A Quantitative Study of Wild Food Resources : An Example from Hida

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In this paper an attempt is made to reconstruct the size of the prehistoric foraging population in a given area, based on the quantity of available foodstuffs. In present-day Japan, however, such an effort faces severe difficulties, since the natural environment has been modified extensively by intense and widespread urbanization and industrial development.
To overcome such problems, I used *Hidagofudoki* (A New Geographical Description and Local History of Hida, compiled in 1874) which contains a detailed record of products (45% of which are foodstuffs) for all 415 villages that existed in the Hida region in the mid-nineteenth century.
Hida is an old administrative unit covering 3280 km^2 of the mountainous region of central Japan. In the mid-nineteenth century Japan was a well-advanced and self-sustained country, with rice playing the most important role as the subsistence base as well as being a monetary unit. But in Hida, because of its mountainous topography, rice production was restricted and a wide range of wild foodstuffs was used by its inhabitants to meet their caloric needs. Thus the situation in Hida, with its mountain lifeways, and the compilation of *Hidagofudoki*, can be used as a baseline to reconstruct the demographic and population characteristics of prehistoric foragers.
In this study, the relationship between food products and population size in *Hidagofudoki* was first analyzed. Then the potential product yields of important wild foodstuffs were estimated in terms of principal ecological zones of the area, to calculate the maximum supporting population. Finally the derived data were compared with and adjusted to the number and distribution of Middle Jomon sites (when the largest population during the prehistoric foraging stage is assumed for this region). [Hida, Middle Jomon, Mountain Adaptation, Population, Rice, Wild Foodstuffs]

INTRODUCTION

Although the population size of a given area is largely determined by the quantity of available foodstuffs, the precise nature of the relationship between the two is generally vague. Such vagueness is especially typical of prehistoric foraging societies in general.

Elsewhere I have listed possible staple foodstuffs available in the environment in order to estimate the population of the Jomon period of Japan [KOYAMA 1978].

But the quantification of these resources remains only approximate and relative (i.e., abundant-medium-scarce). This kind of estimation can theoretically be made more accurate by studying contemporary food resource yields, but this kind of research makes little sense in Japan owing to man's extensive and intensive modification of the natural environment. We have tried to overcome this problem by attempting to reconstruct a pre-modern environment and its food resources in the Hida district of the Central Mountain area. If it is possible to quantify the probable production of the foodstuffs under such circumstances, then the estimation of the potential yield of natural food resources will be much easier. The impetus for this project derived in large part from the availability of the *Hidagofudoki* (A New Geographical Description and Local History of Hida), compiled by Ayahiko Tomita and published in 1874. This book contains highly detailed records on the various economic products of the district during the mid-nineteenth century.

THE HIDA REGION AND *HIDAGOFUDOKI*

The mid-nineteenth century was a tumultuous period in modern Japanese history. The nation opened its ports to foreign shipping in 1854, after two hundred years of isolation, and in 1868 the Meiji Restoration transferred government power from the Shogun to the Emperor. The new government centralized the administrative system by adjusting the old Daimyo's local and hereditary territories into the prefectures of today, and dispatched officials from Tokyo as their governors.

Because of this large-scale national reorganization, a re-evaluation of resources was conducted in many prefectures so that tax systems could be consolidated. The vigorous pursuit of economic modernization through industrialization and international trade dominated national development by the late 1880's, resulting in the transformation of many local economies that hitherto had retained a self-sufficient structure based mainly on the natural resources available in their own territories.

Although privately published, *Hidagofudoki* began as a prefectural resource inventory project in the Hida district. In 1869, the newly appointed governor, D. Miyahara, requested Tomita to make an inventory of Hida. The governor ordered each village head to list all available records (old geneologies, archives, antiquities, famous sites, ancient tombs, shrines, temples, village histories, pastures, crops, trees, wild products and animals), for presentation to his office. The project was completed by 1870, and the inventory was prepared [TOMITA 1964, 1965]. *Hidagofudoki* was compiled based on this inventory and probably supplemented with old taxation records from the prefectural office (because the quantity of products and various demographic data are not documented in the inventory). The quality of data in *Hidagofudoki* is high and amply documents the pre-modern economy of Hida.

Hida is located in the northern part of present-day Gifu Prefecture, but from the seventh century until 1876 it was an independent administrative unit. Today it is divided into Ono, Yoshiki, and Mashita counties, which occupy, respectively, the headwaters of the rivers Sho, Jintsu, and Kiso (Fig. 1). The Sho and Jintsu Rivers

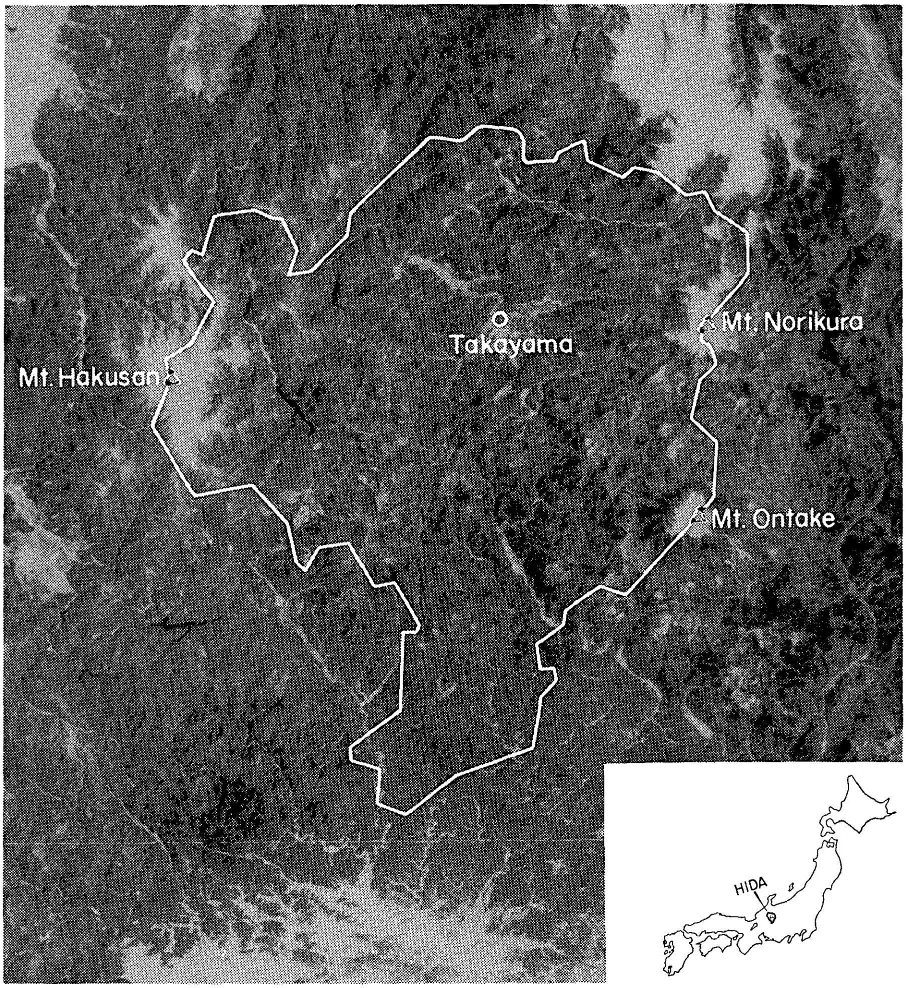

Fig. 1. Topography, hydrology and land use in present-day Hida.

flow to the Sea of Japan and the Kiso flows to the Pacific Ocean. Located on the slopes of the high mountains of the Chubu area of central Honshu, Hida is a rugged and high altitude district that experiences heavy winter snowfalls, particularly in Ono and Yoshiki counties, which face the Sea of Japan. Rice production (the subsistence mainstay in most other areas) was severely restricted by the topographical and climatic conditions of Hida, and its population survived instead on the products of slash-and-burn cultivation, gathering, river fishing, and hunting. The Hida subsistence system was varied and complex, retaining many elements of foraging.

Methodology

The *Hidagofudoki* includes 415 villages and more than 400 economic products, and these data were converted into a computer readable format to produce a village product database. The program was then refined by S. Sugita so that village-product information includes agricultural commodities, fruits, textiles and their raw materials, mammals, birds, edible wild plants, timber, craft products, minerals, and other items [KOYAMA *et al.* 1981]. Data on foodstuffs, especially agricultural products, are those most commonly and precisely recorded in quantitative terms.

The relationship between population size and main foodstuffs was calculated; the quantities of products are the sums of all village records. Grains are given by volume, converted to metric tons. Mammals, birds, and fish are given by either number of individuals or by gross weight, which was also metricized by multiplying by the average established body weight. The figures were then converted to caloric values, which in turn were divided by a constant 730,000, i.e., the caloric value required to sustain an individual person at 2000 Cal/day/yr (Table 1).

Using these selected foods, the calculated population size is 66,292, or 70 percent of the total population recorded in the *Hidagofudoki*. This suggests that Hida was not self-sufficient in staple foodstuffs during this period: according to *Hidagofudoki*, some 3,000 t of rice and millet together with salt and other products were imported from the adjacent Shinano, Mino, and Ecchu districts. The quantity of food imported is enough to support a calculated population of 14,000. When this figure is added to the calculated population it indicates that 86 percent of the recorded population can be supported by the foods listed, a figure which can be verified from *Hidagofudoki* records. Ninety-six percent of the calculated population is supported by agricultural products, of which rice (53%) and barnyard millet (23%) are the basic subsistence products.

Cross-checking of the production records reveals two types of villages; one in which rice is dominant (rice-type) and another in which millet dominates (millet-type). The distribution and quantity of wild food resources are largely determined by ecological conditions, especially by vegetation zones. Gathering, hunting, and fishing, although generally minor in caloric contributions, are of greater importance in the millet-type villages.

The following methodology was used to reveal the characteristics of the subsistence economy of Hida villages during the mid-nineteenth century. The entire area was superimposed on a rectangular grid system derived by dividing each topographical map (1/50,000 scale) into tracts of 4 km^2. Villages are identified on the map in a tract. The following important food resources are selected: grains (rice and barnyard millet), roots (brackenroot and arrowroot), nuts (chestnut, buckeye, acorn), mammals (bear, wild boar, antelope, deer), birds (pheasant) and fish (charr and dace). The values are summed when more than one village occurs in a single tract. A tract is given a value from 1 to 7 according to its average elevation above sea level, which nicely correlates with the vegetation zones (Table 2 and Fig. 2). Data were processed on an IBM-370 computer at the National Museum of Ethnology, and SPSS programs were used for statistical analyses. The population of Hida is summarized in Table 3, using these coded zones. Table 4 reveals the population structure. These statistics reflect the general condition relatively well, although

Table 1. Food resources and population in the Hida area.

Food Resources	weight (t)	caloric value (10^6)	supporting population	(%)
Grains				
rice (*Oryza sativa japonica*)	7,611	25,648	35,134	53.0
barnyard millet (*Echinochloa frumentacea*)	3,562	10,970	15,027	22.7
barley (*Hordeum vulgarel.* var. *hexastichon*)	1,103	3,697	5,064	7.6
wheat (*Triticum aestivum*)	404	1,325	1,815	2.7
broomcorn millet (*Panicum miliaceum*)	145	433	593	0.9
foxtail millet (*Setaria italica*)	168	515	705	1.1
buckwheat (*Fagopyrum esculentum*)	150	521	714	1.1
Beans				
soybean (*Glycine max*)	658	2,580	3,534	5.3
azuki bean (*Phaseolus angularis*)	91	296	405	0.6
Roots				
potato, Irish (*Solanum tuberosum*)	473	364	497	0.8
potato, sweet (*Ipomoea batatas*)	2	3	4	—
arrowroots (*Pueraria lobata*)	4	15	21	—
brackenroots (*Pteridum aquilinum* var. *latiucylum*)	15	49	67	0.1
Nuts				
chestnut (*Castanea crenata*)	61	110	151	0.2
buckeye (*Aesculus turbinata*)	240	841	1,152	1.7
acorn (*Quercus mongolica* var. *grosseserata*)	180	584	800	1.2
Fish (total)	350	350	479	0.7
Mammals				
bear (*Selenarctos thibetanus*)	1	2	2	—
wild boar (*Sus scrofa*)	47	69	95	0.1
antelope (*Capricornis crispus*)	3	4	5	—
deer (*Cervus nippon*)	13	18	24	—
Bird				
pheasant (*Phasianus colchicus*)	1	1	2	—
copper pheasant (*Phasianus soemmerringii*)	2	2	2	—
Total	15,284	48,397	66,292	

Note: missing values are supplied with means.

Table 2. Relationship among tracts and natural vegetation zones.

Zone	Altitude	Dominant Tree	Vegetation Region
1	LT. 400	*Quercus serrata*	*Fagus-Quercus*
2	400–800	*Castanea crenata*	
3	800	*Castanea crenata*	
4	800–1000	*C. crenata* & *Q. mongolica* var. *grosseserata*	
5	1000	*Q. mongolica* var. *grosseserata*	
6	1000–2000	*Fagus crenata*	
7	GT. 2000		*Vaccinium-Picea*

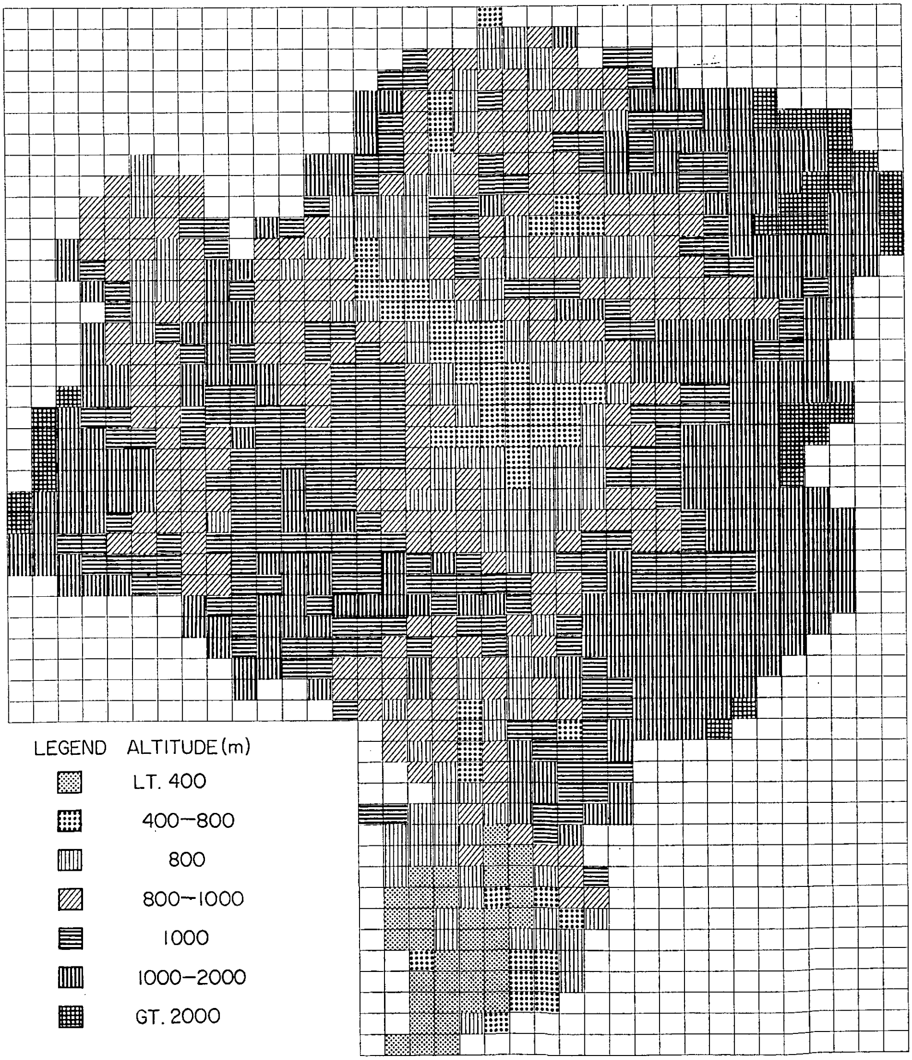

Fig. 2. Zonation of the Hida area by altitude.

Table 3. Population of Hida altitude zones.

Zone	Area Size (km²)	Number of Tracts	Number of Tracts Occupied	Population	Person/km²
1	144	36	14(38.8%)	5,019	34.9
2	232	58	48(82.8%)	41,245	177.8
3	564	141	89(63.1%)	26,736	47.4
4	924	231	68(29.4%)	13,249	14.3
5	880	220	30(13.6%)	5,971	6.8
6	1,136	284	8(2.8%)	11,170	1.0
7	140	35	0(0.0%)	0	0
Total	4,020	1,005	257	93,390	23.2

Table 4. Mean and standard deviation of population by altitude.

Zone Code	Mean	S. D.	N (Number of Tracts Populated)
1	358	330	14
2	859	1,628	48
3	300	276	89
4	194	149	68
5	199	134	30
6	146	126	8
7	0	0	257
Total	363	765	514

standard deviations are inflated: the higher the altitude, the poorer the resource base, which is, in turn, reflected in a decreasing average population size as altitude increases. The unusually large population size (and especially the greatly inflated standard deviation) in Zone 2 reflects urbanization, for even in this period there was a large non-agricultural population in Hida. For example, the tract that includes the present city of Takayama, the county seat at that time, had a population of 11,190, but no record of staple food production. The impact of urbanization may also distort other statistics for Hida, particularly in Zone 2, around this Takayama tract. Zone 7, which is a barren, alpine vegetation area, is excluded in the following statistical procedures.

PRODUCTIVITY OF FOOD RESOURCES IN THE MID-NINETEENTH CENTURY

Agricultural Products

Rice and barnyard millet, which supported about 75 percent of the population, were the most important staple foodstuffs in nineteenth century Hida. Each one of the 275 populated tracts yielded barnyard millet but only 82 percent (212) yielded rice; many tracts produced both crops and a few (37) produced barnyard millet alone. But there are no rice-only tracts, a consequence of the temperature-sensitive nature of rice. Rice does not grow well in cold zones or where the topography is strongly adverse; rice is produced mainly on paddy-fields in flat areas where it is possible to establish extensive irrigation systems. The most productive rice area in Hida is Zone 2, where both gross and mean yields are much higher than in other zones. Zone 2 is warm enough for rice and has a large area of flat land in the Takayama Basin. The mean yield per km^2 decreases significantly with increasing altitude. The relatively low yield of the warmer Zone 1 is a consequence of the mountainous topography of Mashita county.

Barnyard millet tolerates a much wider range of environmental conditions than does rice. The gross production is largest in Zone 3 but the mean yield is larger in Zone 2. The mean yield is also relatively constant for all zones. This tolerance probably explains why barnyard millet was the basic staple food in Hida. The productivity of rice declines during cold summers, for instance, whereas barnyard millet can easily maintain average yields. Yet, it is important to bear in mind that rice was a key currency during this period, giving it an important economic value in addition to its role as a staple foodstuff. Once a system of rice production was established, therefore, production frequently tended to increase at the expense of other products and to skew the distribution of yields. Under such circumstances, the rice-type villages were increasingly forced into the monetary economy of the period by specializing in rice production and other cash crops. Rice cultivation, therefore, involved external factors closely correlated with urbanization.

The life-style (especially the attitude toward exploiting natural food resources) is expected to vary considerably between the two types of villages. The two types of tracts are defined by the difference in yields of rice and millet as follows:

$$\text{Rice type} = (\text{rice}) - (\text{millet}) > 0$$
$$\text{Millet type} = (\text{rice}) - (\text{millet}) < 0$$

There are 96 rice-type tracts and 154 millet-type tracts. Using this code the yield of natural food resources is analyzed in Table 5. It is clear that millet-type tracts always have a greater yield of wild food resources, or depend more on wild food resources, than do rice-type tracts.

Non-Agricultural Food Resources

NUTS

Nuts played the most important role among wild food resources in Hida, and this role seems to have been constant since the prehistoric period. The nuts recorded in *Hidagofudoki* are chestnut, buckeye, acorn, walnut, hazelnut, and Japanese nutmeg, the first three of which were the most important. The record of walnut production is conspicuously low in *Hidagofudoki*, despite its present-day importance and the fairly

Table 5. A. Food resources per tract: rice and millet type.

	Rice type	Millet type
Brackenroots	0	86. 4 kg
Arrowroots	18. 4 kg	172. 8
Chestnuts	45. 0	30. 0
Buckeyes	30. 8	30. 8
Acorn	15. 4	30. 8
Charr	1. 7	8. 1
Dace	1032. 8	585. 7
Bear	0 ind.	0. 5 ind.
Antelope	0	0. 4
Deer	0. 4	0. 4
Wild boar	0. 4	1. 0
Pheasant	3. 3	2. 1

B. Number of tracts by altitudinal zones: rice and millet type.

Zone	Rice type	Millet type
1	11	3
2	39	9
3	38	51
4	8	60
5	0	30
6	0	8
	96	161

dense distribution of the species. Hazelnut and Japanese nutmeg are almost negligible in quantity and distribution.

Chestnuts, the most commonly exploited nut, are reported for 66 percent of the tracts. Domestication and semi-domestication of chestnuts is common in modern Hida villages, probably owing to the inherent tastiness and palatability of this nut. Chestnuts are often recorded as involved with commerce or processed for preservation (dried, pounded and roasted). Their distribution is limited to Zones 2–5, i.e., the chestnut belt of central Japan. Productivity is highest in Zone 3.

Buckeye became an important staple food in the Final stage of the Jomon period [KOYAMA 1978: 26], and remains so in many mountain villages, despite the heavy processing required to remove the poisonous saponin [MATSUYAMA 1977]. The yield and distribution of buckeye coincides roughly with that of chestnuts.

Many species of acorns are found in the Hida district, mainly from trees of the genus *Quercus*. But judging from the modern floristic composition, the most important was *Q. mongolica* var. *grosseserata*. Yields are greatest in Zone 4.

An interesting aspect of nut-gathering is the clear tendency to exploit more than two species (76% of the villages). Chestnuts are the only exception, with 23 percent of the villages recording only chestnut [MATSUYAMA 1979]. In addition, the relationship between chestnut and acorn is somewhat similar to that between rice and barnyard millet; one is high in economic value but vulnerable to blight, insect, or weather damage, whereas the other remained as a subsistence product and survived owing to its variable range.

ROOT CROPS

Root crops often play an important role in a gathering economy, but so far there is no concrete evidence for their role in prehistoric Japan. Dogtooth violet, wild yam, brackenroot, and arrowroot are recorded in the *Hidagofudoki*, but the first two are small in quantity and limited in distribution.

Arrowroot and brackenroot were fairly widely utilized. Brackenroot is concentrated in high altitude zones where its exploitation was extensive. Arrowroot production is recorded in Zones 3 and 4, but the quantity is far less than that of brackenroot. The method of extracting the starch of these two plants is almost identical (the same is true for the acorns and buckeye). The roots are pounded and the starch extracted in water. However, the distribution of tracts which yield them varies sharply, despite little significant difference in natural distribution between the two species, although arrowroot tends to grow in warmer zones than does brackenroot.

All the tracts yielding brackenroot are of the millet-type (22 tracts): 60 percent of these produced no rice. This tendency is also observed in arrowroot tracts (80% of which are of the millet-type). There is also a diverging relationship between brackenroot and nuts: a large percentage of brackenroot starch-producing villages (63%) did not produce nuts. This tendency is not apparent for the arrowroot-yielding tracts. Brackenroot production occurred mainly in a group of villages in mountainous Mashita county (Fig. 3) where the product was used as an efficient commercial crop rather than as a staple food. The value of brackenroot almost equalled that of rice in nineteenth-century Hida.

GAME

Hida was one of the few regions of Japan during this period where hunting was an important subsistence activity. Animals are listed among the important products of Shinano, Echigo, Iwami, Hyuga, and Hokkaido in *Nihon Sanbutsushi* ("A Record of Products in Japan", published in 1874 [see YUKAI and SAITO 1979]); however, the yield was low and far from being sufficient as a staple food. Most of the indigenous middle- to large-size mammals (such as bear, antelope, wild boar, deer, rabbit, monkey fox, and badger) are recorded, but most show low yields and have a limited geographical distribution.

The minor importance of hunting probably resulted from the Buddhist taboo on killing animals. The imperial edict prohibiting the killing of animals had been invoked repeatedly since the eighth century, and priests continually inveighed against

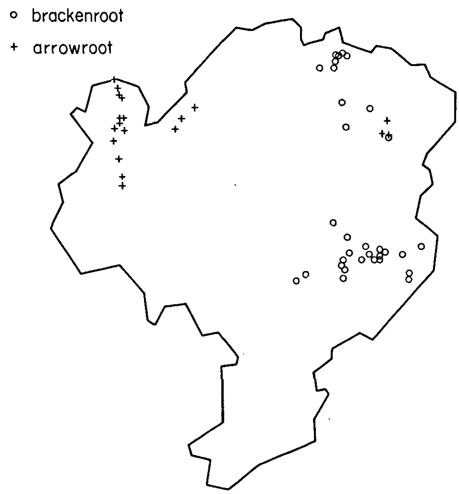

Fig. 3. Hida villages that produced brackenroot and arrowroot.

the killing of animals. Consequently, the Japanese gradually lost the habit of eating mammal meat (particularly in urban areas), and professional hunters (*matagi*) often suffered from social discrimination.

The distribution of game yields closely reflects the distribution of available fauna in the area. Bears (*mode* at 4) and antelope (*mode* at 5) are recorded in the high altitude zones. The ranges of deer and boar are wide, but the largest yield is at Zone 3. This distribution coincides with the accepted theory of mammal distribution of Japan [CHIBA 1969], except that the range of boar is significantly larger and the distribution of deer is lower in altitude than boar. The low level of hunting activity is revealed in *Hidagofudoki* by the yield of bear, which totals only eight individuals. According to statistics (Table 6), from 1971–1977 more than 100 bears were killed annually, despite strong animal protection laws, such as restricted hunting seasons and areal limitation, and despite the decreasing size of their habitat as a consequence of intensive deforestation. Modern firearm technology does not entirely explain this

Table 6. Game yield in present-day Hida.*

	Pheasant	Copper pheasant	Other birds	Bear	Boar	Rabbit	Others
1971	633	1,496	8,979	139	27	3,883	527
1972	2,048	9,565	6,114	129	71	3,983	189
1973	2,115	9,464	7,737	145	177	5,761	281
1974	2,381	8,534	5,441	145	57	4,707	373
1975	1,810	5,452	6,012	138	61	4,110	354
1976	1,137	3,410	5,691	131	47	3,502	277
1977	1,484	5,263	4,897	194	124	2,822	283

* Data from the Dept. of Forestry; Hida branch, Gifu Prefectural Office

difference. Antelopes are today protected by law, so no hunting-yield data are available for comparison. Deer is virtually absent in present-day Hida, perhaps as a consequence of hunting-out in the past century. By contrast, wild boar have maintained past yield levels despite a decreasing animal population. Deer and wild boar have always threatened agricultural crops because their habitat conflicts with that of man. This may explain why deer and boar hunting was relatively popular, the motive being to protect crops. Game products were used to manufacture goods and for folk medicine.

Bird hunting, on the other hand, was much more popular, probably because the Japanese do not classify birds as animals. The yields of pheasants and copper pheasants were almost as high as those of today and were recorded in many tracts (pheasant and copper pheasant 43%). Skylark, jay, rufous turtle dove, wild geese, marmaring duck, and unspecified small birds are recorded in *Hidagofudoki*. The variety of ways in which birds are taken is also recorded.

Deer, boar, and birds share a common hunting zone in the peripheral area of the community. The attitude toward hunting was passive, people being farmers before hunters. Horses and cattle were the only domestic animals listed in *Hidagofudoki*, but they were mostly used for transportation or for draft purposes. Chickens and other fowl are conspicuously absent in the record.

FISH

Fish was the main source of animal protein in traditional Japan, and fish exploitation was popular and intensive in Hida during this period. Since Hida lacked a coastline, fishing was confined to freshwaters, and particularly to rivers. The technology of fishing was sophisticated, and the methods, which vary according to species, included dams, weirs, various kinds of nets, lines, and other techniques.

Dace (*Leuciscus hakonensis*) and trout (*Salmo* spp.) constitute 98 percent of the yield. The distribution of fish is ecologically determined by altitude or river order [AKIMICHI 1979, and this volume]. In the upper streams, charr (*Salvelinus leucomaenis*) was important, at the middle levels it was *ayu* (*Plecoglossus altivelis*), whereas trout and dace dominated in the lower courses. The intensity of fishing activity varied at each part of the river system. The cumulative percentage graph of total fish yield in the four rivers [cf. AKIMICHI, this volume] shows that except for the Miya River the line ascends at a relatively constant interval, indicating that exploitation correlates with the biomass of the fish. A sharp increase between 400 m and 500 m indicates extremely intensified fishing activity in the suburban area of Takayama city.

PATTERN OF EXPLOITING WILD FOOD RESOURCES

Gathering, fishing, and hunting were popular activities in mid-nineteenth century Hida, although their combined nutritional contribution was not significant. How can these three activities be combined into a subsistence strategy? The following code for the analysis of the pattern was made for each tract:

$$
\begin{aligned}
p = & 100\times(1=\text{gathering recorded}, && 0=\text{not recorded})\\
& +10\times(1=\text{fishing recorded}, && 0=\text{not recorded})\\
& +\ 1\times(1=\text{hunting recorded}, && 0=\text{not recorded})
\end{aligned}
$$

A total of 268 populated tracts are tabulated by this code (Table 7).

Table 7. Number of tracts by food procurement strategy. (gathering=G, fishing=F, and hunting=H.)

Code	Number of Tracts	%
G F H		
0 0 0	27	10.5
0 0 1	9	3.5
0 1 0	11	4.3
0 1 1	14	5.4
1 0 0	55	21.4
1 0 1	32	12.5
1 1 0	31	12.1
1 1 1	78	30.4

Eighty-nine percent of the tracts practiced one or more activities, which indicates that the utilization of wild food resources was important in Hida during the nineteenth century. Tracts where all activities are practiced (111) are the most common, followed by gathering only (100). As a single practice gathering is most frequent (196 tracts, 76%), whereas fishing (134 tracts, 52%) and hunting (133 tracts, 52%) are about equal in a lesser number of tracts (Table 7). The importance of gathering nuts and roots among natural food resources is clearly demonstrated.

CLUSTERING FOODSTUFFS

The foodstuffs obtained by hunting, fishing, and gathering tend to cluster according to altitudinal zone. The combination of particular foodstuffs, where they contribute a large portion of caloric supply, could be strong determinants to the lifeways as well as the population size of an area. The following method was used to reveal such clusters quantitatively. First, 14 representative samples of important foodstuffs were selected and their individual yields summed up according to altitudinal zone (Table 8). These data were then changed to rank order value (1–6: Zone 7 was deleted) by zones for each item, and correlation coefficients for all combinations among items were calculated using the Spearman rank correlation:

$$r_S = 1 - \frac{6\sum_{i=1}^{N} d_i^2}{N^3 - N}$$

Table 8. Sum of product yield and rank order by altitudinal zone.

Zone	Population	Bear	Antelope	Deer	Boar	Pheasant	Arrow-root	Bracken-root	Rice	Barnyard millet	Chestnut	Buckeye	Acorn	Charr	Dace
1	5.019	0	0	19	4	28	0	0	2, 311	775	0	41	0	0	467
2	41.245	0	0	9	8	155	0	0	28, 701	5, 351	496	3, 207	304	400	5, 614
3	26, 736	0	0	46	66	246	299	12	12, 613	10, 765	1, 533	1, 355	836	1, 180	526
4	13.249	6	16	28	38	53	113	98	2, 496	8, 017	1, 178	102	1, 844	4, 876	48
5	5.971	0	44	7	50	101	0	934	547	4, 702	8	0	71	908	0
6	1, 170	2	0	1	15	13	0	216	0	518	0	0	25	176	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(RANK ORDER)															
1	5	4.5	4.5	3	6	5	4.5	5.5	4	5	5.5	4	6	6	3
2	1	4.5	4.5	4	5	2	4.5	5.5	1	3	3	1	3	4	1
3	2	4.5	4.5	1	1	1	1	4	2	1	1	2	2	2	2
4	3	1	2	2	3	4	2	3	3	2	2	3	1	1	4
5	4	4.5	1	5	2	3	4.5	1	5	4	4	5.5	4	3	5.5
6	6	2	4.5	6	4	6	4.5	2	6	6	5.5	5.5	5	5	5.5

Where N=number of categories
d=difference of rank value.

The table of correlation coefficients (Table 9) thus produced was then used for the cluster analysis program (Complete Linkage Clustering) developed by S. Miyamoto [OIKAWA, MIYAMOTO, and KOYAMA 1980] at the University of Tsukuba Scientific Data Processing Center.

The results reveal three distinct clusters (Fig. 4). (1) Buckeye, dace, and deer; (2) acorn, chestnut, arrowroot, boar, pheasant and charr; and (3) brackenroot, bear, and antelope (Table 10). Cluster 1 is mainly composed of foodstuffs which attain their maximum yields in Zones 2 and 3; cluster 2 in Zones 3 and 4; and cluster 3 in Zones 4 and 5. These clusters clearly represent three distinct altitudinal zones (low, middle, and high). It is also noteworthy that each cluster always contains both animal (protein) and plant (carbohydrate) foodstuffs. Among the listed foodstuffs, rice and barnyard millet are cultivated plants which eventually became the main source of caloric supply of the nineteenth-century Hida population. However, Japanese archaeologists generally agree that, at the earliest, rice was introduced to this area 2,000 years ago, i.e., sometime during the Middle Yayoi period. Barnyard millet is generally considered to have been introduced at about the same time as rice, or perhaps slightly later [SATO 1971]. On the other hand, despite a lack of the excavated evidence, some archaeologists assume that millet had been cultivated during the Middle Jomon period, i.e., approximately 4,000 B.P., in the mountainous region of central Japan [FUJIMORI 1970]. If these cultivated plants are absent in the Hida region, how can a reconstruction be made of subsistence activity and population size?

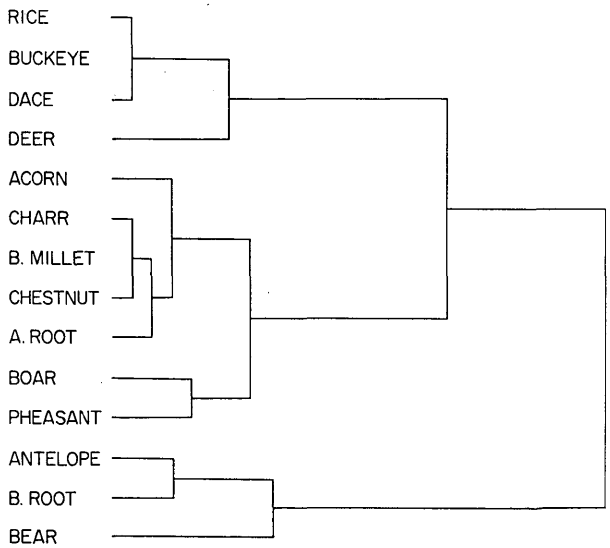

Fig. 4. Dendrogram of Hida wild foodstuft combinations.

Table 9. Correlation coefficients between food items.

	Bear	Antelope	Deer	Wild boar	Pheasant	Arrow-root	Bracken-root	Rice	Barnyard millet	Chestnut	Buckeye	Acorn	Charr	Dace
Bear	—													
Antelope	0.44	—												
Deer	0.09	0.06	—											
Wild boar	0.17	0.51	0.31	—										
Pheasant	−0.31	0.17	0.54	0.71	—									
Arrowroot	0.44	0.30	0.86	0.71	0.57	—								
Brackenroot	0.47	0.84	−0.44	0.59	−0.21	0.13	—							
Rice	−0.11	−0.09	0.65	0.03	0.77	0.51	−0.67	—						
Barnyard millet	0.09	0.26	0.83	0.60	0.83	0.86	−0.19	0.77	—					
Chestnut	0.17	0.27	0.76	0.67	0.81	0.87	−0.07	0.73	0.99	—				
Buckeye	−0.02	−0.17	0.64	−0.01	0.70	0.52	−0.69	0.99	0.73	0.70	—			
Acorn	0.42	0.40	0.60	0.60	0.60	0.80	0.07	0.60	0.88	0.92	0.59	—		
Charr	0.42	0.60	0.54	0.77	0.54	0.80	0.33	0.37	0.83	0.87	0.33	0.94	—	
Dace	−0.23	−0.31	0.59	−0.19	0.64	0.39	−0.83	0.92	0.56	0.54	0.94	0.30	0.04	—

Table 10. Prime altitudinal zones of selected foodstuffs.

Zone	Carbohydrates Grain	Carbohydrates Plant	Proteins Animal	Proteins Fish	
1	—	—	—	—	Cluster 1
2	rice	buckeye	—	dace	
3	barnyard millet	chestnut arrowroot	deer boar pheasant	—	Cluster 2
4	—	acorn	bear	charr	
5	—	brackenroot	antelope		Cluster 3
6	—	—	—	—	

PRODUCTIVITY OF FOOD RESOURCES DURING PREHISTORY: A RECONSTRUCTION

As an initial step in reconstructing the subsistence activities and population size of the foraging stage of Hida, the data on product yield from *Hidagofudoki* can be utilized. But quantitative data for yield are usually badly skewed or show great variance, since there exist some extremely high yielding tracts, especially for plants and fish, as well as many non-yielding tracts. Maximum and average records of product yields are shown in Table 11.

These figures could represent an output from a 4 km^2 tract during this period. The

Table 11. Average and maximum yield per food item in a single tract (kg).

	Maximum	Average
Rice	374, 814	27, 000
Barnyard millet	124, 488	14, 000
Arrowroot	1, 620	17
Brackenroot	2, 160	53
Chestnut	12, 150	4
Buckeye	12, 776	4
Acorn	12, 326	3
Charr	155	6
Dace	135, 600	758
Pheasant*	30	2. 4
Bear*	2	0. 03
Antelope*	20	0. 23
Wild boar*	20	0. 75
Deer*	15	0. 45

* unit=individual

maximum amount per tract may be important for the possible yield of gathered items, because community territories were well-defined and the range of gatherers was often limited to a minimum area, some 3 km in diameter [MATSUYAMA 1979]. The potential yield of wild food resources in Hida is, therefore, quite high. The energy input of a farming society, especially in hydraulic agriculture, is much larger than that of a hunter-gatherer society [HARRIS 1971]; consequently a percentage of the energy put into farming could be switched to the exploitation of wild food resources. Energy output in a foraging society could thus become large and it might not be difficult to attain almost the maximum energy recorded in nineteenth-century Hida for most of its tracts.

Cluster analysis of the wild foodstuffs suggests that there were three distinct subsistence-based groups during the foraging stage in Hida. Assuming discrete territories for each group, they were Group 1 (cluster 1) at the lower elevations (Zones 1 and 2), Group 2 (cluster 2) in the middle elevations (Zones 3 and 4), and Group 3 (cluster 3) at high elevations (Zones 5 and 6).

The size of hypothetical group territories is calculated from the above to be 376 km² (94 tracts) for Group 1, 1,488 km² (372 tracts) for Group 2, and 2,016 km² (504 tracts) for Group 3. Production levels and the human population sustained by dominant foodstuffs can also be calculated using maximum yield per tract within such hypothetical territories (Table 12). The population figures derived from maximum

Table 12. Population and product yield by most productive tract and adjusted figures.

	Max. Yield	Supporting Population	Adjusted. Yield	Supporting Population
Group **1** (Area: 376 km², 94 tracts)				
Buckeye	1, 262 t	6, 059	1, 262 t	6, 059
Deer	1, 479 ind.	197	789 ind.	105
Dace	13, 373 t	18, 320	166 t	228
		24, 576		6, 392
Group **2** (Area: 1,488 km², 372 tracts)				
Acorn	4, 576 t	20, 339	2, 288 t	10, 169
Chestnut	4, 538 t	11, 234	2, 269 t	5, 619
Arrowroot	595 t	3, 125	7 t	34
Boar	7, 440 ind.	2, 815	744 ind.	282
Pheasant	11, 160 ind.	20	11, 160 ind.	20
Charr	44 t	78	39 t	54
		34, 796		16, 178
Group **3** (Area: 2,016 km², 504 tracts)				
Brackenroot	1, 109 t	4, 954	26 t	116
Bear	1, 008 ind.	252	120 ind.	30
Antelope	10, 080 ind.	968	2, 822 ind.	271
		6, 174		417
Total		65, 546		22, 987

yield per tract are high—some 65,000 persons, or more than 50 percent of that of nineteenth-century Hida. The validity of this figure and adjustments to it are discussed below.

Nuts

Nuts supported nearly half of the total calculated population. Acorns were the most important of the nuts, supporting 20,339 persons per year, with a yield of 4,576 t. According to research conducted in a *Quercus acutissima* copse in Senri Expo Park garden, Osaka, acorn yield is 65t/km^2/yr [Koyama 1981]. Assuming the entire mid-elevation area supported a pure *Q. acutissima* forest, an acorn yield of 74,100 t can be expected. This figure is more than 16 times the calculated yields.

Although quantitative data for chestnut and buckeye yield are unavailable, similar amounts could well be expected. In the middle elevation area, however, acorn and chestnut are co-dominants so hypothetical yields should be reduced by 50 percent.

Root Crops

Roots sustained 12.3 percent of the calculated population. Among them, brackenroot was important as a major caloric supply in the high elevation area. Bracken is a common invader of open land after forest clearance. Because of its high economic value (equivalent to rice of same weight) brackenroot starch production was particularly intensive in some villages of nineteenth-century Hida. Nowadays, plots formerly used for collecting brackenroot around such villages are often in pasture, owing to the severe degradation of the original vegetation. Suppose we assume a yield of brackenroot starch as high as 2.2 t/km^2 during the foraging stage, suggested by the data in *Hidagofudoki* for all available land in the high elevation zones, then extensive areas of bracken and grass vegetation or secondary forest rather than original forest would be expected, but as yet there is no evidence to support such an assumption. That assumption would also govern game populations in such environments. Although quantitative data for the production rate of brackenroot are not available, the best estimate, an average yield of 0.05 t/km^2, is used instead of maximum yield.

The same kind of argument is valid also for the production of arrowroot starch, which could possibly correlate negatively with the production of acorn and chestnut in the middle elevation area. The adjusted estimate therefore becomes 116 persons (26 t) for brackenroot and 34 persons (7 t) for arrowroot as the figure for the population supported.

Fish

Fish, mostly dace, supported 27.9 percent of the calculated population. The use of maximum yield for dace, however, is problematical, since the extraordinarily high yield of dace is attributable to the suburban villages of Takayama and Furukawa, which provided the protein resources for urban dwellers. Thus, these villages seem to have exploited a wider area to sustain their economy, and were not limited to normal village territories. Akimichi [1979] calculated that the maximum yield of fish recorded in *Hidagofudoki* was 341 t, suggesting a biomass that would assure a stable annual yield of fish from the rivers of Hida. Because of this, the population supported by dace should be reduced to 228 persons (166 t) in the low elevation area, while 54 persons (39 t) were supported by charr and other fish in the middle elevation area.

GAME

The game yield was estimated to have supported 4,252 people, but this figure is also highly inflated, probably as a result of the difference of hunting range and assumed village territory. Modern data on game population density are used to correct this discrepancy in the estimate of game yield in Hida. Reported densities are: deer 10 ind./km² [MARUYAMA 1973], boar 2.5 ind./km² [CHIBA 1969], bear 0.3 ind./km² [AZUMA 1978] and antelope 7 ind./km² [MIZUNO 1976].

It has been observed that to maintain constant game populations and to ensure sustained annual hunting yields, maximum annual culling of deer should be limited to 18–20 percent of the total population [NISHIDA 1980]. The maximum yield of game may be obtained by multiplying the total population by 0.2 (Table 13).

These estimated figures naturally far exceed both those recorded in *Hidagofudoki*, when a taboo on killing animals existed, and modern statistics, compiled during a

Table 13. Estimated population and yield for game by altitude.

Elevation Area	Game	Population	Yield
Low	deer	3, 760	752
Middle	boar	3, 720	744
High	bear	605	120
High	antelope	14, 112	2, 822

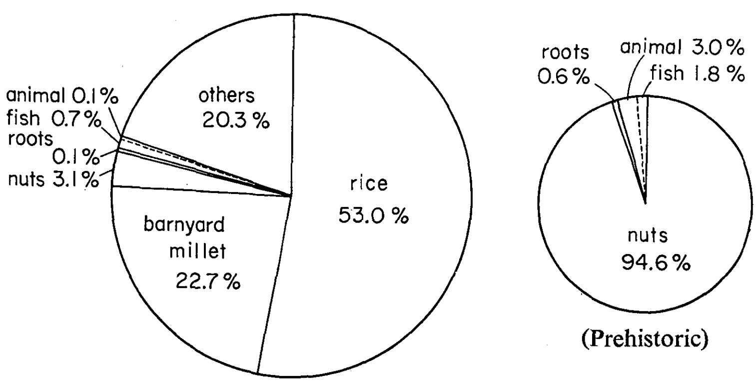

Fig. 5. Caloric proportion of foodstuffs in Hida.

period of extensive environmental degradation. The relatively high yield of pheasant (if we include copper pheasant), however, may be anticipated since some of the present-day figures exceed the calculated maximum yield.

The adjusted figure reduces the human population to about 23,000, possibly the maximum population or limit for the carrying capacity of Hida in the foraging stage. (Note that the caloric proportion of carbohydrate and protein foodstuffs in these reconstructed figures is almost identical to that of nineteenth century Hida.) Only nuts replace the agriculture products, rice and barnyard millet (Fig. 5).

POPULATION AND FOOD RESOURCES

The stage prior to rice agriculture in Japan is known as the Jomon Period, which began about 10,000 years ago, and which is considered as a foraging stage in its entirety. The long Jomon Period is conventionally divided into five sub-periods based on pottery chronology: Initial, Early, Middle, Late, and Final. About fifty radiocarbon dates also support this sequence [KIDDER and KOYAMA 1967]. Although radiocarbon dating has not been reported from Hida, the style and context of material culture of the area coincide well with those of the general Chubu region, of which Hida occupies the northwestern corner.

Jomon culture was prosperous in the Chubu region, especially during the Middle Jomon sub-period (4,500 B.P.). Settlement sites are large and numerous, there is a wide variety of stone implements, pottery vessels are extravagant, ritual objects and accessories (such as figurines, stone-clubs, and earrings) are abundant. But the presence of these traits diminishes significantly in later sub-periods. Cultural fluctuation in a society may be a function of power, or population size, and is reflected directly in the number of archaeological sites. A tabulation of the Jomon sites in Hida clearly indicates that the Middle Jomon sub-period was the optimum for the foraging stage (Table 14).

Population began to decline and slumped badly in the Final Jomon sub-period. This apparent population decline has been explained as resulting from environmental deterioration, specifically as a consequence of a colder and wetter climatic trend which had started in the Middle Jomon sub-period [TSUKADA 1964]. The population record of Hida is relatively well-documented for the last 250 years (since 1721) and a reliable estimate is provided for the eighth century by Sawada, based on the taxation records contained in *Engishiki* [SAWADA 1927].[1] When these figures are transformed to

Table 14. Number of Jomon sites.

Initial	24
Early	26
Middle	52
Late	38
Final	13

logarithmic function and plotted against time, they fit very well on one regression line (Fig. 6). If this line represents the population growth rate (0.2% per year) during the rice agriculture stage in Hida for the last 2,000 years, it projects a population of 2,000 at the beginning of the stage, at 200 B.C.. A population of 2,000, then, can be taken as the figure for the Final Jomon sub-period in Hida.

Only 13 tracts are known to have been occupied during the Final Jomon sub-period. This is barely a quarter of the utilized tracts (52) in the Middle Jomon sub-period. Supposing that conditions remained the same between these two sub-periods, the population during the Middle Jomon can then be estimated at 8,000.

I have calculated elsewhere that the human population of the Central Mountain region in the Middle Jomon sub-period was 72,000, with a density of 2.5/km² [KOYAMA 1978]. If this figure is also true for Hida, then the population should be about 9,700. As an estimate of the population during the foraging stage, 8,000–10,000 is not an impossible figure, since it is still about half of the potential population estimated from the yield of wild foodstuffs.

The distribution of Middle Jomon sites has been plotted on a grid system and arranged according to altitudinal zones (Table 15). More than 90 percent of the tracts are concentrated in Zones 2 to 4, with the mode in Zone 3. Such a distribution reflects explicitly the potential size of wild food resources. It has been demonstrated in the preceding analysis that the largest caloric supplies among wild foodstuffs are derived from nuts, especially acorn and buckeye, from which bitter principles must be removed; brackenroot and arrowroot are also processed in a similar way.

The Middle Jomon settlement sites in this region are often located along streams or close to springs, and yield large stone mortars and grinding stones [SUMITA 1958]. Such settings strongly indicate that the Middle Jomon population was supported by a foraging economy with acorns and roots as the main staple food (Table 7).

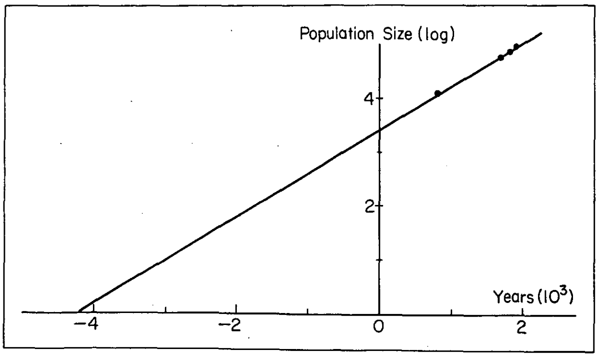

Fig. 6. Hypothetical population increase (regression line) in Hida.

1) Population size (in parenthesis) for the years 800 (12,500), 1726 (68,727), 1804 (81,768), and 1874 (93,390) are from *Engishiki* (延喜式), *Hishushi* (飛州志), *Katsu Kaishu Suijinroku* (勝海舟吹塵録),and *Hidagofudoki* (斐太後風土記), respectively, as shown in Fig. 6.

Table 15. Distribution of tracts of Middle Jomon, Yayoi, and Kofun sites and nineteenth century villages.

Period \ Zone	1	2	3	4	5	6
Middle Jomon	14	19	11	3	1	0
Yayoi	9	12	4	0	0	0
Kofun	19	3	1	0	0	0
19th Century	24	35	26	12	3	0

The site distribution pattern is different in the rice agriculture stage. In the Kofun Period (A.D. 300–700), 83 percent of the site tracts are located in Zone 2. Utilization of other zones was minor, especially of tracts in the higher Zone 4 to 7, which reveal no evidence of occupation during this period. Clearly, the habitat most suited to rice production was strongly preferred: Zone 2 is warm and has a large area of flat land along rivers, which was easily converted to paddy fields. The pattern of land utilization in the Kofun Period also conforms to the distribution of the main staple foodstuff in this case.

The previous Yayoi Period is a transitional stage between foraging and agriculture. Although rice was known during Yayoi times, it had not yet become established as a staple foodstuff. The land utilization pattern is similar to that of the Jomon Period, but the percentage of land used in the lower zones and the non-utilized high zones indicates a shift toward the Kofun pattern. In Hida, by the nineteenth century, the rice-dominant subsistence pattern seems to have been gradually modified, and when the distribution of villages is compared to that of archaeological sites, the

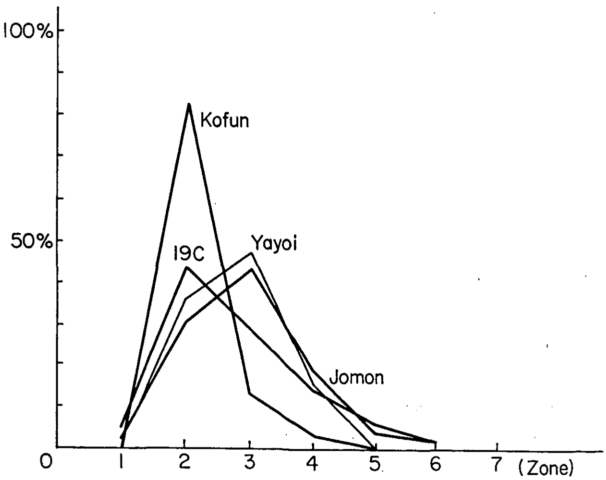

Fig. 7. Distribution of archaeological sites and nineteenth century population by altitudinal zones.

difference can be easily observed. Although the nineteenth century distribution pattern is basically the Kofun type, an increased use of habitats in higher zones (4 to 6) is noticeable. The smaller ratio of use in Zone 2 does not necessarily mean that it was less populated: the actual population size was larger, but only because it supported a non-productive urban population. The use of the area reached a maximum because population pressure forced some of the inhabitants to move upward into the formerly neglected higher zones.

Such movement probably became possible with the establishment of a new production system based on barnyard millet, which is more tolerant of cold and easier to grow in a mountainous environment. Diversification of agriculture recorded in the *Hidagofudoki*, rice in the paddy field and barnyard millet in the shifting field, may be the result of such a trend, and the shifting agriculture of modern Japan might have originated sometime between the eighth and eighteenth centuries. Barnyard millet, however, which is lower than rice in productivity, nutritive, and economic value, forced people to exploit wild food resources, thus returning them to a broader-based food economy similar to that of the Jomon Period.

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