

# **GIS-Based Visualization of Tokyo's Urban History**

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## **Abstract:**

With the rise of interest in "temporal GIS" over the last decade, the use of geographic information systems to document, visualize, and interpret the history of urban regions has become more common. The temporal GIS project presented here is a "GIS spatial history of Tokyo" covering spatial patterns and changes in Japan's capital region over the last 130 years. Historical topographic maps, census data, administrative histories, rail company chronologies, and other spatiotemporal data were used to produce a multifaceted GIS database that includes: changes in physical features such as shorelines, rivers, and canals; the process of urbanization as represented by annexations, mergers, and upgrading of administrative areas from village to town, city, or city ward; population changes mapped by administrative area; development of the region's extensive rail network; and mapping of historical landscape units.

## **Keywords:**

temporal GIS, spatial history, historical visualization, Tokyo, Japan

## **Notes:**

This paper first appeared in the *Proceedings of the Computers in Urban Planning and Urban Management (CUPUM 2001) Conference* held at the University of Hawaii at Manoa in July 2001. Those proceedings were distributed on CD-ROM.

Page numbering used here in the Adobe PDF file is different than that used in the CUPUM 2001 proceedings.

Colors used in the maps were optimized for printing on an Epson Color Stylus inkjet printer rather than for display on a computer monitor.

## **Introduction**

Geographic information systems are widely used for mapping and analyzing current spatial phenomena in fields such as urban planning, geography, environmental planning, and business. Over the last decade, their use for historical analysis has also increased. On the theoretical and software-design side, there has been extensive work by Langran (1992) and others on issues of how to handle time in GIS databases. A bibliography on spatiotemporal database research (Al-Taha, 1994) stated that over 350 papers by almost 300 researchers had been written on the subject of GIS, space, and time. A general survey of issues of GIS and temporal data is given in the summary of a conference held in 1990 (Barrera et al., 1990). There has also been extensive use of GIS techniques for archaeological documentation and analysis, as reported in Gamble (1987) and in an anthology by Allen et al. (1990). More recently, researchers in the social sciences and humanities have started to use GIS for historical analysis (Knowles, 2000).

The historical GIS project reported on here is based on a PhD dissertation entitled "Creating a GIS spatial history of Tokyo" (Siebert, 1997), in which I used a variety of historical sources -- such as topographic maps, censuses, administrative histories, and rail event chronologies -- to document, visualize, and interpret aspects of Tokyo's urban history. This is an ongoing project of creating a multifaceted spatial history archive on computer. In this presentation to the Computers in Urban Planning and Urban Management conference, I will discuss and illustrate some of the many types of spatial phenomena included so far in the historical GIS project. Details of data input, database design, and mapping methods used are given in the dissertation and in a survey article for social science historians (Siebert, 2000a).

The components included in the GIS spatial history database, which covers Tokyo and the surrounding Kanto region, are: (1) shoreline and river/canal changes in Tokyo Bay and its delta lands, (2) administrative history, including annexations, mergers, and status changes of villages, towns, cities, and wards, (3) population changes, (4) rail network development, and (5) an initial mapping of landscape fragmentation in one part of Tokyo prefecture. Recording the history of these spatial phenomena in the GIS required use of a variety of source materials (map, table, text, chronologies) and a variety of GIS data types (points, lines, and areas), thus making them a useful set for developing historical GIS techniques.

## **Historical Maps, Input, and GIS Software**

The Geographical Survey Institute of Japan and its predecessor agencies have produced regular series of maps since the last half of the 1800s. Copies of most can be viewed on microfilm, then selected for reproduction (usually from black-and-white paper copies, even if the original was color). In 1994, reproductions cost about 500 yen each (about \$5 at the time). I inspected samples at the viewing room in downtown Tokyo in 1993. After returning to the United States, I requested and obtained detailed catalogs of published maps, prepared tables to evaluate the spatial and temporal coverage, and selected maps to order.

Due to budget, time, and disk space constraints, I limited my selection to the following: (1) a set of current 1:200,000 maps in color of the nine map sheets covering the Kanto region, (2) a once-per-decade time series of 1:200,000 maps covering Tokyo itself, (3) a set of current 1:50,000 maps in color of the sixteen subsheets of the Tokyo map-sheet area, and (4) a once-per-decade time series of 1:50,000 maps covering six of the subareas of the Tokyo map-sheet. These latter six cover all of Tokyo itself and most of its western suburbs. Figure 1 shows the coverage of the various types of maps.

In some cases, no map was available for a decade, or a catalogued map was not actually available for reproduction when ordered. There are, consequently, several gaps in my coverage, especially for the 1900s decade and for one subarea each in the 1910s, 1930s, and 1940s. For these missing areas, I had to rely on the 1:200,000 map sheet.

Once obtained, the maps were scanned into the computer, georeferenced, and then used for digitizing the required vector layers of the GIS. The scanned maps can also be displayed at any time as backdrops for visual reference, allowing their wealth of information to be accessed even if it has not all been digitized.

The GIS spatial history of Tokyo has been produced in the Maptitude vector GIS software program from Caliper Corporation. This software was selected due to its low cost, ease of digitizing, and, most importantly, its ability to handle the historical rail network data correctly. At the time the project was started, Maptitude was the only software that would allow station information to be attached to the nodes of a line layer, and the only one that kept crossing lines as independent entities (necessary for the many rail lines that cross each other) rather than breaking them apart into separate segments.

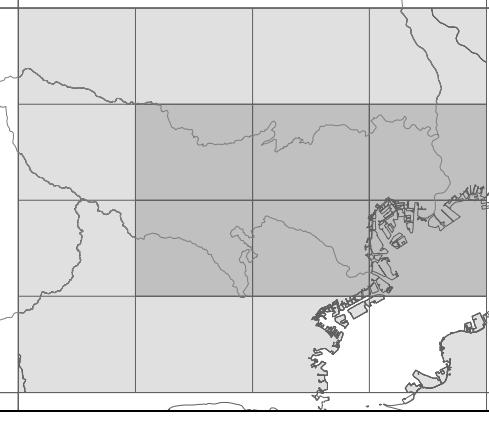
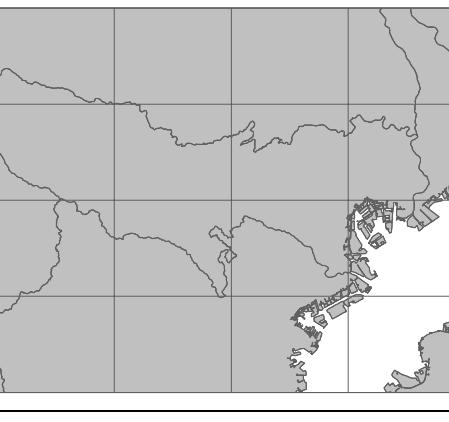
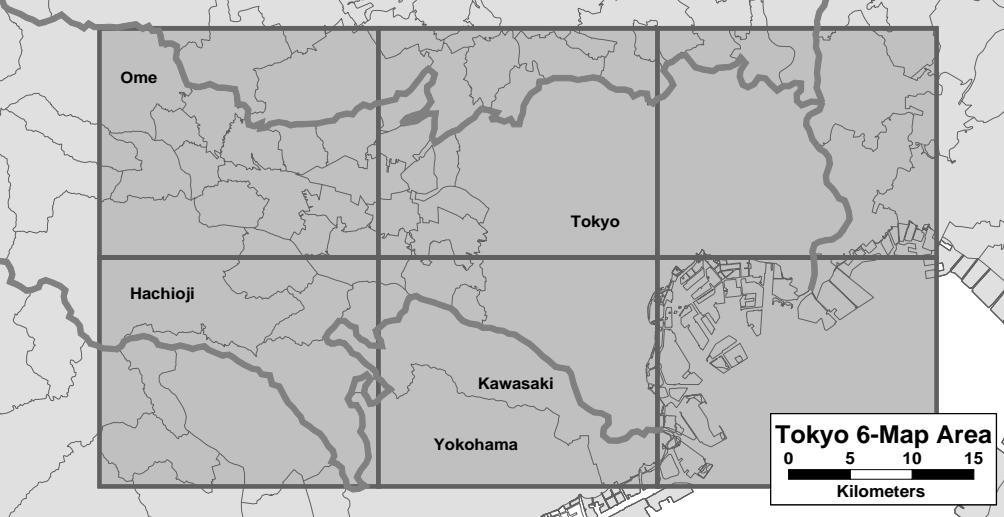
Scale	Time Series for Historical Mapping	Current Maps for Base-Map Production
1:200,000	Once-per-decade in 1900s for Tokyo map-sheet area	Most-recent map for all nine map-sheet areas covering Kanto region
		
1:50,000	Once-per-decade in 1900s for six map-sheet areas covering all of Tokyo itself and most of its western suburbs	Most-recent map for all sixteen map-sheet areas covering 200K Tokyo map-sheet area
		
Closer view of six-sheet area		

Figure 1 Spatial and Temporal Coverage of Maps Used in This Project

## Land Reclamation and River Rerouting

Tokyo has its origins in Edo, a village at the head of a large bay in eastern Japan. In 1603, the Tokugawa military government, which had successfully unified the country three years earlier, established its capital at Edo. As part of the process of building its castle grounds and extensive moat system, the new government made significant changes in the channels of rivers and in the shoreline of Edo Bay.

The Tokugawa-era land reclamation was nothing, however, compared to reclamation in the modern era, after the Meiji Restoration of 1868, when Edo was renamed Tokyo as the new imperial capital city. Figure 2 shows the decade during which land reclamation areas first appeared on historical topographic maps from the 1900s. The GIS database covers all of Tokyo Bay (formerly Edo Bay), but this view shows only the portion around the city of Tokyo itself. The main patterns are:

- (1) 1910s (dark blue): Several sets of small islands were created along the mainland shoreline or next to existing islands (in Minato, Chuo, and Koto wards). This formed a first “tier” of islands.
- (2) 1920s (medium blue): Only a few new islands appear (in Koto ward in the north and Ota ward in the south).
- (3) 1930s (light blue): Many new islands appear, including some that start to form a second tier of islands. Most of the expansion is in the north and west (in Koto, Chuo, Minato, and Shinagawa wards), and just a little in the south (in Ota ward).
- (4) 1940s (medium green): No new land was reclaimed in the area shown here.
- (5) 1950s (light green): No new land was formed in Tokyo; one island was created in Kawasaki.
- (6) 1960s (yellow): Many new islands, including several very large ones, were formed. In the north (in Chuo and Koto wards), these formed a third tier of reclamation. In the west and south (Minato, Shinagawa, and Ota wards) they formed a first or second down-bay (i.e., southward) tier.
- (7) 1970s (light orange): Many new islands and several new areas of mainland were reclaimed. In Koto ward, these formed a fourth tier as well as some outliers. Elsewhere they formed a second or third tier.

- (8) 1980s (dark orange) and 1990s (red): Land area expanded in Ota ward (new Haneda airport) and Koto ward (completion of a new island), forming a fifth tier. Crescent-shaped islands were created in a new park in Edogawa ward.

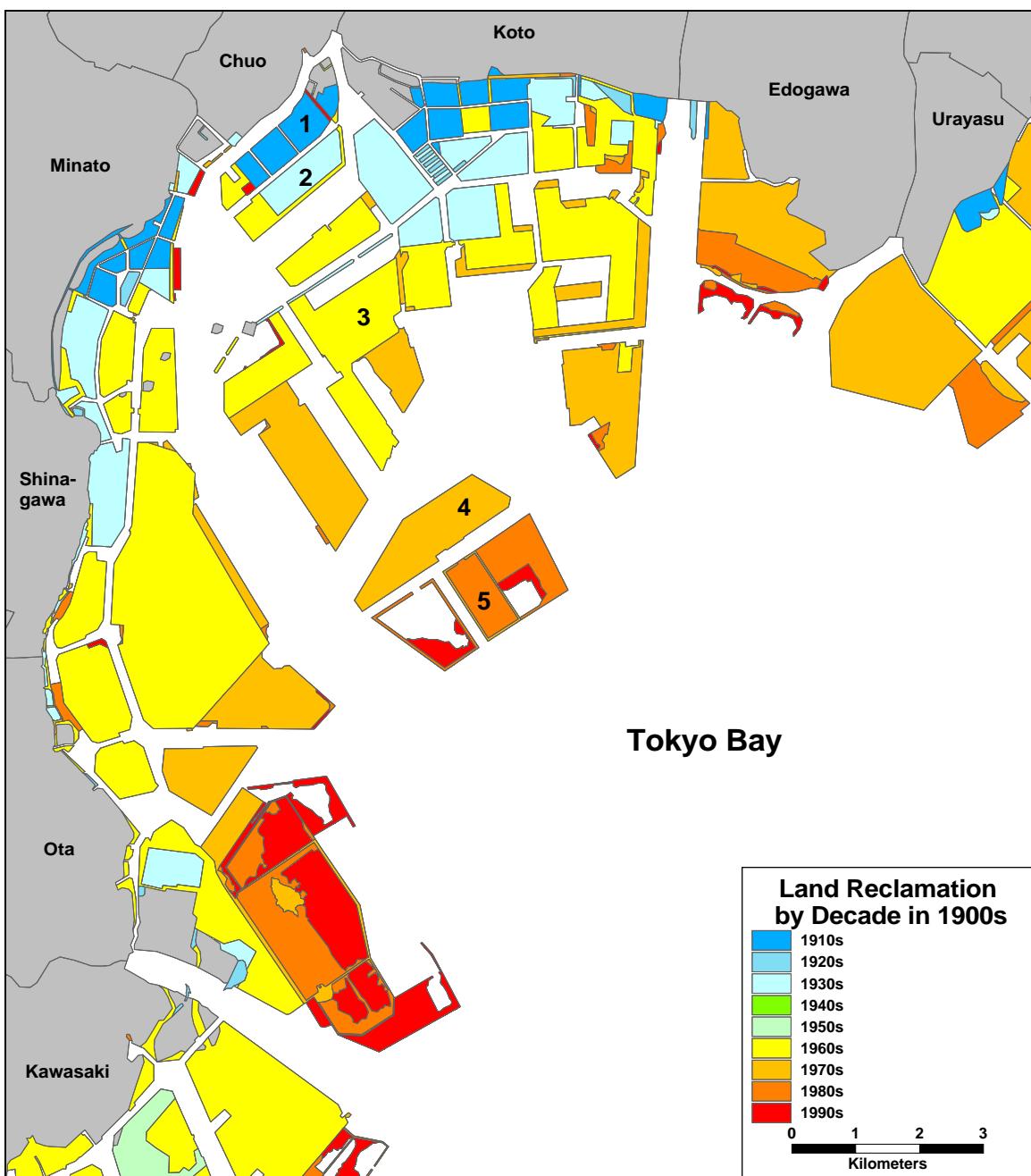
The major pattern observable for Tokyo itself is that land expansion in Chuo and Koto ward areas progressed outward by decade, whereas in Minato, Shinagawa, and Ota wards it progressed both outward and southward along the west shore of Tokyo Bay. Both patterns reflect the southward, down-bay dominance of growth until recently.

The GIS spatial history of Tokyo also includes mapping and interpretation of land-reclamation transition types. For example, not all areas went from water (bay) to land (island or new mainland). Some had a much more complex history, such as first becoming part of an island, then being dredged out as a channel within the island, then finally being filled in again. Another type of analysis conducted with the GIS database is the mapping of phases by which the various portions of Tokyo's harbors were enclosed by breakwaters or outlying land-fill islands.

The 1900s also saw significant changes in rivers flowing into Tokyo Bay. The Tokugawa government had already modified rivers to form Edo's moat system. The modern Japanese government also extensively modified river channels, especially those flowing through the *shita-machi* "low-town" delta lands at the head of Tokyo Bay. Figure 3 shows the extent of modifications of four rivers -- the Sumida-gawa, Ara-kawa, Naka-gawa, and Edo-gawa. The Ara-kawa and Edo-gawa were both given new, wider direct routes to Tokyo Bay, to alleviate flooding along their earlier channels. The Naka-gawa was substantially straightened.

Though not mapped here, these changes in river routes had a significant impact on political boundaries and transportation routes. Villages were split into two parts. Some disappeared entirely, and others were merged into adjacent towns or villages. Similarly, several train lines had to be partially rerouted and stations relocated.

The GIS spatial history database is being expanded to include river channel changes within inland areas as well, not just those in the delta lands.



#### Notes:

Numbers show major “tiers” (and major decades) of island reclamation:

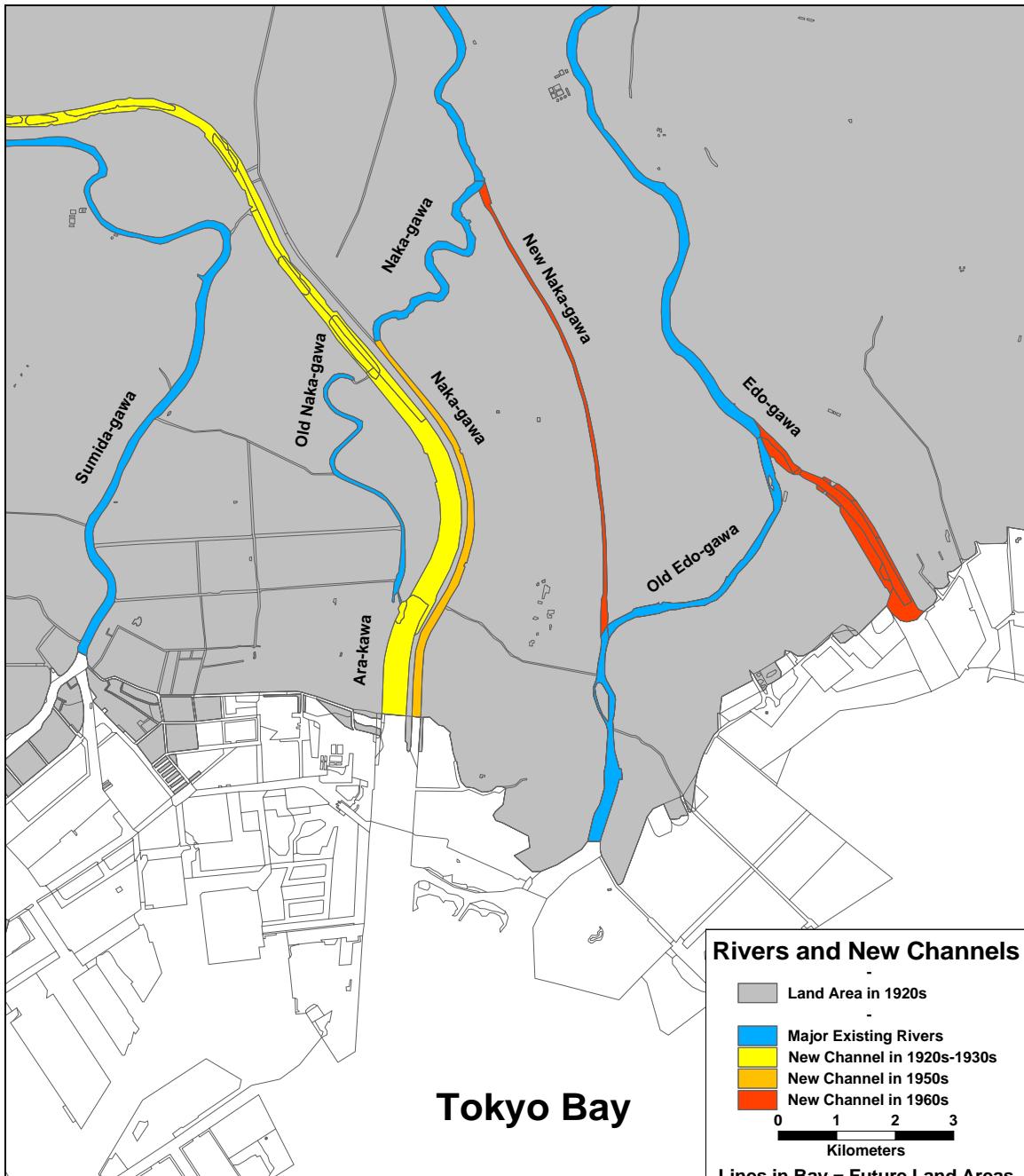
1 = 1910s, 2 = 1930s, 3 = 1960s, 4 = 1970s, 5 = 1980s/1990s

#### Sources and Processing:

Digitized and interpreted from once-per-decade 1:50,000 topographic maps in 1900s.

Color theme of LANDDEC field derived from LANDFIRST field of AREAHOST database.

Figure 2 Land Reclamation in Tokyo Bay by Decade in 1900s



#### Notes:

All channels shown still exist (including those called "Old").

Outlines within a channel indicate dredging stages over multiple decades. Colors group them by decade of completion. Construction stages could be queried in the database and mapped differently.

#### Sources and Processing:

Digitized and interpreted from once-per-decade 1:50,000 topographic maps in 1900s.

Selections from WATERBODY geographic file.

Figure 3 Rivers and New Channels at Head of Tokyo Bay in 1900s

## **Development of Towns, Cities, and Wards**

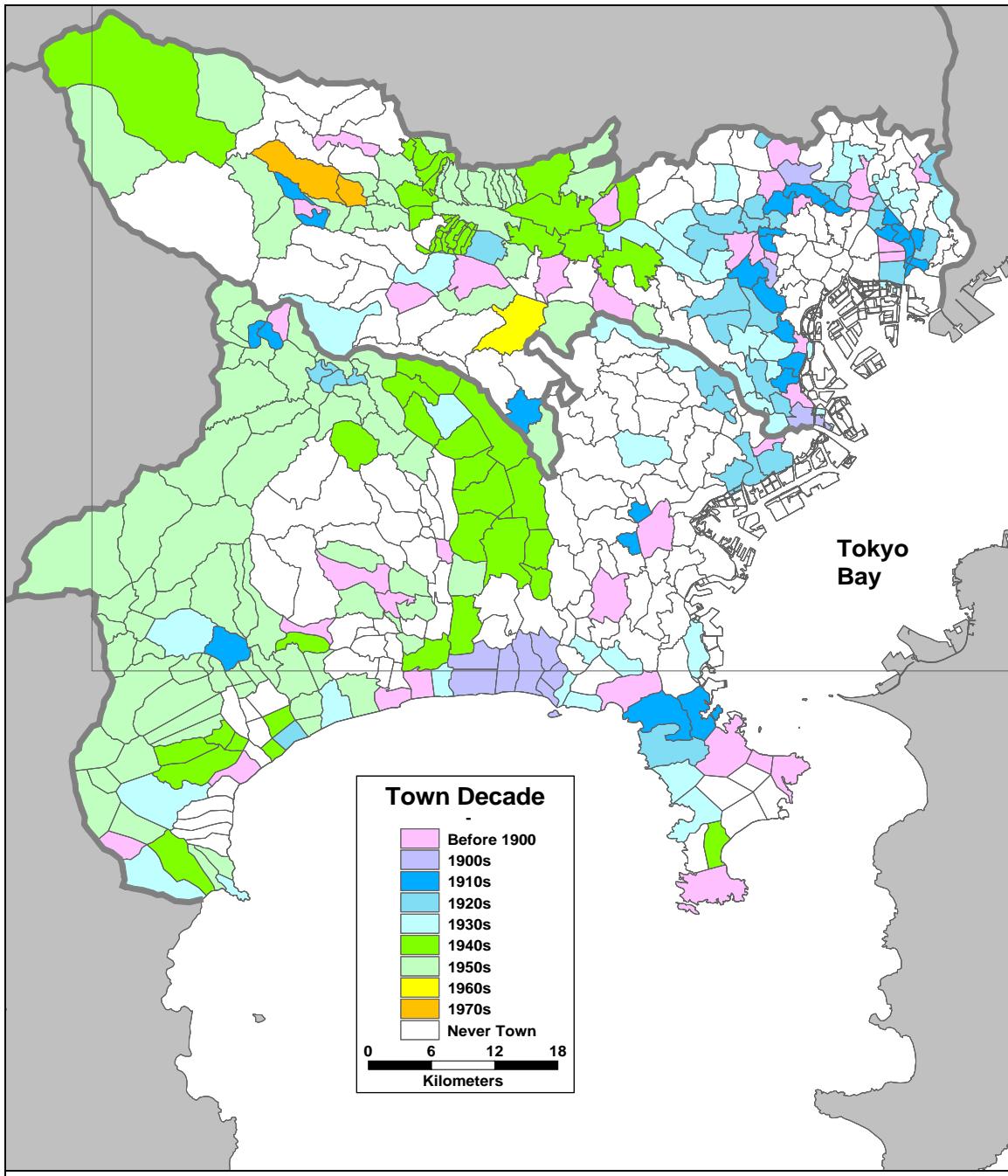
Japanese prefectures are subdivided into villages, towns, cities, and special cities with wards. The history of boundary changes, mergers, annexations, and occasional splits of these administrative units has been recorded in the GIS spatial history database. Each polygon represents an area with a common political history. These "uniform history zones" are like the "uniform analysis zones" used in other GIS applications. The information in this part of the database is based on historical topographic maps, historical censuses, and a chronology of administrative history (Ota, 1995).

Interpretations based on this data have revealed that there were four major zones of transition types, with some areas having sequential changes from village to town to city to ward, and others nonsequential changes, skipping one or two intermediate administrative levels (Siebert, 2000b). Patterns of annexations and mergers have also been mapped and interpreted (Siebert, 2000a).

Three maps are included here to show the decade during which town, city, or ward status was obtained by these administrative units. Figure 4 shows that major decades of conversion to town status were the 1910s through the 1930s for areas ringing Tokyo city itself and along the Kanagawa coast, and the 1940s and 1950s for inland areas.

Figure 5 shows that major decades of change to city status were the 1920s and 1930s for Tokyo and Yokohama and the 1940s through 1970s for other areas. In Tokyo, several large cities formed in the west (at the edge of the mountains) before many of the flat intervening areas became cities.

Figure 6 shows that Tokyo had two stages of ward creation. In 1889, the original core area was divided into 15 wards (pink). In the 1930s, a large outer ring of towns and villages joined the city as new wards. Yokohama also had two stages. The first was in the 1920s (medium blue), when the old core area and some recently annexed towns and villages were consolidated into wards. A second zone of conversion to ward status occurred in the 1930s, when many surrounding villages and towns joined the city and became parts of existing or new wards. Finally, unlike Tokyo but like Yokohama, Kawasaki (medium orange) existed as an ordinary city for several decades before gaining special city status and being subdivided into wards (in the 1970s).



**Notes:**

Town decade means time when area became new town or was annexed into existing town.

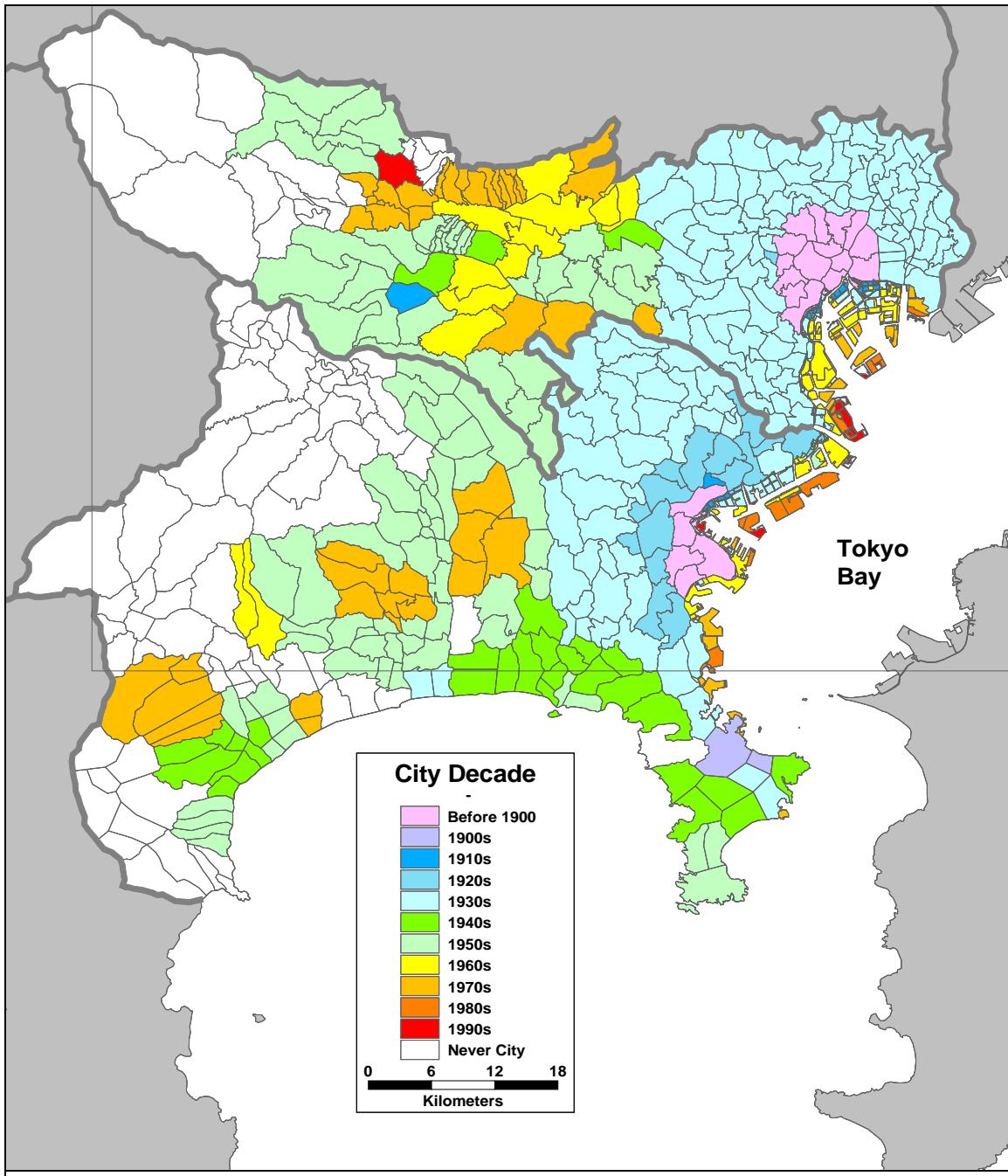
Boundaries of some areas outside Tokyo map-sheet frame are approximate.

**Sources and Processing:**

Once-per-half-decade censuses and once-per-decade topographic maps in 1900s.

Color theme from TOWNDECADE field of AREAHIIST database.

Figure 4 Development of Town Areas in Tokyo and Kanagawa by Decade in 1900s



**Notes:**

City decade means time when area became new city or was annexed into existing city.

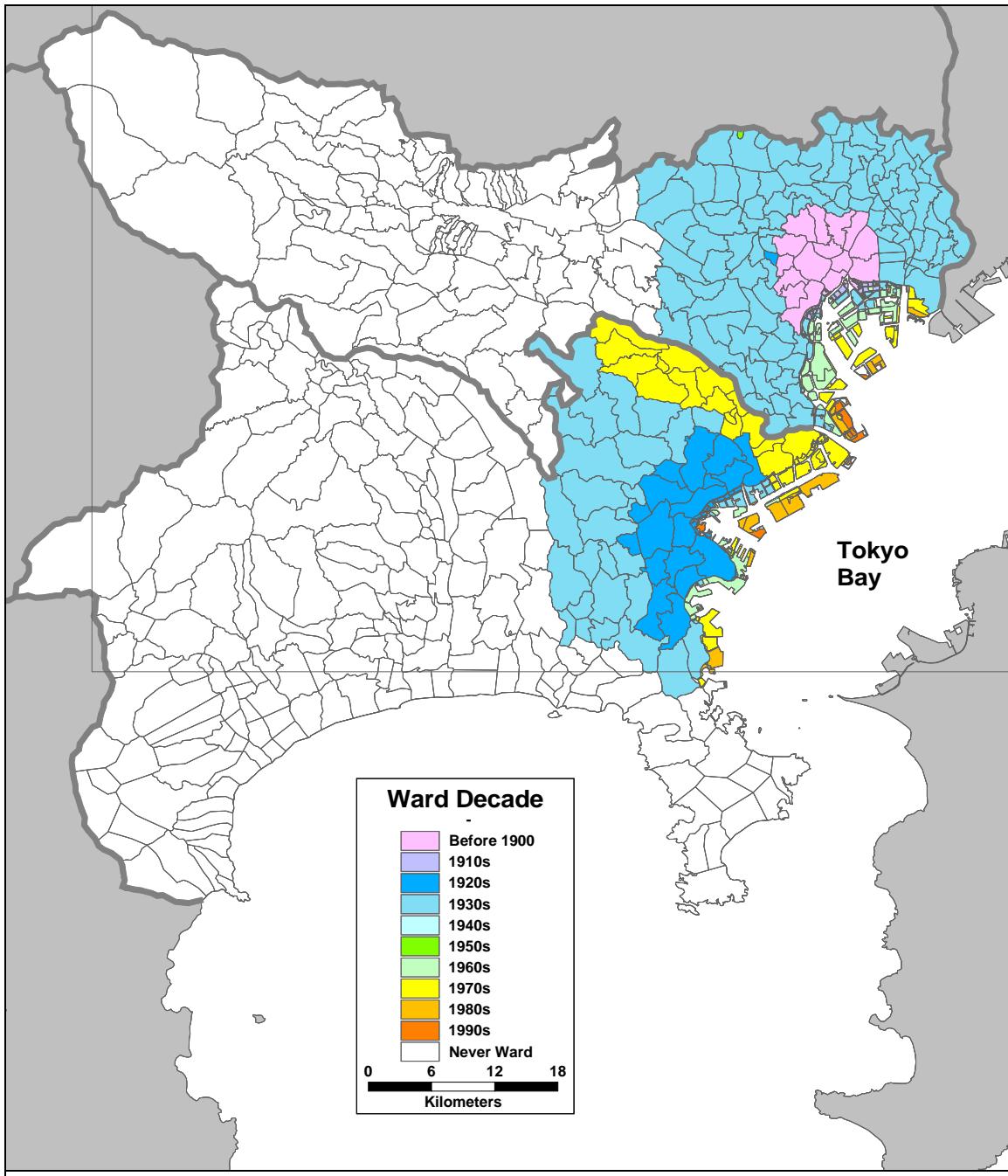
Boundaries of some areas outside Tokyo map-sheet frame are approximate.

**Sources and Processing:**

Once-per-half-decade censuses and once-per-decade topographic maps in 1900s.

Color theme of CITYDECade field of AREAHISt database.

Figure 5 Development of City Areas in Tokyo and Kanagawa by Decade in 1900s



**Notes:**

Ward decade means time when area became new ward or was annexed into existing ward.

Boundaries of some areas outside Tokyo map-sheet frame are approximate.

**Sources and Processing:**

Once-per-half-decade censuses and once-per-decade topographic maps in 1900s.

Color theme from WARD DECADE field of AREAHOST database.

Figure 6 Development of Ward Areas in Tokyo and Kanagawa by Decade in 1900s

## Population in Tokyo

The Japanese government has produced two types of enumerations of population during the modern era (University of Texas, 1966): First, Japan has a system of “registers” kept by local authorities to record legal and actual residents of each administrative district. Estimates of total population were made each year based on the number of changes recorded in these registers, and enumerations were directly produced from these registers every five years from 1898 through 1918. Second, an actual enumeration by surveying all of the population was conducted in 1872, then from 1920 to the present (with some irregularities during the 1940s due to war and postwar conditions and information needs). These methods differ in nature and probably in accuracy (e.g., local officials might pad the registers, especially in times of rationing). However, for simplicity, they can both be called censuses.

The GIS spatial history database includes census data for Tokyo, Kanagawa, Saitama, and Chiba prefectures for all census years from 1903 through 1995; the 2000 census will be added when available.

Figure 7 compares data from the 1920 and 1925 censuses for Tokyo prefecture. The top two maps show the respective density data, and the bottom map shows population change. This was the period during which the Great Kanto Earthquake of September 1, 1923, destroyed much of the delta lands of Tokyo. Large areas of green, representing population decline, can be seen in the bottom map. In contrast, there are many areas (pink) that grew more than 100 percent during that five-year period.

Figure 8 shows population change in Tokyo prefecture during the first half of the 1940s, the World War II years. The top map compares 1940 and 1944 data, the middle map compares 1940 and 1945 data, and the bottom map compares 1944 and 1945 data. Assuming these war-time censuses are accurate, they show that during the first four years of war in the Pacific: (1) Tokyo’s inner ward area (medium green) lost between 10 and 20 percent of its population, (2) Tokyo’s middle ring of wards (light green) lost up to 10 percent of its population, and (3) Tokyo’s outer wards (yellow and medium orange) gained up to 20 percent. Most of the nearby western suburbs grew remarkably (dark orange, red).

Between 1944 and 1945 (bottom) there was a remarkable change. All of the ward area and several suburban areas lost significant levels of population. The westernmost, mountainous areas had large percentage increases.

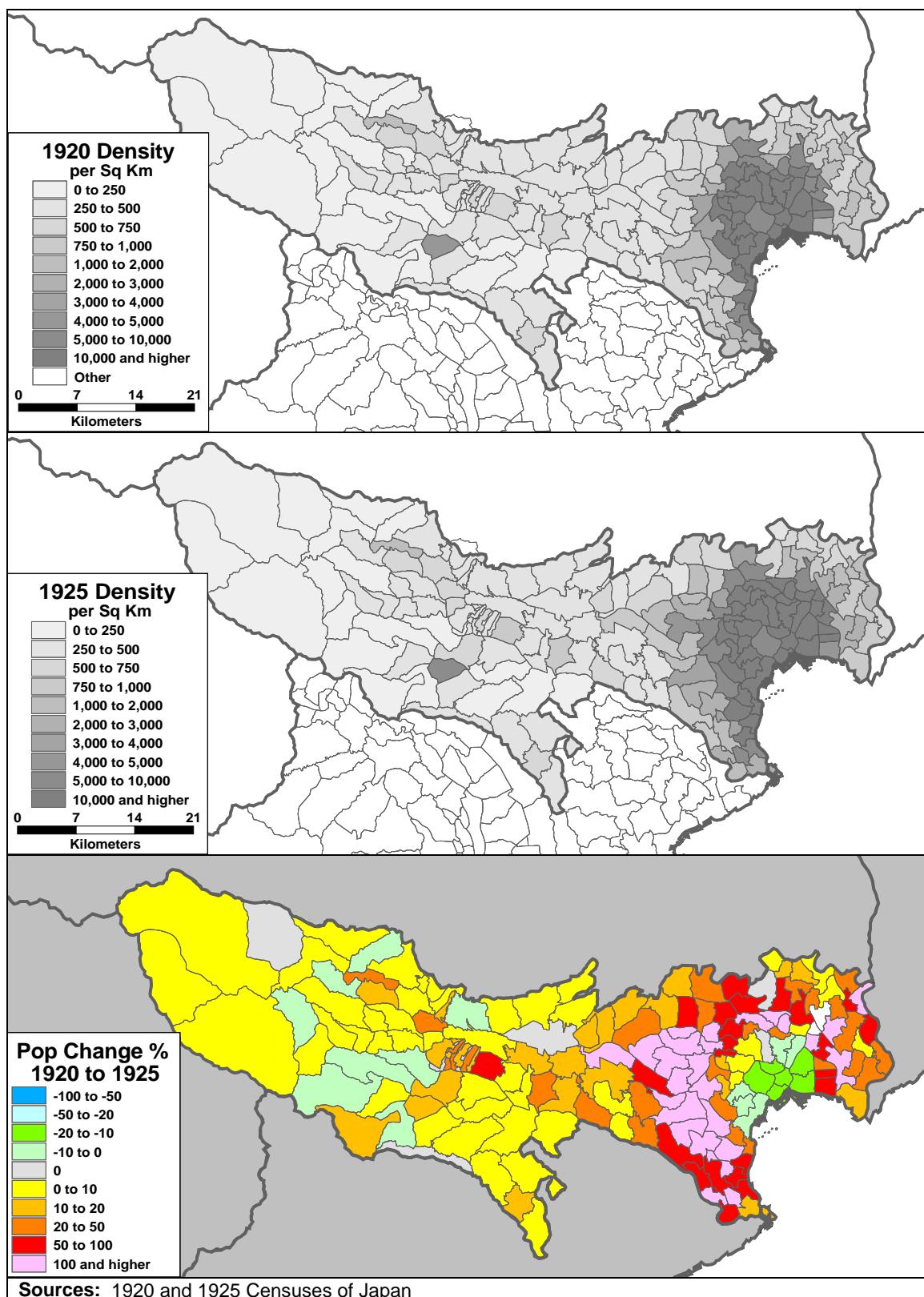


Figure 7 Population Change between 1920 and 1925, Compared with Density

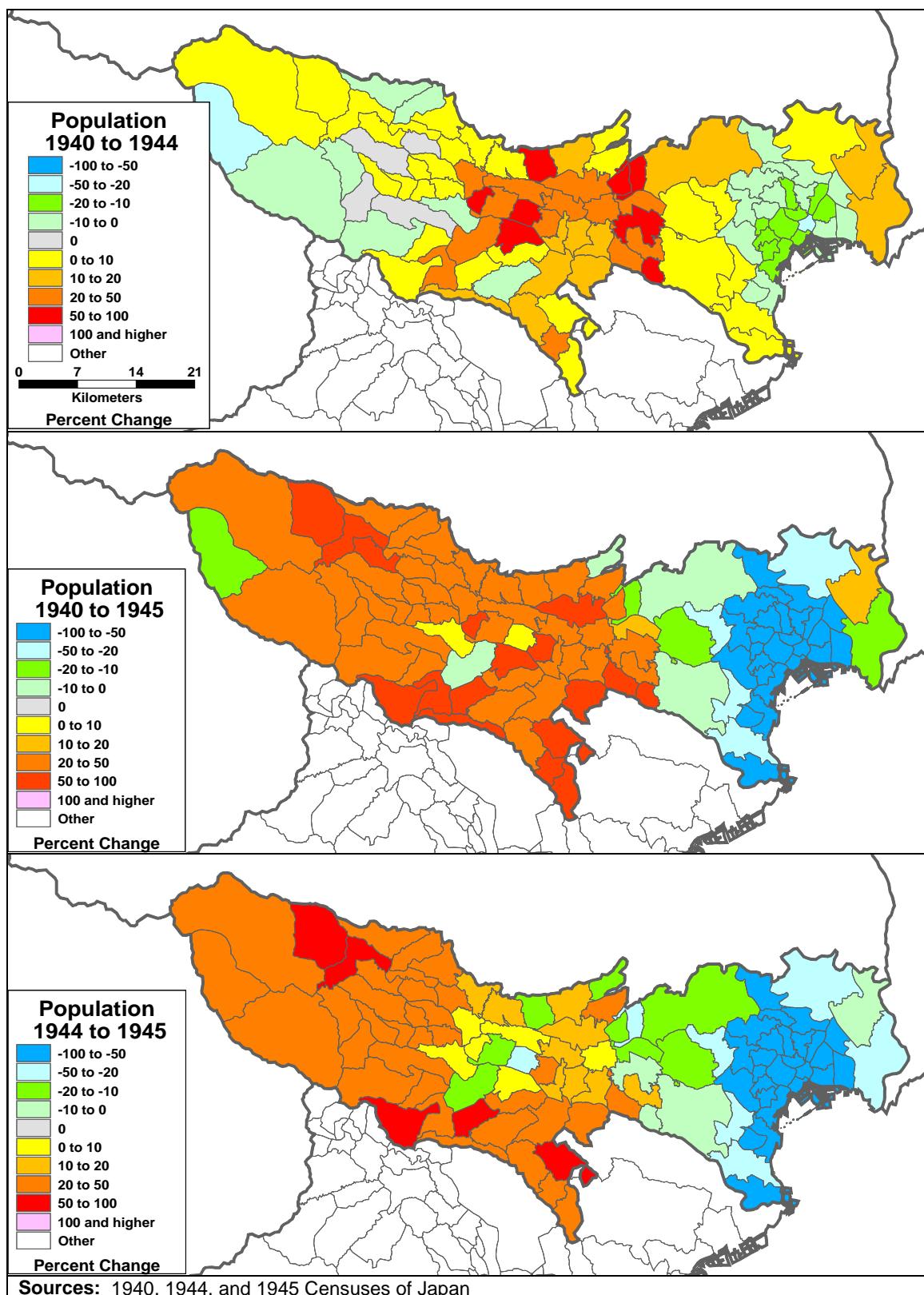


Figure 8 Population Change In Tokyo Prefecture during World War II

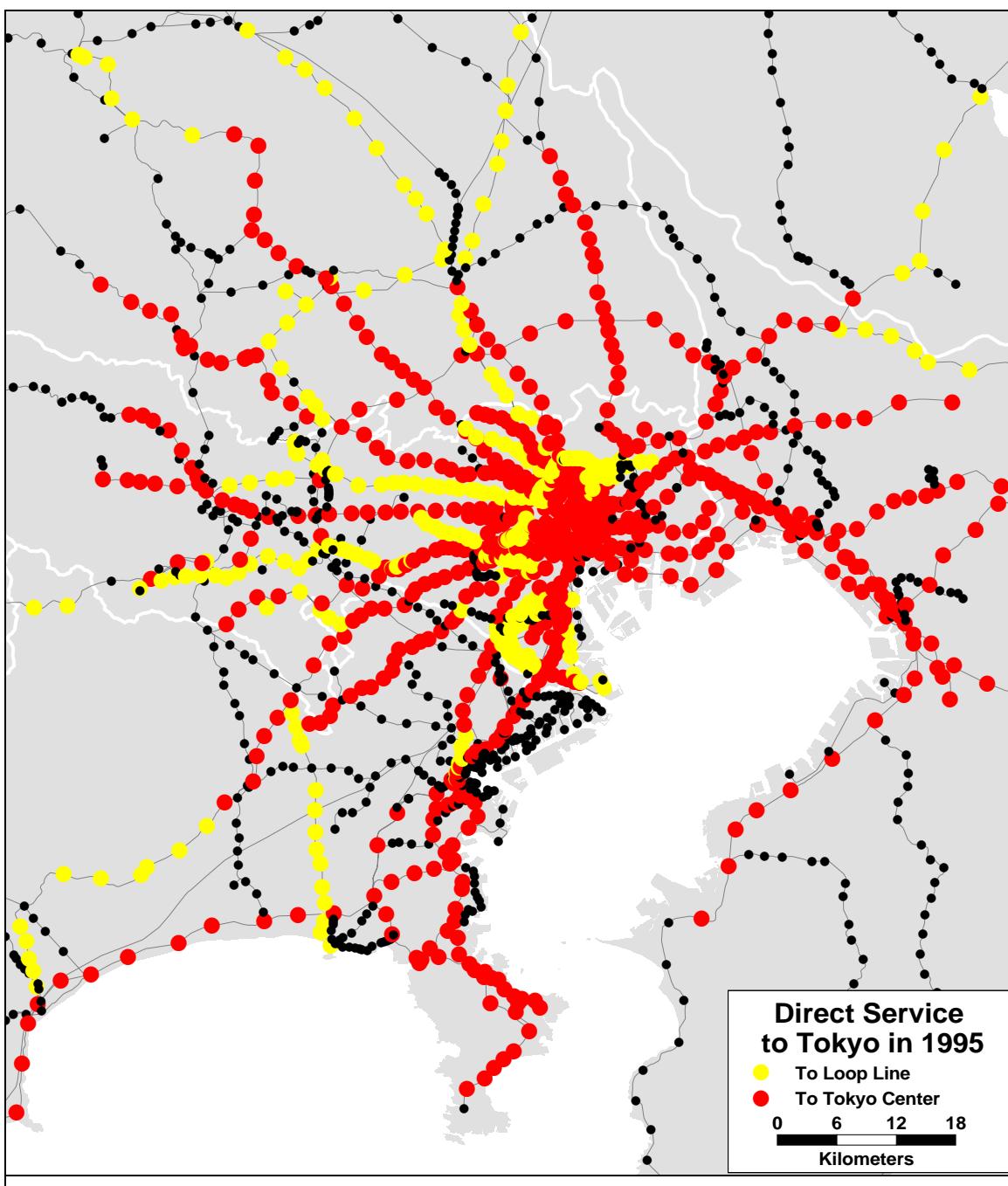
## Tokyo's Rail Network

Japan's first rail line opened between Tokyo and Yokohama in 1872. The Kanto region around Tokyo has had over 100 historical rail lines, and over 2000 stations, producing one of the world's most dense rail networks. Information on rail company, rail lines, and rail stations has been input into the historical spatial database using a variety of sources, including historical topographic maps, company guidebooks with chronologies, and other sources that compile, in table form, lists of rail openings, closing, electrification, multiple tracking, and related events.

Of the many types of mapping and interpretation possible, two will be included here. Figure 9 shows ease of commuting, by comparing direct-service access to downtown Tokyo versus direct-service access just to the Yamanote loop line. Red dots show stations that are within the Yamanote loop or have direct service to that central area. Yellow dots show stations on lines that end at the Yamanote loop, with no direct service to downtown Tokyo. All stops within the direct-service range are shown; in reality, depending on which types of trains stop at a given station, that station may or may not have direct service. Medium-distance direct service is good in all directions, with some lines being exceptions (yellow dots, such as Seibu Shinjuku line).

Figure 10 shows how rail network information can be combined with administrative history information. Stations and lines that existed in 1920 are shown in blue, and those that opened between 1920 and 1925 are shown in red. The background layer shows administrative unit status as of 1925. Companion maps (not included here) can show administrative status change and population change during the same period. Just looking at Tokyo prefecture, we can see that between 1920 and 1925 several new lines opened on the western and southwestern edges of Tokyo itself (some of the lines are hidden by red dots). The administrative status layer shows that most but not all towns and all cities had rail service by 1925. Rail service for the ward area of Tokyo itself was less complete (the wards had streetcar service, which is currently not included in the database).

Other information in the database has been used to analyze such factors as opening dates of lines and stations, multiple tracking, gauge changes, grade separation, company mergers, line reroutings, in-fill stations, interline through service, and rail names and name changes based on provinces vs. prefectures (Siebert 2000c).



#### Notes:

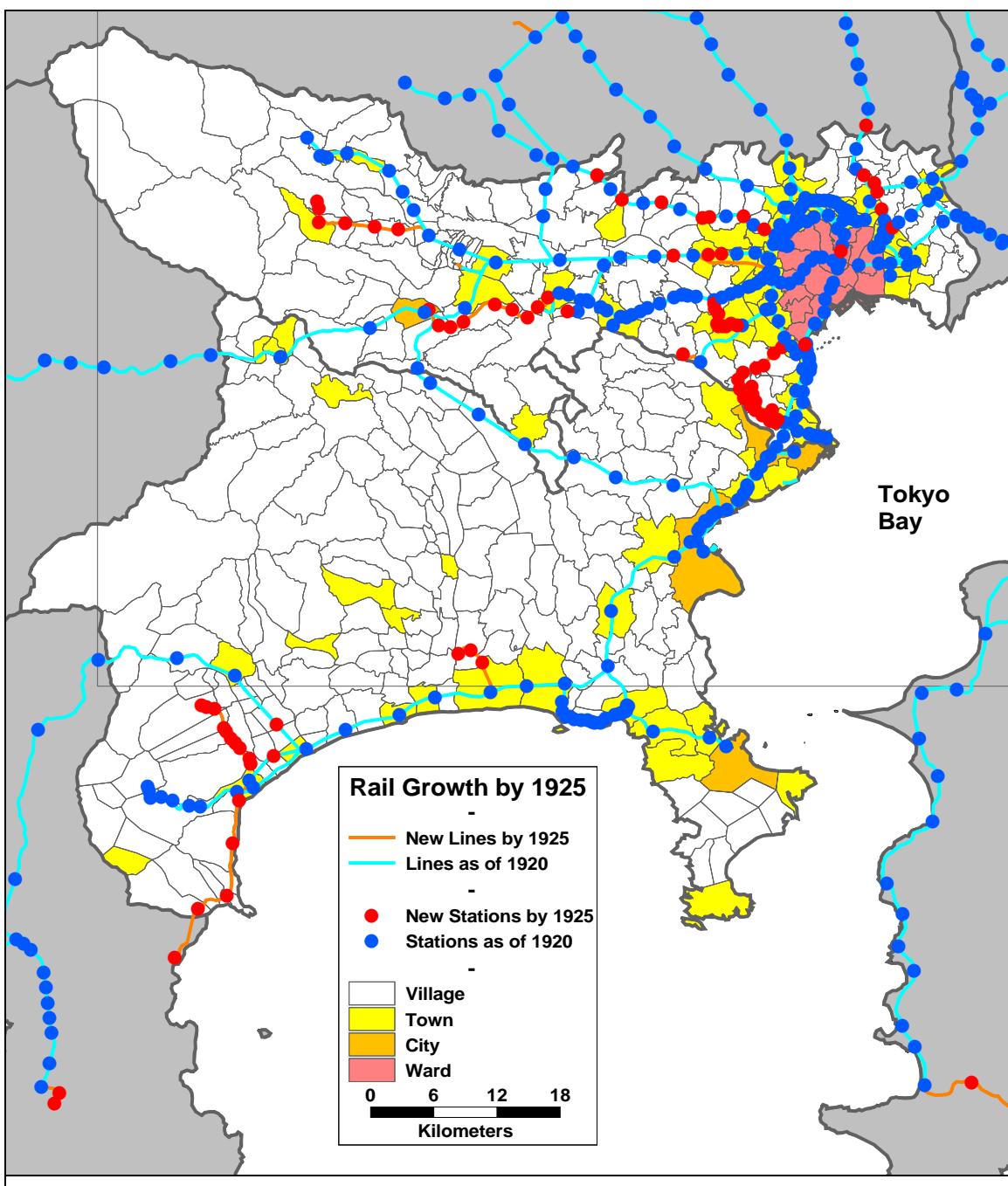
Red stations have direct regular commuter service to Tokyo station or into area within Yamanote loop.  
 Yellow stations have direct regular service to Yamanote loop but not into area within loop line.

#### Sources and Processing:

1993/1994 rail company guidebooks and/or 1995 nationwide time schedule.

Selections of SEAT1CTR and SEAT1LOOP fields of STATION layer of RR-Abs rail database.

Figure 9 Direct Service to Tokyo Center or Yamanote Loop in Tokyo Area in 1995



**Notes:**

Only passenger lines and stations are shown.

Boundaries of some areas outside Tokyo map-sheet frame are approximate.

**Sources and Processing:**

Rail chronologies, once-per-half-decade censuses, and once-per-decade topographic maps.

Selection sets from RR-Abs rail database and color themes derived from AREAHOST database.

Figure 10 Rail Growth between 1920 and 1925 vs. Administrative Unit Type

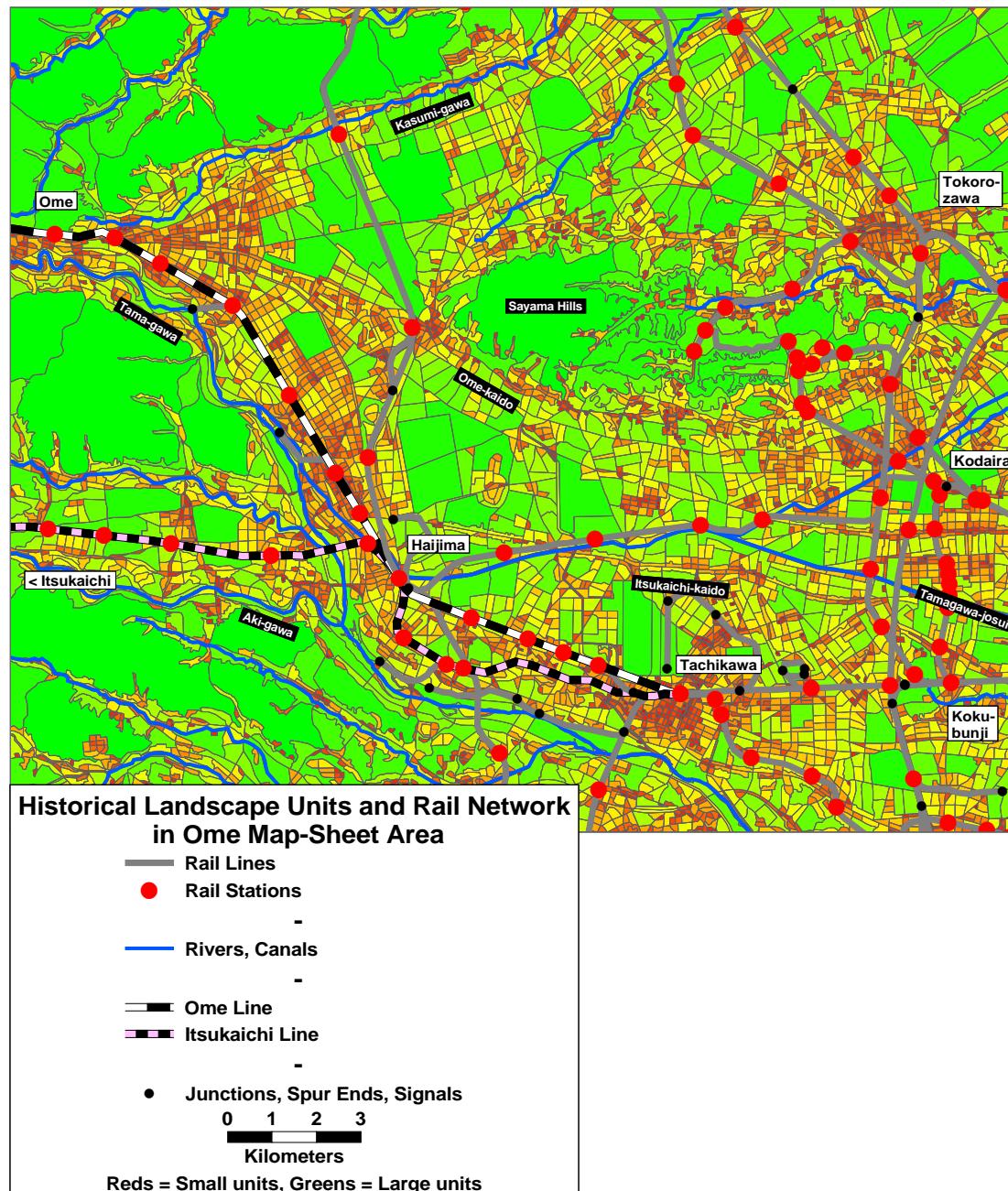
## Landscape Units and Fragmentation

As a preliminary step to the complex process of mapping land cover and land use change in Tokyo, a partial mapping of "historical landscape units" has been conducted for the 1:50,000 Ome map sheet area of western Tokyo prefecture. The basic concept was to divide the landscape into areas that were at some time in the 1900s bounded by either a street, major river, railroad track, or other significant feature that made them a distinct geographic unit. This layer will serve as the initial base for mapping land cover and land use, with each unit being given a primary and secondary class and perhaps rough percentages.

Figure 11 shows the historical landscape units of the Ome area. The units are color-coded by size, with reds for small units and greens for large units. For reference, I also include the full rail network for this region, showing every line and station that existed in the area. Many of the short freight spurs have been closed, and one passenger route has been shortened. Most of the stations shown (red dots) still exist, except for some repositioned stations.

In the map, green indicates large historical units, not vegetative cover. In the west are large hilly areas that are vegetated, as is the central area. Some of the large angular block areas are farmland. Others are airport areas, some of which have now been converted to parks and industrial uses. The two new reservoirs in the center appear only as outlines, with their former village areas as reds and oranges within them.

This map gives an idea of the complexity and fragmentation of the landscape. Although it is not a land-use/land-cover map, it does show development in a general way. The density and population-change maps shown earlier would be useful for comparison in early decades, when the administrative units were still small, but less useful in recent decades, when villages and towns had been consolidated into cities.



#### Notes:

Historical land units are areas bounded by streets, railways, major rivers, and other prominent features. Each unit represents a common history of such subdivision, not a common land cover or land use.

#### Sources and Processing:

Historical landscape units digitized from once-per-decade topographic maps in 1900s.

Rail lines and stations from rail company histories and once-per-decade topographic maps in 1900s.

Figure 11 Historical Landscape Units in Ome Area of Western Tokyo

## **Conclusion**

Geographic information systems can serve as a powerful tool for documenting, visualizing, and analyzing the spatial history of an urban region. In this presentation, I have presented various examples of different types of historical spatial features that can be mapped. Those shown here include: (1) shoreline and river changes in Tokyo Bay and its delta, (2) the decade of conversion of administrative units from villages to towns to cities to wards, (3) population changes during the 1920s and 1940s, two decades that respectively saw major shifts due to earthquake or war, (4) accessibility of the rail network and rail stations, and (5) landscape fragmentation units. These are just a few of the many types of features that can be included in an historical GIS.

## **Acknowledgements**

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