

Historical GIS of Yakushima Island and the Extent of Human Subsistence Activities

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Introduction

Maps often provide important information about land use. Arranged in a time-series, maps can show land use change. However, cartographers have produced a wide variety of maps. For any particular study site, historical geographers need to examine available maps to determine what type of information can be obtained from the maps. For a research project applying a Geographic Information System (GIS), determining exactly how maps depict land use will point towards a strategy for data entry and analysis.

The most commonly used maps in Japan are the topographic maps produced by the Geographical Survey Institute (GSI) of the Ministry of Land, Infrastructure and Transport, and its predecessor institutions. These maps cover the entire land area of Japan. A historical geography project in Japan often starts by obtaining the map history for the topographic maps of a study site. While some parts of Japan may have been surveyed repeatedly by various Japanese government institutions, the earliest topographic map of the GSI will often be the first maps surveyed by modern methods, and the earliest extensive and complete record of land use, for many parts of Japan. A historical GIS project to study environmental changes in Japan must start first with an examination of the topographic maps to determine what they can tell researchers about land use changes on this island.

The objective of this project is to construct a historical GIS database for Yakushima Island in southern Japan. The first step of this project was to examine exactly how Yakushima is depicted in the topographic maps issued by the GSI, and, second, use the topographic maps to carry out time-series analysis to identify major patterns of land use change associated with the livelihoods of the inhabitants.

The goal of this analysis is to identify the spatial extent of the daily subsistence activities carried out by the inhabitants of Yakushima. Human activity has undoubtedly affected the vegetation and land cover of Yakushima. The island has been inhabited since the neolithic Jomon period. In early modern times, the people of Yakushima lived by a combination of farming, fishery, and forestry. However, Yakushima is a mountainous island and human habitation is largely restricted to the coastal plains. While this fact is obvious, the extent to which human subsistence activities extended up the mountain-side is a critical research issue. Research on land use history is linked to a judgment about whether human activity in modern times is expanding or shrinking. In the case of Yakushima, modern farms, especially orchards, have expanded uphill into forested mountains in the post-WWII period. Thus, historical geographical research is necessary to determine whether human activity is expanding into new, previously unused areas.

This study focused, in particular, on a type of land use depicted in topographic maps called “are-chi,” which can be translated as roughland or wasteland. In Japanese topographic maps, wasteland denotes unforested grasslands or bushland (Japan International Map Association, 1990). In a heavily forested landscape as in Yakushima, wasteland implies the presence of human activity that cleared forest. First, the

GIS analysis mapped the estimated extent of wasteland, as well as farmland, as indicators of human activity on Yakushima. Second, time-series analysis identified the location of new land uses in relation to older land uses to determine whether the new land uses were expanding into previously unused areas.

Methods

Yakushima is covered by four map sheets at 1/50,000 scale and seven map sheets at 1/25,000 scale. This project used maps from three time periods for GIS analysis, as follows: (1) 1/50,000 scale maps issued in 1921 in the Japanese polyhedral projection, the oldest topographic maps of Yakushima, (2) 1/50,000 scale maps issued in 1972-73, the earliest in the universal transverse mercator (UTM) projection, based on 1/25,000 maps drawn from 1969 aerial photographs and 1970 ground survey, and (3) 1/25,000 scale maps in the UTM projection issued in 1992 based on 1990 aerial photographs and 1991 ground survey. The maps were georeferenced to the same UTM projection (Tokyo datum, Zone 52) using corner latitude-longitude coordinates printed on the maps, and joined together into single maps for each period.

Land uses demarcated by lines were entered into the GIS as polygons. Land uses marked by free labels were first entered as points from which the GIS generated Theissen polygons, followed by merging all adjacent polygons with the same land use.

The data on altitude was based on the 50 meter-interval topographic data issued by the GSI. The analysis was confined to the area from the coast line up to an altitude of 500 meters above sea level since this project focused on the rural landscape, and large-scale forestry in the higher altitude mountains is beyond the scope of this particular analysis.

Land use change was analyzed, first with a comparison of land uses among the maps of the three time periods, and, second, with an overlay analysis of the three maps at two intervals between maps 1 and 2, and maps 1 and 3.

Results

Mapping history

The mapping history of Yakushima island shows that the first topographic maps of Yakushima were surveyed in 1921 at 1/50,000 scale. The mapping history for one of the 1/50,000 maps is shown in Table 1. These maps were probably the very first time Yakushima was mapped completely by modern cartographic methods. Examination of the maps issued in 1946, 1954, and 1962 found that cartographers had made almost no changes whatsoever compared to the 1921 map. The first map series drawn in UTM in 1972-73 was the first to be completely redrawn, and the map from this year at 1/50,000 scale is used for the present analysis. Subsequently, the GSI updated the maps periodically at both 1/25,000 and 1/50,000 scales. The 1/25,000 map issued 1992 is used as the third map in the present analysis.

Table 1. Mapping history of one of the four 1/50,000 topographic maps of Yakushima titled Northeast Yakushima.

Map number	History			Issue date
153-6- 1	1921	Taisho 10	Surveyed	30 Aug 1921
153-6- 2	1921	Taisho 10	Surveyed	30 Nov 1946
153-6- 3		Missing		
153-6- 4	1953	Showa 28	Updated	30 Apr 1962
153-6- 5	1972	Showa 47	Edited	28 Dec 1973
153-6- 6	1953	Showa 28	Updated	30 Nov 1954
153-6- 7	1978	Showa 53	Modified	30 Nov 1978
153-6- 8	1989	Heisei 1	Additions	1 Sep 1990
153-6- 9AB	1993	Heisei 5	Modified	1 Jul 1994

Land use depicted on Japanese topographic maps

An important characteristic of the GSI topographic maps is that some land uses are demarcated with linear boundaries while others are free labels. The land uses with line boundaries in the maps of Yakushima are rice paddy, dry field, orchard, villages, and some urban areas. These land uses entered the GIS as polygons. The free labels depict broad leaf forest, coniferous forest, wasteland, and some free-standing buildings. These labels are scattered throughout the maps outside of the land uses depicted as polygons. The labels can be used in GIS analysis as points, or they can be used to generate polygons estimating the areas of the two forest types and wasteland. Polygon boundaries were generated from Thiessen polygons based on label points of forests and wasteland as described above. No free-standing buildings were depicted in the 1921 map, and the free-standing buildings in the later maps were ignored for this analysis. Since the labels for forests or wasteland were often clustered, the Thiessen-based polygons depict zones of forest or wasteland. The under-500 m area of Yakushima comprises 45% of the island. All rice paddies, fields, orchards and villages existed in the under-500 m area in all three maps. Figures 1 and 2 show land use within the under-500 m area as depicted in the three topographic maps. The 1921 map depicts the same villages that exist today, although the village settlements appear to be confined to smaller areas. Only a single road is drawn into the 1921 map linking the villages. The map shows large fields and rice paddies around some of the larger villages, and small fields scattered along the coast. Otherwise, the 1921 map is devoid of detail compared to later maps. Wasteland labels, however, are found in many parts of the under-500 m area of the island in the 1921 map. The polygons generated from the wasteland labels cover large areas. Orchards did not exist at all in 1921 map. In the maps of 1972-73 and 1992, orchards are a prominent land use. Many orchards are located along the foothills of the mountains (Figure 2). The highest orchard reach an altitude of about 285 m.

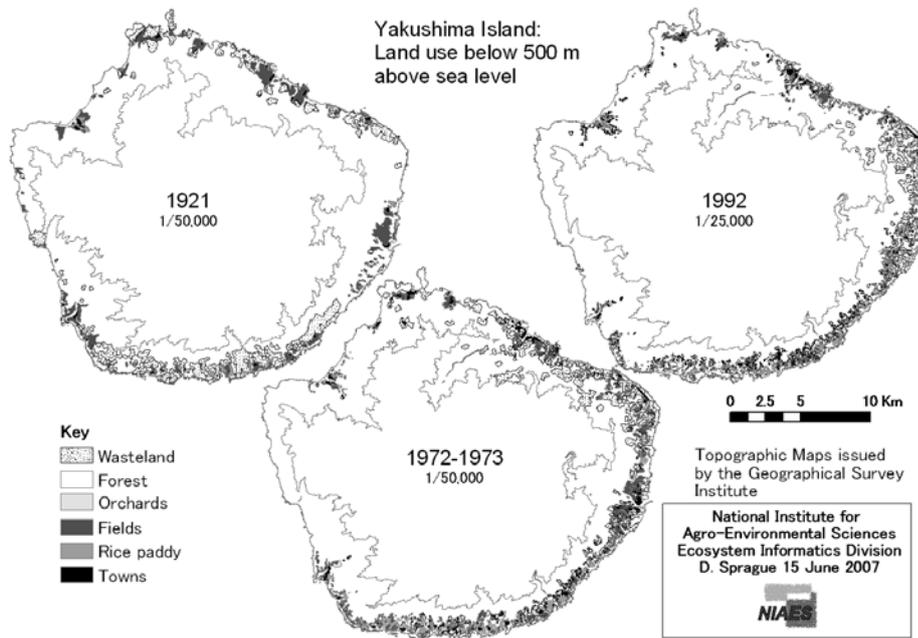


Figure 1. Land use below 500 m above sea level on Yakushima Island reconstructed from topographic maps of three periods.

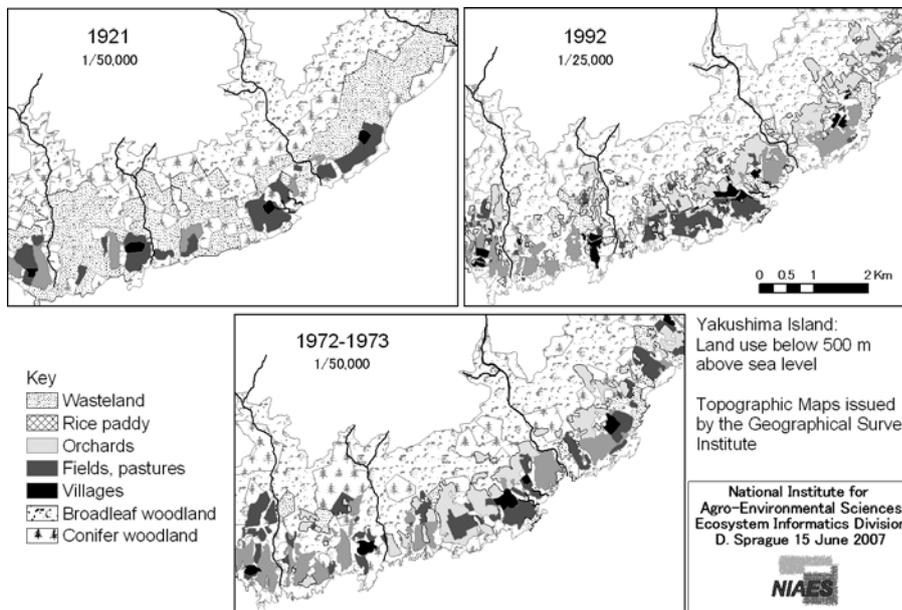


Figure 2. Detail of land use below 500 m above sea level on the southwest side of Yakushima Island reconstructed from topographic maps of three periods.

The proportions of land use depicted in the maps changed among the three periods (Figure 3). Wasteland area was highest in the 1921 map and subsequently declined. Nevertheless, wasteland continued to be the largest land use type, excluding forests, in the area under-500 m in all three periods. Rice paddy and field areas were highest in the 1972-73 map and declined in the 1992 map. Orchards, which did not

exist in the 1921 map, appeared from the 1972-73 map, and increased in area in the 1992 map. Villages and urban areas increased steadily from the earliest to the latest map, although urban area is slightly underestimated in the later periods since the free-standing buildings are ignored in this analysis.

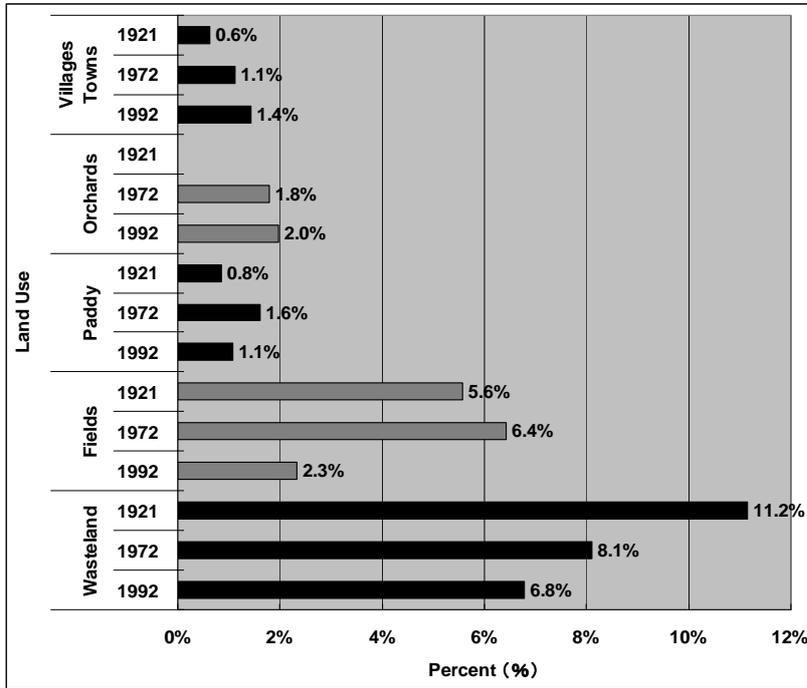


Figure 3. Land use change below 500 m above sea level in Yakushima Island as reconstructed from topographic maps of three periods

Altitude distribution of wasteland

The 1921 map contained 430 wasteland label points. The wasteland point farthest inland was located 2,015 m from the coast. The altitude distribution of the wasteland points showed that a large proportion were distributed at fairly low altitudes, with 90% located under about 200 m. However, the highest wasteland point was located at 459.6 m above sea level (Figure 4).

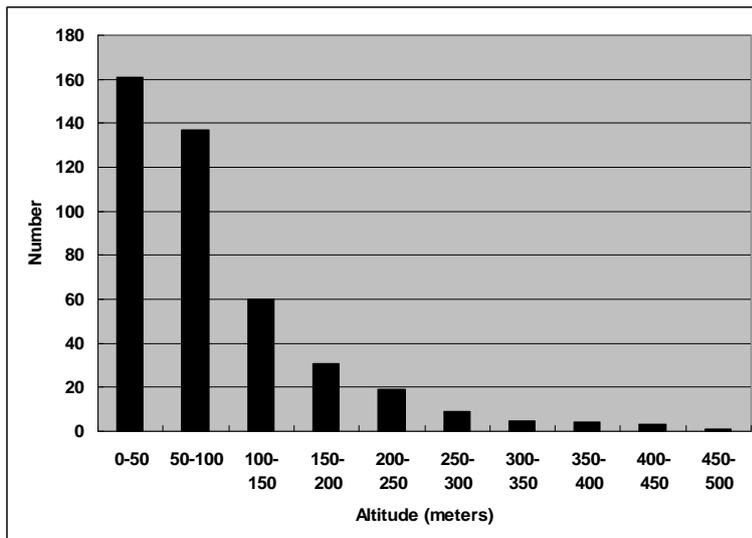


Figure 4. Altitudinal distribution of wasteland labels on 1921 topographic map of Yakushima Island.

Source land uses of orchards

The central research question of this project is whether modern land uses, especially orchards, can be considered an expansion of intensive human activity over a larger area compared to historical land uses. The expansion hypothesis would be supported if land uses in later maps tended to be located in what had been forests in earlier maps. A land use change hypothesis is supported if some type of land use besides forestry had been taking place in a particular location in both earlier and later maps.

The maps reveal that the orchards were cleared in the same area and altitude generally as wastelands (Figures 1 and 2). The overlay analysis provides a more precise, quantitative measure of the overlap between orchards and past wastelands (Table 2). Wasteland in the 1921 map was the source land use for 42% of orchards in the 1972-73 map, and 36.8% in the 1992 map. Other past land uses in 1921 made way for orchards in later periods. In the 1972-73 map, 6.8% of orchards existed in former fields or rice paddy, and in the 1992 map, 19.2% of the orchards existed in former fields or rice paddy. It is important to point out, however, that about 50% of orchards in 1972, and 43% of orchards in 1992, were located in areas depicted as some type of forest in 1921.

Table 2. Source land use in the 1921 topographic map of orchards in the maps of 1972-73 and 1992 after overlay analysis.

Source land use:	Land use in:		
	1921	1972	1992
		Orchard	Orchard
1 Wasteland		42.8%	36.8%
2 Broadleaf		21.3%	14.4%
3 Conifer		29.1%	28.5%
4 Fields		6.1%	15.7%
5 Wet paddy		0.0%	0.0%
6 Dry paddy		0.7%	3.5%
7 Villages		0.0%	1.1%
Total		100.0%	100.0%

Discussion

No geographical study on Yakushima, or in any other part of Japan, would be complete without an examination of topographic maps, and they provide the initial data for further detailed research. Wasteland accounted for a large proportion of land in the under-500 m area of the island, implying that some sort of human activity had prevented these areas from succeeding naturally to forest. Although fields and rice paddies were confined to a smaller area in the 1921 map compared to later maps, the large wastelands suggest that human subsistence activity had extended more broadly throughout the lower altitude regions of Yakushima compared to the extent of permanent fields or villages. Wasteland could extend quite far uphill,

up to nearly 500 m above sea level.

Wasteland depicted on topographic maps may have been produced by a variety of human activities. Wasteland may have been grasslands that farmers maintained by repeated cutting or firing. Under traditional Japanese agriculture, farmers obtained natural resources locally to support their livelihoods, such as green fertilizer, fodder, firewood, or charcoal. On Yakushima, the town histories refer to the practice of swidden agriculture around villages, the importance of charcoal production, and some pasturing of horses (Yaku Township, 1994).

Orchard expansion can give a present-day observer the impression that human activity in general had been expanding. Orchards are a modern form of agriculture. The first orange plants were introduced to the island in 1924 (Yaku Township, 1994). Orchards are absent from the 1921 map but appear from the 1972-73 map. Orchard area has expanded, and often expanded upwards to become the fields located at the highest altitudes among all forms of agriculture. Orchard expansion in some places was accompanied by the expansion of road networks uphill. Mature forests surround many orchards today (Sprague, 2007).

However, the GIS overlay analysis found that a large proportion of the orchards had been built in former wasteland or former fields. The 1921 topographic map shows large areas of wasteland. The altitudinal distribution of orchards generally matches that of wasteland. The highest orchards in the 1992 map reached 285 m. Although 90% of the wasteland labels were located less than 200 m, wasteland labels were located as high as 460 m above sea level. These data lend support to the hypothesis that the orchards were expanded into altitudes that had historically been under the influence of the subsistence activities of the residents of Yakushima.

Some orchards were built in areas that had been labeled as forest in the 1921 map. The topographic maps do not provide sufficient details about forests to judge whether these forests were primary or secondary forests. However, it is reasonable to assume that many of these forests were secondary forests or tree plantations. These forests were within the same altitudinal zone as orchards and wasteland, and the residents of Yakushima were known to have harvested forest resources, such as charcoal or firewood. In addition, natural conifer at low altitudes is unusual in Yakushima, although this island is famous for natural, old-growth cedar forests at higher altitudes (Miyawaki, 1986). The low altitude conifers may have been pines, which were very common in rural Japan under traditional agriculture. Thus, the orchard expansion in forest perhaps can be considered a type of land use change rather than the expansion of human influence into previously pristine natural environments.

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