

# Transition of the *satoyama* landscape in the urban fringe of the Tokyo metropolitan area from 1880 to 2001

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## Abstract

An explicit understanding of past landscapes is a basic and important issue, which enables deeper understanding of current landscapes in a longer context and gives useful suggestion to today's landscape planning. In this paper, transition of the traditional Japanese agricultural landscape (*satoyama* landscape) over a relatively long temporal scale (1880-2001), and its inherent dynamics in each of four socioeconomically based time periods in two topographically different areas around the Tokyo metropolitan area was studied. Information derived from historical records and interviews was used to differentiate four socioeconomic periods, and to support and explain the results of the analysis. Old maps and aerial photographs were used to create land use maps, which were analyzed using GIS. The results illustrated drastic landscape change from agricultural to urban landscape, with unique land use and transition patterns in each study area. A large part of both study areas was affected by bi-directional conversion between woodlands and crop fields in the early part of the study period, in the form of shifting agriculture. Our results also showed that the landscapes are becoming less dynamic and it may suggest reconsideration for land use planning, which will lead to more stabilized landscapes.

## Key words

*satoyama* landscape, dynamics, landscape change, land use, bi-directional conversion

## 1. Introduction

Many traditional agricultural landscapes around the world have been greatly altered, especially during the 20th century, under anthropogenic influences such as urbanization and the intensification and extensification of agriculture (Anderson et al., 1996; Fukamachi et al., 2001; O'Rourke, 2005).

The typical traditional agricultural landscape in Japan is called *satoyama* landscape. It was created in a harmonious relationship between humans and nature. It is a land use mosaic mainly composed of woodlands, paddy fields, crop fields, grasslands, and settlements. Rice was grown in paddy fields and other cereals and vegetables were grown in crop fields. Unlike in Europe, livestock was not a main part of the traditional agriculture in Japan, and fertilizer was directly provided from grasslands and woodlands. Woodlands consisted mainly of *Quercus acutissima*, *Quercus serrata* and *Pinus densiflora* which were

cut regularly for charcoal and fuel wood, and sometimes for building farmers' houses. The stumps of *Quercus acutissima* and *Quercus serrata* were left to sprout whereas *Pinus densiflora* was replanted. Woodlands were also managed by collecting fallen stems and leaves, and clearing underbrush, which were used as fuel and compost.

After chemical fertilizers and fossil fuels came into common use, and as cities grew due to rapid economic growth since the 1960s, the *satoyama* landscape has been changed greatly. A large proportion of woodlands and agricultural land has been abandoned and diminished, and, in many areas, converted into urban land uses. In these circumstances, however, people developed an increasing awareness of nature conservation in their neighborhood (Takeuchi, 2003). The *satoyama* landscape was firstly recognized as providing public goods such as scenic beauty and recreation places and subsequently the importance of the *satoyama* landscape as a place which conserves biodiversity became known (Fukamachi and Sakuma, 1998). Washitani (2003) summarizes the ecological significance of the *satoyama* landscape. The structure of the *satoyama* landscape is a mosaic of different land uses which provides a variety of habitats. Furthermore, disturbances and stresses on woodlands and grasslands by human extraction of plant resources prevent the elimination of uncompetitive species by preventing the domination of competitive species. As a result, diverse species are able to survive. The significance of the *satoyama* landscape in terms of species conservation, as well as its social, cultural, recreational, and educational functions, is now recognized (Fukamachi and Sakuma, 1998).

The need to study past landscapes and their changes has been recognized, since this process helps the understanding of the influences of past land use on current vegetation (Foster, 1992; Russell, 1997; Kettle et al., 2000; Blois et al., 2001), enables the understanding of the direction of change (Skånes and Bunce, 1997) and the dynamics and sustainability of landscape (Käyhkö and Skånes, in press), and provides practical and useful information to aid today's conservation planning (Black et al., 1998; Cousins and Eriksson, 2002; Bender et al., 2005). Moreover, it provides a valid context in which to identify issues, problems, and desired outcomes in planning (Marcucci, 2000), as well as useful wisdom or inspiration for future management, restoration, and creation of landscapes (Antrop, 2005).

In Japan, although many studies have been conducted on changes of the *satoyama* landscape and its vegetation after the 1960s (Kamada and Nakagoshi, 1997; Kimura et al., 2000; Morimoto and Yoshida, 2005), few studies attempted to reconstruct the earlier *satoyama* landscape (Ogura, 1993, 1994; Harada and Harada, 1997) and its transition since then (Fukamachi et al., 2001). Yokohari and Kurita (2003) argue that although woodland portions of the *satoyama* landscape tended to be focused on, grasslands and shrubs, which declined after 1947 at the sites studied, were also important components. Since the landscape continues to change, an explicit understanding of landscape in the context of a longer history is needed (Marcucci, 2000).

The first objective of the present study was to understand long-term landscape transitions. This was studied in relation with the transition of socioeconomic conditions and differences of topographic conditions because these clearly influence the landscape simultaneously (Simpson et al., 1994; Nassauer, 1995; O'Rourke, 2005). Because cultural landscapes have been shaped by the interrelationship between humans and nature, it is necessary to include both aspects in any attempt to understand landscape transitions. Study areas were chosen in suburban areas, where the spread of urban land use is very rapid and therefore such studies are urgently needed.

The second objective was to understand the dynamics of the landscape over the relatively short term

that corresponds to a specific socioeconomic time period. Landscapes are inherently dynamic without extrinsic driving forces (Bürgi et al, 2004). In a study of landscape dynamics using landscape metrics obtained from the analysis of remote-sensing data, Crews-Meyer (2004) argued that the snapshot approach has been limiting in trying to trace dynamism and infer process. Mertens and Lambin (2000) also argued the importance of integrating complexity, including a reversible conversion of land use in the analysis of land-cover change. The *satoyama* landscape will become a good example to observe the inherent dynamics since it includes dynamic aspects such as periodic tree cutting and shifting agriculture. Shifting agriculture, although it was practiced in the past in Japan (Sasaki, 1972; Tanaka, 1981; Kato, 1982, 1993), was rarely focused on (Moriyama, 1988) or presented spatially in landscape change studies. In the present study, the attempt was made to describe the dynamics of the *satoyama* landscape in the analysis of landscape change using old maps and aerial photographs.

## 2. Methods

### 2.1 Study areas

There are two types of *satoyama* landscape in and around Tokyo based on topography. One occurs mainly in hilly areas or low mountains, whereas the other occurs in upland areas (Takeuchi, 2003). These types have different histories and structures. To compare the two types of *satoyama* landscape, two sites which differ in their topography were selected: Ohno, located in the Sagamihara upland area, and Tsurukawa, located in the Tama hills area. They are both located in the suburban part of Tokyo's metropolitan area, approximately 40 km from the center of Tokyo (Fig.1). The unit for each study area was the former administrative village.

The topography of the Ohno area which covers 24 km<sup>2</sup>, is mostly flat since a large area covers the middle river terrace (Musashino Surface). There is a small area of lower river terrace in the northeastern part of the middle river terrace and a valley flat along Sakai river. Tsurukawa covers 21 km<sup>2</sup> area in the Tama hills and has undulating topography. Hilly slopes dominate a large part and erosion and sedimentation of these by rivers has created flat valley bottoms. There are narrow terraces along the sides of some valley bottoms. The height of the hilly area ranges from 80 to 220 m. Since the 1960s, a large area of the land has been transformed into extensive housing developments in the Tama hills that include Tsurukawa. Hilly slopes were flattened and the removed earth was used to fill in the valley bottom and create flat land.

The mean temperature at the sites is approximately 14°C, and the mean annual precipitation is 1570 mm. At both sites, the current woodland consists of broadleaf deciduous trees such as *Quercus acutissima*, *Quercus serrata*, and conifers such as *Pinus densiflora* and *Cryptomeria japonica*, which were the commonly dominant species in managed woodland in the *satoyama* landscape in and around Tokyo.

Ohno was integrated into Sagamihara Town in 1941, and reorganized as Sagamihara City in 1954. Tsurukawa was integrated into Machida City in 1958. The northern part of Tsurukawa was then included as part of Tama City in 1973. Part of Tsurukawa was removed from this study because of a lack of data. Urbanization and population have increased in both cities especially over the past half century. The population of Sagamihara City grew from 68 000 in 1950 to 606 000 in 2000 (Sagamihara City, 2004). In Machida City, it grew from 52 000 in 1950 to 378 000 in 2000 (Tokyo Metropolitan Government, 2005).

## 2.2 Methods

### 2.2.1 Survey of socioeconomic conditions

The general transition of the socioeconomic condition in Japan from the end of the 19th century until the present was studied by referencing Hayami (1975), Teruoka (2003a) and Ishida (2004). References on local history published by each city (Editorial Board of History of Sagamihara City, 1968, 1971; Editorial Board of History of Machida City, 1976) were also consulted to understand the local socioeconomic conditions. They describe the history of the area including agriculture and urbanization. Four elderly farmers, two farmers from each area, who were in their 70s and who were engaged in agriculture for much of their lives were interviewed. It was difficult to interview more people or to interview people who were alive during the early part of the study period because the study extends back more than 100 years. Therefore, secondary sources such as records of past interviews (Committee of Cultural Assets of Machida City, 1972; Sagamihara City Board of Education, 1986) were used. Information on agricultural practices, products, technology, energy sources, woodland use and management and urbanization was also obtained. Information relating to woodland was also provided by the written reports attached to the *jinsoku-sokuzu*, records of past interviews, and the interviews with elderly people. *Teisatsuroku* (Rikugun Sanbo Honbu, 1986) are written reports attached to the *jinsoku-sokuzu* describing the mapped area's social and natural conditions. Management and use of woodland were also described in the reports. Research which recorded the results of investigations of agricultural woodland conducted in 1955, entitled *Nouyourin ni kansuru chousa* also described the uses of the woodland (Kanagawa Prefecture, 1957).

The number of farm households was obtained mainly from census data provided by the Ministry of Agriculture and Forestry and other reports (Tsurukawa Elementary School Research Club of Social Study, 1954; Sagamihara City Board of Agriculture, 1965; Kanagawa Prefecture, 1966; Editorial Board of History of Sagamihara City, 1968; Editorial Board of History of Machida City, 1976).

### 2.2.2 Preparation of land use maps

In order to understand landscape transitions and dynamics, multiple land use maps were prepared. A range of materials was used to create GIS-based land use maps for 1880, 1921, 1947, 1961, 1968, 1974, and 2001. The oldest maps created using modern survey methods in Japan are called *Jinsoku-sokuzu*, which means a "quick survey map". These were created by the Japanese army during the 1880s using plane-table surveys at a scale of 1:20 000. The maps are rendered in different colors for each land use (woodland, crop field, rice paddy field, river, road, grassland, and so on) so that the boundary of each land use was easy to recognize (Fig. 2). Facsimile maps are published by the Japan Map Center in Tokyo prefecture. 1:25 000 scale topographic maps which cover the study areas were surveyed since 1921 and published by the Geographical Survey Institute in Ibaragi prefecture. The 1921 topographic maps have a boundary line for each land use and can be used as land use maps (Fig. 2). Land use maps for other years were made by interpretation of aerial photographs using a mirror stereoscope (Nikon) and with assistance of topographic maps. The oldest available aerial photographs for the study areas were taken in 1947 at a scale of 1:10 000 by the U.S. military. The other aerial photographs used were provided by Geographical Survey Institute: 1961 (1:14 000), 1968 (1:20 000), 1974 (1:8000), and 2001 (1:12 500). The aerial photographs taken before 1968 are in black and white, and those taken after 1974 are in color.

Generating land use maps for each year from different sources may lead to spatial errors between the

maps. To minimize this error the 1961 topographic maps were used as the base maps to which to fit the other sources spatially because these are the oldest maps produced using aerial photogrammetry. Newer maps were not appropriate because the landforms have been greatly transformed within Tsurukawa, and matching the new landforms with their coordinates on older maps would become prohibitively difficult and error-prone. After scanning the paper-based 1961 topographic maps, the longitude and latitude shown in the maps were used to geo-reference using GIS software TNTmips 6.6 (MicroImages Inc., 2001). The 1921 topographic maps were then scanned, and generalized by establishing many control points for piecewise-affine transformation (MicroImages, 2001) (Fig. 3). The control points were points that were believed to be unchanged, such as street-crossings, shrines, or temples, and points representing geographical features such as mountain tops or the endpoints of valleys. Regarding *Jinsoku-sokuzu*, these were also scanned and generalized using control points for piecewise-affine transformation. However, because it was found that few control points had not changed between 1880 and 1961, they were generalized according to the 1921 maps, which already had been generalized. The land use boundaries were then traced on the 1880 and 1921 maps respectively, preparing vector data.

Land use maps after 1961 were generated by interpretation of aerial photographs. On the base maps (1961 topographic maps), the land use boundaries were drawn as vector lines based on the results of aerial photo interpretation of 1961 with the assistance of the land uses shown in the topographic maps. The 1947 and 1968 land use maps were created by comparing aerial photographs with the ones of 1961, respectively. When a place where land use had changed was found, the map was updated. The 1974 and 2001 land use maps were created in a similar manner, but compared each aerial photograph to the one of the previous period.

Land use was classified into seven categories: woodland, crop field, paddy field, bare land, large scale development, urban land, and open water. Woodlands in this area have been mainly coppiced woodlands. The main tree species of which woodland consists still remain the same, although in detail the vegetation structure has been changing because of the abandonment of management. The 1921 topographic maps do not differentiate between “crop field” and “vacant space” in the legend. However, it was believed that vacant places did not exist since there were no large compounds such as military facilities or schools, which would have been classified in this category, and vacant places without any particular use would become grassland. The category “bare land” has several meanings: grasslands which were managed and used for manure or roofing materials in the past; abandoned agricultural land where herbaceous plants have started to grow; and the areas of tree logging, interpreted from aerial photographs. Large scale development is a place under large scale development which started mainly in 1960s, and often involves large scale transformation of landform especially in Tsurukawa. It is possible to classify in aerial interpretation.

First, all data was prepared as vector maps. To make the data analysis manageable, the data were then converted into raster maps with a 20-m mesh size. The areas of each land use in each year were obtained to describe the transition of land use. Overlay analysis was done between consecutive years to examine the inherent dynamics of the landscape in each time period. Changes of land use from 1880 to 1921 were identified as the dynamics of the pre-war period, from 1947 and 1961 as those of the reconstruction period, and from 1961 through 2001 as those of the economic growth period. For the wartime period, multiple maps did not exist. Therefore, it was not possible to analyze the dynamics during the wartime period with GIS analysis alone. Results of overlay analysis from 1921 to 1947 were used along with

references on local history, interview results, and secondary sources of records of past interviews, in order to try to understand the dynamics of the wartime period.

### **3. Results**

#### **3.1 Socioeconomic condition**

##### ***3.1.1 Pre-war period (1880s to the latter half of the 1930s)***

The pre-war period extends from the 1880s to the latter half of 1930s. This period includes the time of drastic change in Japan's political, social, and economic system after the feudal structure of the Edo period (1603-1868). Industrialization started from light industries such as spinning and yarn-making since 1880s, followed by heavy industry after World War I, with the development of a capitalist economy. Improving agricultural productivity was also promoted, first by developing indigenous technology constrained by the feudal system (Hayami, 1975), and then by science based technology due to the development of a capitalist economy. At the study sites, agriculture was the main and important industry. Adding to the traditional production of serials and vegetables for self-sufficiency, the production of commercial crops and raising silk worms was started to obtain a cash income.

##### ***3.1.2 Wartime period (the latter half of the 1930s to the latter half of the 1940s)***

This period is the time in which the whole country, including its economy, politics, citizen's daily lives, and cultures, was under the influence of the wars (Sino-Japanese War and subsequently World War II). The development of agricultural technology started in the pre-war period stagnated since manpower and production of materials for war were given high priority. Agricultural production also decreased because of a labor shortage, with many young men being diverted into the military. Sericulture also diminished after the steep fall in the silk market (1930s) and cease of exports to the United States. During this period, the government policy to decentralize industrial facilities led to the construction of factories, including military facilities, throughout Japan (Ishida, 2004). Sagami-hara, including the Ohno study area, was one area selected for the construction of military facilities (Editorial Board of History of Sagami-hara City, 1971).

##### ***3.1.3 Reconstruction period (the latter half of the 1940s to the latter half of the 1950s)***

This period corresponds to the time of recovery from wartime devastation. Policies for democratizing the agrarian society and institutions were promoted under the direction of the American occupation forces (Hayami, 1975). Food shortages and population increases as a result of repatriation from overseas territories created an urgent need to secure food supplies. Agricultural production was strongly promoted and gradually started to recover.

##### ***3.1.4 Economic growth period (after the latter half of the 1950s)***

As a result of the economic growth which began in the latter half of the 1950s, gaps between farm and non-farm incomes increased and became a serious problem in Japan and rationalization of agricultural production was promoted. In the study areas, intensive production of fruits or livestock was promoted instead of the traditional production of rice, other cereals, and vegetables during the 1960s and 1970s (Sagami-hara City Board of Agriculture, 1965; Editorial Board of History of Machida City, 1976). At the same time, young people began to work in cities, and the number of farm households decreased (Fig. 4).

Furthermore, with the increase in population, urbanization was accelerated by laws and plans for active and organized urban development and the improvement of civil engineering technology.

Details of each time period are described in Table 1.

### 3.2 Land use changes

During the pre-war period, large areas were dominated by woodlands and agricultural land in both areas (Fig. 5). However, the proportions of the total area accounted for by each land use showed different patterns (Fig. 6). In Ohno, woodlands and crop fields covered as much as 34% and 59%, respectively, of the total area in 1880. Paddy fields covered 1.2% of the total area, and urban land use covered 2.5%. In Tsurukawa in the same year, woodlands, crop fields, and urban land covered as much as 54%, 30%, and 2.4%, respectively, of the total area. Paddy fields covered 15% of the area, which is considerably more than in Ohno.

During the wartime period, Ohno had already begun to show an increase in urban land from only 4.0% in 1921 to 19% of the total in 1947. In contrast, Tsurukawa maintained similar proportions of land use during this period with low urban activity.

The transitions among land uses and the extent of each land use through time (Fig. 7) obtained from the overlay analysis show that considerable amounts of woodland were converted into crop fields and vice versa. Figure 8 shows a wide distribution of the converted area between woodland and crop field. Figure 7 also shows that bi-directional conversion continued between 1921 and 1947.

During the reconstruction period, a relatively gradual increase in the area of urban land use occurred in Ohno, reaching 33% in 1961. In Tsurukawa, on the other hand, the proportions of each form of land use remained nearly unchanged during this period. The increase in urban land use was only from 6.8% in 1947 to 7.9% in 1961. In terms of the landscape dynamics, bi-directional conversion had already ceased by this period in both areas.

During the economic growth period, the increase in urban land use was more rapid in both sites than during earlier time periods. Large areas of woodland and crop fields were converted into urban land, bare land, or large scale development. Especially in Tsurukawa, woodland and agricultural land started to decrease rapidly by around 1961. Bare land and large scale development also increased during the 1960s and 1970s. The decrease in woodland and agricultural land slowed down after 1974, but the rate of urbanization (conversion into urban land) remained unchanged after 1974. In 2001, urban land accounted for as much as 88% of the area of Ohno, and woodland and agricultural land had decreased to 5.9% and 4.5% of the total, respectively. In Tsurukawa, urban land use was also dominant, at 60% of the total, with large scale development accounting for 6.1% of the area in 2001; woodland, crop field, and paddy field decreased to 20%, 7.4%, and 1.1% of the area, respectively.

## 4. Discussion

### 4.1 Difference in landscape and its transition at the two study sites

The early landscapes at the two study sites presented differences in the proportion of land use. This represents a difference in the topography of the location of the *satoyama* landscape; one in an upland area and one in a hilly area. With a large area of the middle river terrace, and a small area of flat valley bottom, Ohno had a large area of crop fields and a small area of paddy fields. The woodland area in Ohno was smaller than that in Tsurukawa, where woodland dominated and paddy fields were present in relatively

large areas.

Urbanization also proceeded in different ways in the two areas. The process began with the construction of military facilities in Ohno, which nonetheless experienced a relatively gradual transition into an urban landscape, whereas Tsurukawa experienced rapid and drastic change into an urban landscape after the 1960s. The large flat area within Ohno enabled the construction of military facilities (Takeuchi, 1972). In contrast, Tsurukawa is spread over a large area of hilly slopes; large-scale landform transformation enabled by advances in civil engineering led to residential development of large areas after the 1960s. Such differences in the urbanization process between upland and hilly areas have also been reported in other areas in the Kanto district (Tsunekawa, 2003). The decrease in woodland and agricultural land slowed down in both areas after 1974, but in Tsurukawa the rate of urbanization (conversion into urban land) has remained unchanged, supported by the conversion from bare land and large scale development, which increased more obviously in Tsurukawa since the 1960s, into urban land.

#### **4.2 Dynamic mechanisms inherent in landscape**

Overlay analysis using GIS showed a common characteristic in both areas: large parts of both areas showed a bi-directional conversion between woodland and crop fields (Fig. 8) at an early time of the study period. It must be noted, however, that using old maps in overlay analysis in GIS may bring apparent conversion of land use, that is, conversion which may not have occurred actually but seems to have occurred as a result of overlay analysis, which comes from inaccuracy in old surveys and limitations in generalization between two maps using GIS software. The apparently converted areas tended to be long and thin, due to slight misalignments between the borders of each land use in consecutive maps. Figure 8 nonetheless shows that large areas underwent this conversion and that this conversion occurred on a large scale.

It is considered that these areas show the existence of shifting agriculture, from the references of local history and records of past interviews, which describe this practice as cultivation and subsequent replanting of trees (Committee of Cultural Assets of Machida City, 1972; Sagami-hara City Board of Education, 1986). According to these sources, the practice was as follows: after cultivating woodland, farmers grew cereals such as wheat, barley, millet, barnyard grass, and upland rice. After about 10 years soil fertility had become low, seedlings of *Quercus acutissima*, *Pinus densiflora*, or both were planted and woodland was grown again.

By focusing on inherent dynamics using overlay analysis, an existence of shifting agriculture and wide distribution of it could be revealed. It must be remembered that the historical landscape may have involved conversion of land use as its mechanism, and that the old maps used to reconstruct the historical landscape show only one state in the dynamic system of landscape transition. Further study is needed to reveal detailed processes, which were not clear only from overlay analysis, such as how many cycles there were between each year, or how much area was converted at once. While reducing the intervals between map dates is essential for understanding the transition process, historical records and interviews are also important tools.

#### **4.3 Changes in the mechanisms in the satoyama landscapes**

As regards the exact time that this shifting agriculture ceased, it is not possible to determine whether it occurred during the pre-war or wartime period from GIS analysis alone. Some literature describes this

conversion process as common until the 1920s (Editorial Board of History of Machida City, 1976; Sagami-hara City Board of Education, 1986). It was not possible to obtain enough information about this custom from the interviews probably because the elderly inhabitants interviewed were not born when the *satoyama* landscape was maintained in this way. Based on these observations, it is probable that the conversion occurred mainly during the pre-war period and has declined since wartime period.

In the reconstruction period, although the influence of urbanization is still low and management of the woodland was still done (Table 1), bi-directional conversion between woodlands and crop fields ceased completely. Then in the economic growth period, management of woodlands also ceased and urban land use increased rapidly. This means that the mechanism underlying the *satoyama* landscape had changed: from landscapes involving dynamic conversion of woodland and crop fields and also management of woodlands in the pre-war period and wartime period, to one with only management of woodlands in the reconstruction period, to one without any management of woodlands in the economic growth period.

In shifting agriculture, cereals grown as subsistence crops were mainly grown without manure (Editorial Board of History of Machida City, 1976; Sagami-hara City Board of Education, 1986). Because trees were replanted after soil fertility became low, woodland which involved shifting agriculture may have been in a more oligotrophic condition than woodlands under the influence of only periodically cutting which continued until the 1960s (Table 1). This may suggest that species composition of woodland floors differed between each other. The great decline of woodlands and agricultural land in the economic growth period means a great loss of natural habitat. Clear relationships were found between fragmentation of woodlands and the decrease of rare species and interior species of woodland floor plants (Iida and Nakashizuka, 1995) in the coppice woodlands in the Kanto district. Management of woodlands, such as coppicing trees and clearing woodland floor, which were stopped in the 1960s in the study areas also have negative influences on the plant species diversity of wood floor plants (Tsuji and Hoshino, 1992).

The landscapes have become less dynamic through the study periods. Vos and Meekes (1999) described the changes in the industrial landscape of Europe from the mid-18th century until the mid- and late 20th century as being influenced by specialization and spatial segregation; similarly, today's land use planning in Japan aims to create segregated and specialized land use by means of a zoning system. This approach may, as a consequence, stabilize the landscape. Considering that shifting agriculture was done by bi-directional conversion of land use, the land use planning, which leads to a stabilized landscape, may need reconsideration.

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## Figures and a Table

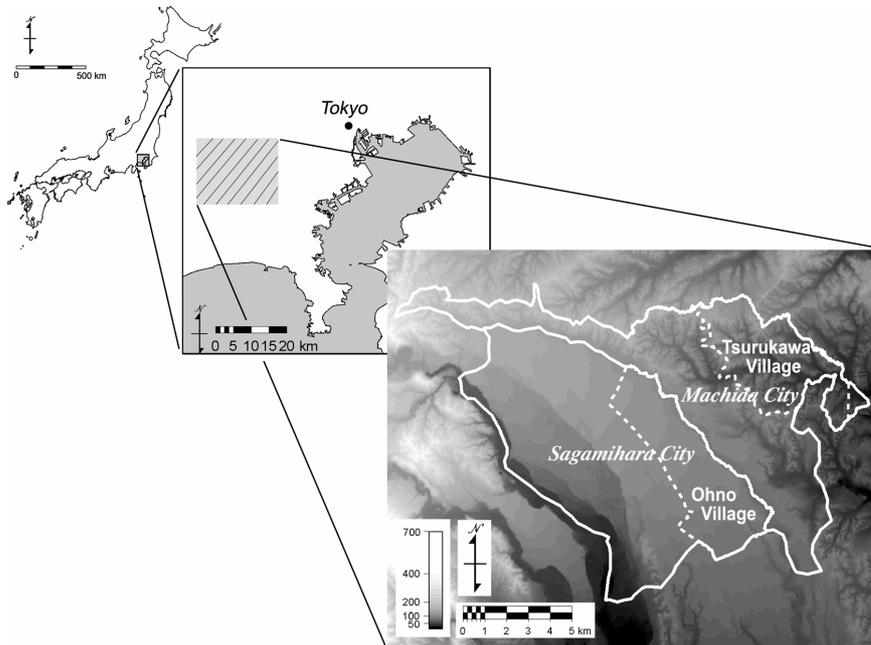


Figure 1. Map of the study areas.



(a)

(b)

(c)

Figure 2. Examples of data sources showing same area in Ohno: (a) *Jinsoku-sokuzu*, (b) 1921 topographic map, (c) 1974 aerial photograph.

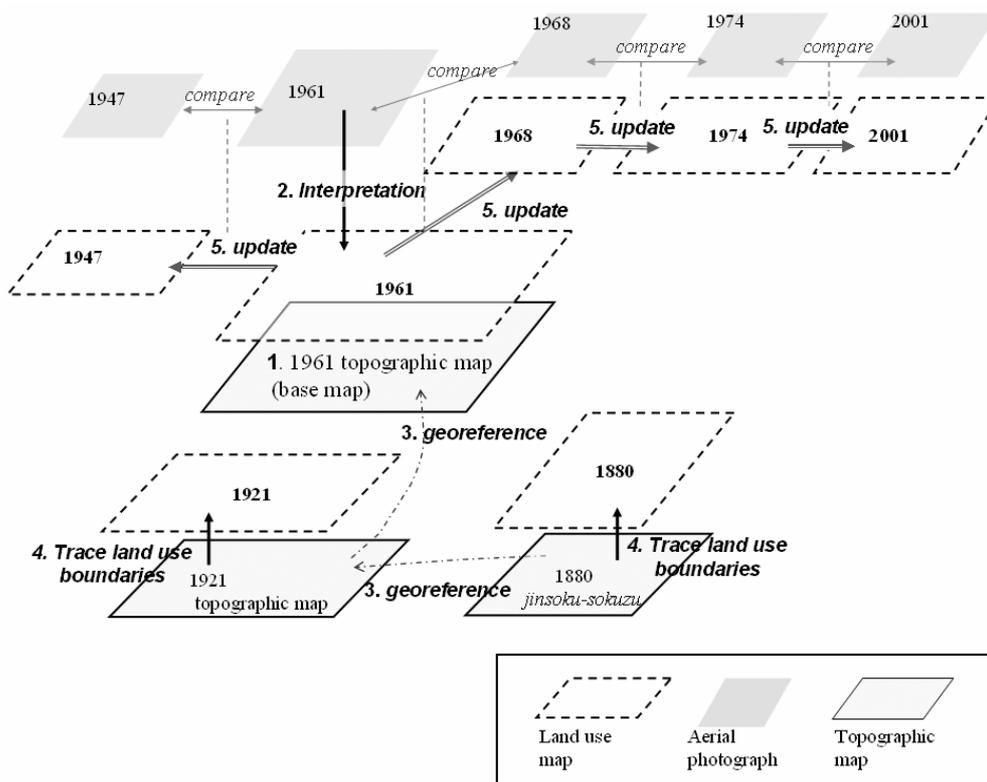


Figure 3. Preparation of land use maps. (1. Scanning and geocoding of 1961 topographic maps; 2. Creating 1961 land use maps by interpretation of the aerial photographs; 3. Scanning and generalizing of 1921 topographic maps and 1880 jinsoku-sokuzu according to 1961 and 1921 topographic maps, respectively; 4. Creating 1921 and 1880 land use maps by tracing land use boundaries; 5. Updating 1961 land use maps by comparing each aerial photograph and creating 1947, 1968, 1974 and 2001 land use maps. See text for detail.)

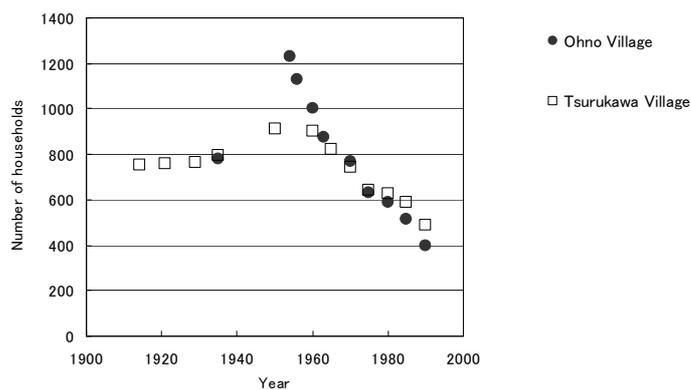
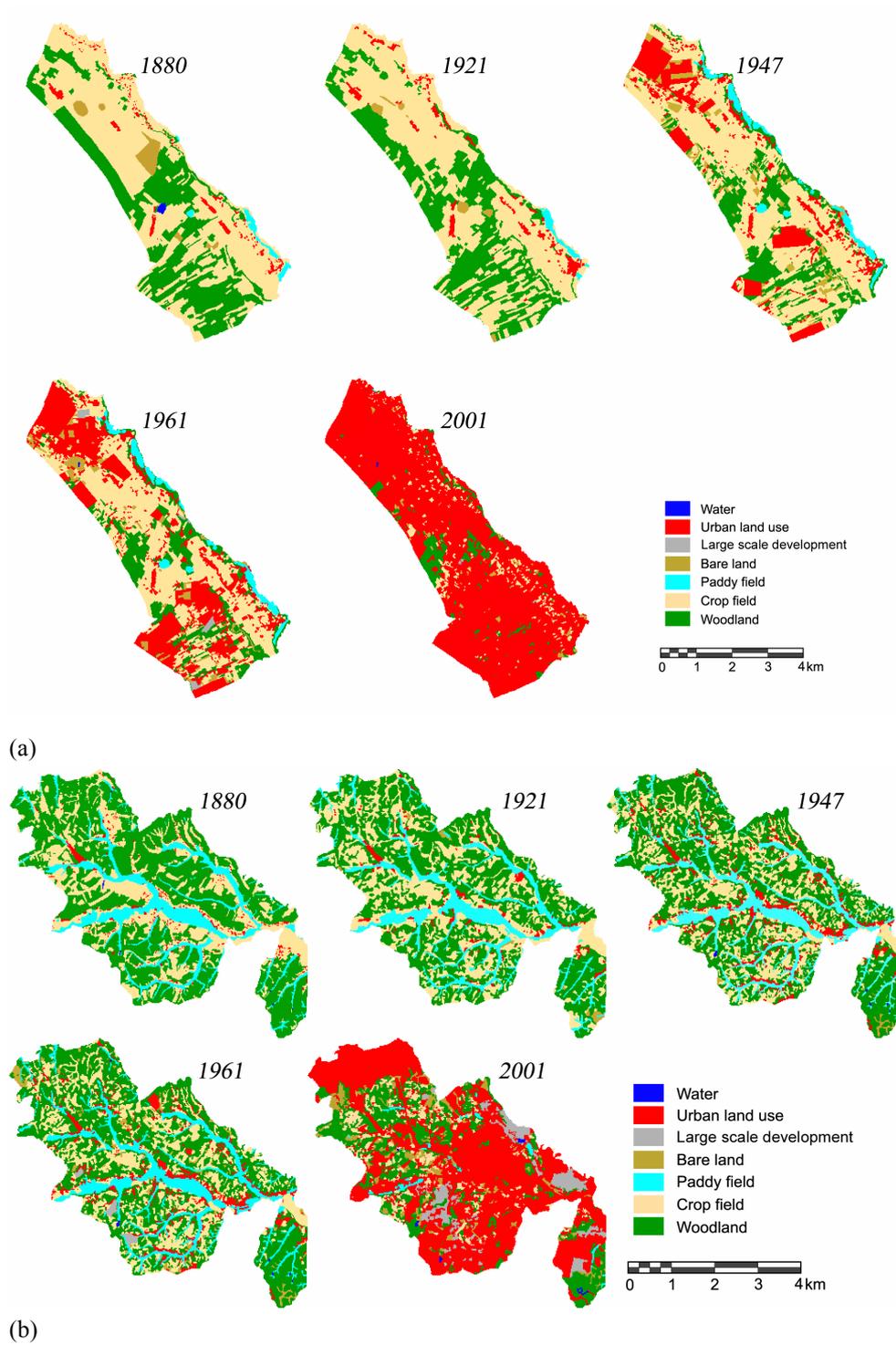


Figure 4. Transition in the number of farm households during the study period.

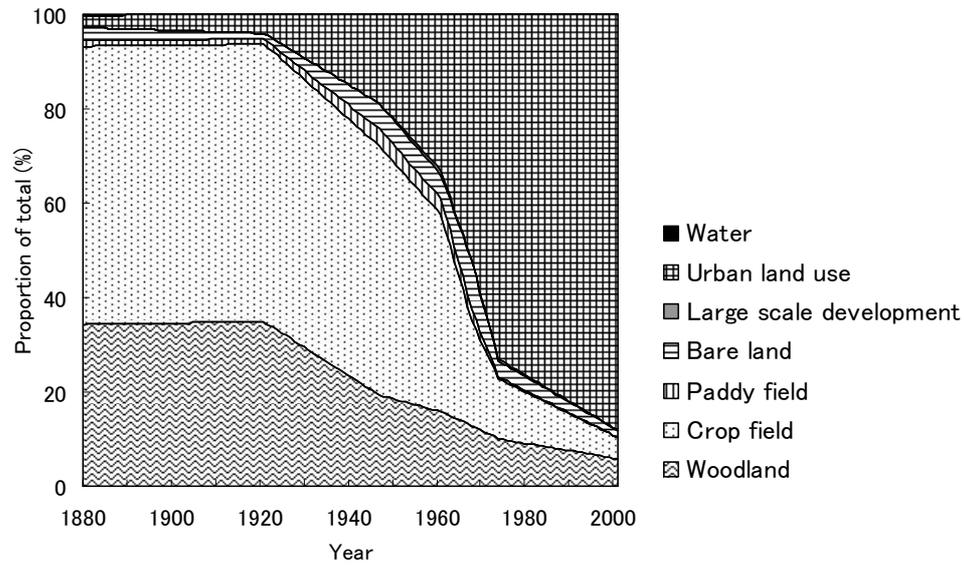
Sources: Tsurukawa Elementary School Research Club of Social Study, 1954; Ministry of Agriculture and Forestry, 1955, 1961, 1966, 1971a, b, 1976a, b, 1981a, b, 1986a, b, 1991a, b; Sagami-hara City Board of Agriculture, 1965; Kanagawa Prefecture, 1966; Editorial Board of History of Sagami-hara City, 1968; Editorial Board of History of Machida City, 1976



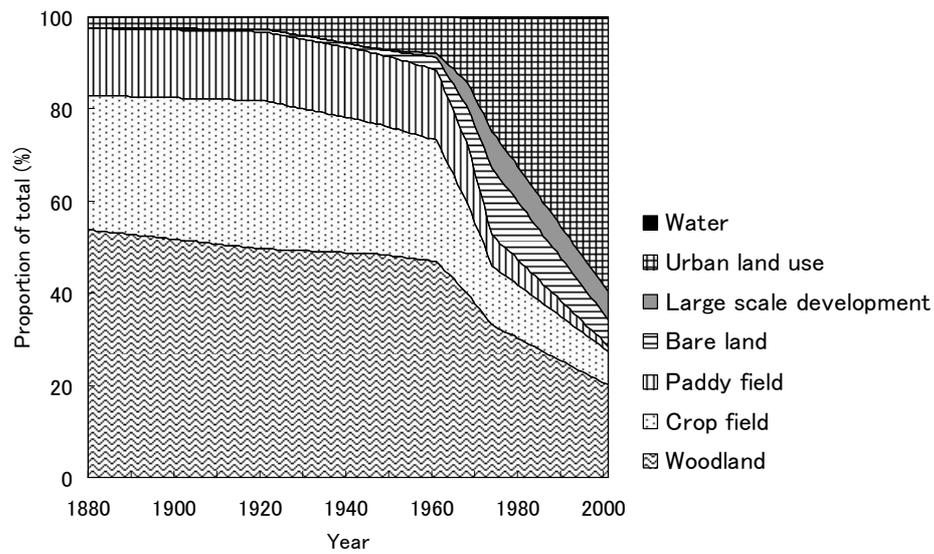
(a)

(b)

Figure 5. Land use patterns in (a) Ohno and (b) Tsurukawa from 1880 to 2001. Land use in Ohno in 1880 shows wide distribution of crop fields and small area of paddy fields in southeast part. Woodlands dominate large area and paddy fields distributed along valleys in 1880 in Tsurukawa.

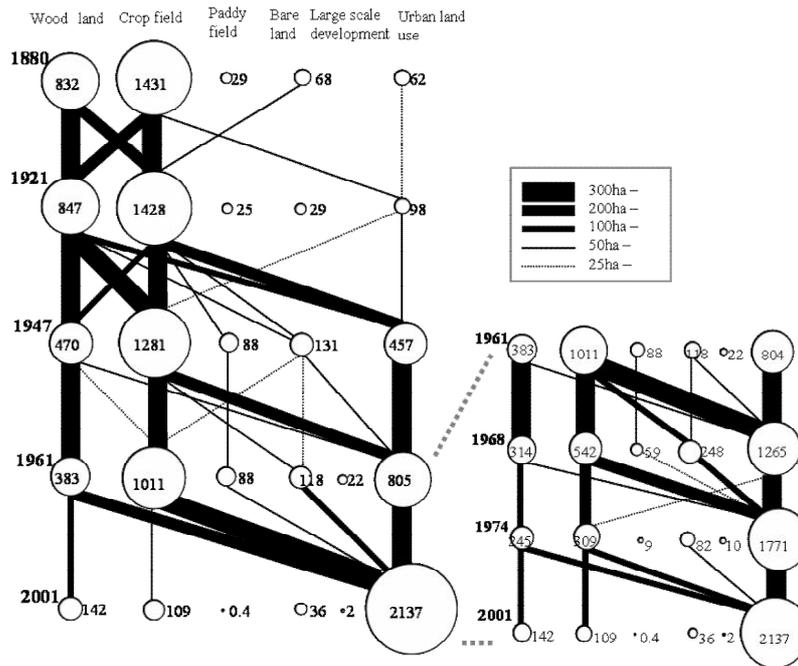


(a)

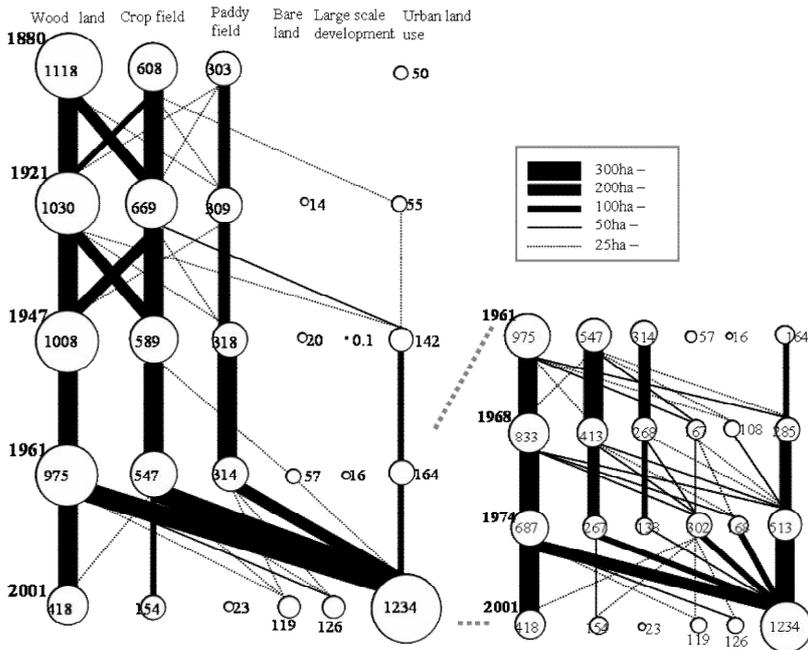


(b)

Figure 6. Transition in the areas of each land use in (a) Ohno and (b) Tsurukawa from 1880 to 2001. In Ohno, increase in urban land use started before 1947 whereas in Tsurukawa, urban land use increased drastically after 1960s.



(a)



(b)

Figure 7. Transitions among land uses and extent of each land use (ha) in (a) Ohno and (b) Tsurukawa from 1880 to 2001. Changes larger than 25ha are described. Size of circle corresponds to the area of each land use and width of arrow corresponds to the area of conversion. Great amount of woodland and crop fields were converted each other, between 1880 and 1921, and 1921 and 1947 in both study areas. After 1947, there was almost no conversion between woodland and crop fields. Right part of each figure shows detail process of urbanization, in which bare land and large scale development as steppingstones to urban land use especially in Tsurukawa are clearly shown.

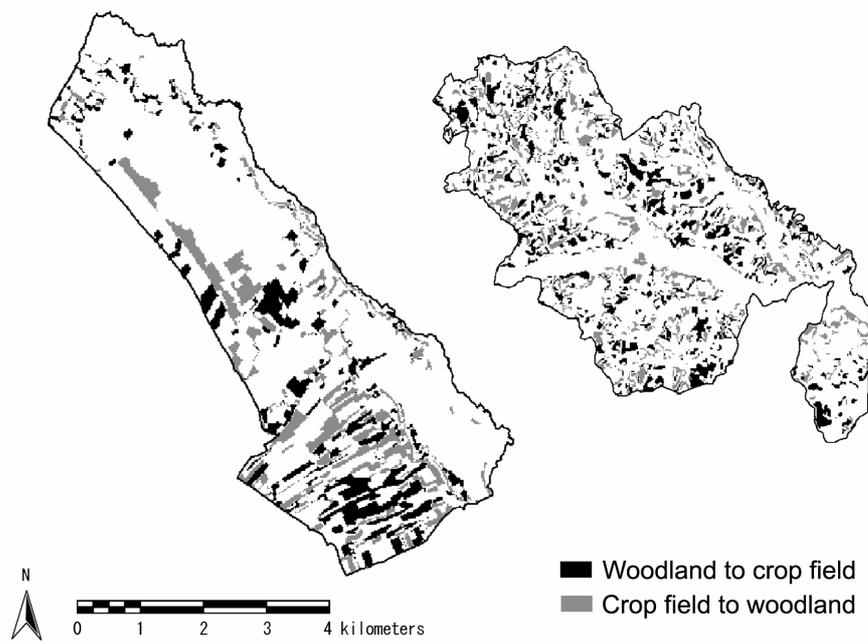


Figure 8. Areas converted from woodlands to crop fields and vice versa from 1880 to 1921.

Table 1. Characteristics of each time period.

	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	
Land use maps	● 1880				● 1921			● 1947	● 1961 ● 1968 ● 1974				● 2001	
Time period	Pre-war period			Wartime period				Reconstruction period					Economic growth period	
Population and number of farm households	<ul style="list-style-type: none"> <li>In Ohno, 88% of households practiced farming (831 farm households) in 1935 (Editorial Board of History of Sagami City, 1968).</li> <li>In Tsurukawa, 90% (783 farm households) in 1935 (Tsurukawa Elementary School Research Club of Social Study, 1954).</li> </ul>			<ul style="list-style-type: none"> <li>Labor shortage in agriculture (Hayashi, 2003; Editorial Board of History of Sagami City, 1971)</li> </ul>				<ul style="list-style-type: none"> <li>Farm households increased in number from 831 in 1935 to 1127 in 1956 (Fig. 4), however, they decreased in share from 88% to 13% in Ohno (Kanagawa Prefecture, 1966).</li> <li>It remained high, 65% in 1950 in Tsurukawa (Tsurukawa Elementary School Research Club of Social Study, 1954)</li> </ul>					<ul style="list-style-type: none"> <li>Decrease in the number of farm households (Fig. 4)</li> </ul>	
Agriculture	<ul style="list-style-type: none"> <li>Increase of production was promoted firstly by improving traditional methods (Hayami, 1975) and then by science based technology due to the development of a capitalist economy (Improvement of manure, the introduction of chemical fertilizers, and plant improvement through breeding).</li> <li>Main products were cereals and root vegetables. With an increase in exports of silk, raising silkworms and growing mulberry, which is the primary food of silkworms, was done in most farm households (Tsurukawa Elementary School Research Club of Social Study, 1954; Editorial Board of History of Sagami City, 1968)</li> <li>Production of commercial crops such as vegetables, fruit, and livestock were started (Editorial Board of History of Machida City, 1976; Editorial Board of History of Sagami City, 1971).</li> </ul>			<ul style="list-style-type: none"> <li>Restriction of supply of manure by quotas, and decrease of production of agricultural instruments due to a lack of ferrous material or the conversion of agricultural factories to military uses or closing of them (Hayashi, 2003).</li> <li>Each crop was allocated a fixed quantity to be delivered (Hayashi, 2003).</li> <li>Decrease in sericulture after the steep fall in the silk market (Editorial Board of History of Sagami City, 1971; Editorial Board of History of Machida City, 1976)</li> </ul>			<ul style="list-style-type: none"> <li>Democratization of the agrarian society and institutions. Land reform and reorganization of the agricultural cooperative associations (Hayami, 1975).</li> <li>Production of food was promoted and government control of food commodities continued until 1952 to secure the food supply (Hayami, 1975).</li> <li>Production of rice was especially promoted (Editorial Board of History of Machida City, 1976).</li> </ul>		<ul style="list-style-type: none"> <li>Establishment of the Agricultural Basic Law (1961) to modernize and rationalize agricultural production encouraged enlargement of scale of the production units and selective expanding of the production (Teruoka, 2003b).</li> <li>Rice production became larger than the demand and production adjusted since 1972 (Teruoka, 2003b)</li> <li>Shift from cereal and vegetable production to fruit or livestock during the 1960s and 1970s (Sagami City Board of Agriculture, 1965; Editorial Board of History of Machida City, 1976; Authors' interviews with elderly people).</li> <li>Distribution of machinery and chemical fertilizer (Teruoka, 2003b).</li> </ul>			<ul style="list-style-type: none"> <li>Decline of use and management of woodland during first 10 years of this period because of the change of primary energy source to oil and propane distribution of chemical fertilizer (Authors' interviews with elderly people).</li> <li>The National Capital Region Development Law (1956) in which the two study sites were designated as a satellite city with the goal of establishing an industrial and residential area (Editorial Board of Policy Formation History in Three Major Metropolitan Areas, 2000).</li> <li>Large-scale development projects such as Tama New Town (plan to develop 3000 ha of residential area to provide houses for 300 000 people (Ishida, 2004)).</li> </ul>		
Woodland	<ul style="list-style-type: none"> <li>Woodland was managed and used for agricultural production and supporting daily life, such as manure, fuel wood, charcoal and construction timber and also for providing a cash income for farmers (Rikugun Sanbo Hombu, 1986).</li> </ul>													
Urbanization				<ul style="list-style-type: none"> <li>From 1932, construction of military facilities such as an arsenal and hospitals, and camps for workers in these facilities in Ohno started (Editorial Board of History of Sagami City, 1971).</li> </ul>				<ul style="list-style-type: none"> <li>Construction of urban facilities (e.g., schools, hospitals and factories) using former military facilities and related infrastructure in Ohno (Takeuchi, 1972).</li> </ul>						