Chapter 4

TORA: TOPOGRAPHICAL REGISTER AT THE SWEDISH NATIONAL ARCHIVES

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FOR RESEARCH ON historical landscapes and settlements, Sweden holds two comprehensive source materials: the cadastral registers from the sixteenth century and the large-scale maps from the seventeenth century. These sources describe and depict hamlets and farms during the early modern period but are also invaluable for tracing medieval landscapes. For several years work has been going on at the National Archives in Stockholm to make them available for research.

A digital and spatial entrance to these sources has now been created called TORA: Topographical Register at the National Archives (Riksarkivet).[1] The core of this register consists of 26,000 geo-referenced *historical settlement units* to which other data are linked, above all 15,000 digitized historical maps. The work has been coordinated by the National Archives of Sweden, which is also responsible for the data created within the project. Coordinates are assigned using geographical information system (GIS) technologies, and web applications have been created using linked open data (LOD) techniques. With a map search, it is possible to acquire an overview of historical settlements and see their locations on today's modern map.

This chapter addresses the methods, choices, and experiences gained from the TORA project (2015–2019). Above all, the question of how large-scale historical maps can form the basis for a historical GIS (HGIS) is discussed. A further discussion relates to questions on how to model historical data as linked data.

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1 Riksarkivet, "TORA," https://riksarkivet.se/tora-english (accessed May 24, 2021). The TORA project has been conducted with external funding from Kungl. Vitterhetsakademien and Riksbankens Jubileumsfond as a collaboration between cultural heritage institutions and the research community: the National Archives of Sweden, the Institute for Language and Folklore, and researchers at Uppsala University, Stockholm University, and the Swedish University of Agricultural Sciences.

Historical GIS as a Tool and Method

GIS as a term refers to tools and applications for creating spatial data. It is also used in connection with methods and analysis of spatial data, such as the visualization and plotting of spatial data on digital maps. As a discipline in science, the development of GIS can, among others, be traced to the early work of geographer Torsten Hägerstrand, who highlighted the idea of setting spatial coordinates to landscape elements.[2] In the 1950s and 1960s digital methods were used to capture and analyze geographical data in connection with regional planning and by geographers in general. As the amount of data has increased, especially since the 1990s and through the use of satellite data and geodesy for automatic geometric measuring, GIS has become integrated into a variety of types of systems. Historical GIS (HGIS) is much developed as a subdiscipline related to methods within GIS that historians, geographers, archaeologists, and other scholars use to analyze and understand historical landscapes and change over time and space. HGIS has also been considered a research field of its own.[3]

A common problem, related to GIS in general but especially HGIS, is data capture and data accuracy. The spatial data used in HGIS are usually created by researchers through the interpretation and analysis of archaeological remains or by extracting information from historical maps, aerial photos, or satellite images. As part of a GIS, the source excerpts will be associated with coordinates corresponding to positions on the Earth's surface. The data can be in raster and vector formats, and may include lines, polygons (areas), and point objects according to a predefined coordinate system, such as the World Geodetic System 1984 (WGS 84) and Swedish reference frame 1999 (SWEREF 99).[4] It can be limited to geographical positions, as longitude and latitude coordinates (X and Y coordinates), but it can also include height, to add a third spatial dimension (Z coordinates). Hence, the methods used for collecting historical data for a GIS must be documented, preferably as metadata associated with spatial coordinates. Otherwise, it will be difficult for future users to understand and assess data quality and see possible errors and limitations.

As part of data capture, the most common challenge for HGIS is probably managing changes over time. Historical data cannot be easily mapped or geo-referenced to modern maps as landscapes are constantly changing. Urbanization and other societal changes affect the landscape. For instance, the boundaries of administrative divisions, such as parishes and counties, tend to change.[5] Boundaries may be adjusted, new divisions can be added or subdivided, and divisions may be replaced and renamed. This has implications for historical and longitudinal studies. In order to track and compare

2 Ellegård and Svedin, "Torsten Hägerstrand's Time-Geography," 8.

3 Gregory and Ell, *Historical GIS Technologies*, 1.

4 Lantmäteriet, "SWEREF 99"; National Geospatial-Intelligence Agency, "WGS 84."

5 See Dam, this volume.

population statistics related to administrative divisions, such changes need to be taken into account. Historical comparisons may therefore involve data manipulation. Areal interpolation is one such spatio-temporal technique, used to transfer data between the source unit and the target unit.[6] The boundaries of administrative divisions over time are difficult to reconstruct, however. It may be easier to reconstruct the boundaries based on the known locations of individual settlements.[7] Another option would be to relate the data collected to places represented by point objects instead of polygons. A point object allows comparisons over time without consideration of administrative division changes, although it requires a method for setting points.

A prerequisite for HGIS is access to the source material and primary historical maps. Besides ancient remains and heritage sites, registered by authorities, and written sources about geography and places, there is no better source than maps for approaching and understanding historical landscapes. The sources needed depend, of course, on an HGIS's area of use. Modern GIS data may be combined with historical data. For example, the regional distribution of population data can be illustrated with approximate administrative boundaries. Open data from services such as GeoNames and other map services could then be used.[8] To answer questions about historical settlements, landscapes, and other spatial phenomena, however, an HGIS is likely needed. For instance, when measuring an archaeological site for protection according to law, accurate measurement and observation in the field are necessary. When analyzing and compiling the distribution of settlements during the Middle Ages and early modern time, the places need to be defined on the basis of historical sources. An important aspect is thus the scale or level of detail for which an HGIS is intended.

What basic units should be used, then, in historical GISs? In Sweden, taxes and other levies have been reported as land holdings (*hemman*) related to hamlets and other settlements, sorted by parish, counties, and provinces. Such accounting first appeared during the Middle Ages and became formalized during the first half of the sixteenth century under the rule of Gustav I.[9] *Kronans jordeböcker* (the Crown's cadastres) from this period set the standard for accounting until the end of the nineteenth century, when taxes on land holdings ceased. The number of individual land holdings changes over time; most of the settlements (hamlets and villages) remain, however. Based on the cadastral sources, it is possible to reconstruct the sixteenth-century village community and part of the social structure and follow the developments in more recent periods. Settlements, within which agriculture was organized in rural society, are therefore suitable as basic units in a historical GIS and the chosen method for TORA.

6 Gregory and Ell, *Historical GIS Technologies*, 138.

7 Berman, "Boundaries or Networks," 121.

8 See www.geonames.org (accessed May 24, 2021).

9 Brunius, *Vasatidens samhälle*, 26–29.

The approach shares some similarities with historical atlases, lexicons, and dictionaries, where the core consists of an index of geographical names and places.[10] A characteristic of these older standard works is the categorization of geographical units, from planets and moons, down to continents, countries, regions, cities, towns, etc. Today's web services in this area of study are often referred to as gazetteers—i.e., lists, registers, or authority files of different types of geographical elements (places, lakes, roads, etc.).[11] The method chosen for the TORA project is not based on hierarchies of geographical units, however. Only places found in the historical sources and maps have been included in the project, and geo-referencing and linking to the original sources form the basis. The inspiration for the TORA project thus does not come from gazetteers; rather, the task has been to compile geographical data on settlements from selected source materials.

The aim has also been to provide an HGIS as open data for reuse.[12] Within the digital humanities and cultural heritage sector there is a trend toward using application program interface (API) and uniform resource identifiers (URIs) to promote open data on the Web. This opens up for the integration and linking of different types of sources, as well as crowdsourcing for adding statements and metadata, not least Wikidata, which aggregates data from many sources and has a large collection of geographical units.[13] Historical geographical data are also collected, by, for example, the Pelagios network.[14] The challenges are much the same as before, however. How should historical places be defined and conceptualized? Which places should be included, and how can time and space be handled and treated as data in a historical GIS?

Seventeenth-Century Maps of Rural Settlements

Theoretically, a historical GIS of Sweden could be based on the central (state) archives from the early modern period. As mentioned, the cadastres from the middle of the sixteenth century cover much of the settlements at the time. The possibility of setting spatial coordinates for locations in GIS is dependent on the availability of historical maps, however. The map archive in Sweden is comprehensive. For the seventeenth century alone there are about 15,000 so-called large-scale cadastral or geometrical maps, covering about a third of all settlements and farms during this time. Starting in the middle of the eighteenth century, land surveying was intensified as a result of Swedish

10 Early works in this field in Sweden are *Geographie öfver konungariket Swerige*, by Eric Tuneld, and *Utförlig geografie och Geografiskt lexicon*, by Daniel Djurberg, published in the late eighteenth century.

11 Goodchild and Hill, "Introduction to Digital Gazetteer Research," 1040–41.

12 All data in TORA can be used freely. Pending a general policy within the National Archives, there is as yet no licence, such as Creative Commons.

13 The Wikimedia Foundation, www.wikidata.org/wiki/Wikidata:Main_Page (accessed May 24, 2021).

14 The Pelagios Network, https://pelagios.org (accessed May 24, 2021).

land reforms. This means that almost every settlement in Sweden had been surveyed and depicted on a large-scale map before the beginning of the twentieth century, often more than once. The exceptions apply to manors and holdings that belonged to privileged classes (the nobility), which the Crown had less interest in mapping. The nobility's land possessions, which during the sixteenth and seventeenth centuries amounted to about 25 percent of Sweden, were often located within settlements where the Crown or free farmers also owned land, however. The surveyors mapped all the cultivated land within hamlets. Therefore, much of the nobility's land (the tenants' holdings) is included on the maps made by the Crown. Some noble landowners, including Axel Oxenstierna, hired surveyors to measure their manors and land properties. Several of these map collections have been preserved and are included in TORA.[15]

The mapping was carried out by land surveyors in the field, on site in each hamlet, through observations and measurements of the land using a plain table and measuring instruments. Initially, a scale of 1: 5,000 was used, but other scales—from 1: 2,000 up to 1: 10,000—also occur. The geometrical method for accurate mapping, based on triangulation, can be traced back to work by, not least, Gemma Frisius in the 1530s. Techniques for measuring land are much older, and were widely used during the Middle Ages for land assessment and taxation. The new invention, dating to the end of the sixteenth century, was the method of transferring land measurements to accurate maps, made to scale, on paper.[16]

It was, therefore, a rather new mapping method and map production that the Swedish Crown adopted and developed during the 1630s, when the initiative was taken to train surveyors and start surveying farmland. The Swedish government likely took impressions from similar maps, such as polder maps and other estate maps made a few decades beforehand in the Netherlands. Unique to Sweden is that the initiative to map the entire country began as early as the first half of the seventeenth century. Although geometrical mapping occurred earlier in other countries, no similar systematic mapping is seen elsewhere at this time, often not taking place till the nineteenth century.[17]

What also distinguishes the Swedish maps is the central control of the process and uniformity in map production. The mapping initiative came from King Gustav II Adolf in 1628 and was planned by his close associates.[18] At the start, a small group of students from Uppsala University were trained as surveyors by cartographer Anders Bureus. In the early 1630s they were dispatched across the country and began to map the hamlets, parish by parish.[19] Towns and important industries, such as mines, were also mapped,

15 See, for example, "Projekt Äldre geometriska kartor, Riksarkivet, SE/RA/81003/2/Fiholm," Riksarkivet, https://sok.riksarkivet.se/bildvisning/R0000493 (accessed May 24, 2021).

16 Wästfelt, "Ambiguous Use of Geographical Information Systems," 212–13.

17 For instance, the large-scale mapping of the Austrian Empire from 1817 to the 1880s; see Dolejš and Forejt, "Franziscean Cadastre in Landscape Structure Research," 132.

18 *Samlingar i Landtmäteri*, 1–4.

19 *Samlingar i Landtmäteri*, 6; Tollin, "De första lantmätarna," 16–17.

but a large number of maps depict rural settlements. The work was guided through letters and instructions from the Stockholm Palace. The instructions, which were refined several times during the 1630s and 1640s, provide invaluable information on how the mapping was supposed to be carried out. The surveyors were expected to map and compile the information in the same way. The same measuring units and map colours would be used. To a large extent, these rules were met, although the cartographic styles varied between different surveyors. The maps also became more uniform over time, especially during the 1640s.

The purpose of the mapping is stated in royal letters. By having all farms and land measured and mapped, the Crown wanted to be informed about the conditions for agriculture across the country—that is, to be able to "overview and ponder" each hamlet and farm holding.[20] This motive needs to be seen in connection with the great power and military state that Sweden was at this time. The mapping has also been linked to the military thinking and ideology of the time.[21] The large-scale maps can be seen as tools for control of territorial areas of strategic and economic interest. At the same time as Sweden conquered land around the Baltic Sea, the Crown wanted to increase control over settlements and agriculture within the country. The maps also came to be of more practical use. By defining property boundaries for settlements and farms, land disputes—which often occurred—were assumed to be prevented.[22] Few of the maps appear to have been used, however, as they are preserved in very good condition.[23]

The geometrical mapping was closely linked to the state's fiscal (cadastral) management. Until the 1680s the maps were collected in the Chamber at Stockholm Palace. Here the bailiffs' tax reports on each farm holding were registered. By the middle of the sixteenth century the cadastres constituted a comprehensive land register of Sweden. The maps were designed similarly, and the surveyors would use excerpts from the land registers. In this way, they had information on every hamlet and farm to be surveyed. The text description that belongs to every map, titled *Notarum Explicatio*, is partly transcribed from the land registers. The surveyors then contributed with more details concerning the size of land, yield, soil quality, etc. Some of the information the surveyors provided, such as access to the forest, fishing, and grazing, also occurs in the sixteenth century registers. Through the surveyors' work in the seventeenth century, though, this information is systematically recorded for each hamlet for the first time.

Registrations of land ownership and holdings, which monasteries, churches, and other elites had carried out since the Middle Ages, thus laid the foundation for the geometrical mapping in the seventeenth century. The main difference and contribution concern the maps' spatial contents, which on a large scale show farmsteads, fields, meadows, etc., and the overall farming organization. Today the maps are not only images

20 *Samlingar i Landtmäteri*, 1.

21 Baigent, "Monarchs, Ministers, and Maps," 50–52.

22 *Samlingar i Landtmäteri*, 15.

23 How the maps were used by the Crown at the time has not been studied in any detail.

of seventeenth-century rural society, they are also a valuable source for understanding how landscapes develop over time. Thanks to the high level of detail, and the measuring of individual farms and fields, the maps can also be used to investigate and formulate hypotheses on older rural conditions. This is especially true of the late Middle Ages and the sixteenth century. The settlement development was then characterized by the desertion and reorganization of farmland—processes that can be traced in the seventeenth-century maps.[24]

Although the geometrical method allowed for accurate measurements, this does not mean that all maps are accurate or free from inaccuracies. Besides the generalizations and simplifications that accompany cartography, the surveyors worked under time pressure. The names of about forty surveyors are known from the first half of the seventeenth century. They did not work alone but had the help of assistants, which becomes evident if the so-called concept maps or original sketches are surveyed.[25] One of the more productive surveyors from this time was Johan Larsson Groth, who was in service from 1633 to 1648. He appears as the author of almost 1,400 maps, which represents an average of about ninety mappings per year. Such a high work rate is explained by the fact that he used several assistants. Even if a surveyor worked most of the year, time needed to be set aside for travel. Bad weather could also hinder work. In addition, to complete the maps, the conceptual field maps needed to be transferred to coloured renovated maps. Even with the help of several assistants, the surveyors could not spend more than one to three days per village.[26]

The errors and omissions that appear in these historical maps are therefore probably due to lack of time. The methods used were accurate, but sections and parts of the maps were measured with greater accuracy than others. The cultivated fields were mapped, but not the outlying land, including forest and pasture. The farmsteads and other buildings are marked on the maps with stylized symbols. More effort was devoted to mapping the cultivated arable land, meadows, property boundaries, and fences separating the fields.

An example, the hamlet of Östra Älgsjö, will illustrate this; see Figure 4.1. The surveyor Johan Larsson made two renovated versions of this hamlet. The two map images are very similar, which means that they are probably based on the same original concept map. The hamlet is located on the border between the districts (hundreds) of Aska and Göstring in the province of Östergötland. The maps were bound into volumes by district, which explains the two versions. The main focus of the maps is thus the distribution of arable land and meadowland. Three farmsteads are marked next to the lake. Patterns of stylized trees indicate wooded areas. Less information is provided about the farmstead. It was more important to describe the plots of land than to depict actual farmsteads, although the village green—that is, the common area of the farmsteads—is

24 Karsvall, *Utjordar och ödegårdar*.

25 Helmfrid, *Östergötland "Västanstång,"* 15.

26 Tollin, "De första lantmätarna," 30.

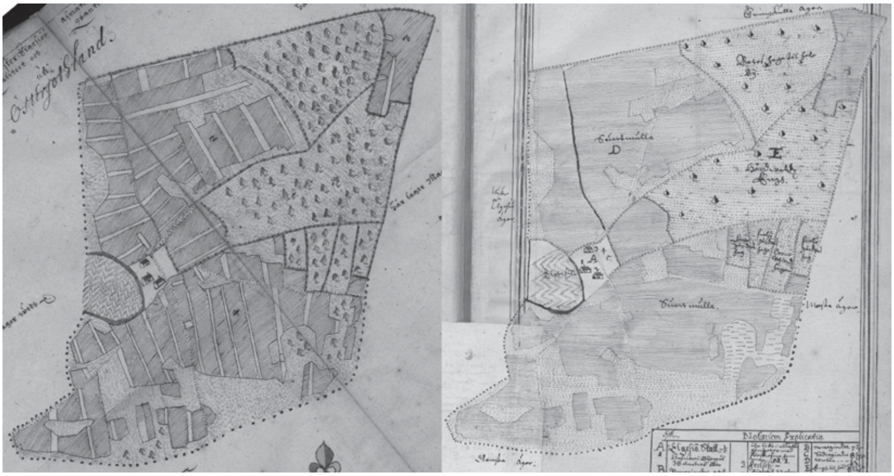

Figure 4.1. Östra Älgsjö, Bjälbo parish. The image to the left shows a map by Johan Larsson made around 1635–1637. Source: Projekt Äldre geometriska kartor, Lantmäteriet, SE/RA/81003/1/D5, Riksarkivet, D5:284–85 https://sok.riksarkivet.se/bildvisning/R0000162_00153. The map to the right, dated 1638–1639, depicts the same hamlet and is made by the same surveyor. Projekt Äldre geometriska kartor, Lantmäteriet, SE/RA/81003/1/D7, Riksarkivet, D7:191, https://sok.riksarkivet.se/bildvisning/R0000164_00111. Images are in the public domain.

demarcated. The road that leads through the hamlet is marked on both maps, but more details are provided on the Göstring map; see Figure 4.1. The Göstring map also shows traces of abandoned farms. The surveyor reported two uninhabited units, the so-called *utjordar*, which are noted with the numbers 4 and 5 next to the farmsteads. The Aska map also shows traces of lost farms, in the form of long narrow parcels, which run north–south and east–west through the arable fields. It is known from research that such field patterns are often remnants of previously abandoned farms.[27] The same phenomenon can thus be reported in different ways. The Aska map shows separated arable parcels; the Göstring map includes a text description along with a marker on the map. This also applies to other phenomena: information about hop gardens, mills, and other belongings could be either depicted on the map or reported as a note. The maps content thus needs to be read carefully and examined with consideration of other (younger) maps and sources.

The great value of geometrical maps in landscape research, apart from their function as a source for historical GISs, is their high level of detail. The spatial organization of hamlets, the conditions and allocation of cultivated fields, farmsteads, arable land, and meadows, as well as fences, pastures, streams, etc., are all reproduced clearly. The text

27 Karsvall, *Utjordar och ödegårdar*, 22–35.

descriptions that complement the visual components of each map indicate the sizes of the different fields and each farm's share of the land.

These historical maps are not only suitable for the interpretation of the seventeenth-century landscapes; they can also be used for reconstructions of older, medieval, historical landscapes. The settlements that were surveyed in the seventeenth century had, in most cases, been formed much earlier. In historical geography, the long-lived basic patterns of rural settlements have been used for so-called retrogressive studies of medieval settlements and landscapes.[28] It is, of course, difficult to prove when and how settlements developed. Older sources must be considered, but no other sources clearly show the actual location and spatial organization of settlements and individual holdings. The large-scale maps in Sweden could therefore form the basis for an extensive historical GIS that can be useful in different ways, not least for research and community planning; see Figure 4.2.

Settlements as Basic Units in TORA

A starting point is the question as to how settlements described on historical maps can be represented with coordinates in a GIS. The preferred method, used in the TORA project, has been developed in previous map projects at the National Archives of Sweden.[29] Each settlement, described on a geometrical map, is identified and geo-referenced as a point object (a coordinate pair) in GIS. Each point object represents the territory of a settlement (as a hamlet)—more specifically, the cultivated area of the property. In other words, the coordinates in TORA show where each settlement has been located, according to the historical maps. They do not mark positions for individual farms or physical buildings; rather, the point object refers to the settlements as a unit or property.

Representing villages, hamlets, cities, etc. with the help of point objects is common in GIS. For instance, Google Maps or the map service provided by the Swedish Land Survey (Lantmäteriet) show places on interactive online maps as point objects.[30] Using today's coordinates for a historical GIS provides approximate identifications of many historic settlements that remain today, such as well-preserved older cities. But these coordinates have little significance for the places and the land occupied by rural farms hundreds of years ago. The transformation of the landscape, not least the expansion of towns and municipalities, means that modern geographical data do not correlate to historical places. Place-names can be preserved, but the accurate location of the former hamlet is today not obvious without the help of historical maps. Moreover, the principles of how coordinates are set today are not clear. Modern geo-referencing services provide different coordinates for the same geographical place. The coordinates from

28 Karsvall, "Retrogressiv metod," 412.

29 Tollin and Karsvall, "Sveriges äldre geometriska kartor," 99–102; Riksarkivet, "Sveriges äldsta storskaliga kartor."

30 Google, "Google Maps," www.google.com/maps; Lantmäteriet, "Min karta," https://minkarta.lantmateriet.se (both accessed May 24, 2021).

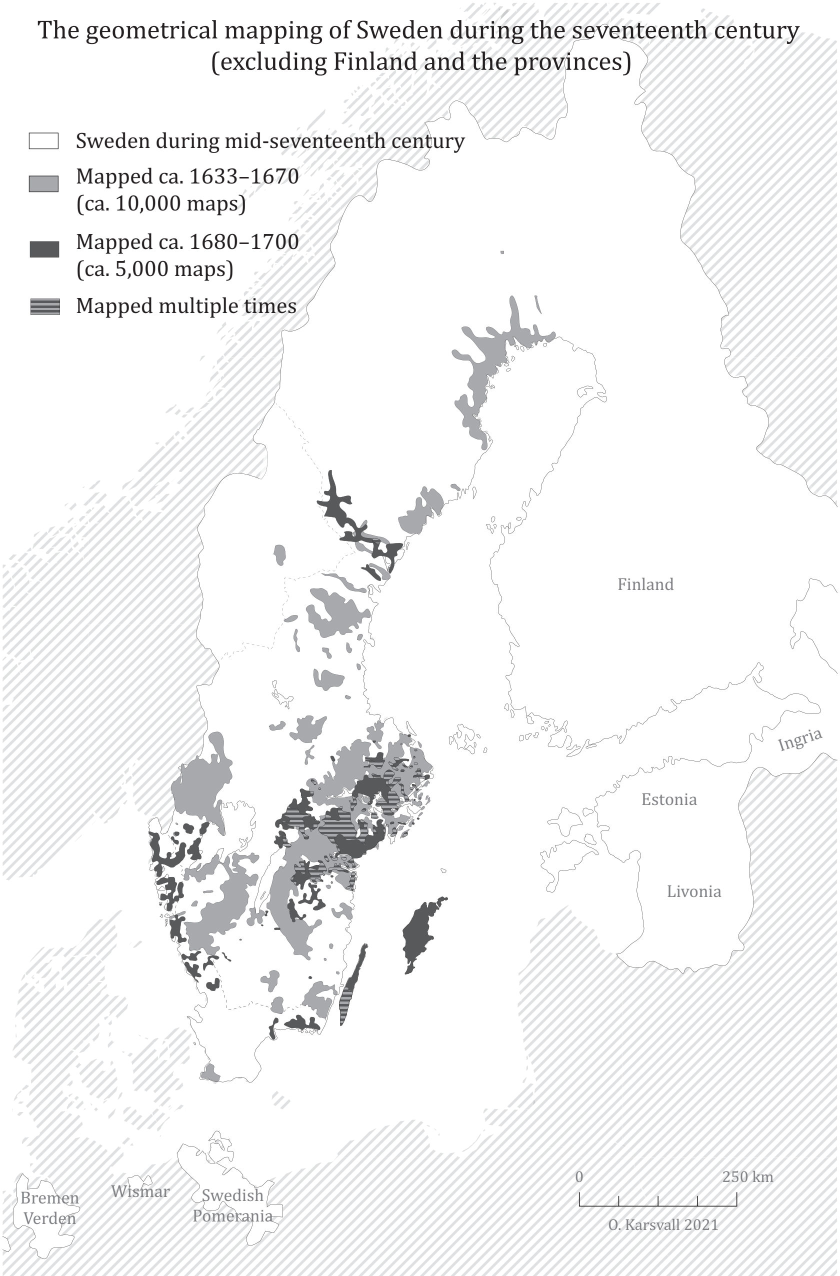

Figure 4.2. The extent of large-scale maps in Sweden during the seventeenth century. Image by Olof Karsvall.

the Swedish Land Survey refer to locations of official place-names on the map, using a cartographic and stylistic principle. A GIS pointing to the sites of historical settlements would therefore be an important addition.

Settlements could also be defined by polygons, with lines as vector data, corresponding to the villages' boundaries. The seventeenth-century maps usually show the property boundaries. In theory, it should be possible to transfer the villages' boundaries to a GIS, but this requires map rectifications—that is, scaling and adapting historical maps to modern coordinate systems.[31] Such work is time-consuming and suitable for detailed studies but is not an appropriate method when creating an HGIS for thousands of units.

The central concept created for TORA is the "historical settlement unit."[32] The term "settlement" is preferred over "hamlet" or "village," because the registration also includes uninhabited places, such as deserted and abandoned farms. By referring to "historical" settlements, although many places still exist today, it is said that they are spatially defined on the basis of historical maps. In other words, the core of TORA consists of well-defined early modern rural settlements, but other types of settlements, such as manors, towns, and smaller isolated single farms, are also included.

Most settlements of that time in Sweden were, in a European context, smaller hamlets of two or three farms. In a hamlet, the farmsteads stood close to each other. The land was divided into fields and subdivided into plots and parcels of different sizes and shapes. The plots were intermingled and distributed according to rules and customs (known as *tegskifte*). Such division and scattering of plots characterized many rural settlements from the Middle Ages until the late eighteenth century. It should be mentioned that how farms and hamlets in practice cooperated and functioned as agrarian units does not have to correspond to the formal cadastral registration and the way land surveyors mapped the hamlets in the seventeenth century. Farms from several hamlets often cooperated regarding, for instance, sowing, harvest, fencing, and pastures.[33]

Nevertheless, the functional appearance of the hamlet, its size, and patterns of land distribution are of less importance for the GIS registration. Regardless of size and appearance, any settlement that occurs in a historical source and that can be located on a map can be defined as a settlement unit in TORA. No categorization or typology takes place. Instead, the registration is based on source references, primarily links to the historical maps.

In order to be able to locate and set GIS coordinates, it is crucial that the area of cultivated land within the property boundary for a hamlet can be identified and separated from other settlements. Each village constituted a property area, consisting of arable land, meadows, paddocks, and other land types, which were spatially defined within the property boundary and marked on the map. The property boundaries on

31 Wästfelt, "Ambiguous Use of Geographical Information Systems," 210.

32 Karsvall, "Historical Settlement Units," 260.

33 Jupiter, *The Function of Open Fields*, 15–16.

the historical maps are therefore important for setting coordinates, as they show how different villages border each other. The borders are shown on the maps with dotted lines. On some maps, the boundaries appear indirectly, through the fences, which two or more hamlets could share, and which could coincide with property boundaries. When the coordinates are set in TORA, the cultivated land is in the centre. The aim is to place the coordinates in a central location for each settlement, primarily in the core arable land next to the farmsteads, barns, and other buildings. The arable land closest to the settlement often has the best soil and can be assumed to be the land that first came under cultivation.

In historical research in Sweden, the oldest part of the arable land is referred to as the *kärnåker*, which is "core arable land." This is the original or oldest part of the arable land, which farmers had used most intensively. Studies of core arable land and their patterns are used when the origin or genealogy of settlements are studied.[34] The core arable land is found next to the farm buildings, especially barns, because the fields needed to be fertilized from manure. It was most beneficial, and least strenuous, to have the source of the manure next to the fields.

It is thus the continuous sowing, ploughing, and fertilization of the arable that makes it a suitable geographical reference marker for settlement units in the medieval and early modern period. Farmsteads and other buildings could be abandoned, relocated, and rebuilt in new locations. Arable land, on the other hand, remained. Land that the farmers had once taken under cultivation and invested time on appears to be resilient. Admittedly, the arable ground lay in fallow every second or third year, meaning it was left unused to restore nutrition. During a crisis arable land could be converted into a meadow permanently. The best plots of land were seldom abandoned, however.

In some cases, though, the setting of spatial coordinates of settlements may be unclear or arbitrary. New farms—those established close in time to the surveyors' mapping—have, of course, no core field used for a longer period. There is usually some arable land, however, that the spatial coordinates could be based on. In parts of central and northern Scandinavia, rural settlements did not depend on grain cultivation but, rather, on extensive cultivation, animal husbandry (pastoralism), fishing, and other activities. Access to meadows, forest, and water was then more important than arable land. Historical maps, however, show that even the hamlets in the far north, where settlements were often found along rivers, lakes, and bays, had arable land under cultivation. This also applies to the smallest isolated farms in the forest areas. The arable land can thus form the basis for geographical coordinates in an HGIS for most rural settlements. When no arable land existed, which may apply to deserted settlements, the meadowland or other cultivated parts can be used as spatial markers.

It should be emphasized that the coordinates in TORA do not mark arable land per se. The arable land, and hypotheses about where the core parts have been located, constitute the main principle for where the coordinates in TORA are to be set.

34 See Ericsson, *Terra mediaevalis*, 329–30.

The coordinates in TORA thus correspond to an estimated point of reference: the core part of the settlement units; see the next section below. GIS registration according to this principle presupposes access to historical large-scale maps, which clearly depict the hamlets, their boundaries, and the distribution of land. The coordinate source is, in other words, always a historical map. On the oldest Swedish maps from the seventeenth century, which have been used in TORA, the spatial organization of settlements is read directly from the map itself.

No map archive covers a whole country. To create a nationwide register, the seventeenth-century maps need to be supplemented with large-scale maps from the eighteenth and nineteenth centuries. The next step for TORA would be to include GIS registration of units based on younger maps. Changes over time then need to be handled. By adding younger data, new settlements will appear, and those previously defined may be abandoned or relocated.

Method for Setting Spatial Coordinates

The discussion has so far been about the principle of how historical settlement units are defined. A further question is how the settlements are geo-referenced—that is, how the information from the historical maps is transferred to modern maps and assigned GIS coordinates in a modern coordinate system.

To identify the settlements, each map is read and processed manually. The transfer to GIS is also a manual step, in which the map image is visually interpreted and placed on a modern map. Points and line objects on the historical map, not least property boundaries, field patterns, roads, ditches, and impediments such as slopes and other terrain forms, are compared with today's landscape and maps. Despite major changes in the landscape over the centuries, several elements are usually preserved, which can form the basis for geo-referencing.

Reading and interpreting historical maps from the seventeenth century against today's maps and landscape is associated with several difficulties. Settlements that no longer exist, which have been deserted as a result of urbanization, for example, are obviously more difficult to locate. The traces of previous agriculture may be gone. Roads, boundaries, and other natural elements, such as watercourses and terrain forms, often remain, however, and these can form the basis for an approximate location of former settlements. Settlements and agrarian land thus do not need to remain today in order to be registered by the TORA project. The precondition is that the landscape information in the historical map can be transferred to and placed on a present-day modern map.

Historical maps also contain various scale errors. More precisely, different parts of the map were measured with different degrees of precision. The surveyor measured a map from different positions, which were later combined into one map image. Some parts could be measured better than others, and, when connecting the different parts, angular errors could occur. The distances between different parts of the map, such as between the plots, fields, and meadows, can, therefore, be misleading. The map can also be reversed; in other words, the upward direction is not always north as on a modern map, even though there is a north arrow illustrated on the map. These difficulties lead, above all, to problems when large-scale maps are rectified—that is, when lines and areas on a historical map are transferred to polygons. Setting coordinates as point objects, which occurs in TORA, is much easier.

One way to get round the various sources of error found in older maps is to compare them with other historical maps. A seventeenth-century map that is compared with maps from the eighteenth and the nineteenth centuries, over the same hamlet, is easier to interpret and relate to today's landscape in a GIS. The changes that have taken place over time can then more easily be decoded and interpreted into their spatial context.

Adding settlements in TORA is thus always based on interpretations of where a hamlet has been located in relation to today's landscape. The registration, therefore, involves a certain amount of uncertainty that needs to be documented. In TORA, spatial uncertainty is registered as *coordinate accuracy* according to a three-point scale, as "high," "medium," or "low"—similar to the *precision* mark-up used in the Text Encoding Initiative (TEI).[35] "High" precision means that the core arable land or central parts of the settlements have been matched against a modern map in a GIS. Since a point object in TORA represents the cultivated land of a hamlet and not a physical object on the ground, a margin of error of 50 to 100 metres is tolerated. "Medium" precision means that the unit can be located in an assumed correct location, but with uncertainty about where the core parts of the settlement are located. These coordinates, therefore, become more approximate, with an estimated error distance to the location of 200 to 400 metres. "Low" precision means that there is greater uncertainty about the spatial registration. References to historical maps still allow a presumed location to be given coordinates, which indicates where the settlement may have been placed with a margin of error of 1 kilometre. Uncertain units can, hopefully, be located more accurately in the future.

Out of 26,000 units currently in TORA, 80 percent are registered as high, 12 percent as medium, and 2 percent as low accuracy. The presence of high precision reflects that most registrations, when there are historical maps available, can be matched to modern maps. In addition, there are units in TORA—about 6 percent—that have been registered *without* spatial coordinates. This applies to hamlets and other units, which appear in older maps or are mentioned in medieval or early modern written sources, but no longer exist and cannot be located today.

The work of setting coordinates in a GIS has been time-consuming. The work started in 2001 and has continued with varying intensity up to the present day. A trained person is able to register ten to fifteen units per hour. It would be possible to continue to register systematically, area by area, in order to create a comprehensive historical GIS of settlements in Sweden. Since most large-scale maps from the seventeenth century have been included in TORA, the next step of the project needs to be based on later maps.

35 Text Encoding Initiative Consortium, "P5: Guidelines for Electronic Text Encoding and Interchange."

The ever-changing landscape might then be a problem when the HGIS covers data extracted from sources of different dates. For example, how could restructured and relocated units be spatially defined? Regarding hamlets that have been divided into several units or relocated, should they be registered twice, as separate units, or defined once, marking out the first known location? The latter principle so far applies in TORA.[36] Many of the eighteenth-century hamlets refer to the same places as the previous ones, although new settlements have to be added. During the nineteenth century land and settlements were transformed more quickly and more drastically. Presumably, such late units cannot be included in TORA, as this would mean too many new methodological choices. Therefore, a limit should be set at around the year 1800 regarding the units and historical maps that should be included in TORA.

To summarize, coordinate accuracy is an important attribute that is attached to every TORA settlement unit. In addition to the coordinates, which are stored as data according to SWEREF 99 and WGS 84 standards, reference is included to the historical maps that form the basis for the coordinates. Primarily, the oldest maps from the seventeenth century can be used, but so can maps from the eighteenth century.

TORA and Related Datasets

The aim of the TORA project has been not only to establish a historical GIS but also to enable links to other datasets and sources. An HGIS becomes much more useful if it is related to data found in historical sources and databases. As described, TORA is structured as a simple register of the settlement units with relatively few attribute data regarding primary spatial coordinates, place-names, accuracy, and references to historical maps. The register can be used to plot the location and distribution of historical settlements on digital maps. It can also serve as a geospatial index in data-driven research on historical places and place-names. For example, by using named entity recognition, the place-names appearing in editions of medieval letters could be automatically matched with the names and in TORA.[37] The real benefit arises, however, when more datasets—data from medieval and early modern sources—are linked to the HGIS.

Six datasets, related to different historical sources, have so far been added to TORA. Two datasets, which are connected to TORA, concern excerpts from seventeenth-century geometrical maps. One is related to maps from the 1630s and 1640s, and the other to later maps from the end of the seventeenth century.[38] These datasets compile the cadastral information that the surveyors provided on the maps, above all regarding the size of individual farms (holdings). In addition, GIS data have been created corresponding to the physical objects the surveyors' have depicted on the maps, such as farmsteads, church buildings, and watermills. All these data, including 15,000 settlements, are linked to TORA. For instance, Tollsta was first mapped in 1636, and

36 See also Dam, this volume.

37 Karsvall and Borin, "SDHK meets NER," 44–47.

38 Riksarkivet, "Sveriges äldsta storskaliga kartor."

later in 1690.[39] In the future, transcripts of the map texts, statistics, and GIS data from the maps will be added to the TORA URI.

Another database linked to TORA is the digital edition of the *Suecia antiqua et hodierna*.[40] It includes the engravings and drawings of towns and manors that Erik Dahlbergh initiated during the second half of the seventeenth century. The whole collection refers to 231 settlement units in TORA. Several of these also appear in the seventeenth-century maps. For instance, a drawing of the fortification of Borgholm Castle was first made in 1625. In 1683 its land and surroundings were surveyed on a geometrical map. Both maps and the engravings from the *Suecia* collection have been linked to TORA.[41] In other cases, there are no historical maps of the places depicted in the *Suecia* collection. The images in *Suecia*, together with modern maps, have then formed the basis for the coordinate setting. Drawings are in most cases not suitable as coordinate sources, but, since the places depicted in *Suecia* apply to towns and other known places, the coordinates can be determined by using modern maps.

A similar principle of setting coordinates to well-known places has been applied in a database of Swedish manors managed by economic historian Göran Ulväng.[42] At present this database contains information on some 4,000 manors and similar institutions in Sweden, documented in written sources from the Middle Ages and later. Two-thirds of these correspond to settlements that have already been defined in TORA by historical maps. Using younger maps, especially from the eighteenth and nineteenth centuries, it has been possible to set coordinates for the remaining ones, often with high accuracy, as the places are usually well known and present in today's landscape.

The largest addition to TORA has come from the digitization and inclusion of the standard work *Det medeltida Sverige* (DMS).[43] All settlements reported in the book volumes, published before 2021, have been added to TORA. This has resulted in an addition of over 7,000 settlement units. The GIS registration has been based on the oldest available map, usually a map from the eighteenth century or later. It can be perceived as anachronistic to add coordinates to settlements known only in medieval and sixteenth-century sources. Before the seventeenth century, however, no maps are available. A historical GIS of medieval settlements thus needs to lean toward complementary younger sources and archaeology. As previously stated, the hamlets' core cultivated land and property boundaries are often stable over a longer period. This means that not only seventeenth-century maps but also younger, detailed large-scale maps are important sources when interpreting medieval settlement patterns. Mentions of places in medieval written sources, such as letters and accounts, can thus form the basis for registration in TORA, although the coordinates in GIS are based on younger

39 Riksarkivet, "TORA."

40 Kungliga biblioteket, "Suecia."

41 Riksarkivet, "TORA."

42 Svenska herrgårdar, www.svenskaherrgardar.se (accessed May 24, 2021).

43 Riksarkivet, "Medieval Sweden DMS."

maps. There are also reports on undefined hamlets and farms in DMS that cannot be located. These are still registered in TORA as settlement units without coordinates. In this way, the entire DMS will be connected with TORA. The digitization of DMS is an ongoing project at the National Archives. Links to the information reported in DMS, on land acquisitions and other subjects, will be gradually added to TORA. DMS will also be a digital service in the future, with TORA to be used as a map service.

The sixth dataset connected to TORA applies to another standard work on place-names and name evidence called Sveriges ortnamn (SO).[44] As a pilot study, parts of the content from one book have been related to the geographical locations in TORA.[45] For instance, Mångsbo settlement in the hundred of Våla is geocoded based on a seventeenth-century map and assigned a TORA ID (9837). The identifier has then been added to a prototype of a digital SO, based on XML and the TEI mark-up standard, following the principle used for DMS. Descriptions in SO and DMS that contain TORA ID could be exported and integrated into the TORA map service. As a result, it is possible to view Mångsbo and other settlements, with details from the two digital editions and the historical maps, in one place.[46]

In this way, through collaborations with researchers and by including several datasets, the number of settlement units in TORA has increased. Henceforth, it would be possible to include more of SO, not least the provinces that still to a large extent lack TORA coordinates, such as Scania. Above all, TORA serves as a hub, connecting and providing a spatial entrance to datasets that otherwise are kept separated and lack geo-references.

A Linked Data Approach

The method of linking and embedding datasets from various sources utilizes linked data (or linked open data) principles and technologies. The basic idea of linked data, formulated by Tim Berners-Lee, is that the Internet is to function as a large database—more precisely, a semantic and interconnected web.[47] In the TORA case this means that the data have been modelled and published on the Web according to a few basic principles.

The reason why a linked data approach is used in TORA is related to a broader issue, namely the requirements placed on research data today. Research data are usually created for specific purposes in research projects and are collected and designed to handle the problems and questions that the researchers try to answer. It may serve as raw material, from where some parts are included in the analysis, compilation, and results, but the data themselves can also be the result, such as a digital edition, catalogue or service of a collection, or several related sources.

44 Institutet för språk och folkminnen, "Sveriges ortnamn."

45 Wahlberg, *Ortnamnen i Västmanlands län*.

46 Riksarkivet, "Mångsbo," http://toramaptest.riksarkivet.se/view/9837/en (accessed May 24, 2021).

47 Berners-Lee, "Linked Data."

As the Internet is the channel for all types of digital publishing, terms such as "data," "database", and "dataset" become synonymous and less important to keep apart. Data on the Web could easily be adopted and remixed for purposes other than those they were originally established for. Several benefits can easily be highlighted. There is an increase in transparency, and possibly also data quality, as a wider audience takes part of the data, and corrects, reuses, and builds on what has previously been created. Technological development, not least in the field of artificial intelligence, promotes data-driven research that uses and adapts data in a machine-readable way. This will very likely change the way research data should be made available. It is no longer sufficient to publish data behind a custom interface, such as a search application, which facilitates some users but prevents access to all data, data reuse, and data-driven methods. Moreover, Web applications created in research projects tend to become obsolete when the projects are completed. The need for special interfaces or websites is also, in my opinion, often overestimated. An easier way, at least in some cases, would be to make data available through repositories for direct access and download, although dynamic data, frequently updated, will need some services. In those cases, the research data could be made available via existing major infrastructures. A problem within HGIS and humanities, in general, is that such research infrastructures are lacking.

That being said, the long-term goal of TORA is to establish a digital research infrastructure for historic settlements within Sweden, Finland, and the Baltic region—the areas that were mapped during the seventeenth century. Early in the project the decision was made to use linked data as a method for this infrastructure. Creating a large database of all information related to historical settlement would simply not be possible. As shown, the datasets and sources used in TORA are simply too diverse to be integrated into a single data model and ontology.

A linked data approach enables a decentralized solution, whereby each dataset is described separately and linked together according to a few basic principles. One principle is about making data linkable by using uniform resource identifiers.[48] It is thus a matter of exposing data using the HTTP addresses as identifiers that point out the unique records. In TORA, each settlement unit has a unique URI under the National Archives, according to the pattern: data.riksarkivet.se/tora/[identifier].

Another linked data principle is to model the data according to the Resource Description Framework (RDF).[49] The data are expressed as relations between a subject, predicate, and an object—so-called triplets: statements that express links between URIs or string values. Standardized vocabularies such as the Simple Knowledge Organization System (SKOS)[50] and Dublin Core[51] are used to define the predicates. One such relation (triple) is as follows: TORA ID 9837 (subject),[52] having a preferred name (predicate)

48 Berners-Lee, "Linked Data."

49 W3C, "Resource Description Framework (RDF)."

50 W3C, "SKOS Simple Knowledge Organization System."

51 Dublin Core, "DCMI Metadata Terms."

52 Riksarkivet, "Mångsbo," https://data.riksarkivet.se/tora/9837 (accessed May 24, 2021).

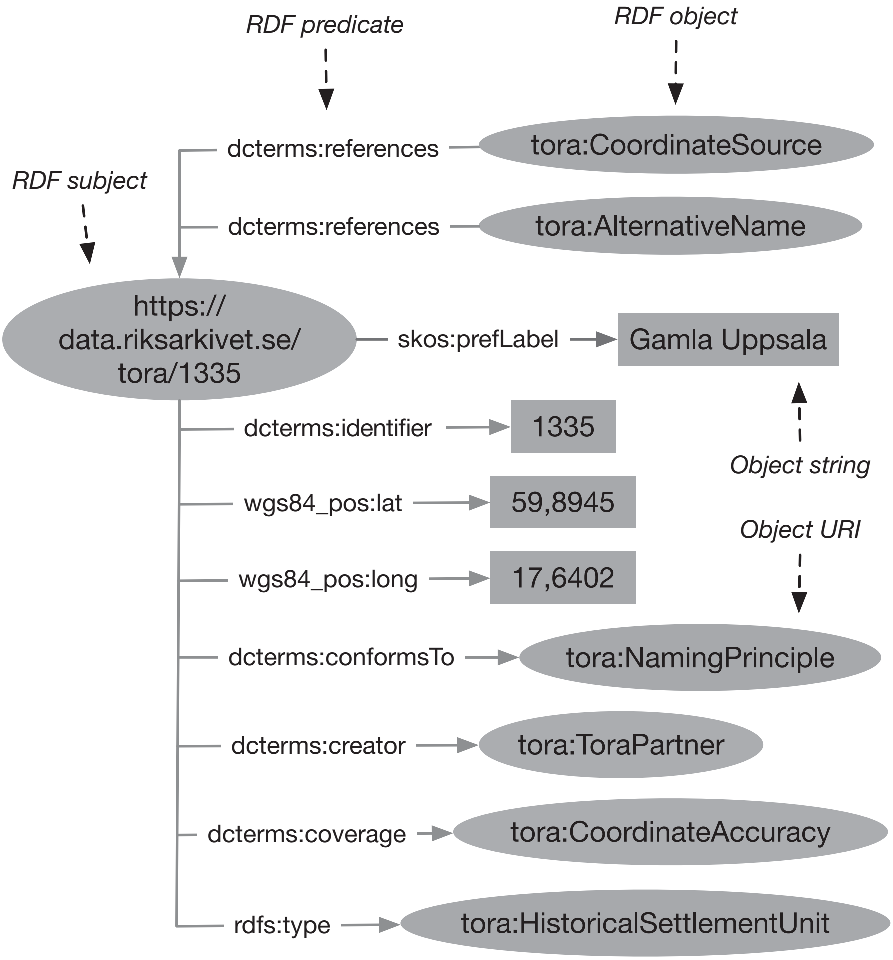

Figure 4.3. Data model or graph in RDF used to describe relations (triples) in TORA. Image by Olof Karsvall.

defined using skos:prefLabel,[53] pointing to "Mångsbo" (object) as a data string value.[54] The central parts of the TORA graph are exemplified in Figure 4.3.

An aim of linked data is to make statements explicitly understandable by humans and machines. Relationships and terms that express general phenomena (such as names,

53 See W3C, "SKOS Simple Knowledge Organization System: Preferred Label," www.w3.org/2009/08/skos-reference/skos.html#prefLabel (accessed May 24, 2021).

54 The creation of historical settlement units as Linked Open Data is described in more detail in Karsvall, "Historical Settlement Units."

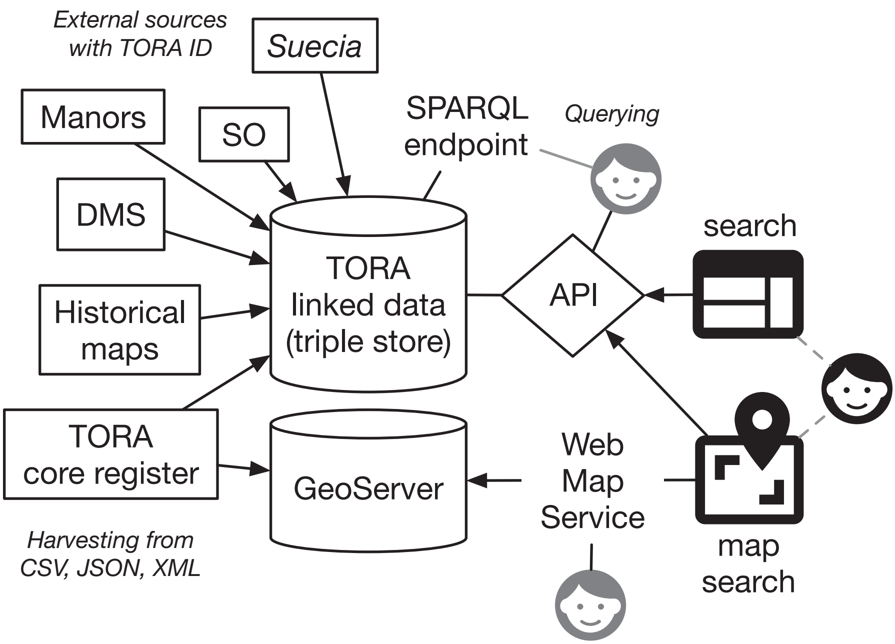

Figure 4.4. Architecture and data flows in TORA. Image by Olof Karsvall.

events, sources, dates, etc.) can in most cases be mapped to existing vocabularies. Most concepts used in TORA are therefore based on standards. In order to express historical places, other domain-specific terms are also needed. The central concept in TORA, "historical settlement unit," refers to the agrarian settlements that were registered and surveyed during the Middle Ages and early modern period. Adding this term clarifies that these are historical settlements that should not be confused with modern GIS data. Hence, linked data statements can be expressed freely, as long as they express RDF triples and URIs to name the relationships.

To illustrate how TORA uses linked data, the architecture and the data flows should be commented on; see Figure 4.4. The extended RDF graph consists of two parts: a "core" part, holding the basic register of historical settlements and its spatial coordinates; and a "cache", holding all the other data that are being harvested from various sources. The "cache" is a temporary storage, in the sense that related datasets are created somewhere else; hence, the harvesting process has to be redone as soon as the data are updated at the source. In both cases, the datasets are added to TORA by harvesting and mapping to the RDF model. The core TORA register, DMS, SO, and the historical maps are harvested from CSV and JSON files. In the case of the *Suecia* collection, the data are retrieved from an open API,[55] which

55 Kungliga biblioteket, "Xsearch." An example (Aspnäs, TORA ID 12320): http://libris.kb.se/xsearch?query=uri:(data.riksarkivet.se/tora/12320)&format=marcxml (accessed May 24, 2021).

enables a more or less seamless data embedding. All transformations are made using mainly JavaScript on the TORA server. The RDF statements are then stored using a so-called triple store database, which exposes each settlement and its related data in RDF formats.

There are several ways of accessing the data: either using the linked data API or a SPARQL endpoint, or by downloading and embedding settlement units as RDF files.[56] As another alternative, there is a GIS server that can plot the spatial data of each settlement unit on maps, which also connect with open-source applications such as QGIS.[57] Using these data sources, a map search application has been built that serves as a frontend to the historical settlements units.[58]

Linking historical data in this way is thus a method of mapping and combining data from different sources. Datasets added to TORA need to hold a TORA ID, but may otherwise have different formats and structures. Through a process of RDF mapping, metadata and content from various sources are directly embedded in TORA. The continued development for TORA will be about adding other historical datasets, and thus creating a larger graph of relations between historical settlements and historical sources.[59]

Final Remarks and Conclusions

The historical GIS called TORA that has been described and discussed in this chapter compiles historical places, more particularly rural settlements in medieval and early modern Sweden. Historical maps and other sources have been systematically reviewed for reconstructions of the actual sites for historical places in Sweden. The core in TORA consists of "historical settlement units"—more precisely, villages, hamlets, and farms.

A basic question for any historical GIS is how units and places are to be defined and conceptualized. The starting point must be taken from source material that can be extracted and transformed into GIS data, especially historical maps and sources with location references. The tradition of registering hamlets and farms in Sweden on a national level goes back to the 1530s. Related to this, surveyors measured, described, and depicted the farmland during the seventeenth century. These large-scale maps are therefore suitable as the basis for an HGIS. A method for assigning accurate coordinates from large-scale maps has been further developed in the TORA project. The settlement units are geo-referenced as spatial point objects showing the locations on a modern map with references to the oldest large-scale map or several maps.

Researchers can integrate the TORA register into their own datasets. It is also a service on its own, proving data harvested from related sources. Duplication of work will

56 See Riksarkivet, "TORA."

57 See QGIS, https://qgis.org/en/site (accessed May 24, 2021).

58 Riksarkivet, "TORA," http://toramaptest.riksarkivet.se (accessed May 24, 2021).

59 The documentation, datasets, and code of the TORA service will be available at the National Archives as open data in the future. For updates, see Riksarkivet, "TORA."

be avoided if places appearing in historical sources are defined by spatial coordinates once. Moreover, the reuse of place identifiers (URIs) promotes data analysis. Different sources that deal with a certain place or area can be compiled and compared based on geographical locations. For example, when a dataset of medieval settlements is linked to TORA, it will be possible to create a map that shows its spatial distribution, according to and with reference to the oldest known maps. The analysis can be combined with other GIS data, such as that related to ancient remains. In fact, a large amount of data from historical sources is linked to places in some way. For instance, manuscript sources (as diplomas) are created in specific places and often deal with issues such as land transactions that can be linked to places. The point to be made is that datasets that lack geo-references can be analyzed spatially if they are connected to an HGIS.

A future challenge is whether HGISs created for different countries can be harmonized and compared. TORA is built using seventeenth-century large-scale maps that are unique to Sweden and Finland, although it is possible to create HGIS coordinates using a simplified method. As highlighted in this chapter, other sources, such as engravings depicting landscapes and written sources describing places and place-names, could be used as coordinate sources in an HGIS. The minimum requirement is one historical source and a declaration (metadata) about coordinate accuracy and a coordinate reference system. HGISs built as linked data can be simplified and made lightweight because most of the metadata needed to analyze historical places are extracted from other linked sources.

Undoubtedly, the historical GIS of settlements, as well as administrative divisions, are important in historical research, as basic registers and for creating geo-references to source materials. The use of HGIS data would likely increase if they are expressed as linked data and act as nodes on the Web, available to a wider audience. Linked data principles can also form the basis for collaboration between HGIS projects, digital historians, and others, as a way to share data and applications, which is the model for the future.

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