The Rapid Survey Maps: Japan's First Modern Topographic Maps and the GIS Analysis of Historical Land Use in the Kanto Plain

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Introduction

Working with historical maps is a great challenge for spatial analysis using geographical information systems (GIS). Older maps may be spatially distorted to various degrees, or drawn to highly variable scales, accuracies, and precisions. Many older maps have no map projection, no coordinate grid, or even no indication of latitude and longitude. Worse, older maps may lack reasonably precise spatial reference points to match them to other maps. Maps existed for many purposes, not necessarily familiar to modern scholars. The land use or attribute information may be vague, inconsistent, mysterious, or simply incomplete. Nevertheless, historical maps provide such rich material for scholars who wish to learn about land use in historical perspective that GIS analysts must take up the challenge to incorporate historical maps into digital spatial analysis.

In historical GIS projects, one of the most efficient ways to start building a map database is to find the earliest maps surveyed by modern cartographic methods that may be available in a study area. In Japan, the Rapid Survey Maps, or *Jinsoku Sokuzu*, are the first series of topographic maps covering a large area of Japan. The mapping project started in the year 1880, or Meiji 13, the 13th Year of the reign (1868 - 1921) of the Emperor Meiji, and the same number of years after a new government had set Japan on a path towards modernization and westernization. These maps cover much of the Kanto Plain surrounding the city of Tokyo.

The Kanto Plain is the largest plain region of Japan. It is a river valley through which several of Japan's largest rivers flow out to the Pacific Ocean or into Tokyo Bay. The Kanto Plain has been inhabited since the Neolithic Jomon period and in early modern times, became a major supplier of agricultural products and natural resources for the city that became Tokyo. The topography of the Kanto Plain is composed of lowlands and upland plateaus. In general, the swampy lowlands were often converted to rice paddy fields. The uplands were relatively drier, and subject to dry field farming. Some large uplands are well enough defined that geographers gave them names. Tokyo is built at the eastern edge of the Musashino Plateau and bounded further to the east by many great rivers. The hilly parts of the city are up on the plateau, while much of the original downtown is built in the lowlands on reclaimed land. Historical geographers point out that not all of the Kanto Plain turned into farmland. It is very

common in Japan for flat places to be farmed while hills are left as woodlands or grasslands. Many rural areas combine flat and hilly topography. However, Kanto is relatively flat. The Kanto area is famous among geographers for the plains woodland (*heichi-rin*).

The Rapid Survey Maps provide the essential temporal baseline to measure change in the landscape of the Kanto Plain. The maps capture the Kanto Plain at a critical point in its history at the start of modernization. The landscape remained much as it had been in feudal times under the Tokugawa Shogunate (1603-1868). There were still no railways, motorways, or bridges. Government policy had barely started to force major changes in land use through the break-up of more local and customary land management. Farmers still managed the land to support fields and paddies using local natural resources and traditional fertilizers. Land uses included resource areas for supplying natural resources to local farmers as well as shipment to Tokyo. Many features of the Kanto Plain revealed by these maps disappeared before later topographic maps could record their existence, and are largely forgotten to most Japanese today.

In this paper, we first provide a brief history to explain why and how the Rapid Surveys Maps were produced. Next, we introduce research by geographers utilizing the Rapid Survey Maps, followed by our own project to apply GIS analysis to the Rapid Survey Maps depicting the rural landscape of Ibaraki Prefecture in the northern Kanto Plain.

The Rapid Survey Maps: A Brief History

The Japanese Army produced the Rapid Survey Maps for military purposes. The Army felt a strong need for maps following a military campaign to suppress a rebellion. The rebellion had occurred in 1877 in the island of Kyushu, in southern Japan, where the Army had been severely hampered by the lack of maps during its campaign. At that time, Japan did not yet possess topographic maps covering large areas of any part of the nation. Following that campaign, the Army set out to rapidly map the key regions of Japan, hence the name of the map series, the Rapid Survey Maps. The surveyors were military officers. Many maps were stamped "secret."

The Army initiated the mapping project with the Kanto Plain surrounding the capital city of Tokyo. The project mapped an area approximately 170 km east-west and 175 km north-south, covering most of the relatively flat areas of the Kanto Plain, and extending into more hilly areas around the edges of the plain and in the Boso Peninsula (Figure 1). The surveyors fanned out into the Kanto Plain to draw the maps by plain-table surveying at 1/20,000 scale on Japanese paper. Each map covers an area about 4 km wide and 5 km tall. At this scale and size, a total of over 800 maps covered most of the Kanto Plain.

The mapping project started under the supervision of French military advisors.

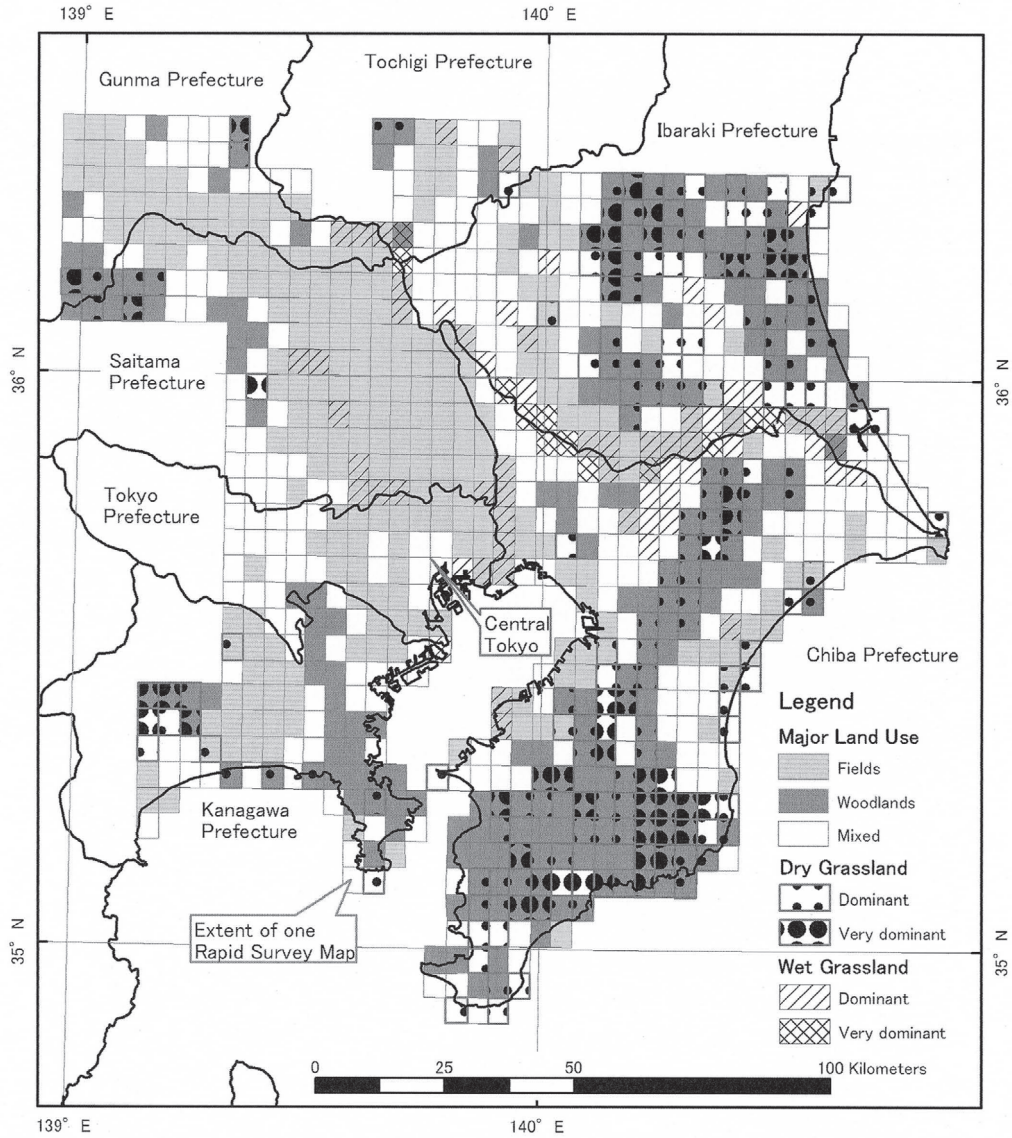

Fig. 1 The Kanto Plain area covered by the Rapid Survey Maps, and the land use classification by Ogura (1996) based on those maps.

Following French cartographic practice, the maps were colorfully coded with detailed information on land use, as well as characters denoting further details on various forms of agriculture, woodlands, and grasslands. Roads and paths are drawn in great detail. Paintings in the margin depict important topographic features. Many are buildings, shrines, or monuments at crossroads, landmarks that may be useful to soldiers for identifying their location while on the march. Some maps show fortifications located within that map. Maps that include a large river may have a drawing of the river's depth profile at crossings. Each

Fig. 2
An example of a Rapid Survey Map (*Jinsoku Sokuzu* Reprinting Committee, 1991), surveyed in 1881 showing the village of Ushiku in southern Ibaraki Prefecture, the original map for the lower left quadrant of Figure 3.

drawer and surveyor was named in the corner of the maps (Figure 2).

Unfortunately, the Army never used the maps in their original form. Even as the mapping project proceeded, the Army switched its model from the French to the German army. The cartographic style changed also, from the multi-colored French style to the black-and-white German style. The Rapid Surveys Maps were published later in black-and-white while the original maps went into storage. They remained in storage for about a century, moving from one institution to another as Japan's cartographic institutes evolved. They eventually arrived at the Geographical Survey Institute, the institution that produces Japan's topographic map today, where they were rediscovered, and pulled out of storage. The original Rapid Survey Maps for the Kanto Plain finally reached publication in 1991, to become available at last to scholars and the public (*Jinsoku Sokuzu* Reprinting Committee, 1991).

Land Use and Environmental History of the Kanto Plain

The Rapid Survey Maps have been a boon to geographers and historians studying the land use history of the Kanto Plain. It is the point of departure for many scholars who start their

research on land use change by examining the land use of their study area in the early Meiji Era. The maps are especially useful for environmental historians who are given the opportunity to study land uses that have disappeared after the Rapid Survey Maps were surveyed (Inui, 1992; Moriyama, 1997). However, the Rapid Survey Maps defy easy summarization, first, because of the sheer number of maps, and second, the variety of landscapes depicted in them.

Ogura (1996) attempted to summarize the entire set of Rapid Survey Maps. He viewed all the maps to identify broad land use patterns (Figure 1). First, he classified each map according to whether the major land use was agricultural or woodland. Next, he identified maps in which grasslands were dominating land uses.

Although Ogura's study is based solely on his visual impression of each map, it is more than sufficient to reveal the intensity of land use in the Kanto Plain in the 1880's. Farmland occupied much of the areas that now constitute the Tokyo and its satellite cities. Intense land use, however, did not mean that farmers turned the entire plain into farmland. The large areas of woodland impressed Ogura. Next, he was struck by the large proportion of grassland revealed in many maps, both dry grassland on the uplands, and wet grasslands in lowlands along rivers. It is important to realize that neither woodlands nor grasslands consisted of natural vegetation. Both were products of human land use. Much of the woodlands were hardy pines, or coppice broadleaf trees. Farm communities maintained rural grasslands by repeated cutting or firing.

Shirai (2002) carried out a more detailed study of woodland products shipped to Tokyo. He started his report by pointing out the large areas of woodland found on the Shimousa Plateau in northern Chiba Prefecture, by contrast to the farmland to the west of Tokyo. He used a more quantitative method to summarize the maps in his study area. In his most detailed analysis, he constructed a 1 km grid over the Rapid Survey Maps, ranked the major land uses by visual inspection, and assigned each grid cell to the highest-ranking land use. In his study area of northern Chiba Prefecture, he found that the major land uses assigned to grid cells were the rice paddies accounting for 31%, dry fields 10%, pine woodland 39%, and other trees 5%. With documentary evidence from Tokyo wholesale markets, he showed that northern Chiba was among the top suppliers of charcoal and firewood to Tokyo. Pines supplied firewood and lower quality charcoal. Broadleaf trees provided the higher quality charcoal. Grasslands, in the case of northern Chiba Prefecture, were often pasture for horses. Shirai (2002) notes that the new Meiji government redistributed the grasslands to new farmers, mostly unemployed samurai, to be colonized as new farmland.

The fate of rural woodlands is another important research topic for scholars of environmental history. Tsunekawa and Besho (2001) focused on the woodlands of the Tama

Hills to the west of Tokyo. Their objective was to trace changes in woodland composition from a succession of topographic maps, starting with the Rapid Survey Map. They faced the problem that the Rapid Survey Map does not mark all woodlands at the species level. They chose to base their GIS analysis on the locations of the species markings where they existed in the Rapid Survey Maps. They digitized the markings as points. They found that the largest number of marker points were for coppice broadleaf trees, followed by pine, with only a few for cedar plantations. By the 1990's, 74% of the woodland had been lost, primarily to urbanization, and secondarily to farms.

GIS Analysis of the Rapid Survey Maps

Applying GIS techniques to historical maps requires caution because older maps may not have the same degree of accuracy or consistency as modern maps in the quality of either the surveying or land use notations. Analysts must examine closely the historical maps to determine whether they can be transformed into a GIS data model with modern spatial coordinates.

The Rapid Survey Maps are well suited for vector GIS analysis. The maps depict many linear features, especially roads and paths. Linear features demarcate most land uses. The mapping carried out by plain-table surveying is quite precise. The 1/20,000 scale of the Rapid Survey Maps is, at least nominally, more precise than the standard Japanese topographic map published at 1/25,000 scale. The color-coded land use allows attribute data to be filled in for the entire map.

The disadvantages of the Rapid Survey Maps are, first, that these maps have no notation for longitude, latitude, or any form of map grid. Technically, "rapid survey" refers to a quick surveying method that does not use formally established triangulation points. While triangulation points appear in many maps, they do not match any modern triangulation points, and no information remains, either in documents or on the ground, as to precisely where they had been located. Fortunately, many roads and paths drawn in the Rapid Survey Maps still exist, and can be found in modern topographic maps. The maps can be fitted approximately to modern Japanese maps in the universal transverse mercator (UTM) projection using these roads and paths. Second, surveying errors remain in the map, which may need to be adjusted by rubber sheeting techniques to match modern maps. Third, more detailed land use is not marked consistently among the maps. Some maps provide enough information to label every woodland polygon at the species level, but most maps do not. Nevertheless, the color-coded land use allows comparison among Rapid Survey Maps, and with later maps, for broad land use categories: rice paddy, dry fields, woodland, and grassland or bushland. Fourth, not all land use units are delimited by a clear border, and in some maps, it may be necessary to add line segments to close a polygon.

The authors are carrying out GIS analysis of the Rapid Survey Maps to track land use changes, quantify the amount of natural resources available to rural communities, and elucidate the spatial structure of rural land use in the 1880's (Iwasaki and Sprague, 2003; Sprague, 2002, 2003; Sprague et al. 2000). The study area is primarily the plateau area surrounding Tsukuba Science City in the northern Kanto Plain.

Tsukuba is located on the Inashiki Plateau, which starts at about 50 km northeast from Tokyo. The main highway from Tokyo to the city of Mito passed through this plateau. However, this area of the Kanto Plain is quite remote from Tokyo. A traveler would cross the great Tone River and some of its tributaries to reach the Inashiki Plateau. River transport was highly developed along the Tone River and its tributaries, but the central Inashiki Plateau would not have been accessible by boat. We can assume, therefore, that trade in farm produce was limited compared to agricultural areas immediately adjacent to Tokyo.

The goal of our research is to understand how rural communities structured land use to sustain their livelihoods at a time when most natural resources were acquired locally. The GIS analysis of the Rapid Survey Maps allows us to quantitatively analyze, first, the proportions of land uses, and, second, the spatial structure of land uses.

Although the plateau is quite flat, topography had subtle effects on land use. The middle of the flat upland plateau is about 20 m to 25 m above sea level. Parallel rivers flow through the plateau towards the southeast. The rice paddies are confined mostly to the river valleys. The uplands, distributed between the river valleys, have few hills that limit land use.

Did farmers turn all the available land into farms? Agronomists around the world know that farmers under traditional agriculture usually did not turn the entire landscape into fields. Rural communities of the Inashiki Plateau distributed dry fields, woodlands, and grasslands throughout the flat upland. Thus the spatial research issues are, what proportion of land was maintained as woodland or grassland, and where did the farmers distribute woodlands and grasslands in relation to their villages and paddy fields.

Figure 3 shows a region that is now in the vicinity of the cities of Tsukuba, Ushiku, and Tsuchiura, in southern Ibaraki Prefecture. This figure is based on four adjacent Rapid Survey Maps. The four maps were digitized, fitted to the UTM projection, and aligned to each other. Land use attributes correspond to the color-code of the Rapid Survey Map.

One fortunate characteristic of the land use in Ibaraki Prefecture for vector GIS is that virtually all land use units were bounded. This is partly due to the density of roads and paths in this landscape that the map-makers carefully recorded. Another reason may be the hedges and windbreaks commonly found around homesteads. We speculate that the military map-makers drew in the hedges, since they are physical obstacles to soldiers on foot, and, consequently, drew boundaries around almost all of the villages and residences. Only in a

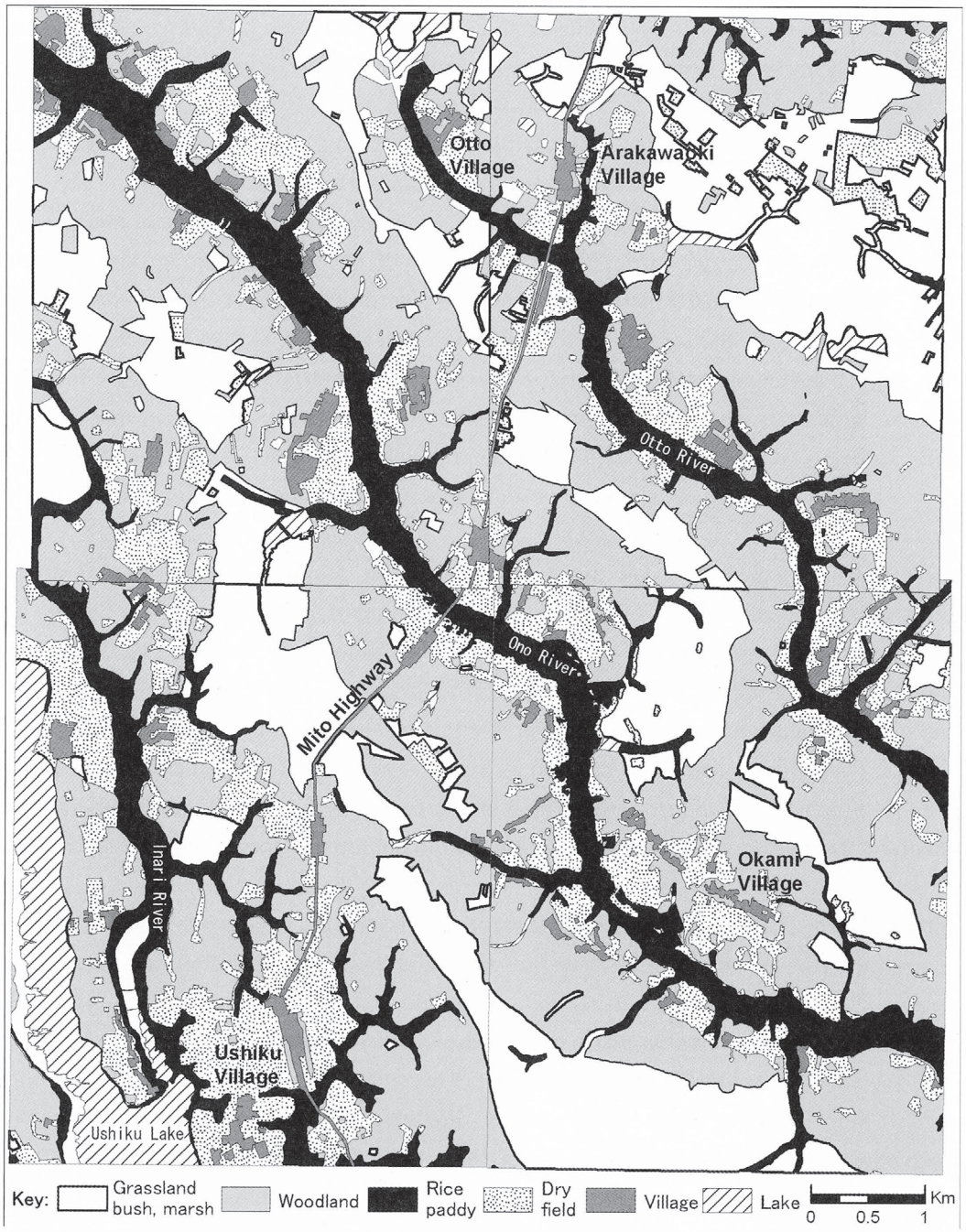

Fig. 3 Land use map of a rural area on the Inashiki Plateau of southern Ibaraki Prefecture based on four Rapid Survey Maps surveyed in 1881 (lower half) and 1883 (upper half).

few locations did we need to add line segments to close a polygon.

The maps show clearly the basic land use pattern on the Inashiki Plateau in the 1880's. The upper half was surveyed in 1883, the lower half in 1881. The four maps were named after the main villages located in them, the villages of Otto (upper left), Arakawaoki (upper right), Ushiku (lower left), and Okami (lower right). The largest river in the map is the Ono River, one of the several rivers that flow form the north-west towards the south-east through the map area. The Mito Highway, passing through the map from north-east to south-west, still remains, and most of it has become incorporated into the National Road No. 6. The railway has yet to be built; it will eventually run parallel and to the east of the Mito Highway.

Clearly, the farm communities of southern Ibaraki Prefecture had not turned all of their land into fields. A majority of the land was resource area left uncultivated. Within this four map area, 42% was woodland and 21% grassland, while dry fields comprised 18%, rice paddy 12%, and villages 3%. The woodland labels give the impression that a majority of the woodland was pine, along with coppice broadleaf and the occasional cedar plantation, mixed among the pines.

The large grasslands are a particularly important feature for appreciating the value of the Rapid Survey Maps. The grasslands disappear from the landscape, at least as large land use units, very soon after the maps were made. They do not appear in the topographic maps surveyed in later years. It is primarily through the Rapid Survey Maps that scholars are aware of their existence and extent in the Kanto Plain, including Ibaraki Prefecture.

A closer look at figure 3 reveals that the land use seems to have a pattern. The land uses extend in parallel rows between the rivers. The rice paddies are confined to the narrow river valleys. Villages are distributed to either side of the rivers. Dry fields and woodlands spread out around the villages. The grasslands extended down the center of the plateau, parallel to the rivers.

GIS analysis can show whether quantitative measures would support this visual impression. The following analysis was carried out on the lower half of the map in figure 3. Since a parallel land use pattern seemed to existed between the rives, a series of buffers zones were created extending out from the rice paddies. Buffers were each 100 m wide, i.e. the first buffer extended from the rice paddy boundary out to 100 m, the second from 100 m to 200 m, and so on towards the center of the plateau to cover the entire map, excepting the rice paddies. In figure 4, each buffer is called a distance zone.

Histograms in figure 4 show the distribution of land uses on the plateau based on the distance zones. The histograms confirm that land uses tended to be distributed at different distances from rice paddies. Grasslands comprise a larger proportion of distance zones the further away they are from rice paddy. Woodlands are distributed quite evenly among distance zones. Fields were distributed closer to rice paddies. Villages were distributed

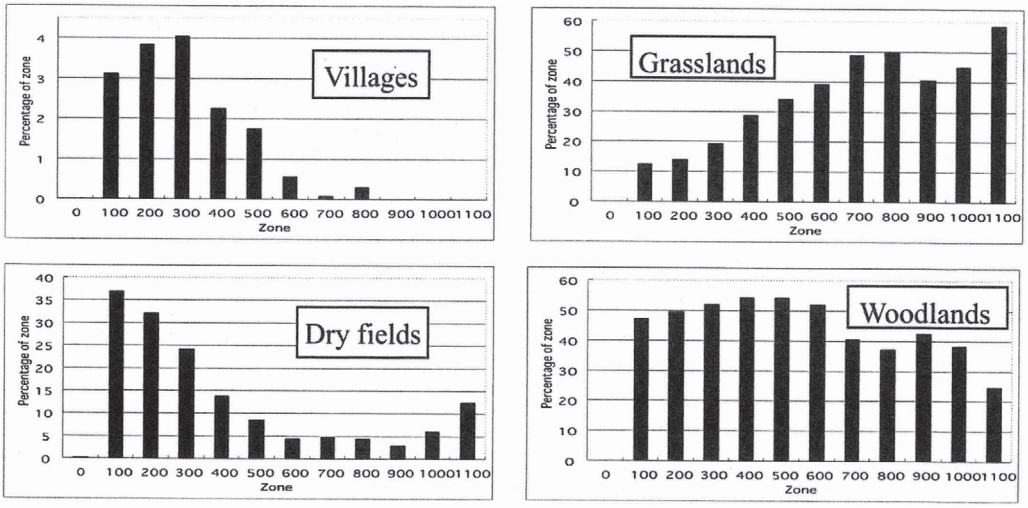

Fig. 4 Land use structure of a rural area on the Inashiki Plateau based on two Rapid Survey Maps (lower half of figure 3), showing the percentage of each land use within distance zones defined by 100 m wide buffers extending out from the rice paddies, where, for example, the 100 m zone extends from 0 meters to 100 m.

slightly further from rice paddies compared to fields. The modal distance zone for fields is the 0-100 m zone. The modal distance for villages was the 200-300 m distance zone.

Our interpretation of this pattern is that farm communities built villages near rice paddies but up on higher and drier ground on the plateau. They arranged the dry fields and woodlands around the villages. The grasslands were placed in the center of the plateau, perhaps because they were marginal land accessed less often by farmers than land for other uses, constituted a fire hazard since they were occasionally burned deliberately or by accident, and grasslands were a commons shared by multiple villages (Sprague et al., 2000).

Discussion

Historical spatial analysis is a fast growing area of GIS application. GIS analysis offers the possibility that the areas, percentages, and spatial structures of land uses can be extracted from historical maps at a precision on a par with modern maps. The Rapid Survey Maps are a good example of early maps that can be incorporated into GIS. The Rapid Survey Maps are far more spatially accurate than earlier maps, and cover the entire Kanto Plain. They provide as much or even more detail about land use as modern topographic maps. These maps are suited for vector GIS because of the many linear features drawn into them.

Most importantly, The Rapid Survey Maps are invaluable because they take us back to the time just before railways and automobiles changed transportation costs in the Kanto Plain to allow more resources to be transported more rapidly in larger quantities. Indeed, Japan as a whole obtained most of its natural resources domestically. Even Tokyo obtained

most food and natural resources from sources within a few days transport by boat, horse cart, or pack horse. The Rapid Survey Maps depict the food and resource base for Tokyo. Farms close to Tokyo supplied the city with fresh produce while rural communities further afield supplied Tokyo with lumber, firewood and charcoal (Shirai, 2002).

Another valuable aspect of the Rapid Survey Maps is that they reveal to us the resource base for Japanese rural communities. Much of outlying agriculture was self-sustaining, subsistence farming, dependent on local natural resources, where local in this case meant within the walking distance of farmers. Farmers obtained most of their own fuel, fertilizer and fodder from the woodlands and grasslands immediately surrounding their villages or fields (Inui, 1992; Moriyama, 1997).

Southern Ibaraki Prefecture in 1881-83, as revealed in figures 2, 3, and 4, is an example of an area that probably practiced subsistence agriculture while supplying resources to Tokyo. To sustain this livelihood, over 60% of this landscape was resource area in the form of woodlands or grasslands. Farmers collected leaves and grasses from woodlands and grasslands to serve as fodder for their horses, and material for making compost. The grasslands in figure 3 were common-lands shared by several villages. In the 1880's, however, the new government confiscated the grassland commons of Ibaraki Prefecture from the villages and redistributed them to new farmers, often unemployed samurai, as they had in Chiba Prefecture (Shirai, 2002). The loss of grasslands lead to a shortage of compost, partly made up by purchased fertilizer, and, later, as chemical fertilizers completely replaced compost, woodlands and grasslands lost value to the farmers (Iwasaki and Sprague, 2003). Meanwhile, in the 1880's, southern Ibaraki Prefecture, including some of the area within figure 3, was a major supplier for fuel-wood and charcoal to Tokyo. According to Tateishi and Sawada (1975), two-thirds of the fuel-wood supplied to Tokyo originated from southern Ibaraki Prefecture in Meiji 10 (1877), but the region lost its role as a major supplier of fuel-wood as improved transportation allowed Tokyo markets to obtain fuel-wood from suppliers further away. During the Meiji Era, grasslands and woodlands started to lose their value as sources of compost as farmers were able to easily purchase inexpensive fertilizers, such as soybean cake imported from northeast China. The changes in rural livelihoods also lead to the break-up of the land use structure observed in the Rapid Survey Maps. The land use pattern seen in figure 4 has disappeared, initially, as new farmers turned grasslands into farms and woodlands. More recently, with the advent of chemical fertilizers, woodlands have lost their value to farmers and more have been turned into farms or housing. Furthermore, even southern Ibaraki Prefecture is now subject to development and urbanization, as new rail lines have brought the area to within an hour's commuting distance from Tokyo.

The Rapid Survey Maps, by providing such high quality information at a critical time

in Japan's history, provide a temporal baseline to study land use change in Japan, projected both towards the future and to the past (Sprague, 2002). Historians working in time periods prior to the Meiji can see the end-point of the agricultural expansion that spread farms across the Kanto Plain, while supplying food and natural resources to the rapidly growing urban center that was to become Tokyo. For historians seeking to understand the post-Meiji development of Japan, the Rapid Survey Maps reveal the starting point from where modern technology and economics intervened to change largely self-sustaining rural communities into the setting for intensive modern agriculture, industrialization, and suburban residential areas. For GIS analysts, the continuing challenge will be to combine the Rapid Survey Maps with spatial data from both earlier and later sources into integrated spatial databases that will allow historians to test specific theories about land use change in the Kanto Plains.

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(Note: J - in Japanese)

迅速測図－日本初の近代的測量手法による地形図と関東平野における歴史的土地利用法のGISによる解析－

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迅速測図は日本で初めて広い地域を対象に近代的測量手法により作成された地形図である。1880年代における関東平野および東京について詳細な土地利用情報を提供する。迅速測図は地理情報システム（GIS）による解析に適しており、現代の地形図に匹敵する精度で量的情報を得ることが可能である。茨城県南部のGIS解析から、農村で自給する、または都市部へ出荷する資源の供給地として、この地域で広範囲に分布していた樹林地や草地の空間構造が判明した。