complete (pigeon breast)
05	Radicle emerged from caryopsis
06	Radicle elongated, root hairs and/or side roots visible
07	Coleoptile emerged from caryopsis
09	(in water-rice this stage occurs before stage 05) Imperfect leaf emergence (still rolled) at the tip of the coleoptile

Principal growth stage 1: Leaf development^{1,2}

10	Imperfect leaf unrolled, tip of first true leaf visible
11	First leaf unfolded
12	2 leaves unfolded
13	3 leaves unfolded
19	9 or more leaves unfolded

Principal growth stage 2: Tillering³

21	Beginning of tillering: first tiller detectable
22	2 tillers detectable
23	3 tillers detectable
29	Maximum number of tillers detectable

Principal growth stage 3: Stem elongation

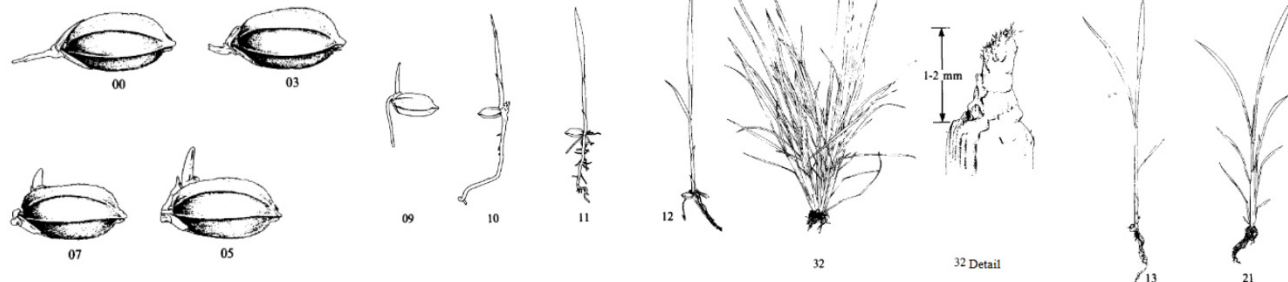
30	Panicle initiation or green ring stage: chlorophyll accumulates in the stem tissue, forming a green ring
32	Panicle formation: panicle 1–2 mm in length
34	Internode elongation or jointing stage: internodes begin to elongate, panicle more than 2 mm long (variety-dependent)
37	Flag leaf just visible, still rolled, panicle moving upwards
39	Flag leaf stage: flag leaf unfolded, collar regions (auricle and af aligned (pre-boot stage)

```

- <bbch2>
- <element>
  <codice>00</codice>
  <description>Seme asciutto</description>
  <id>24e41d30-0317-44f1-9333-62b5b018f9be</id>
</element>
- <element>
  <codice>01</codice>
  <description>Inizio imbibizione</description>
  <id>b2b563ec-af2a-4364-9a5d-ed6bd80c9bc5</id>
</element>
- <element>
  <codice>03</codice>
  <description>Imbibizione completa dei semi</description>
  <id>006e5d21-ac2c-4f26-872e-e7e1f15a4e72</id>
</element>
- <element>
  <codice>05</codice>
  <description>Emergenza radichetta dalla cariosside</description>
  <id>601557ed-687c-40db-a0e6-20c11abd9163</id>
</element>
- <element>
  <codice>06</codice>
  <description>Allungamento radice, formazione peli radicali e/o radici laterali</description>
  <id>22556cec-c721-4888-99b9-6547e834f496</id>
</element>
- <element>
  <codice>07</codice>
  <description>Emersione coleoptile dalla cariosside (con semina in immersione prima dello stadio 05)</description>
  <id>b72319ca-fa5e-41b5-918c-9167cf0d9659</id>
  
```



Rice



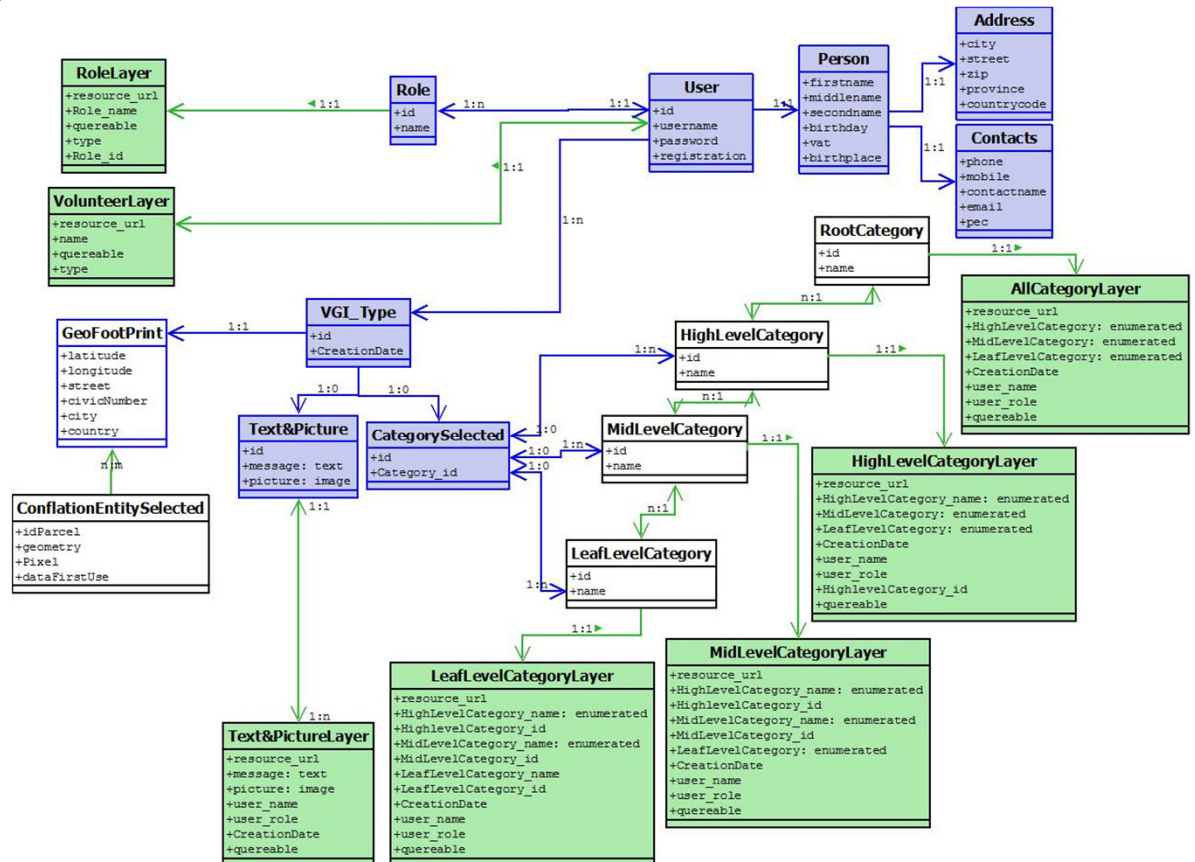
Space4Agri case study: VGI creation by the smart App



Geo Database Schema for VGI storage

From the Geo database several geospatial data sets are automatically deployed on the Web as data layers:

- Layer of textual & picture items
- Layers of categorical items
- Layers of users' roles
- Layers of specific users



VGI visualization (as Tagged Entities of Interest)

The screenshot displays a web browser window with multiple tabs open, including 'Review Paper Dow...', 'Wr359_1697.pdf', 'Wr281_9640.pdf', 'Wr359_1697.pdf', 'Wr284_1635.pdf', 'Wr281_9640.pdf', 'Paper Title (use styl...', and 'Wr229_9804.pdf'. The address bar shows the URL 'http://1...Portal/' and the page title '155.253.20.86:8080/Space4AgriGeoPortal/'.

The main content area features a map visualization of agricultural land use. A legend titled 'Legenda:...' is visible, listing the following categories:

- Cereali (Red)
- Foraggiere (Green)
- Mais (Yellow)
- Riso (Blue)
- Soia (Light Green)
- No Value (White)

The map shows various agricultural fields and roads, with labels for locations like Vidigufo, Gualdrasco, Bormasco, Ceranova, and Castel Lambro. The interface includes a navigation panel on the right with tabs for 'Profile', 'Active Maps', 'Maps', and 'Timeseries'. The 'Active Maps' tab is selected, showing 'Active Layer : none'. Below this, there is a 'Select Tile Layer' dropdown menu set to 'MapQuest-Sat'. The 'Visualized Layers' section shows 'APP:culture_bbch_campo' with a transparency slider and several control icons (search, close, print, info, refresh, and layers). Navigation arrows are visible at the bottom of the interface.

VGI visualization (VGI as Points)

The image shows a web browser window displaying a map of the Milan region. The browser's address bar shows the URL `http://155.25...griGeoPortal/`. The map interface includes a sidebar on the right with the following elements:

- Space 4 Agri Geo Portal** logo and navigation links: Profile, Active Maps, Maps, Timeseries.
- Active Layer:** none
- Select Tile Layer:** MapQuest-Sat
- Visualized Layers:**
 - BBCH_point
 - APP:bbch (Transparency: 91)
- Navigation and map controls: Home, Search, Refresh, Full Screen, Print, and a layer management icon.

The map itself shows a satellite view of the area around Milan, with numerous green tree icons overlaid, representing VGI (Volunteered Geographic Information) points. The icons are concentrated in several clusters, particularly in the northern and eastern parts of the city area shown.

VGI analysis (full concepts descriptions)

155.253.20.86/Space4AgriGeoPortal/

Most Visited Gloria Bordogna Getting Started Amazon Raccolta Web Slice Siti suggeriti Toshiba Places Geoportale Naziona...

Mappa Wiki Fenologia Scala BBCH Arpa Meteo

Legenda...

- Cereali
- Foraggere
- Mais
- Riso
- Sola
- No Value

Space 4 Agri Geo Portal

Profile Active Maps Maps Timeseries

Active Layer : APP:culture_bbch_campo

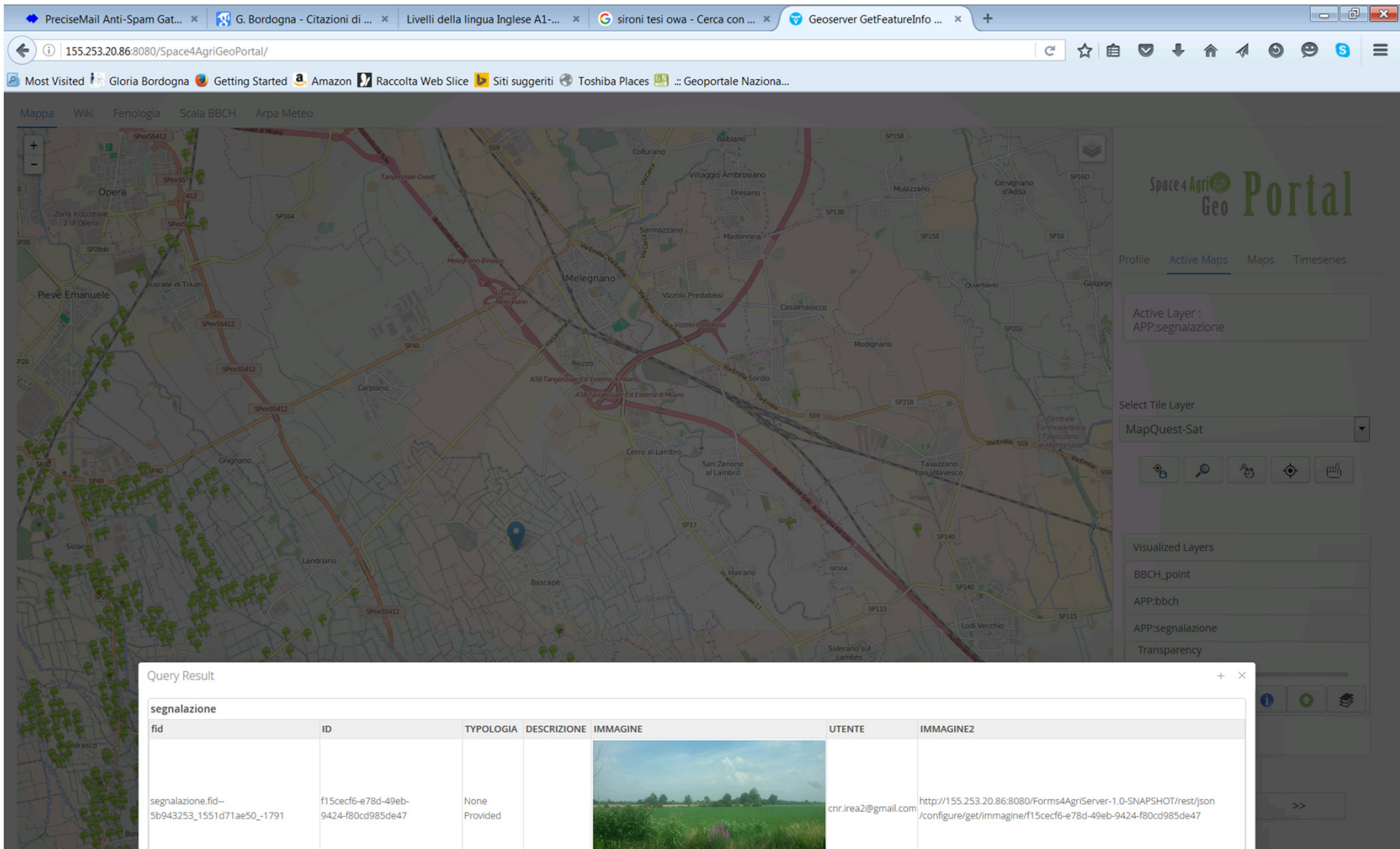
Select Tile Layer MapQuest-Sat

Visualized Layers APP:culture_bbch_campo Transparency

Query Result

fid	COLTURA	DATA_CREAZIONE_CICLOCOLTURA	CODICE_BBCH	BBCH	BBCH2	DATA_RILEVAMENTO_BBCH	BBCH_SELEZIONATO_USERNAME
colture_bbch_campo.663265	Riso	May 18, 2015 12:16:32 PM	1_12	Sviluppo fogliare (una foglia è dispiegata quando la sua ligula o la punta della foglia successiva è visibile. Accettimento e allungamento fusto possono avvenire prima della fase 13; in questo caso continua con lo stadio 21 o 30)	2 foglie dispiegate	May 18, 2015 12:16:57 PM	cnr.irea@gmail.com
colture_bbch_campo.663265	Riso	May 18, 2015 12:16:32 PM	1_12	Sviluppo fogliare (una foglia è dispiegata quando la sua ligula o la punta della foglia successiva è visibile. Accettimento e allungamento fusto possono avvenire prima della fase 13; in questo caso continua con lo stadio 21 o 30)	2 foglie dispiegate	May 18, 2015 12:16:32 PM	cnr.irea@gmail.com
colture_bbch_campo.1522520	Riso	May 18, 2015 12:17:54 PM	1_12	Sviluppo fogliare (una foglia è dispiegata quando la sua ligula o la punta della foglia successiva è visibile. Accettimento e allungamento fusto possono avvenire prima della fase 13; in questo caso continua con lo stadio 21 o 30)	2 foglie dispiegate	May 18, 2015 12:17:54 PM	ranghetti.l@irea.cnr.it

VGI analysis (full content)



Space4Agri Geo Portal

Profile Active Maps Maps Timeseries


Active Layer : APP:segnalazione

Select Tile Layer MapQuest-Sat

Visualized Layers

- BBCH_point
- APP:bbch
- APP:segnalazione
- Transparency

Query Result

fid	ID	TIPOLOGIA	DESCRIZIONE	IMMAGINE	UTENTE	IMMAGINE2
segnalazione.fid--5b943253_1551d71ae50_-1791	f15cecf6-e78d-49eb-9424-f80cd985de47	None Provided			cnr.irea2@gmail.com	http://155.253.20.86:8080/Forms4AgriServer-1.0-SNAPSHOT/rest/json/configure/get/immagine/f15cecf6-e78d-49eb-9424-f80cd985de47

VGI discovery

A Metadata record for each VGI layer is created and managed by a catalogue: it is automatically updated by harvesting WMS service endpoint and completing metadata templates

The screenshot displays a web browser window with a metadata record for a VGI layer. The browser's address bar shows the URL `155.253.20.86:8080/Space4AgriGeoPortal/`. The page title is "Query Result". The main content area is titled "Layer Metadata" and includes a search bar, a "Sign in" button, and a language dropdown set to "English". A cookie consent banner is visible, stating "This webpage uses cookies. If you continue navigating this page, we will assume you accept this." Below the banner, there is a "Back to search" button and the layer name "COLTURE BBCH CAMPO" with a "Updated: 15 hours ago" timestamp. The "Download and links" section contains a table with the following entries:

Link/Action	Description
colture_bbch_campo	This dataset is published in the view service http://10.0.5.7:8080/geoserver/APP/wms?SERVICE=WMS&with_layer_name=colture_bbch_campo
(LegendURL)	

The "Associated resources" section includes a "Related service" link for "APP: Space4Agri Project Web Map Service - Segnalazioni della S4A APP". The right side of the metadata window shows an "Overview" section with two small map thumbnails. The background of the browser shows a map interface with a legend for agricultural layers: Cereali, Foraggiere, Mais, Riso, Soia, and No Value.

Lesson Learned within the case study of Space4Agri project

Number of Volunteers that installed the S4A App	85
Number of active Volunteers (who created at least 10 VGI items)	21
Number of farmers	28
Number of VGI items about BBCH stages	2592
Number of VGI items as free text	132
Number of VGI items about agro-practices	137
Number of VGI items reporting seeding dates	223
TOTAL VGI items	3084

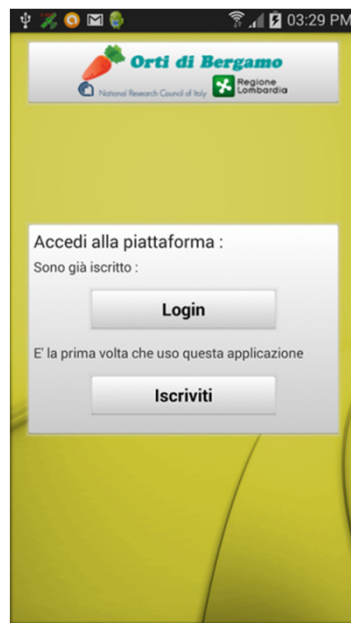
Semantically annotated text is created when volunteers have:

- Doubts in interpreting the meaning of the text associated with a BBCH code;
- Difficulty to clearly distinguish/observe the characteristic aspects of a BBCH code in the crop sample;
- Hesitancy to select a unique BBCH code for several observed crop samples close in space within the same parcel, because of the variability of their characteristics.

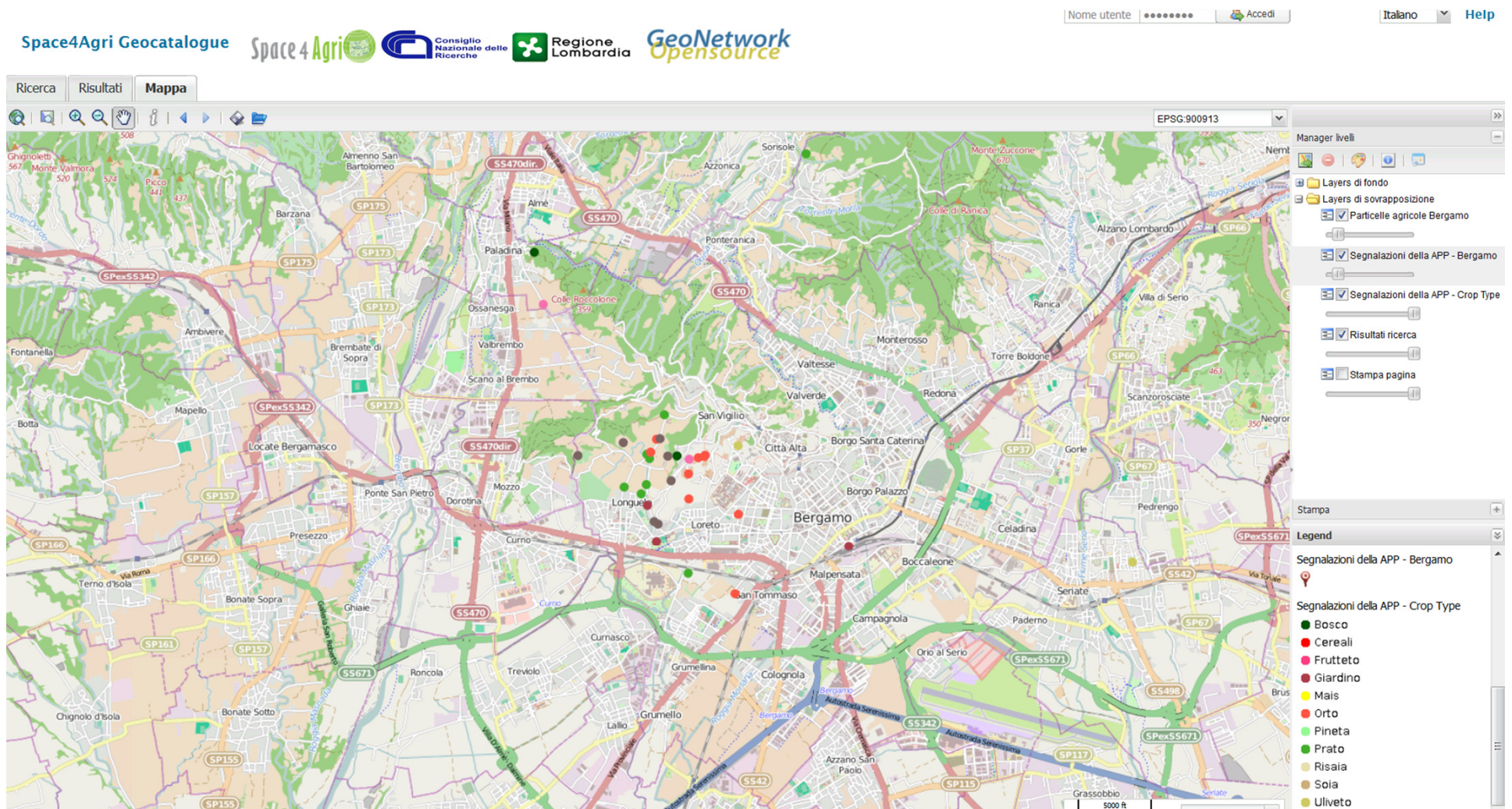
SMART APP Orti di Bergamo

APP for Android devices to tag crops typical of Bergamo area

- Orchards, vegetable gardens, vineyards, etc.
- Photos and Texts



VGI points created by Orti di Bergamo Smart APP



Both Categorical and Photos&text VGI created by Orti di Bergamo Smart APP

Nome utente: Accedi Italiano Help

Space4Agri Geocatalogue Space 4 Agri Consiglio Nazionale delle Ricerche Regione Lombardia GeoNetwork Opensource

Ricerca Risultati **Mappa**

EPSG:900913

Feature info

orto
2014-09-21T13:27:09
gloria.bordogna@gmail.com

Manager livelli

Layers di fondo

Layers di sovrapposizione

Particelle agricole Bergamo

Segnalazioni della APP - Bergamo

Segnalazioni della APP - Crop Type

Risultati ricerca

Stampa pagina

Stampa

Legend

Segnalazioni della APP - Bergamo

Segnalazioni della APP - Crop Type

- Bosco
- Cereali
- Frutteto
- Giardino
- Mais
- Orto
- Pineta
- Prato
- Risaia
- Soia
- Uliveto

VGI points created by Orti di Bergamo Smart APP overlayed with VGI tagged Eol created by Space4Agri smart App

The screenshot displays a web-based GIS application interface. At the top, there are logos for Space4Agri Geocatalogue, Space 4 Agri, Consiglio Nazionale delle Ricerche, Regione Lombardia, and GeoNetwork Opensource. The interface includes a search bar with 'Ricerca', 'Risultati', and 'Mappa' tabs. The main map area shows a detailed view of agricultural land with various colored overlays and points. A 'Feature info' window is open on the left, displaying a description, date (2014-10-09T13:21:48), user (gloriabordogna@gmail.com), and a photo of a field. On the right, there is a 'Manager livelli' panel with 'Layers di fondo' and 'Layers di sovrapposizione' sections. The 'Layers di sovrapposizione' section includes 'Particelle agricole Bergamo', 'Segnalazioni della APP - Bergamo', 'Segnalazioni della APP - Crop Type', 'Risultati ricerca', and 'Stampa pagina'. Below this is a 'Stampa' section and a 'Legend' section. The legend includes 'Segnalazioni della APP - Bergamo' and 'Segnalazioni della APP - Crop Type' with a list of crop types: Bosco, Cereali, Frutteto, Giardino, Mais, Orto, Pineta, Prato, Risaia, Soia, and Ilva.

Conclusions

Smart App to create semantically Interoperable VGI :

- Semantic Interoperability of different VGI applications
- Semantic Interoperability with authoritative and scientific geospatial data
- Exploitation of semantically annotated VGI to filter VGI based on quality

Ongoing work

- Adoption of fuzzy ontologies to represent and deal with imprecision of tassonomies and uncertainty of volunteer when creating VGI

Thank you for your Attention!

Something more

CALL FOR CHAPTERS FOR THE BOOK ENTITLED:
Mobile information Systems leveraging VGI for Earth Observation

G. Bordogna & P. Carrara eds.

bordogna.g@irea.cnr.it carrara.p@irea.cnr.it

PUBLISHED IN THE NEW SPRINGER SERIES
“Earth Systems Data and Models”

CONTENT

- A. *EXPERIENCES OF VGI CREATION & EXPLOITATION FOR EO*
- B. *TOOLS AND METHODS FOR VGI CREATION BY MOBILE DEVICES AND VGI SHARING ON THE WEB*
- C. *QUALITY, PARTICIPATION AND TRUST ISSUES OF VGI USAGE*