Cartographic data harmonisation for a cross-border project development

Applied Geomatics

Cartographic data harmonisation for a cross-border project development

--Manuscript Draft--

Manuscript Number:	AGMJ-D-14-00026R3
Full Title:	Cartographic data harmonisation for a cross-border project development
Article Type:	Original Paper
Corresponding Author:	Francesca Noardo Politecnico di Torino ITALY
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Politecnico di Torino
Corresponding Author's Secondary Institution:	
First Author:	Francesca Noardo
First Author Secondary Information:	
Order of Authors:	Francesca Noardo
	Andrea Lingua
	Irene Aicardi
	Bartolomeo Vigna
Order of Authors Secondary Information:	
Funding Information:	
Abstract:	An essential support for environmental monitoring activities is a rigorous definition of a homogeneous cartographic system required to correctly georeference and analyse the acquired data. Furthermore, since the 2007, the European INSPIRE Directive (INfrastructure for Spatial InfoRmation in the European Community) affirms the necessity to harmonize the European maps for permitting cross-border analysis. For satisfying these requirements, the authors have developed a procedure for the cartographic harmonisation in the cross border area studied during the European project ALCOTRA (Alpes Latines- COopération TRAnsfrontalière) - ALIRHyS (Alpes Latines- Individuation Resources Hydriques Souterraines). It concerns the hydrogeological study of various springs and other water resources in an area between Italy and France including their constitution in a cross-border system. The basic cartographic information is obtained from existing national maps (Italian and French data), which use different coordinate systems or projections methods and are produced from different data acquisitions and processes. In this paper the authors describe the methods used to obtain well-harmonised middle-scale maps (aerial orthophotos, Digital Terrain Model and digital maps). The processing has been performed using GIS (Geographic Information System) solutions or image analysis software in order to obtain useful and correct cartographic support for the monitoring data, even if the obtained maps could be further analysed or refined in future works.
Response to Reviewers:	Thank you for your evaluation, we tried to correct the weaknesses you poined out. We improved as possible the value of the paper as a universal methodology. Unfortunately, the specificity of each data is so high and different from the others (even between different Italian Regions' maps) that a high component of manual or specific operations is necessary. However, we emphasized the criteria, parameters and characterisitics to consider and procedures to be used for performing the harmonization, whatever were the original data. Furthermore, we added some more general considerations in order to encourage the use of the method in a more extended framework. The suggested corrections in the detailed comments were realized. In the figures, a reference was inserted for the studied area in a coordinate frame.

	All the images were corrected and improved following your suggestions.

Manuscript

Cartographic data harmonisation for a cross-border project development

Francesca Noardo[1*], Andrea Lingua[1], Irene Aicardi[1], Bartolomeo Vigna[1]

[1]Politecnico di Torino, Department of Environment, Land, and Infrastructure Engineering (DIATI), Corso Duca degli Abruzzi 24, 10129 Torino, Italy

(*) Corresponding author

[1]Politecnico di Torino, Department of Environment, Land, and Infrastructure Engineering (DIATI), Corso Duca degli Abruzzi 24, 10129 Torino, Italy
Tel. 0110907687; E-mail: francesca.noardo@polito.it

Abstract An essential support for environmental monitoring activities is a rigorous definition of a homogeneous cartographic system, required to correctly georeference and analyse the acquired data. Furthermore, since the 2007, the European INSPIRE Directive (*INfrastructure for Spatial InfoRmation in the European Community*) affirms the necessity to harmonize the European maps for permitting cross-border analysis. For satisfying these requirements, the authors have developed a procedure for the cartographic harmonisation in the cross border area studied during the European project ALCOTRA (*Alpes Latines- COopération TRAnsfrontalière*) – ALIRHyS (*Alpes Latines-Individuation Resources Hydriques Souterraines*). It concerns the hydrogeological study of various springs and other water resources in an area between Italy and France including their constitution in a cross-border system. The basic cartographic information is obtained from existing national maps (Italian and French data), which use different coordinate systems or projections methods and are produced from different data acquisitions and processes. In this paper, the authors describe the methods used to obtain well-harmonised middle-scale maps (aerial orthophotos, Digital Terrain Model and digital maps). The processing has been performed using GIS (Geographic Information System) solutions or image analysis software in order to obtain useful and correct cartographic support for the monitoring data, even if the obtained maps could be further analysed or refined in future works.

Keywords *cartography, data harmonisation, DTM, orthophoto, digital cartography, INSPIRE, ALCOTRA*

1. INTRODUCTION

A basic issue for the European cartography, since the publication of the INSPIRE European Directive (*Infrastructure for Spatial InfoRmation in the European Community*), is the harmonisation of national maps of European States to perform correct cross-border environmental analysis (INSPIRE directive, 2007).The necessity of procedures for cartographic harmonisation has produced numerous researches (Jaroszewicz et al., 2013). Various studies analyse the harmonization of reference systems (e.g. HELIDEM project) or the maps themselves (Dabove et al. 2013b) for general purpose product, some other ones describe the harmonisation of the mapping applications on specific thematic data, for example for environmental studies (Fabbro, Haselberger, 2009). Furthermore, some study for the harmonisation of semantic data based on INSPIRE have been performed, but often they concern specific themes: e.g. land cover / land use (Valcarcel et al., 2008), hydrography (Reis, Barrot, 2010, Vilches-Blázquez et al., 2007), information for fire management (San-Miguel-Ayanz, 2003), environmental thematic information (Zsófia, 2011). Several researches are today aimed to the effective use of semantics in the management of spatial information (http://wogis2.igig.up.wroc.pl/wogis/), which will offer some more specific tools and procedures for future automatic harmonisations. Few projects aim to the harmonisation of the whole digital map (Jakobson et al., 2013, Batista et al., 2013), as the presented study do. In particular, the investigated area between Italy and France presents various problems, which are not completely resolved but are object of current researches (Haase, Frotscher, 2005, Şahin, Alkış, 2013): since it is a cross-border area, different national standards are used for symbology, acquirement and plotting methods, data semantics, data languages, distinct coordinate systems and projection methods. The major difficulties are also due to the fact that it is an Alpine area, so that the represented topography is complex. Our work wants to solve these problems in order to obtain harmonised orthophoto and DTM (*Digital Terrain Model*). The performed study manages the harmonisation in order to produce maps suitable for a representation scale 1:25000, useful for performing environmental studies about subterranean water resources, which is the objective of the European project ALCOTRA – ALIRHyS. To properly understand the real utility of this study it is important to note that the official mapping agencies of two involved countries (Istituto Geografico Militare, IGM, in Italy and Institut Géographique National, IGN, in France) have not yet developed common mapping projects for cross border areas. Moreover, some differences exist even between the regional maps, which can be downloaded from the geoportals, belonging to the same State (for example, at present, in Italy, even if a standardisation process is in progress).

Therefore, in this paper, the authors analyse the existing maps in a critical way for pointing out the problems and the characteristics to consider for similar processes. A simplified procedure is proposed: starting from the accuracy of a medium scale map required for current project, it is possible to easily solve some of the various problems of cartographic harmonization (DTM, orthophoto, the semantic of digital map) using common GIS management systems and image analysis software. The proposed approach is realized on a specific area and case study, since it is not possible to generalize such a processing, which uses potentially very different original data. However, a methodology is proposed, considering the parameters and characteristics to be analysed when harmonizing a map. The described procedures can be applied also using different data. Some of them were already tested during other similar projects, having different original data (Dabove et al. 2013a), and a further refinement was made. The methodology can be therefore easily exported to different cases study, caring the characteristics of the maps and further cartographic products to be harmonized, from the transformation among different cartographic reference and projection systems, which is a well-affirmed issue in geodetics, to further more specific aspects.

1.1 The INSPIRE Directive

Every harmonisation activity has followed the INSPIRE Directive (http://inspire.jrc.ec.europa.eu/): a European Union directive aimed at creating a European spatial data infrastructure, able to establish a unique underground for sharing the environmental spatial information among European States. The directive has been in force since 15th May 2007 and, after passing through various stages, will be fully implemented by 2019.

Two of the main principles of INSPIRE are: "It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications; […] Easy to find what geographic information is available, how it can be used to meet a particular need, and under which conditions it can be acquired and used" (INSPIRE, 2007). As in some other works related to cartography harmonisation (Afflerbach et al. 2004; Tóth, Smith 2007) and also in the ALIRHYS project, our purpose was to respect these two principles, by producing some harmonised cartography and possibly sharing it on a WebGIS together with every useful metadata.

Concerning the semantic content of digital maps, the INSPIRE Directive also provides a Conceptual Model including 34 spatial data themes. This standard was used as reference for the harmonisation of the digital cartography.

1.2 The data for testing the methodology: the project ALCOTRA – ALIRHyS

The European project ALCOTRA – ALIRHyS (*Alpes Latines- Individuation Resources Hydriques Souterraines*) is realized by the partnership among Politecnico di Torino, Politech Nice Sophia, Université Nice Sophia - Antipolis, Regione Piemonte, Nice-Côte d'Azur Metropole. The aim is the monitoring of the subterranean hydric resources in the cross-border mountainous territory between the provinces of Cuneo and Nice (including the regions: Piedmont, Alpes-de-Haute-Provence, Hautes-Alpes, Alpes Maritimes, Fig.1) from 2013 to 2015. These activities are required in light of the climatic changes that have occurred over the last years increasing the risks caused by climate inconstancy: periods of drought alternated with flooding are becoming more and more frequent (Pasini et al., 2012). Subterranean hydric resources feed several springs in the area from which the local hydrographic network originates. These resources also feed several aqueducts that supply drinking water to users; for this reason it is essential to know the chemical composition of the water and foresee the influence of rainfall and snow fusion on the behaviour of the springs in order to optimize their management. These parameters can only be studied from a cross-border point of view: the geological assets influence both sides of the Alps, therefore studies must be carried out in an overall way.

The main activities of the project were:

- to determine and monitor chemical and physical parameters of the springs by means of newly-installed instruments;
- to analyse previous data in order to integrate historical information;
- to determine the areas of alimentation by means of tracking tests;
- to determine the influence of meteorological parameters of rainfall and snow fusion on the behaviour of the springs;
- physical data modelling;
- hydric resource optimisation;
- cartography harmonisation for the determination of a unique base for data study and representation;
- data base and GIS construction for an integrated data management and to publish the project results in journals, videos, conferences and a web site including a WebGIS for the sharing of data and project outputs.

It is essential to have a unique cartographic base to model the acquired data in an effective way, support the necessary analysis, contextualise the information and represent the results. In this paper, the part of the project regarding cartographic data harmonisation is presented, which was carried out by the authors following the available instructions of the INSPIRE Directive. The harmonised cartographic products are DTM, orthophoto and digital maps, which are useful for modelling water behaviour, individuating geographic information and view the final results on a homogeneous base.

2. Common coordinate system and unique cartographic representation

The national datasets used different coordinate systems, which were transformed following the INSPIRE Directive. The residual differences in the projection systems is harmonized as a preliminary processing step. In the past, the Roma40 coordinate system was used in Italy. It's based on the Hayford ellipsoid oriented in Monte Mario (Roma) used with Gauss-Boaga projective representation, a suitably modified conformal Gauss representation (with false origins for the two zones: 1500 km for the west zone and 2520 km for the east zone; the overlapping zone between the two is 30' and the contraction module is 0.9996). IGM (*Istituto Geografico Militare*) vertices of the triangulation compose the reference network realizing this reference system. The same system is used in the Region of Piedmont.

Following the INSPIRE Directive, used in Italy in accordance with the decree passed on 10th November 2011 "*Adoption of the national geodetic reference system*", the geodetic Italian system is now the ETRF2000 (*European Terrestrial Reference Frame*) at the 2008 version of the reference System ETRS89 (*European Terrestrial Reference System*), obtained by IGM in the Dynamic National Network. This network is the set of GNSS (*Global Navigation Satellite System*) permanent stations, which enable us to continually trace their location in respect to the reference ellipsoid, now the IAG GRS80, by adapting their own coordinates to residual deformations of the Eurasian plate. The final projection is the conformal representation (based on the Gauss one) internationally named Universal Transverse Mercator (UTM), using the zone 32 for the study area (Fig.2). Heights are measured with the most recent model of Italian geoid, named ITALGEO 2005, derived from integrated gravimetric measurements, GNSS and geometric levelling using the tide gauge of Genoa as starting point.

In France, the IGN (*Institut Geographique National*) historically used a reference system based on the Clarke 1880 ellipsoid oriented at the Paris Astronomic Observatory and represented the maps produced with a conformal Lambert projection (Mugnier, 2001). This is a conic projection, used as Lambert 93 for a unique representation of the whole metropolitan France by means of digital data. The representation uses 44°N and 49°N as secant parallels, 3°E (Greenwich Meridian) as reference meridian, 46°30' as origin parallel and X_0=700000 m, Y_0=6600000 m as origin coordinates. The "Lambert 9 zones" projection is used for the regional cartography. It subdivides the national territory into 9 zones, each with different, adapted, secant parallels and origins, for limiting linear deformations. IGN only recommends the use of this representation for paper maps, in order to permit a correct direct measurement of distances. By following the INSPIRE directive, that is used in France in compliance with decree n° 2006-272 of the 3rd Mar. 2006, *"Land Management and development concerning the conditions of execution and publication of survey plans undertaken by public services"*, the metropolitan French reference system is based on the ellipsoid IAG GRS80. The geodetic reference network, named RGF93_v2 (*Réseau Géodésique Français*), is a realization of ETRF2000 in the 2009 version of the ETRS89 and it is based on a permanent GNSS station network (RGP – *Réseaux GNSS Permanents*). The cartographic representation used continues to be the Lambert 93(Fig.3). Heights reference system is composed by integrated normal height and gravimetric measurements, GNSS and geometric levelling (RAF09). The Marseilles tide gauge is the point of origin of the height system.

A preliminary requirement for producing a harmonised cartography is to choose a reference and projection system in which to transform the existing national products by applying some geodetic transformation, choosing the best fitting method (Carosio, 2006). The coordinate system selected for the data representation of ALIRHYS project is based on the ETRS89 in the ETRF2000 version with the UTM representation in the zone 32, in accordance with the INSPIRE directive. The data conversion in this reference system can be achieved thanks to the fact that Italy and France have a common geodetic datum, IAG GRS80 used in Europe for the ETRF2000. Consequently, the geographic coordinates (ϕ, λ) of the same point coincide in the two national reference systems. Moreover, the UTM 32 zone (6°-12° east longitude from Greenwich) includes the whole region of Piedmont and the whole study area in France. It is therefore possible to use the UTM representation with the well-known cartographic deformations and characteristics.

2.1 The conversion procedure

The available mapping data of Italy and France, that have been recently produced, are partly coherent with the chosen reference system, except for the used projection type: the Italian projection system is already UTM, while some transformations are still required for the French maps.

Considering these assumptions, for harmonisation step, all the French data must be converted into the selected projection system in order to obtain seamless unique maps. The conversion procedure is quite simple, and it is developed by following three main steps:

1. you can define geographic coordinates (ϕ_{FR},λ_{FR}) with the relationships provided by the IGN website (http://geodesie.ign.fr/index.php?page=algorithmes), for a point in the Lambert93 cartographic system, known in its cartographic coordinates (E, N);
2. it is then possible to calculate the geographic coordinates in the ALIRHyS system (IAG GRS80): $\phi_{AL}=\phi_{FR}$, $\lambda_{AL}=\lambda_{FR}$;
3. by using Hirvonen formulas (Hirvonen, 1972), geographic coordinates ϕ_{AL}, λ_{AL} can be transformed in cartographic coordinates (E_{UTM}, N_{UTM}) in the reference system UTM ETRF2000 zone 32.

The conversion does not require datum change, so it is based on known formulations in a closed form: therefore it is possible to perform it by using the automatic conversion of the GIS software.

Some raster maps, derived from paper map, were used to increase the cartographic information; these were manually georeferenced using Ground Control Points through GIS georeferencing tools to perform the transformation (Fig.4).

From the heights point of view. The INSPIRE directive foresees the use of a quasi-geoid named European Vertical Reference Frame (EVRF) for the height reference system. There are only a few centimetres of difference between this system and the two national height reference systems considered, which can be important for some kinds of applications, but ALIRHyS case requires a middle-scale representation (about 1:25.000), therefore, for this reason, these discrepancies can be ignored.

3. The Orthophoto harmonisation

First harmonised datasets have been the orthophoto coverage of study area: a unique cross-boarding orthophoto was mosaicked in order to obtain a homogeneous base on which visualize the data and that can be support for an easy multidisciplinary photo-interpretation at small scale.

The Piedmont Region recently produced a collection of orthophotos of the entire regional area, which are available in Creative Common licence and downloadable from the regional website in raster format (JPeG). The original files are georeferenced, with a 40 cm GSD (*Ground Sample Distance*) which is suitable for a nominal scale of 1:10000.
The French data were provided by IGN in raster format (.ecw), for research activities: the orthophotos are georeferred, with a 50 cm GSD for a nominal scale of 1:25000 scale.
The two datasets have different coordinate systems and different GSDs: these are the parameters to be harmonized to obtain unique common data. The French orthophotos were therefore exported into the ALIRHyS coordinate system (UTM ETRF2000 zone 32) using GIS conversion tools (implementing the procedure described in section 2.1).
All the georeferred 3-bands orthophotos were then mosaicked in a unique image using operators considering the values of the first introduced raster (which was the Italian one, since it was clipped on the border, with a 250 m buffer) as values for the overlapping areas (Fig.5). The images were resampled with a nearest-neighbour algorithm to obtain a homogeneous pixel dimension and a better management of the final map thus obtaining a final product with a 5 m GSD. There are no visible geometric discontinuities at the border between the two states on the final orthophoto. Some colour differences are visible probably due to the different times in which the original photos were taken.

In some cases different amounts and distributions of snow can be seen in the original orthophotos of the two States (Fig.6), especially in the high mountain areas. This problem does not affect the final results, because the important geometries are anyway well recognizable. It is not possible to eliminate this problem, unless acquiring some new photos of the boundary, better in a period without snow, for merging the results in a continuous texture.

4. The DTM harmonisation

Other essential data for the modelling of the project information is the harmonised DTM. It was fundamental to have these data for analysing the alimentation areas, the rainfalls and the watershed of the studied springs. The available height data consist in the Italian and French DTM (Table 1).

The Piedmont Region recently produced the DTM of the entire regional area, which is available in Creative Common licence and downloadable from the regional website in raster format (ESRI ASCII grid). These data are georeferred in the Italian coordinate system and they are classified as level 4 (grid size of 5m, 0,60 m accuracy in normal situation, 1,20 m accuracy for high vegetation areas).

The French DTM was provided by IGN for research activity, in raster format (ESRI ASCII grid). It is georeferred in the French reference system and it is classified as a level 1 (25 m grid-step, 15 m accuracy).

	Author	Grid cell size	Year	Coordinates System	Accuracy
DTM Italy	Piedmont Region	5 m	2012	UTM ETRF2000 32 zone	0.6 m 1.2 m with trees presence
DTM France	IGN	25 m		Lambert 93	15 m

Table 1 - Original National DTM characteristics

As we can see, the original data are different, therefore it is essential to make them similar (same reference system and same grid size) in order to compare, analyse and harmonise them. The Italian DTM was resampled to 25 m using bilinear interpolation, so that its accuracy became about 2.4 m (Table 2). The French DTM was exported in the ALIRHyS coordinate system (UTM ETRF2000) using GIS conversion tools and resampled (bilinear technique) to obtain a regular spaced grid with 25 m cell-size.

	Author	Grid cell size	Year	Coordinates System	Accuracy
DTM Italy	Piedmont Region	25 m	2012	UTM ETRF2000 32 zone	2.4 m
DTM France	IGN	25 m		UTM ETRF2000 32	15 m

				zone	

Table 2- Pre-processed Alirhys DTM

The Italian DTM covers the Italian zone, plus a buffer zone of 250 m from the border over the French border zone. The French data cover the entire ALIRHyS area, so that the overlapping zone of the two data is the whole Italian area and a strip of 250 m in the French area on the boundary (Table 3).

	Area [km²]	**%**
Italy	1557	97.2 %
France	45	2.8 %
TOT.	1602	100 %

Table 3 - Overlapping DTM area

The DTMs have been compared following the methods proposed by heli-DEM project (Dabove et al. 2013b), for evaluating the discrepancies and determining the possible integration problems. The final solution must satisfy the quality properties of a level-1 DTM according to a representation scale of 1:25000.

The height differences between the two models (Δh) on the overlapping area can be calculated by means of the Raster Math tool in ArcGIS. These were classified following the variance propagation law applied to a difference: the precision of the difference between the two DTMs is about 10 m, from which other classes derive. More than 75% of the DTMs values are coherent with the individuated tolerance (10 m) as we can see from the statistical analysis (Tables 4 - 5) and the processed map (Fig.7). The differences of most of the points (about 99.8 %) are less than 50 m in absolute value; some limited tails (0.13 %) show differences greater than 50 m, reaching more than 300 m in some cases. As we can see from statistical values, the average value is very close to 0, therefore it is possible to exclude the presence of systematic errors between the two DTMs, probably due to the reference system or the acquisition system. A different acquisition system can bring very different results, from a large – scale mapping (Chiabrando, Spanò 2009, Pirotti, 2013) to a lower level of detail using even satellite images (Poli, 2004). The standard deviation (sd) of the differences fits the expected accuracy. The distribution of differences is normal (kurtosis value near to 0) with a light asymmetry towards the left, as underlined by the median value.

Limits	**%**
O ≤ |Δh| < 10 m	76.01 %
10 m ≤ |Δh| < 50 m	23.86 %
50 m ≤ | Δh| < 150 m	0.13 %
150 ≤ | Δh|	0.002 %

Table 4 - Percentage of classified values of Δh on the entire overlapping area

Statistic	**Values**
Δh min [m]	0
Δh max [m]	306
Average [m]	-0.007
Median value [m]	72.5
SD	9.39
Skewness	-0.0000002
Kurtosis	-0.000000024

Table 5- Statistics of Δh on the entire overlapping area

Having verified the presence of some strong discrepancies, which were greater than expected from Italian DTM, we decided to use the Italian data for the main Italian part (since they are more accurate) and the French data (which are the only available data) for the main French zone. These were harmonised on a 500 m strip between the two States, on which the two DTM overlap symmetrically, by means of a proposed fusion methodology.

The same analysis procedure used for the entire overlapping zone was adopted for analysing the discrepancies of the two DTM on the 500 m strip of land on the borders of the States, in order to evaluate the possibility of harmonising them without meaningful problems. The results of this new comparison (Fig. 8) are very similar to the results obtained over the entire area, since they have the same statistical tendencies as this zone (Tables 6-7). Therefore, there are no systematic errors or other problems involved in the harmonisation.

Limits	**%**
O ≤ |Δh| < 10 m	70.3 %
10 m ≤ |Δh| < 50 m	29.4 %
50 m ≤ | Δh| < 150 m	0.3 %
150 ≤ | Δh|	0.0 %

Table 6 - Percentage of classified values of Δh on the 500 m border strip

Statistic	Values
Δh min [m]	0
Δh max [m]	149
Average [m]	-0.25
Median value [m]	17.0
SD	10.8
Skewness	-0.0000048
Kurtosis	-0.00000038

Table 7- Statistics of Δh on the boundary 500 m strip

The values of the harmonised DTM on the border strip were calculated by means of a weighted average of the original values, following the relation:

$$H_A = DTM_{France\ A} * \frac{D}{500} + DTM_{Italy\ A} * \frac{500 - D}{500}$$

where H_A is the height of the final harmonised DTM used for ALIRHyS; D is the distance of the considered point from the extreme line of the same strip toward the Italian territory; $DTM_{France\ A}$ is the French DTM adapted to the ALIRHYS system by means of the required transformations; the same is for $DTM_{Italy\ A}$.

In order to apply this relation practically, a raster image containing distance values was obtained in GIS: the values are 0 in correspondence to the extreme line toward Italy and 500 on the opposite side, on the extreme line toward France (Fig. 9). Having obtained this product, it is possible to implement the individuated equation using mathematical operations with bands of raster processing software for obtaining the final values of the selected strip (Fig. 10). The next step is to mosaic the three parts into a unique harmonised DTM considering the created strip overlapping the original DTM (Fig. 11).

Some sections were extracted in order to test the results (Fig. 12) and we computed some differences with the national DTMs. The sections show that there are no meaningful errors in the final land shape: no peak-effect due to interpolation algorithms are verified and profiles are similar to the ones which can be extracted on continuous DTM (for example the French DTM, which covers also the Italian part can be a good reference for this task). The discrepancies between the new DTMs and the original DTMs, computed in a second test, are coherent with the national DTM tolerances if we consider the differences between each national DTM and part of the final DTM in the respective territory, as shown in Fig. 13.

In the future, an EuroDEM will be available for Europe, at a 1:100000 scale (http://www.eurogeographics.org/content/products-services-eurodem). This will be processed with national height data. Different product quality levels are defined according to the origin of the data: 8-10 m accuracy is expected if the States have national DTM. If a State does not provide heights data, low quality SRTM data (Shuttle Radar Topography Mission) is used with a +/- 15m error. For this product the grid cell-size will be 2 arc-seconds (about 60 m in the meridian direction). This European data could not be used for analysing our data as it was still being processed.

5. The harmonisation of digital map

Finally, the harmonisation of digital maps has been performed, in order to have a homogeneous base for interpreting and analysing the project data. No advanced semantic harmonisation has been performed, since it was not a goal of the project: DTM was necessary for hydrological analyses and orthophoto for visual interpretation of mainly natural environment, where little (urban) entities are represented in digital maps and, thus, semantically manageable. Anyway, the maps have been harmonised bearing in mind both their representation geometry and their data base coding (semantic).

There are some differences between the original digital maps of Italy and France. Each case must be considered as a single case, since the heterogeneity of the original maps make impossible to state a universal procedure. However, a common conceptual model is provided by INSPIRE, and problems, which are common to several existing national digital maps are pointed out through the specific analysis of the Italian and French cases.

The Italian digital map is available on the Piedmont Region website in ESRI shapefile format (SHP) in both 1:10000 and in 1:50000 scale (the version 1:50000 is an adapted product that uses as source data the 1:10000 version). The French data were provided by IGN in ESRI shapefile format (SHP) for research purposes. It is projected in the RGF_1993 coordinate system, Lambert projection for a 1:50000 scale (having an accuracy of a standard deviation from 15 to 50 m depending on each theme).

Considering the represented geometry, it is necessary to change the coordinate system and to consider the differences caused by various represented objects, representation scales and probably different acquisition systems of original data. In this case we re-projected the maps in the ALIRHyS reference system, with the same procedure used for previous data, but the data geometry was not changed since it was far from the aims of the project. It would be necessary to produce the data from the acquisition phase (different acquisition method can generate the big differences in accuracy among the same French data for different themes, for example) to the plotting and structuring of data.

To harmonise the map data structure, the authors propose a solution, in according to original data characteristic and INSPIRE directive requirements. The national databases were analysed in order to determine the data structure used for constructing the data system. The conceptual models observed were represented using a UML (Unified Modeling Language) schema, in which only entities, attributes and relations relevant to our purposes were considered, that is, the ones representing the land on which hydric resources are located; we therefore considered a simplified version of the original cartography (Fig. 14-15).

The two data must be harmonised in a unique database, which, in turn, must have a data structure based on a third conceptual model. This is derived from the INSPIRE UML model (http://inspire-twg.jrc.ec.europa.eu/datamodel/draft/r4530/), established as reference for the European digital map. This model can be considered as the general ontology, from which to extract the needed entities for the specific application at the needed representation scale (Fig.16).

Comparing the three models, we can see how similar the represented objects actually are, although they have a very different structure and hierarchy and sometimes their definition is based on different attributes, so that some entities can only be merged using a first hierarchical level. For example, in the Italian cartography the roads are classified mainly as being "paved" or "unpaved", while in the French map they are classified according to their hierarchical function. Therefore, the only correct way of classification is to merge them into the general concept of "road". This problem will be further investigated in future work: it is worthy to consider better transition from very different national data models and the general reference ontology.

The simplified INSPIRE UML model is considered as a reference for the harmonisation of the ALIRHyS digital map and each entity is extracted from the original database to be translated by means of the necessary processing in the new digital map. Origin entities are selected according to their attributes and exported into new shapefiles, making sure that extracted objects belong to the same domain (points, areas, lines…). If they are not homogeneous, some transformations are carried out to obtain the same kind of object, even if it is not completely correct for some traditional representations. For example, if a building or area is indicated with a point and it needs to be represented as a polygon, a buffer is applied to the point in order to obtain an area that can be merged with other similar objects. The resulting area does not represent the shape of the object, but it becomes conceptually correct in coherence with the defined model.

Wherever possible, other attributes defined by the INSPIRE model were added; they are filled in through a database correspondence table joined to the shapefile with reference to present values (through a join function in GIS).

Lastly, the different shapefiles are merged in order to represent a unique entity. By using this method we obtain a unique output entity and preserve the original data. Moreover the correspondences among the three models were documented (in the three respective languages: Italian, French, English). A "DB_Origin" attribute was included in order to explain the provenance of the data in which the data origin Nation ("it" or "fr") can be observed with the link to the respective metadata. These data are included in the new database using the *Field Calculator* tool through *VBscript* option.

Whenever attribute values from various origin fields in a unique field are required, a new attribute is added to the merged shapefile table and it is filled in using the Field Calculator tool through "*if*" *VBscript* option in reference to the previous values of the field. This is useful, for example, for geographical names, considered as points, which are called "RefName" in the Italian DB and "Toponyme" in the French DB. These were used as described above in order to create a new field called "INSGeoName": the prefix "INS" indicates the provenance of the attribute from the INSPIRE model, followed by the attribute name stated in the INSPIRE UML model. This is useful for simplifying queries and representation options, such as labels or symbols.

The resulting digital map is less complicated than the original one, and asymmetries can be observed in the representation geometries, as already mentioned in considerations concerning the nature of the data (Fig.17). The main aim is to harmonise the structure of the data so that it can be read and interpreted as a homogeneous system. This harmonisation could be carried out using an automatic procedure in other circumstance, as some previous studies realised (Du et al. 2011). This is one of the actual aims of establishing standards such as CityGML and reference domain ontologies, like the INSPIRE Conceptual Model. For realizing ALIRHyS digital maps these methods were not used because of the previously explained difficulties; furthermore, it would have required more processing steps which would go far beyond the specific necessity of the project. Anyway, future works will be addressed to these aims. The future work can not even stop here, since the interested entities (which are environmental entities, present in the

INSPIRE model) are not always represented in national digital maps. Moreover, it is evident that such procedures must start from quite similarly conceived data, since, if they are radically different in the representation and in the conceptual level structure and classifications, the harmonisation procedure could not be suitable anyway. In the example of the roads, previously reported, the necessity of an almost manual intervention is clear.

6. CONCLUSIONS

The characteristics of cartographic products have therefore been harmonised and they have been successfully employed in the modelling and analysis of the ALIRHyS project data.

First of all, the coordinate system was harmonised, then the specific characters of each cartographic product was analysed for being sufficiently kept after the translation to the new harmonised map. In the end of this harmonisation process, the obtained results are correct according to the quality characteristics at a nominal scale of 1:25000, both for their geometric and semantic contents.

Some methods have been employed, deriving from previous research (e.g. the statistical analysis on the DTMs have has reference the Heli-DEM project), while other processing have been experimented for the specific application. No specific processing has been used for mosaicking the orthophotos, because the change of reference system was sufficient. To harmonize the DTM, the nature of original data was considered and the processing was adapted in order to keep some symmetry between the available data. Finally, the digital map structure was harmonised through several automatic steps, or with some manual passage, considering as reference the INSPIRE UML model. In all the cases some critical evaluation of the origin data and analysis of the requirements and characteristics of the final products are indispensable, and must be evaluated from a skilled point of view in order to avoid possible errors to which a simple a-critical operating processing could lead. Once established and controlled the procedure, simple GIS tools can build up batch-processing which can be used by common operators.

Nevertheless, the final products show some unavoidable differences due to the distinct origin of the data. Regarding the orthophotos the incoherence is due to the different periods in which data were acquired where some colour differences on the state borders can be observed. Even if the DTM were harmonised on the borders, there are still some variations in accuracy between the two national territories, due to various original representation scales, data acquisition or interpolation methods. In the digital maps, the asymmetries are due to the independent original data structure for the DB part and a different representation scale or plotting methods and data origins for the geometric configuration.

Concerning the semantics of digital cartography, INSPIRE lays the basis for the map's harmonisation: it gives the reference conceptual model to be followed for maps production and maps harmonisation. However, some application infrastructures is missing: national cartography uses very different schemas and logic models, which often are different even between different Districts of the same Country. For this reason in future works, it would be suitable to arrange some intermediate schemas fitted to the different kinds of application schemas for easily and correctly harmonising the maps, without permitting too much interpretation of the data in the passage from the national to the harmonised cartography. If similar study will be performed, the INSPIRE model could be enhanced where necessary in order to keep the granularity and the specification of national maps, when greater than the one concerned by the INSPIRE model. Some more future work on the theme will concern the automatic translation in the new shared schema, instead of the manual extraction of the entities, even if the best solution could be the establishment and use of common practises and rules for the acquisition, plotting and structuring of the data.

For this application, both proprietary commercial software (e.g. ESRI ArcGIS and Excelis ENVI) or open-source solutions (such as PostgreSQL-PostGIS, QGIS, GRASS, OTB, etc.) can be used. For the aims of interoperability of the current tendencies in standardisation, next studies will prefer open source software also because they offer more customizable plug-ins. Moreover, some National and International lows (such as the Italian Circular 63/2013) encourage public institutions to use open-source software.
Another characteristic to be considered in future development is the object-oriented language on which models, such as INSPIRE UML model, are based. This permits to exploit useful constructs, for example inheritance, which are important for cartographic object management.

Acknowledgements

Project ALCOTRA – ALIRHyS, partnership: Politecnico di Torino (DIATI), Univ. Nice Sophia -Antipolis – Polytech Nice-Sophia, Regione Piemonte, Métropole Nice – Côte d'Azur (NCA); 2013-2015.

References

Afflerbach S, Illert AandSarjakoski T (2004), The Harmonisation Challenge of Core National Topographic Databases in the EU-Project GiMoDig. In: Proceedings of the XXth ISPRS Congress, July 2004, Istanbul, Turkey. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, XXXV(B4/IV), pp.129-134.

Batista T, Caballero C, Ceballos F, Carriço C, Mateus J, Lopes H, White P.V, Cabezas J, Fernández L, Pinto-Gomes C (2013). IDE-OTALEX C. The First Crossborder SDI between Portugal and Spain: Background and Development. In: Journal of Earth Science and Engineering, 3(6), p.393-400.

Carosio A, Piras M, Salvini D (2006), The forward search method applied to geodetic transformations. In: Zani S, Cerioli A, Riani M,Vichi M (ed), Data analysis, classification and the forward search Book Series: Studies in Classification Data Analysis and Knowledge Organization, pp. 181-188 DOI: 10.1007/3-540-35978-8_21.

Chiabrando F, Spanò A, (2009). Digital wide scale orthoprojections and mapping from low-height aerial images. Journal of Cultural Heritage, vol. 10 pp.e49-e58.

Dabove P, DeAgostino M, Manzino A M, Taglioretti C (2013), Analisi e validazioni condotte dal Politecnico di Torino. In: Bollettino della Società Italiana di Fotogrammetria e Topografia, Numero Speciale 2013, Il progetto HELI-DEM, SIFET, pp. 91-97.

Dabove P, Manzino A.M, Taglioretti C, (2013), The importance of the orthometric correction in the North of Italy considering a global model of geoid: a real case study. In: IAG Scientific Assembly 2013, Potsdam, September 1–6, 2013. p. 102.

Du H, Jiang W, Anand S, Moreley J, Hart G, Leibovici D and JacksonM, (2011), Ontology Based Approach for Geospatial Data Integration. In: International Cartography Conference 2011.

Fabbro S, Haselsberger B (2009), Spatial Planning Harmonisation as a Condition for Trans-National Cooperation. The case of Alpine-Adriatic Area. In: European Planning Studies, vol.17, pp. 1335-1356 DOI: 10.1080/09654310903053521

Haase D, Frotscher K (2005), Topography data harmonisation and uncertainties applying SRTM, laser scanner and cartographic elevation models. In: Advances in Geosciences, European Geo-sciences Union (EGU), 2005, 5, pp.65-73.

Jakobsson A, Ostensen O, Lovell D, Hopfstock A, Mellum R, Kruse D, Portele C, Urbanas S, Hartnor J, Bray A, Aslesen L (2013). European location framework—One reference geo-information service for Europe. In: Proceedings of the 26th international cartographic conference, Dresden p. 25-30.

Hirvonen, R. A., 1972. Matemaattinengeodesia. TeknillisenKorkeakoulunYlioppilaskunta, p. 223.

Jaroszewicz J, Denis M, Rutkowska A.Z, (2013), Harmonization of spatial planning data model with INSPIRE implementing rules in Poland. In: 13thSGEM GeoConference on Informatics, Geoinformatics And Remote Sensing, SGEM2013 Conference Proceedings, vol.1 pp.745-752 DOI: 10.5593/SGEM2013/BB2.V1/S11.017.

Mugnier C (2001), Grids and datums, the French republic. In: Photogrammetric engineering & remote sensing, January 2001.http://www.asprs.org/a/resources/grids/01-2001-france.pdf Accessed 12 September 2013.

Pasini S, Torresan S, Rizzi J, Zabeo A, Critto A, Marcomini A (2012), Climate change impact assessment in Veneto and Friuli Plain groundwater. Part II: A spatially resolved regional risk assessment.Science of The Total Environment, Volume 440, pp.219–235.

Pirotti F, Guarnieri A, Vettore A, (2013), State of the Art of Ground and Aerial Laser Scanning Technologies for High-Resolution Topography of the Earth Surface. European Journal of Remote Sensing, vol.46, pp.66-78.

Poli D, Remondino F, Dolci C (2004), Use of Satellite Imagery for DEM Extraction, LanscapeModeling and GIS Applications. In International Workshop on Processing and Visualization Using High-Resolution Imagery.

Reis R, Barrot D (2010), Testing Cartographic Data Harmonization in the INSPIRE Context: The Case for Hydrography. In: Proceedings of 6ª ConferênciaNacional de Cartografia e Geodesia, Lisboa: Lidel, 2010, p. 452-461.

Şahin İ, Alkış Z, (2013) Developing a registration entry and query system within the scope of harmonizing of the orthophoto metadata with the international standards. In: ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences 1.2, p. 207-211.

San-Miguel-Ayanz J, Barbosa P, Liberta G, Schmuck G, Schulte E, Bucella P (2003). The European forest fire information system: a European strategy towards forest fire management. In: Proceedings of the 3rd International Wildland Fire Conference, Sydney, Australia. Washington, DC, US Dep Interior, Bur Land Management CD-ROM.

TóthK, Smits P (2007), Infrastructure for spatial information in Europe (INSPIRE): from cartography to spatial objects and network services, In: Proceedings of the 23rd Cartographic Conference – Cartography for everyone and for you, 2007, Roskartografija, p.1-11.

Valcarcel N, Villa G, Arozarena A, Garcia-Asensio L, Caballero M. E, Porcuna A, Domenech E Peces, J. J (2008), SIOSE, a successful test bench towards harmonization and integration of land cover/use information as environmental reference data. In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 37(B8), p. 1159-1164.

Vilches-Blázquez L. M, Rodríguez Pascual A. F, Mezcua Rodríguez J, Poveda B, Angel M, Corcho Ó (2007). An approach towards a harmonized framework for hydrographic features domain. ICA.

Zsófia T. V (2011). Harmonisation of thematic maps in the European Union – Setting up some types of environmental analytical maps. PhD thesis, Universitéd'Orléans.

European Parliament and the Council of 14 March 2007 (2007), Directive 2007/2/EC establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), Official Journal of the European Union, 25.4.2007, L.108/1.

http://wogis2.igig.up.wroc.pl/wogis/ Accessed on 26 January 2015

http://inspire-twg.jrc.ec.europa.eu/data-model/draft/r4530/. Accessed 15 February 2014

http://www.eurogeographics.org/content/products-services-eurodem . Accessed 18 March 2014

http://inspire.jrc.ec.europa.eu/ . Accessed on 10 February 2014

http://areeweb.polito.it/ricerca/ALIRHYS/

Figure captions

Fig.1 Studied Area.

Fig.2 UTM projection system and the 32 zone, with the studied area remarked.

Fig.3 Lambert93 and Lambert 9 zones projections.

Fig.4 Paper French map (georeferred in the ALIRHyS reference system) on the boundary with the Italian digital cartography (transparent at 50% for viewing eventual overlapping).

Fig.5 Mosaicked orthophoto.

Fig.6 Boundary orthophoto detail in which chromatic differences are evident.

Fig.7 Graphic representation of height discrepancies between the two DTM (Δh) on the whole overlapping area.

Fig.8 Graphic representation of height discrepancies between the two DTM (Δh) on the boundary 500 m strip.

Fig.9 D matrix raster.

Fig.10 New DTM on the 500 m boundary strip.

Fig.11 New DTM for the whole area.

Fig.12 Example section.

Fig.13 Example section on the discrepancies map computed between the new DTM values on the boundary and the original French DTM.

Fig.14 Italian cartography's conceptual model - UML Schema.

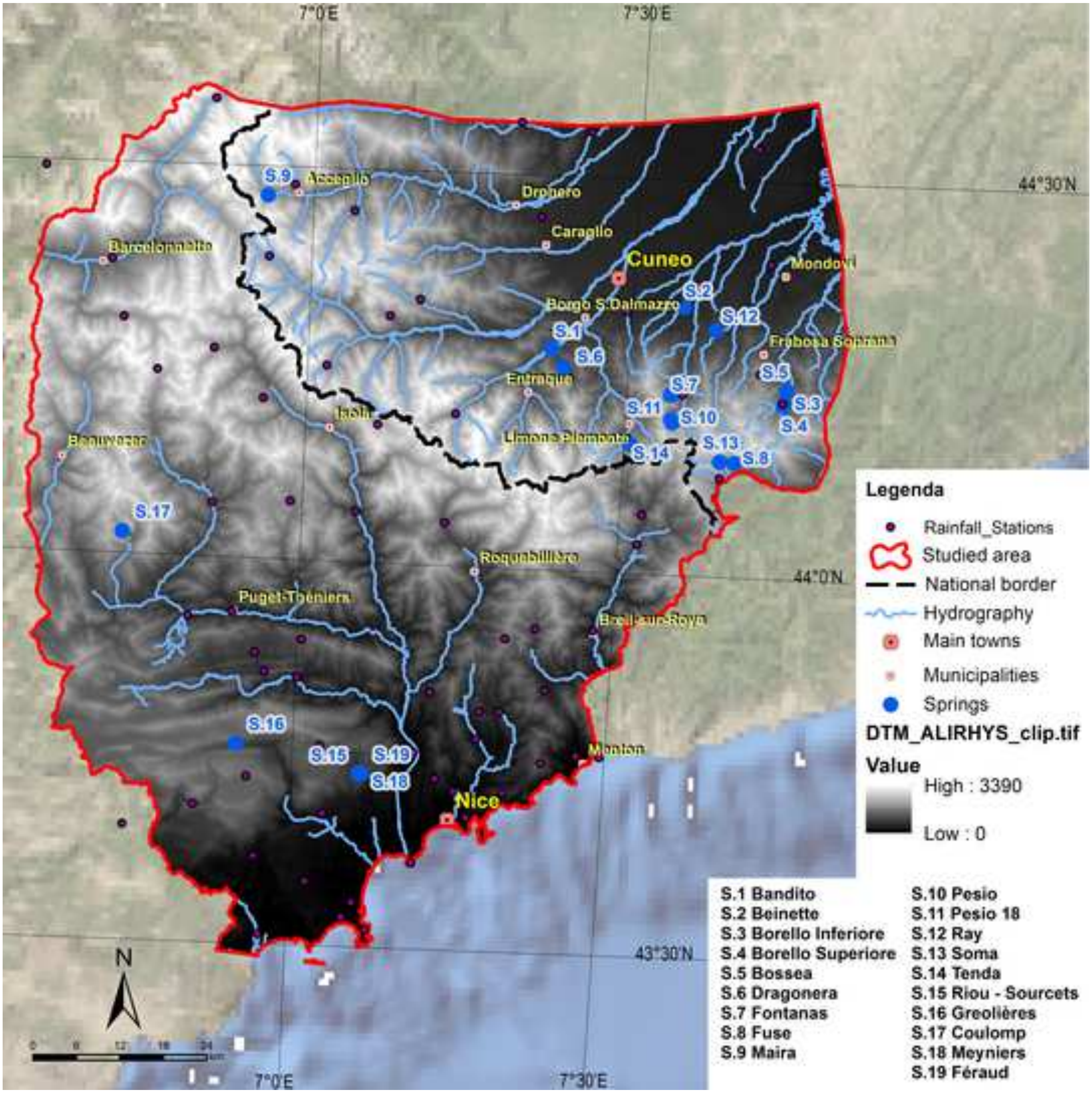
Fig.15 French cartography's conceptual model – UML schema.

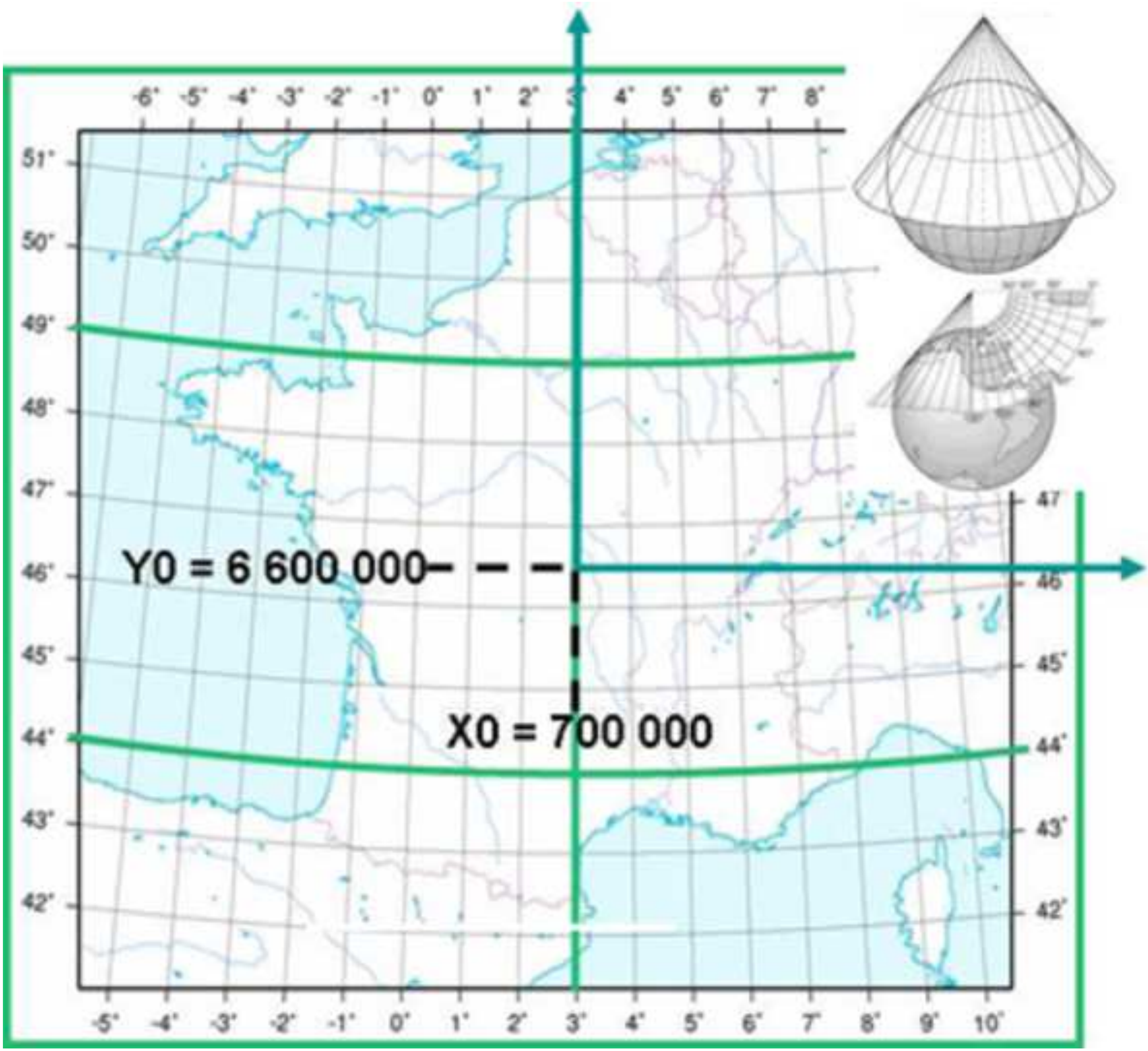
Fig.16 Simplified INSPIRE cartography's conceptual model – UML schema.

Fig.17 Resulting harmonised digital map in a cross-border area.

Figure

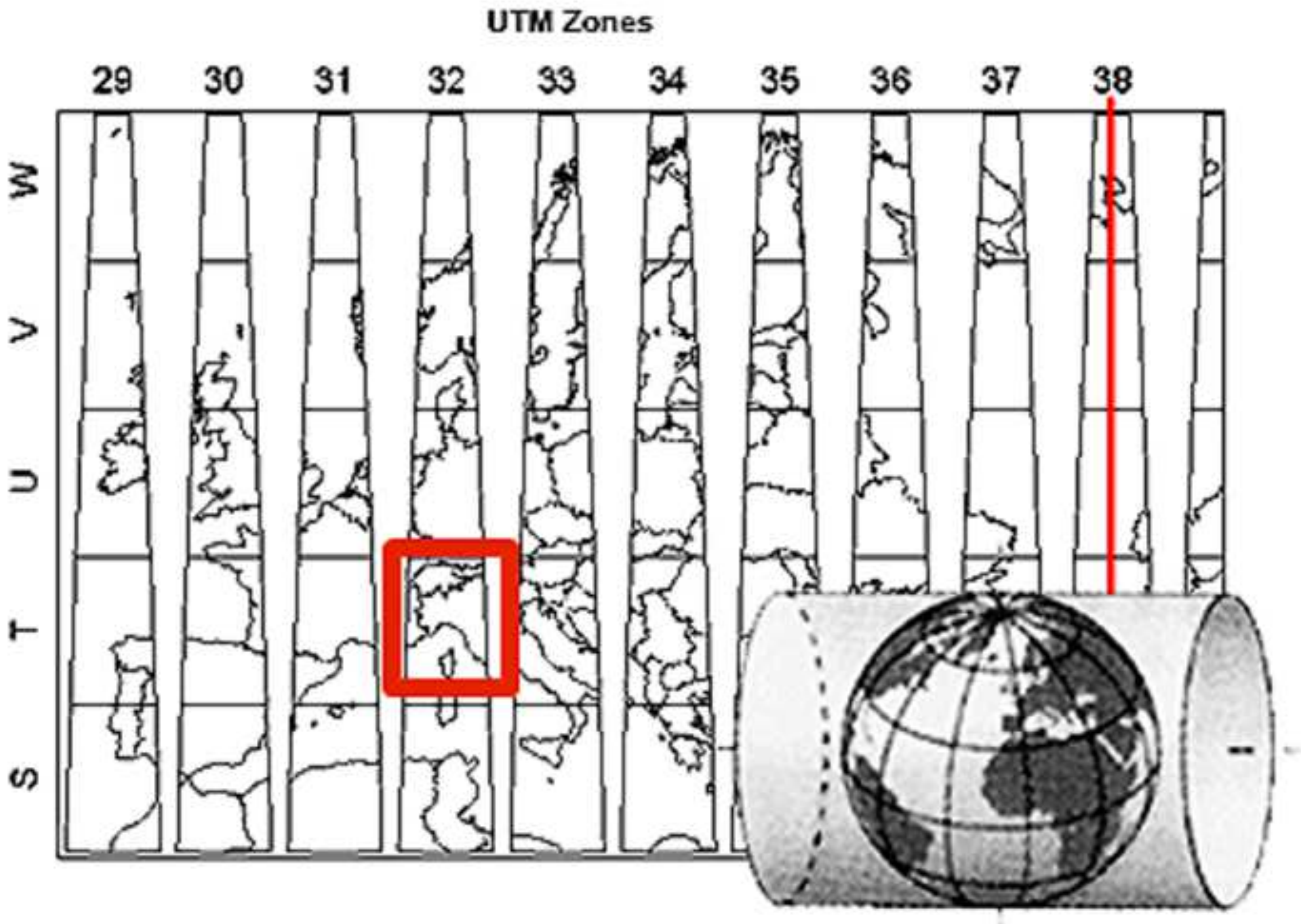
Click here to download Figure Fig1.tif




Y0 = 6 600 000
X0 = 700 000
-6° -5° -4° -3° -2° -1° 0° 1° 2° 3° 4° 5° 6° 7° 8°
51° 50° 49° 48° 47° 46° 45° 44° 43° 42°
-5° -4° -3° -2° -1° 0° 1° 2° 3° 4° 5° 6° 7° 8° 9° 10°
47 46 45° 44° 43° 42°

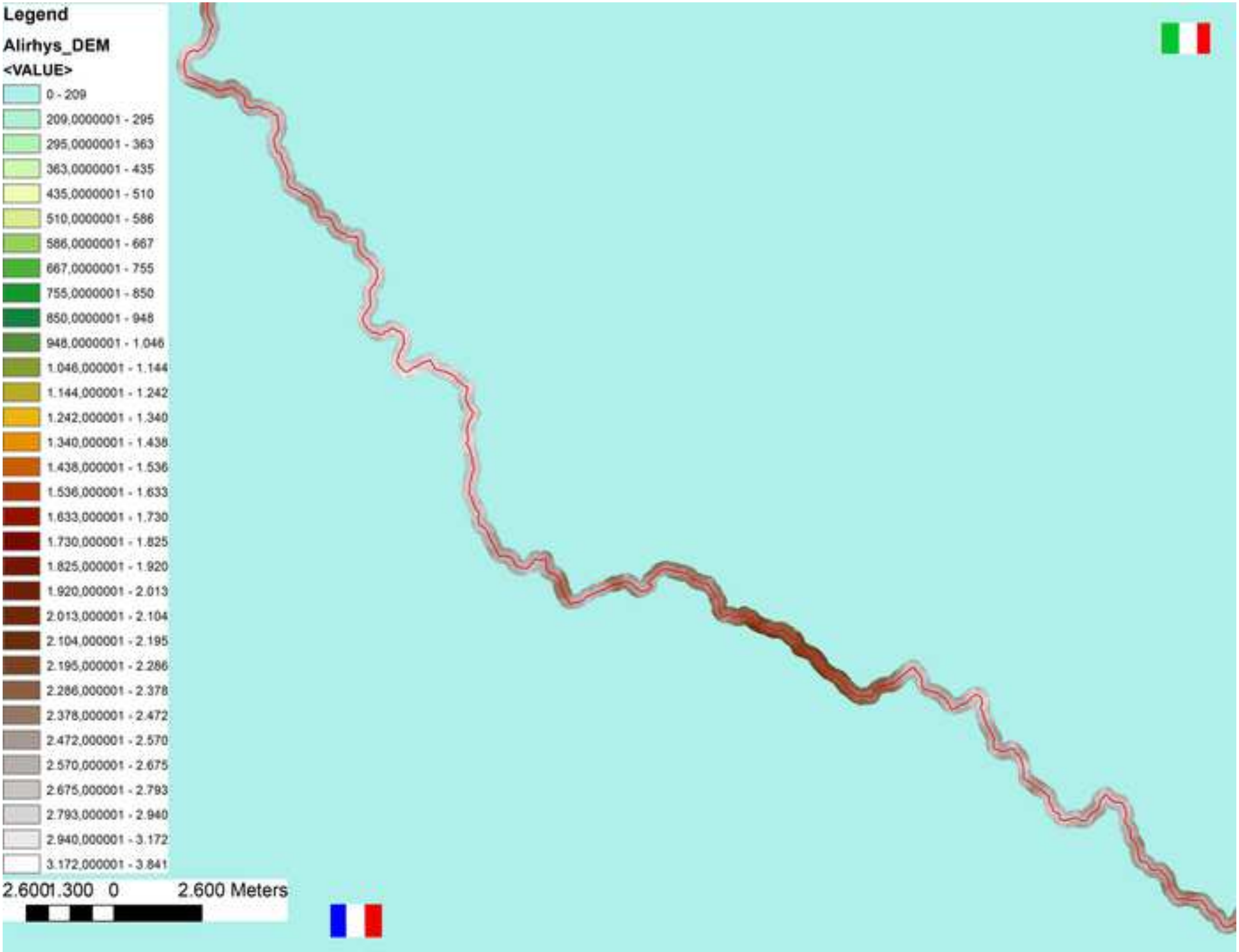
Figure

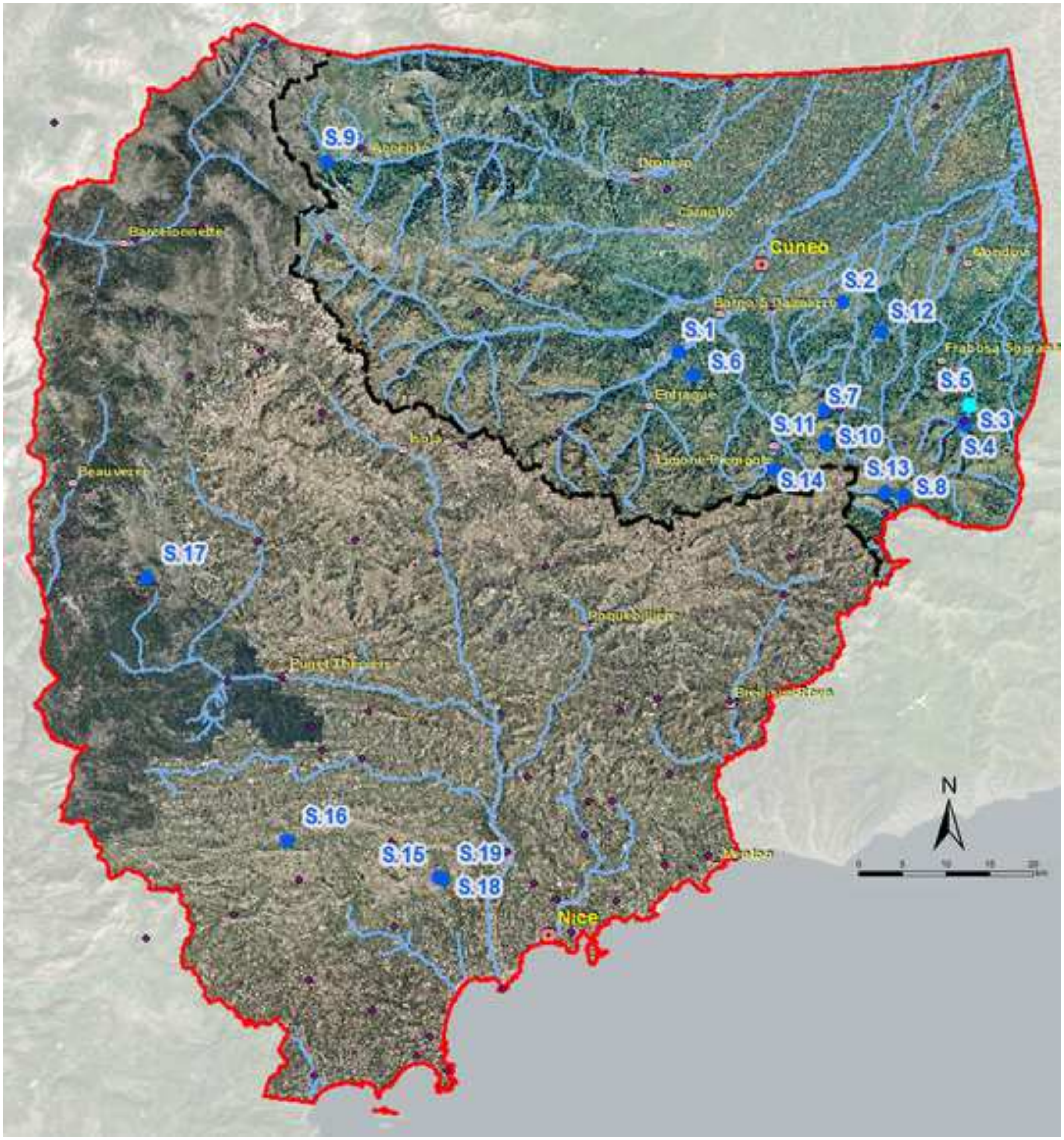
Click here to download Figure Fig.2.tif



Figure

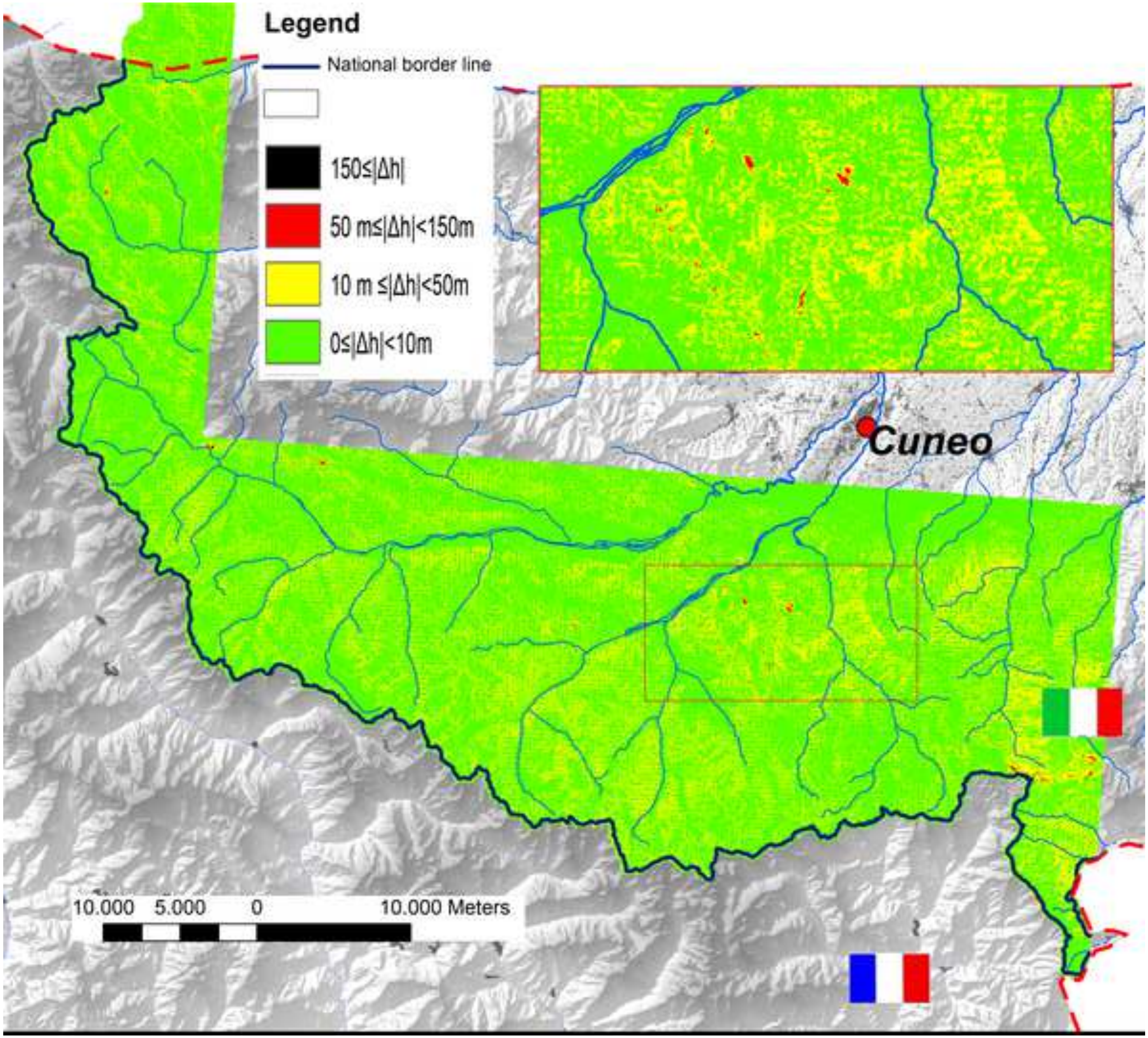
Click here to download Figure Fig.10.tif

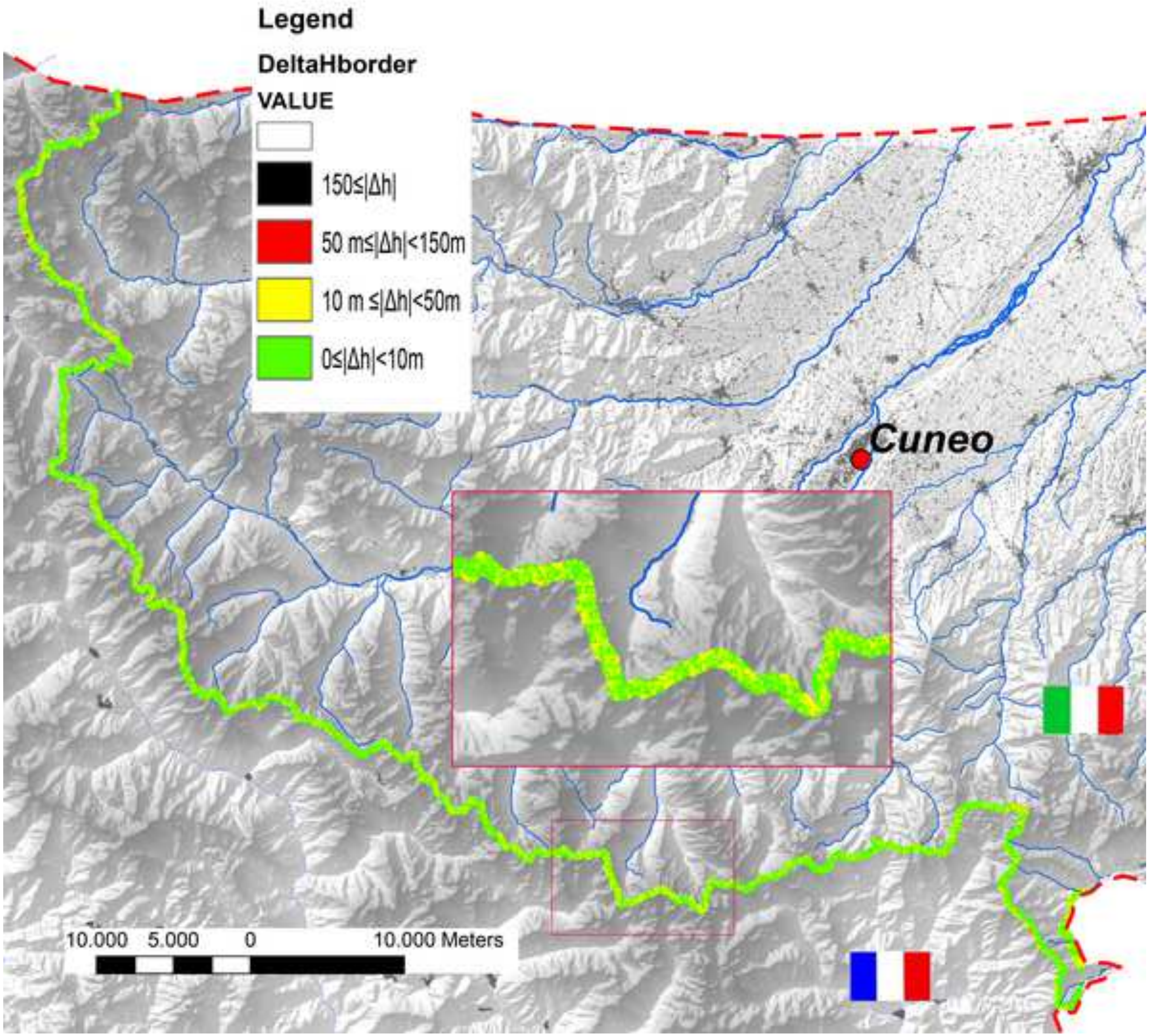



S.9
Cuneo
S.2
S.12
S.1
S.6
S.5
S.7
S.3
S.11
S.10
S.4
S.13
S.14
S.8
S.17
N
S.16
S.15
S.19
S.18
Nice

Figure

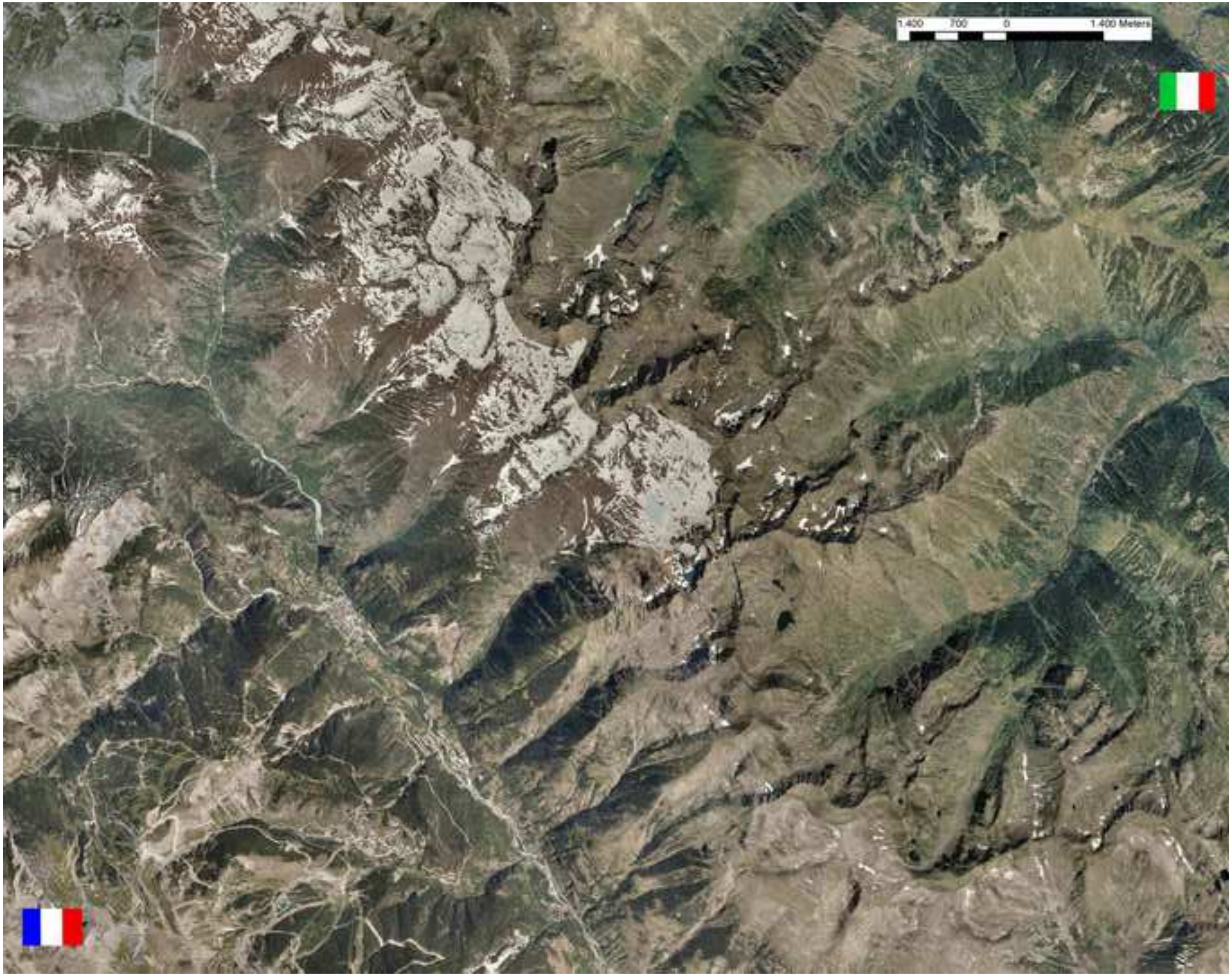
Click here to download Figure Fig.7.tif




Legend
DeltaHborder
VALUE
150≤|Δh|
50 m≤|Δh|<150m
10 m ≤|Δh|<50m
0≤|Δh|<10m
Cuneo
10.000 5.000 0 10.000 Meters

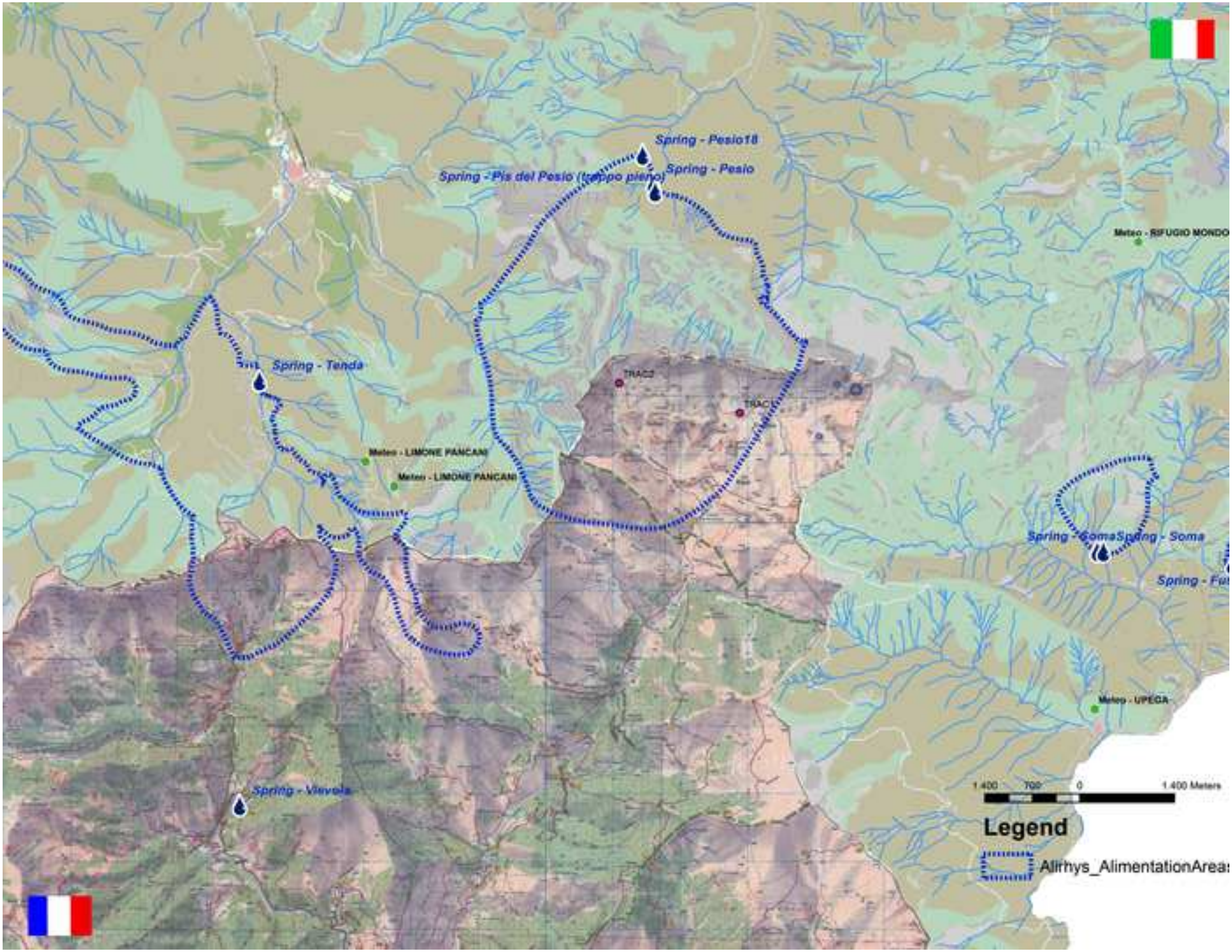
Figure

Click here to download Figure Fig.6.tif



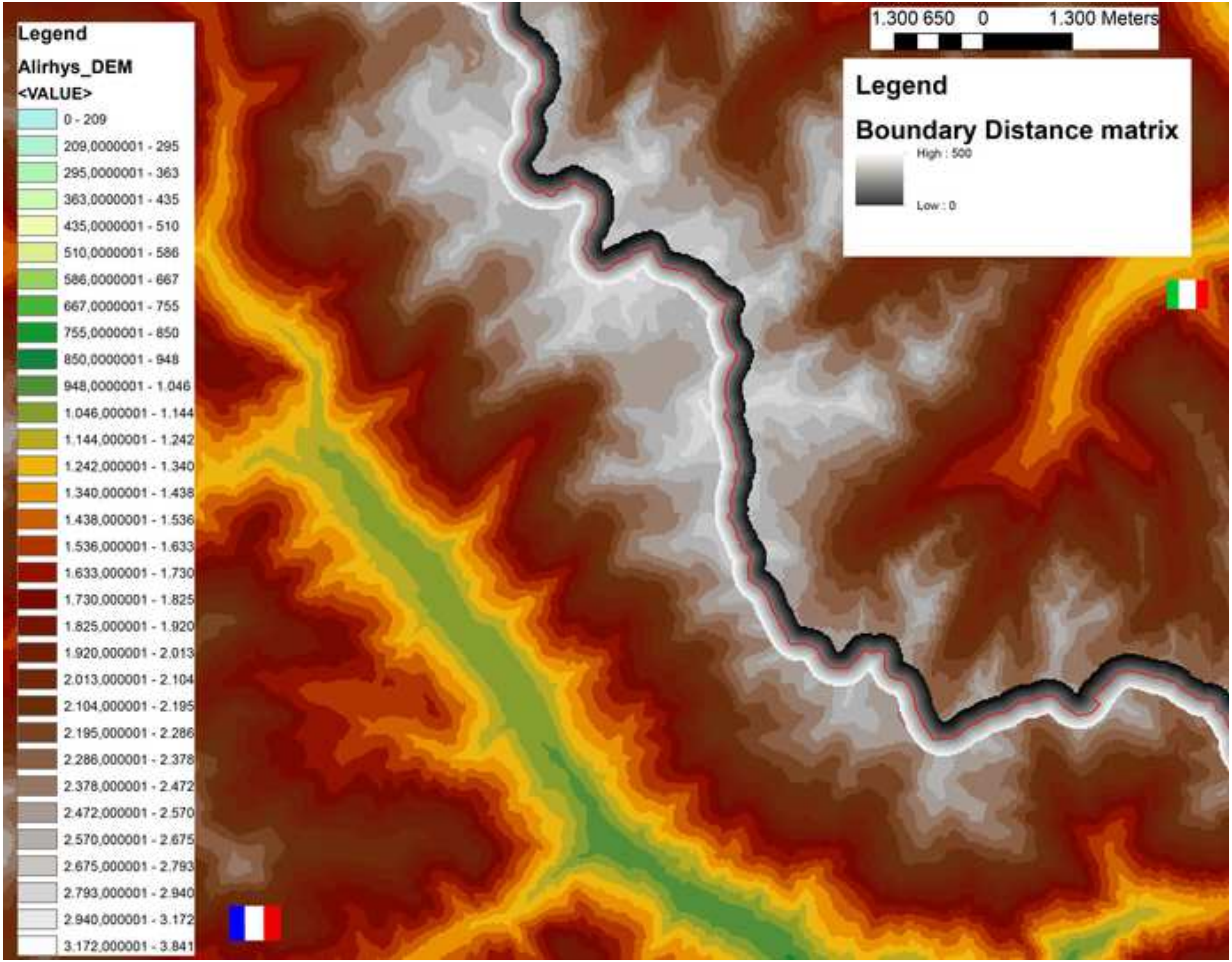
Figure

Click here to download Figure Fig.4.tif



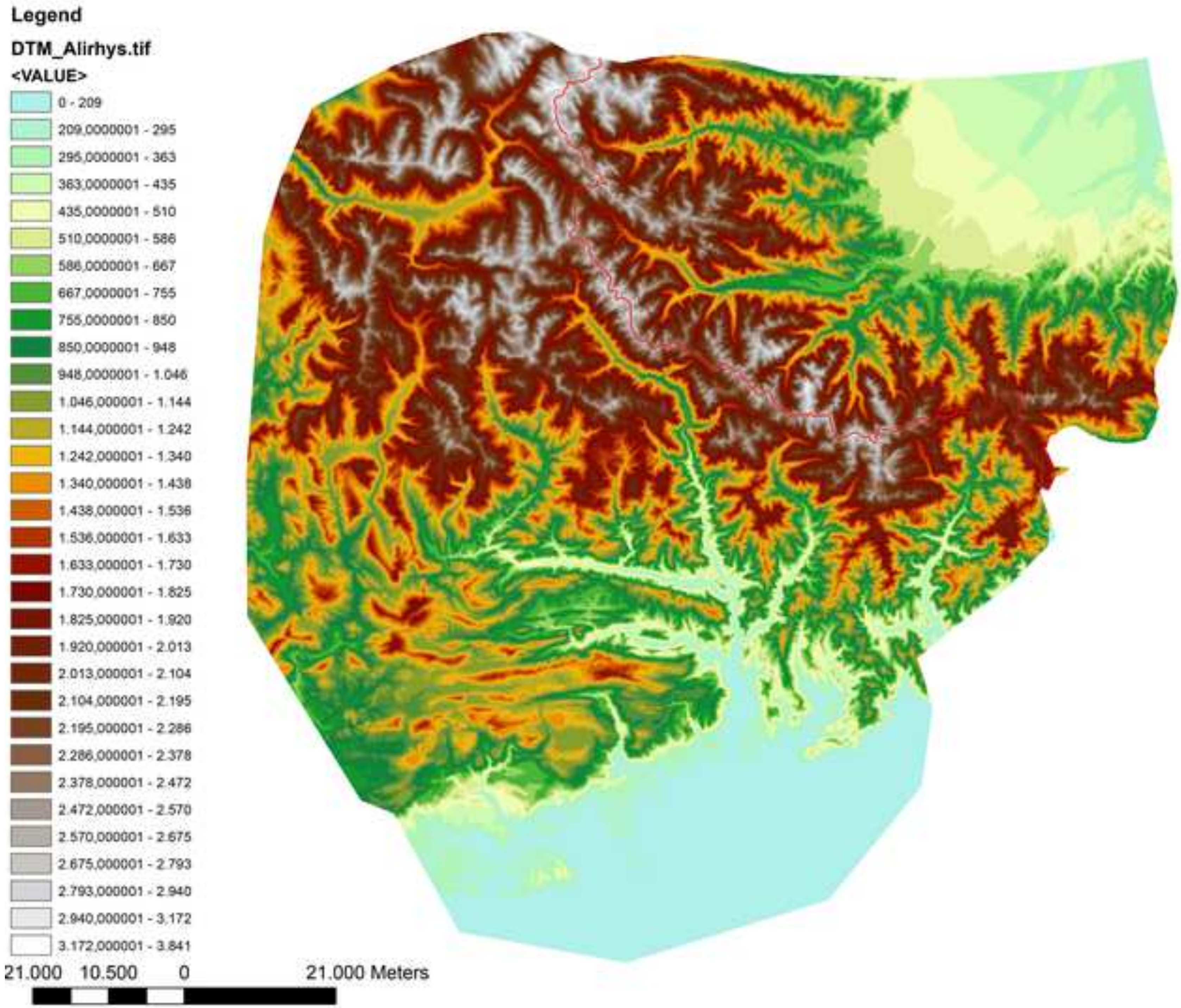
Figure

Click here to download Figure Fig.9.tif



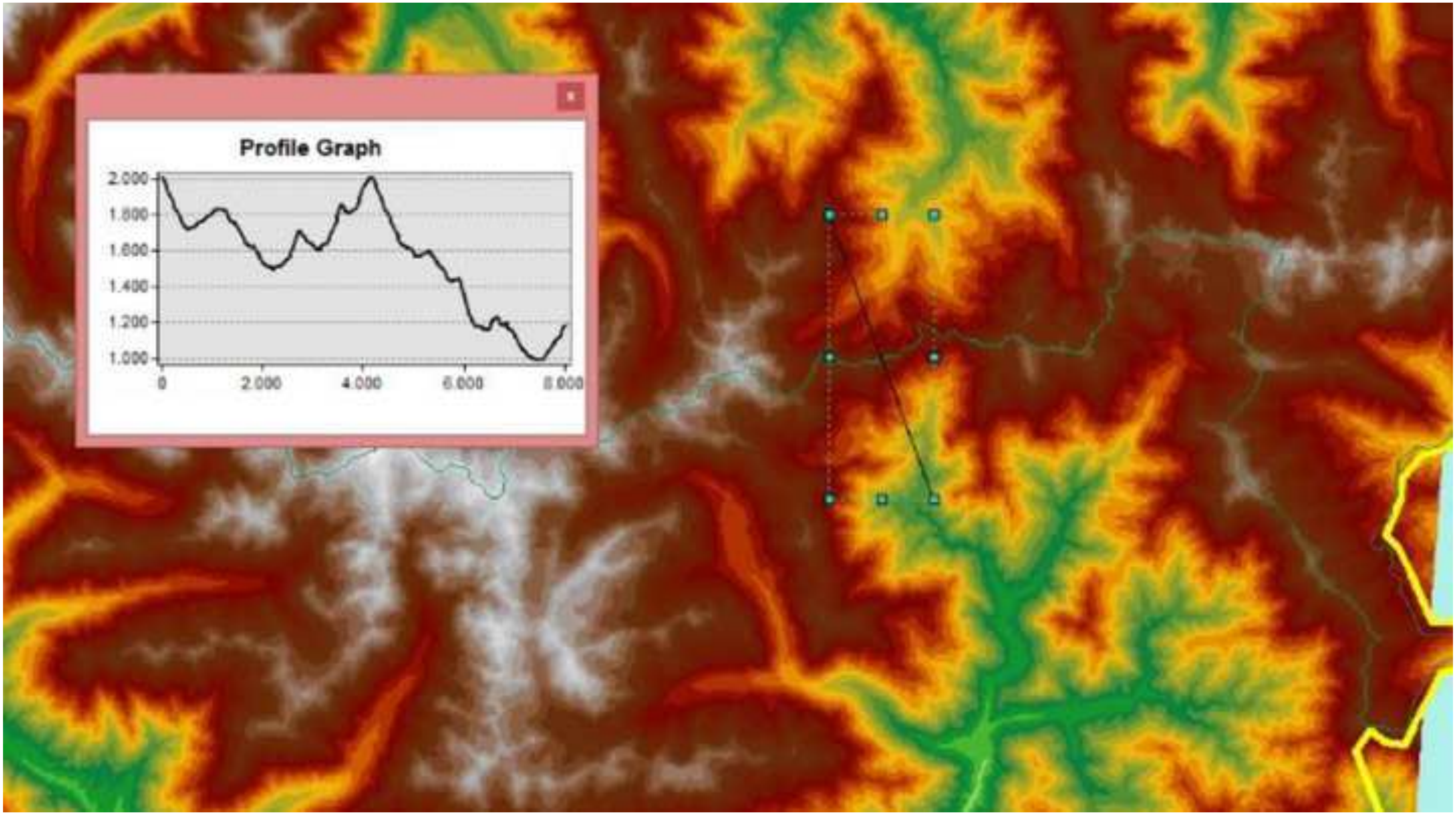
Figure

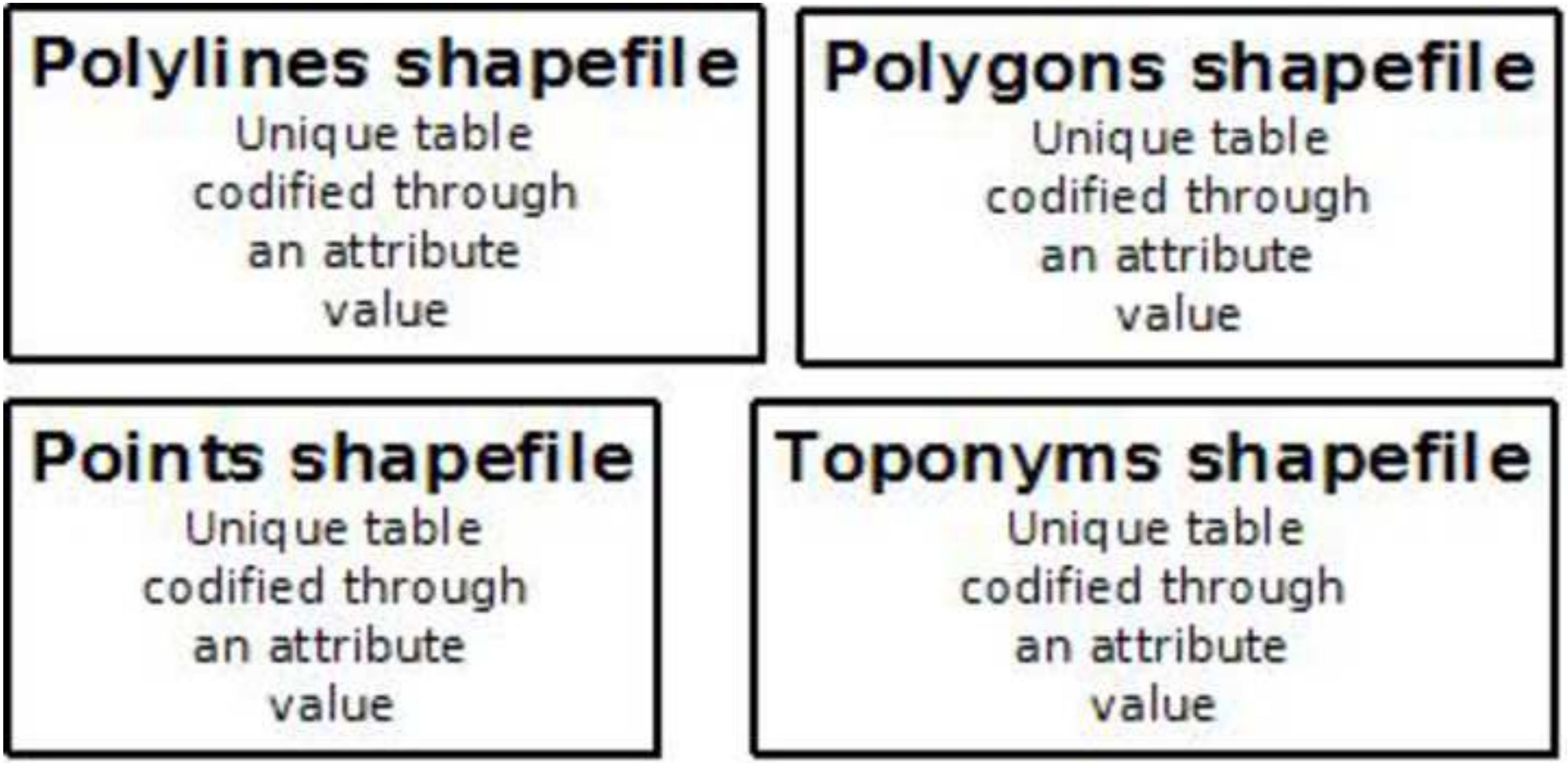
Click here to download Figure Fig.11.tif



Figure

Click here to download Figure Fig.12.tif




Polylines shapefile
Unique table codified through an attribute value
Polygons shapefile
Unique table codified through an attribute value
Points shapefile
Unique table codified through an attribute value
Toponyms shapefile
Unique table codified through an attribute value

Figure

Click here to download Figure Fig.13.tif

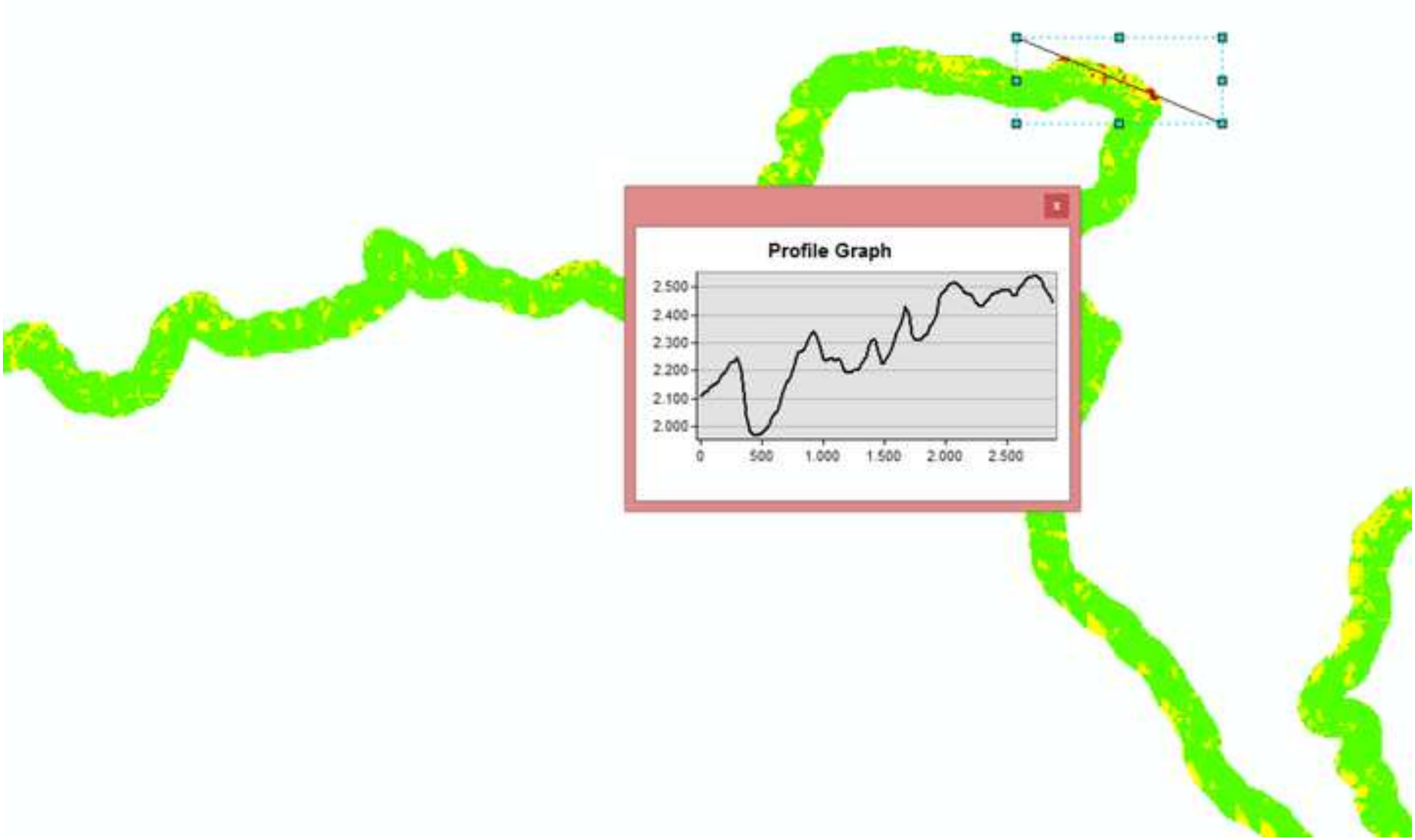
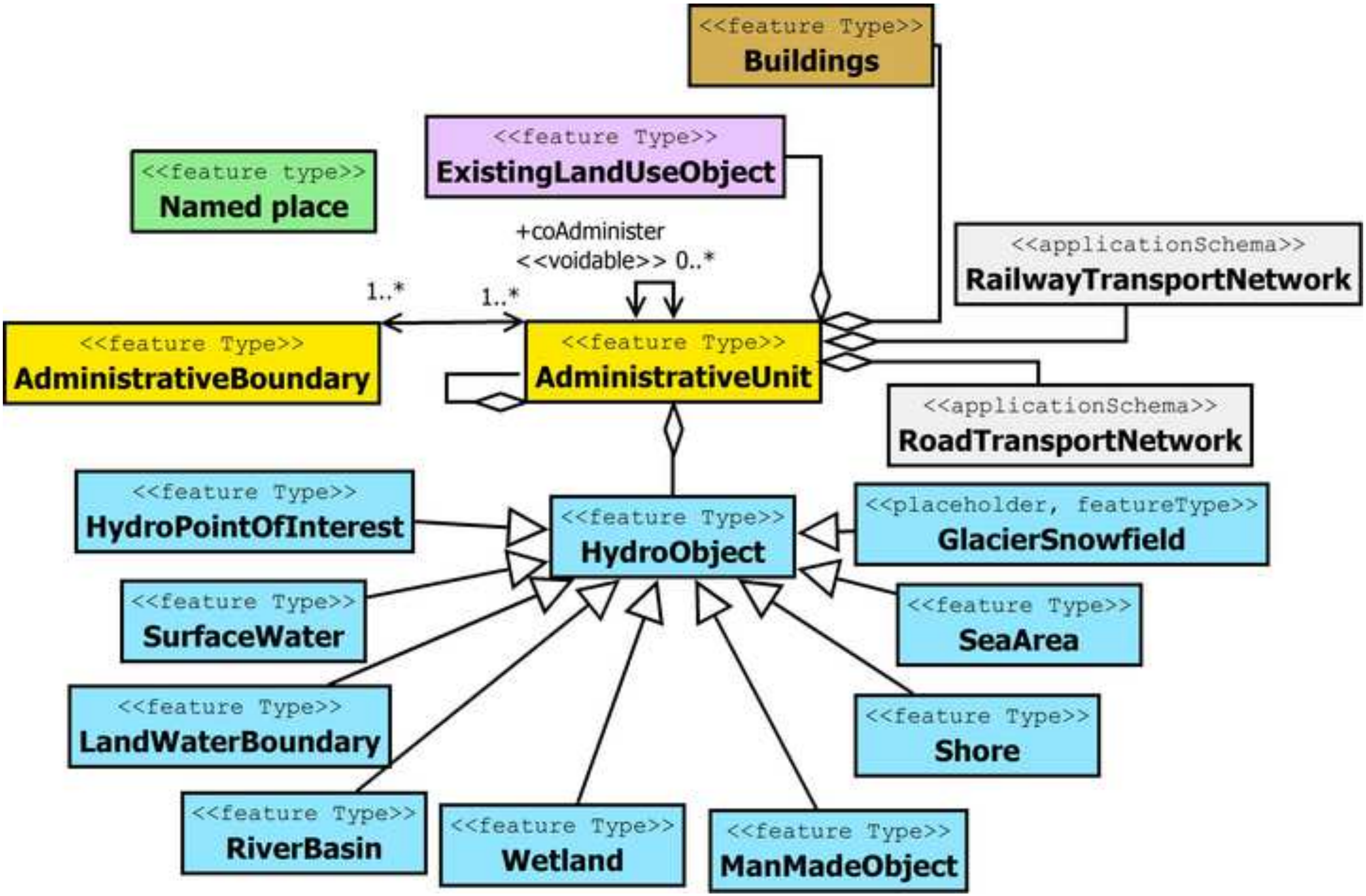


Figure Click here to download Figure Fig.16.tif



Figure

Click here to download Figure Fig.17.tif

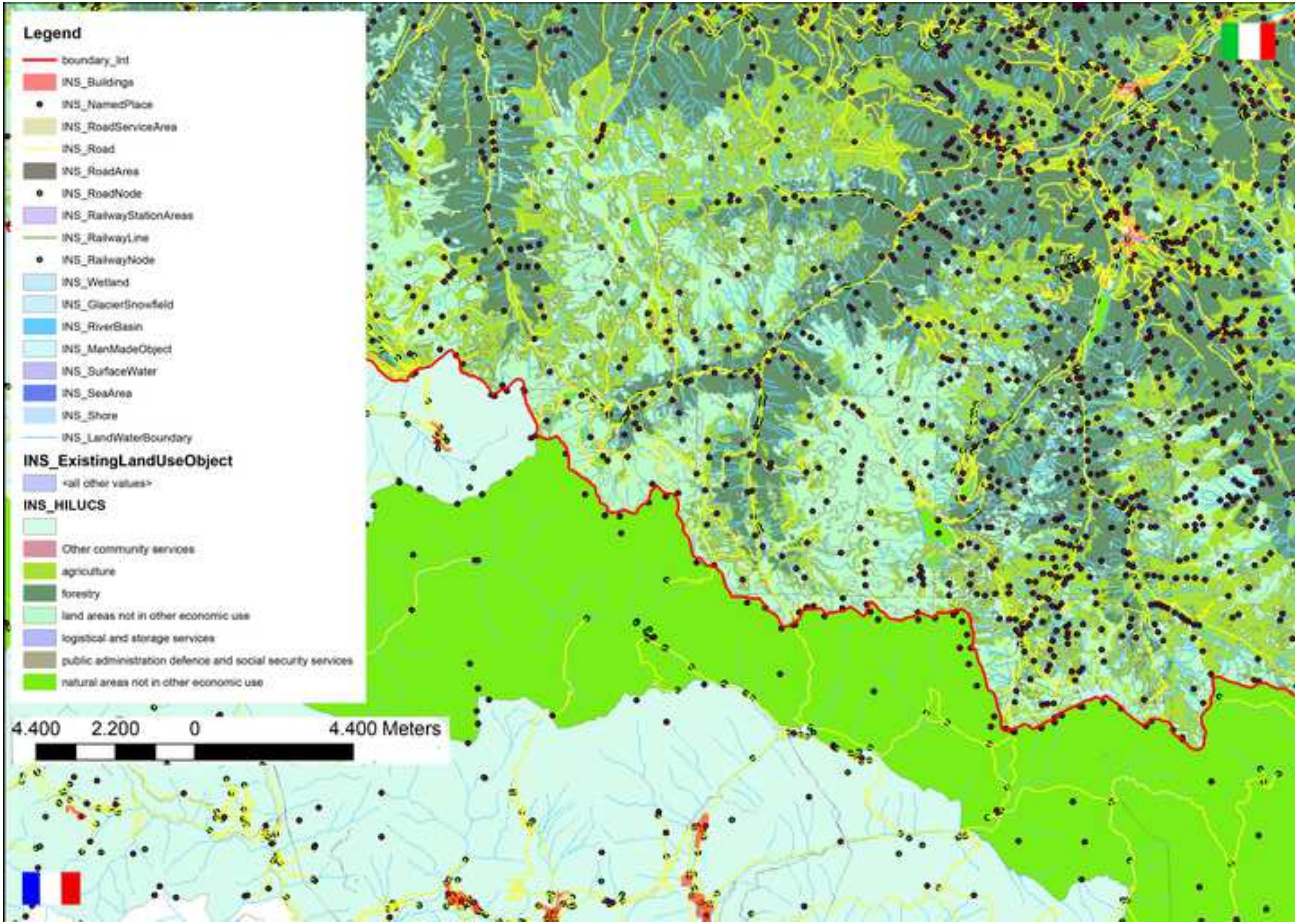


Figure Click here to download Figure Fig.15.tif