

# A STUDY ON TEMPO-SPATIAL CHANGE OF INTERACTION BETWEEN THE HUMAN ACTIVITY AND PALEO ENVIRONMENT IN JOMON PERIOD, JAPAN

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## ABSTRACT:

This paper refers to the prehistorical interaction of human and environments through the reconstruction of spatial structure of the site-catchment over the archaeological sites. The aim of the study is to examine the prehistorical living to find a hint for symbiosis lifestyle, which is a big interest for modern society. Prehistoric period (Jomon period) of Aichi prefecture in Tokai region, Japan is selected as a case study area. The different reaction of Jomon settlements against the global environmental change occurred in the period was considered. The consideration pointed out the conditions and factors which influence the environmental endurance of the settlements. The reconstruction of the site-catchment was implemented based on the geoinformatics technology, especially by utilizing GIS as a supportive measure. The spatially analysed results were translated into realistic representation by Computer Graphics. The integration of spatially analysed results and the archaeological knowledge have deepened the understanding of the prehistorical events.

## 1. INTRODUCTION

### 1.1 Prehistorical Study and Modern Society

Human activities have expanded drastically in these few centuries. Modern leap of human activity which started with the industrial revolution, in other words “modernization”, was the driving force of expanding. “Technology” has kept improving day by day from then, and still shows no sign of slowing down. It is true that these advanced technologies have brought convenience to the world, but it is not negligible that it is causing global environmental problems at the same time. The constitutive problem of modernization is in its loss of sustainability. This tendency is strengthened with the economic principle lying beneath the modern society. World is currently going through an urgent situation in this sense. Heightened sense of crisis is now encouraging the exploration toward the ecological way of living, environmental conservation, and way to construct sustainable society. This exploration is facing difficulties, because the answer has to be searched in a context different from the modern society. Some of the answers can be searched in the history. Historical study can give some examples of sustainable way of living, which was practiced by the ancient people. Especially, prehistorical study is focusing its interest on the period which most of the people were living in symbiosis and sustainable lifestyle. Of course the ancient lifestyle cannot be applied directly to the modern society. Even though, the statement of historical study can be useful because its consideration is based on “regionality”. Lifestyle is fostered through the accumulation of temporally continuous activity of culture, religion, and all the matter concerned with living which took place in the “region”. Sustainable lifestyle may differ by its belonging regionality, and it does not necessarily mean that there is a common lifestyle to satisfy the sustainability. Prehistoric living of the region can be considered as a start point of the regional society, and most basic lifestyle for keeping both natural environment and human life style in sustainable condition.

### 1.2 Aim of the Study

Aim of the study is to clarify the prehistoric tempo-spatial change of interaction between human and environments from the context of symbiosis lifestyle and its environmental endurance. It is well known that there is a rise and fall of the prehistorical living resulted from the environmental changes. The study will examine the difference and its temporal change of the environmental endurance among prehistorical sites. Environmental endurance will be considered through the reconstruction of spatial structure of internal (in-territory) environment. The final goal of the study is to quantify (or to model) the prehistorical living in aspect of spatial structure, interaction, conformity of the activity (food-gathering activity) for the region, and environmental endurance. The quantification may indicate a tangible and comparable criterion between sustainable lifestyle and the subsequent lifestyle. Also the effectiveness of Geo-Informatics technologies as a supportive measure for studying and quantifying of prehistorical interaction between human and environments will be evaluated.

### 1.3 Case Study

#### 1.3.1 Focusing Period

Case study area is prehistorical period in Tokai-Region, Japan. The focusing period is called Jomon period, which continued from 10,000 BC to 300 BC. Jomon period is divided into 5 stages: Subearliest (10,000 BC – 7,000 BC), Earliest (7,000 BC – 4,000 BC), Early (4,000 BC - 3,000 BC), Middle (3,000 BC – 2,000 BC), Late (2000-1000), and Final (1,000 BC-300 BC). The period is regarded as a substratum culture of Japan by some of the researchers (e.g. Sasaki, 1986; Yasuda, 1987). It is also particularly worth noting that Jomon period was based on highly sustainable lifestyle, which enabled the culture to continue for a long period of time (i.e. about 10,000 years). In this sense, clarification of the Jomon period may be considered

as an exploration toward the optimal and basic (standard) sustainable lifestyle in Japan. This study is focusing on the Final stage of Jomon period, which is subdivided into the beginning, the middle portion, and the later half. The Final phase was one of the most significant paradigm shift occurred in early Japan, which was the transition from hunter-gathering lifestyle to agricultural lifestyle.

### 1.3.2 Focusing Region

The study is focusing on the Aichi prefecture, Tokai region of Japan (Figure 1). The area is located near the border of western and eastern region of Japan, which regionality can be still seen today. Precisely, case study area is located in the eastern edge of the western region of prehistoric cultural zone, which is assumed to be fostered by the evergreen forest. Study area is recognized from archaeologists as an important area which provides useful information not only for interaction between the natural environment and human activities but also for figuring out their cultural interaction as well.

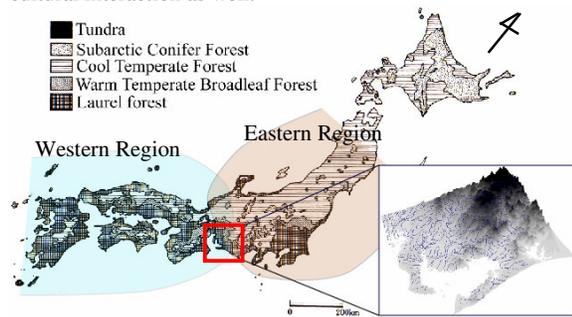


Figure 1. Case study area is located in the border of the western and eastern cultural group as well as vegetation zone (Cultural border and 3D-images added by author to the vegetation map of Latest stage of Jomon period (Yasuda, 1980)).

## 2. HUMAN ACTIVITIES AND ENVIRONMENTAL CHANGES

### 2.1 Human Activities

The capable activities in settlement are restricted by the characteristics of surrounding environments to some extent, especially when its impact of human activity to the environments is low.

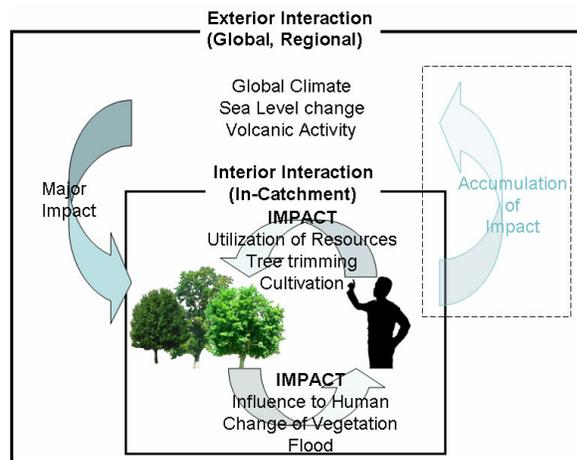


Figure 2. The framework of the interaction between human activities and environments.

Even though, surrounding environments were changed by the human activity, sometimes consciously and sometimes unconsciously. The interrelation of surrounding environments and human activities can be depicted as above figure (Figure 2). Arrow which stands for impact from the interior box to the exterior box is diluted, because the impact of human activities to global environment was slight in prehistorical period. The study will understand the prehistoric interaction based on this framework.

### 2.1.1 The Site-Catchment

The daily activity field of the settlement is called “site-catchment”, which is most basic territorial unit of the daily life. Vita-Finzi (1978) has pointed out that the site-catchment of hunter-gatherer is defined by the time distance, and there is often a considerable difference with the “on paper estimation” (i.e. drawing a settlement centered circle which radius is time distance). The difference is mainly stemmed from topography and barriers (Figure 3.).

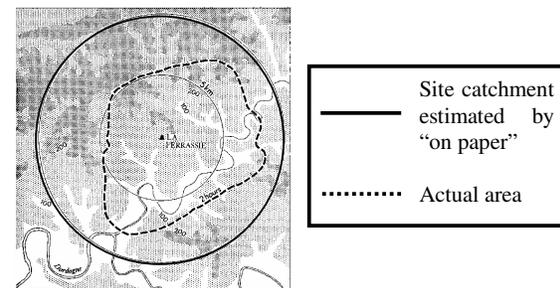


Figure 3. Difference of site-catchment estimation result between the real value and the “on the paper estimation” (Vita-Finzi, C., 1978)

The error of catchment estimation can be corrected by using hiking function (Tobler, 1993) and terrain layer which includes the barrier. Hiking function is a mathematical formula which transfers the unit distance and slope values into corresponding travel time.

$$Time = 6 \exp(-3.5 \times \text{abs}(S + 0.05)) \quad (1)$$

Where  $Time = \text{Travelling time}$   
 $S = \text{Slope}$

The calculation of site catchment using GIS resulted as following figure (Figure 4). White circle is the result of “on the paper estimation (radius set to 10km)” while the dark-grey area is result of GIS calculation (Restricted within 120 min from settlement).

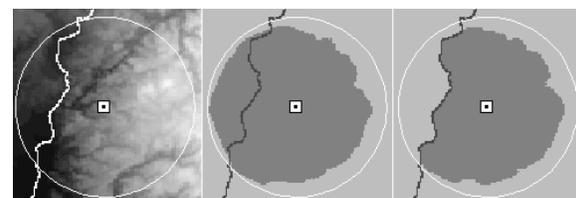


Figure 4. Result of the site-catchment estimation using Tobler’s hiking-function (left: DEM and Settlement; Middle: Calculation result without considering the river;

right: Calculation result setting river as insurmountable barrier).

The calculated area is corresponding to the topographic characteristics, and still its extent is reasonable comparing with the tentative threshold (i.e. 10Km radius). The study is going to apply this method for site-catchment area estimation.

### 2.1.2 Utilization of Wood Resource and Its Impact to the Change of Vegetation

Wood was most commonly used resource through the Jomon period. Suzuki (1997) indicated the change of the decay of wood resource consumed quantity corresponding to the distance. Change of the consumed quantity was examined in three different usages, which is A) dwelling construction, B) fuel, and C) livingware making. The disturbance range was set to 5km, and the transition of the vegetation in site catchment is described (Figure 5).

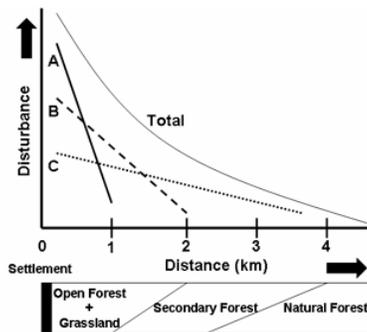
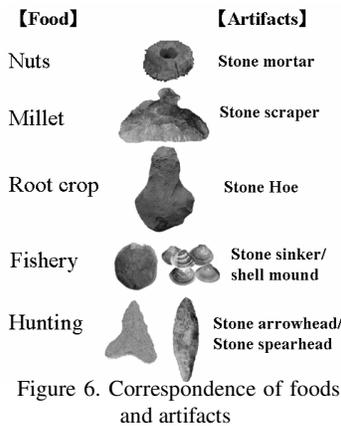


Figure 5. Frame of the forest disturbance and Vegetation transition surrounding the settlement (Suzuki, 1997; Translated by author)

In this study, this model of disturbance over the vegetation is adopted to the reconstruction of environments surrounding the settlement.

### 2.1.3 Food Gathering Activity

Most fundamental daily activity for prehistorical people was food-gathering based on hunting and gathering economy (i.e. hunting, fishing, plant collecting, and some of cultivation). The types of food-gathering activities which took place in the settlement were estimated from the corresponding artifacts and the excavation reports (Figure 6).



## 2.2 Environmental Changes in Jomon Period

Global climate is changing in the long term. Jomon period have experienced several climate changes through the period. Mid Final stage of Jomon is a period when the temperature was gradually dropping. Climate change sometimes severely influences the human living. Especially the change of vegetation and sea-level brought by the climate change directly impacts the food-gathering activity. Settlement may not be able to survive by

their previous food-gathering activity when these environmental changes occur. They will have to cope with the new environment by changing their way of living (e.g. moving the settlement, developing new method of food gathering).

The previous researches have revealed the changes of vegetation and sea level through Holocene epoch of Japan (Figure 7). Jomon period was in warm temperature trend in general, which is known as Postglacial Hypsithermal. The climatic optimum was around 6000 years ago in Early stage of Jomon. The global warming also brought the Jomonian transgression (marine transgression). After the climatic optimum, the temperature has dropped eventually, but still fluctuating. Late stage of Jomon has came up with an unstable temperature and ended up with a warming trend of temperature. In the Latest stage of Jomon, again the temperature began to drop, and this trend continued until the Jomon period was over.

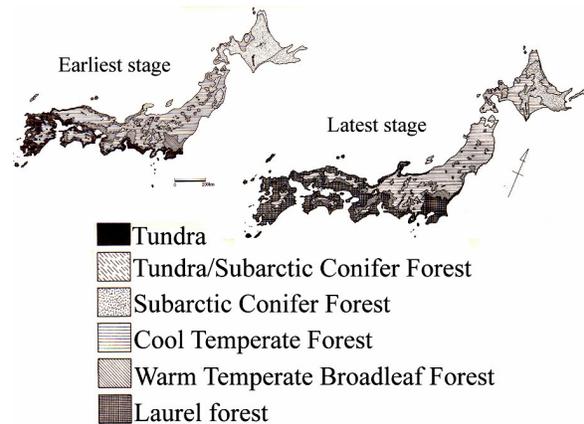


Figure 7. Change of vegetation through Jomon period (Yasuda, 1980; Revised by author.).

In the study, vegetation and sea-level change is considered as an essential environmental factor which gives direct impact over the food gathering activities. Ancient vegetation surrounding the settlement and the sea-level change was tempo-spatially reconstructed.

## 3. ESTIMATING THE INTERACTION

Interaction of human activities and environmental changes occurred in the region were considered through the comparison between Shingu archaeological site and Karekinomiya archaeological site. The relation between the spatial structure of natural environments within the site-catchment and food-gathering activities were examined.

### 3.1 Shingu Archaeological Site

Shingu site was one of the main settlements of mid Latest stage of Jomon period. Site is located in the middle stream of Yahagi river basin (Figure 8). The artifacts uncovered from the site indicated that the people have kept living in this location until medieval times (Education Board of Okazaki, 2001).

#### 3.1.1 Estimating the Site-Catchment of Shingu Settlement

The catchment area of Shingu site was calculated by applying the Tobler's hiking function (Figure 8). Territorial border (i.e. 120 minutes walk from settlement) is decided from the hunter-gatherer study of Vita-Finzi (1978).

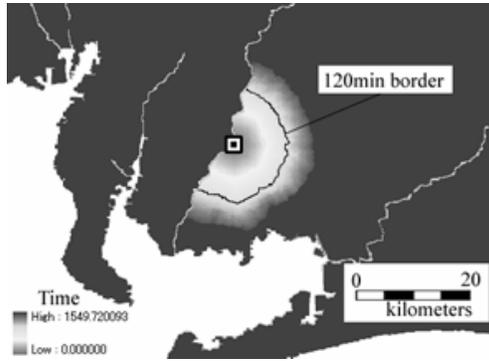


Figure 8. The estimated site catchment of Shingu settlement

### 3.1.2 Environment within the Catchment Area of Shingu Settlement

Surrounding environments of Shingu settlement were counted on an areas defined by time-distance from the settlement (area1: 0-20min; area2: 20-40min; area3: 40-60min; area4: 60-80min; area5: 80-100min; area6: 100-120min). The percentages of each environmental factor per unit area (i.e. areas defined by time-distance) were calculated (Figure 9).

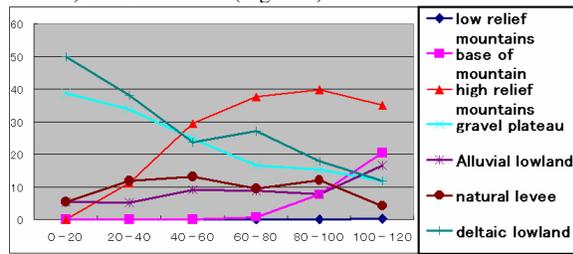


Figure 9. Graph shows the percentage of environmental factor per unit area (Shingu settlement).

The result shows that the percentage of the low land, plateau and mountains inverts around the distance of 50 minutes walk from the settlement. This result implies that the environmental characteristic changes from the plain to mountainous area around the threshold of 50 minutes.

### 3.1.3 Activities held in Shingu Settlement

Several structural remains (i.e. dwelling, pit, and grave) and a number of artifacts (i.e. pottery and common stone tools known in Jomon) were uncovered from the Shingu site (Education Board of Okazaki, 2001). The uncovered artifacts imply that there were a hunting, nuts and root crop gathering, and freshwater fishery, (and millet cultivation). Uncovered amount of stone arrowhead and the tool set for grinding is suggesting that the activities were emphasized on the hunting and nuts gathering. Also the unearthed polished stone axe is an evidence for their using of the wooden resources.

## 3.2 Reconstructing the Shingu Site and Surrounding Environment

### 3.2.1 Reconstructing the Vegetation of the Catchment

The realistic transition of vegetation, which is particular vegetation type of the site-catchment, was reconstructed. Reconstruction is based on the potential natural vegetation, which is interpreted from geographic characteristic of the land and Warmth Index (WI). WI is an index conceived by Kira (1985), which indicates the correspondence between the monthly temperature and vegetation type. Ancient potential natural vegetation surrounding the site can be estimated by using GIS

modelling based on the pollen diagram, WI, and terrain characteristics (Watanabe, 2004). Also the influence of the human activity indicated by Suzuki (1997) within the catchment is taken into account for the reconstruction. Four different vegetation areas, which are 1)settlement, 2)open forest, 3)secondary forest, 4)natural forest, were decided based on the study of Suzuki (ibid.) (Figure 10). The corresponding time distances to the physical distance decided by Suzuki (ibid.) were used to restrict these areas (i.e. same as the area decided in 3.1.2).

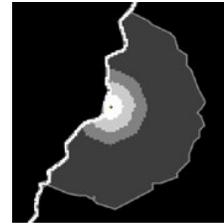


Figure 10. Different vegetation area inside the catchment

$$WI = \sum_{tm>5} (tm - 5) \quad (2)$$

Where  $tm$  = average temperature of the month

### 3.2.2 Visualizing the Spatial Structure of the site catchment

Spatial structure surrounding the site is depicted in realistic representation based on the Digital Elevation Model (DEM) and estimated vegetation (Figure 11). Computer Graphics (CG) is generated by planting the tree image on the corresponding vegetation distribution layer (Yoshida, 2001). Land use of Late Jomon period is estimated by considering the graph and the CG. Site catchment area contains various environments, and there were various food-gathering activities held inside. As is referred, Graph (figure 9) shows invert of the land characteristics in 50 minutes walk from the settlement. This threshold, 50 minutes is corresponding to the border of the vegetation disturbance according to the CG. The land utilization of Shingu site may be classified into cultivation, nuts gathering area (Secondary forest tends to be rich in nuts.) and hunting zone at the border of 50 minutes (Figure 11).

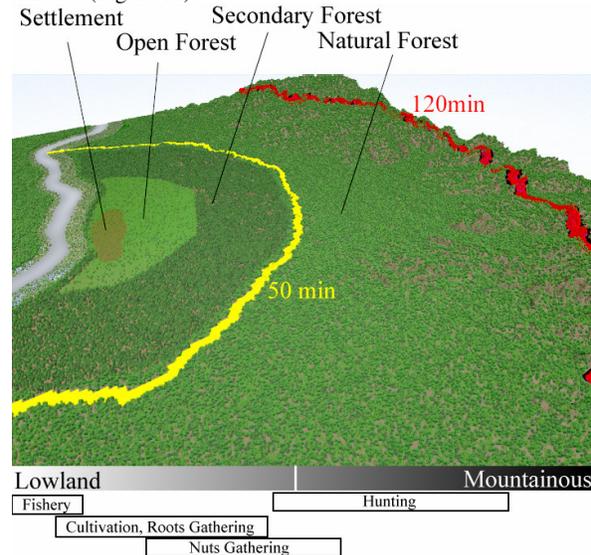


Figure 11. The environment inside catchment area and its spatial structure referred with the corresponding food-gathering activities (Shingu settlement).

### 3.3 Karekinomiya Archaeological Site

Karekinomiya site was a settlement of latest stage of Jomon period. The settlement was located in the coast area, near the river mouth of the Yahagi river (Figure 12).

### 3.3.1 Estimating the Site catchment of Karekinomiya Settlement

The same procedure used in the Shingu settlement is applied to estimate the catchment (Figure 12).

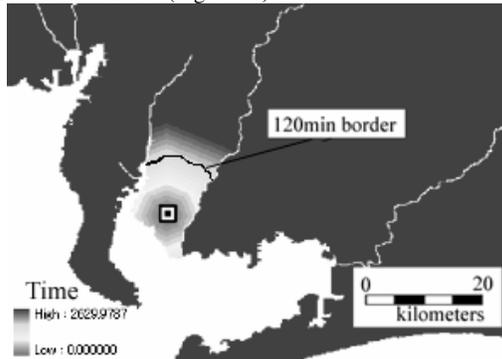


Figure 12. The estimated site catchment of Karekinomiya settlement

### 3.3.2 Environment within the Catchment Area of Karekinomiya Settlement

The same procedure used in the Shingu settlement is applied to calculate the percentage of environmental factor per unit area (Figure 13).

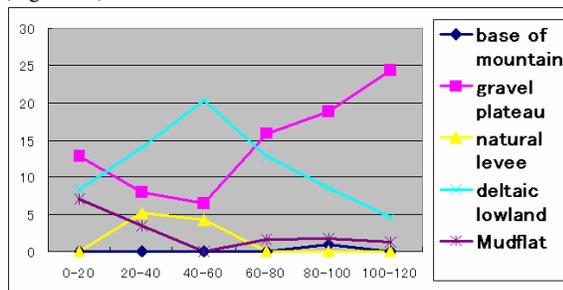


Figure 13. Graph shows the percentage of environmental factor per unit area (Karekinomiya settlement).

Again, the graph indicates the turning point of surrounding environments at around 50 minutes walk from the settlement. The graph indicates that the peak of accessible deltaic lowland is around the 50 minutes walk from the settlement. Also, the percentage of gravel plateau and mudflat is inverted around the threshold of 50 minutes. Especially, increase of the gravel plateau after the 50 minutes threshold is significant. The result implies the existence of marshy landscape at area below the threshold, and comparatively dry landscape at area above the threshold. It is reasonable to assume the existence of different way of land utilization according to the environmental difference.

### 3.3.3 Activities held in Karekinomiya Settlement

The significant characteristic of the site is the existence of shell mound and the uncovered natural remains (i.e. animal bones and fish bones). The shell mound and bones implies that the food gathering activity of Karekinomiya was emphasized on the fishery and hunting. In fact, the composition of the uncovered artifacts supports this hypothesis. Stone arrowhead, stone spearhead, and stone sinker have been uncovered from the site, while grinding set did not. According to the excavation report (Education Board of Nishio, 1981), most of the animal bones were of the animals which habitats in forest area.

### 3.4 Reconstructing the Karekinomiya Settlement and Surrounding Environment

Same procedures used for Shingu settlement was adapted for reconstructing the vegetation, and for visualization (Figure 14). The land utilization of Karekinomiya settlement was considered based on the graph (Figure 13) and the CG (Figure 14). The land use of catchment can be estimated as coast area for fishery, and other area as hunting site. Especially around the border of the marshy condition and dry condition, which is around 50 min threshold can be important for the hunting site.

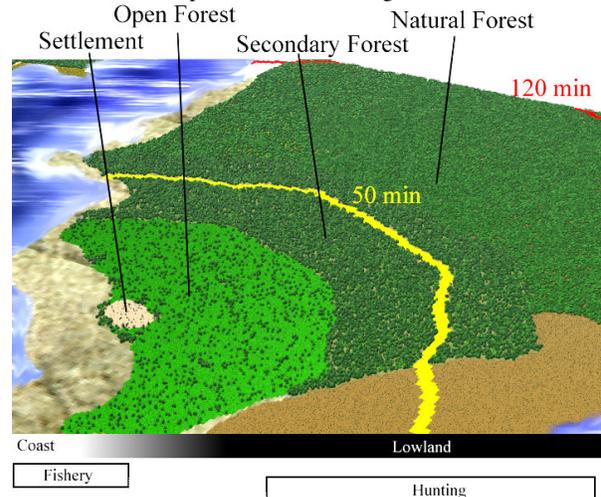


Figure 14. The environment inside catchment area and its spatial structure referred with the corresponding food-gathering activities (Karekinomiya site).

### 3.5 Comparing Shingu Settlement and Karekinomiya Settlement from the Viewpoint of Environmental Endurance

Shingu site and Karekinomiya site were contemporary settlements (i.e. first half of the latest stage of Jomon period). But only Shingu site survived the next later half of the last stage. It is known that some other settlements have perished after the first half of the latest stage as same as Karekinomiya site. One of the leading hypotheses is the influence of the dropping of temperature and relating sea level change occurred in this stage. Excavation reports explains that there was an increase of *pinus* and the decrease of *Quercus*, which implies a dropping temperature and influence to the vegetation. On the other hand, Koumura (1983) pointed out that the marine regression of about 3m decrease in sea level is expected, and the environmental changes have severely influenced the life of the Jomon people. The marine regression is estimated by thresholding the DEM by sea level (Figure 15).

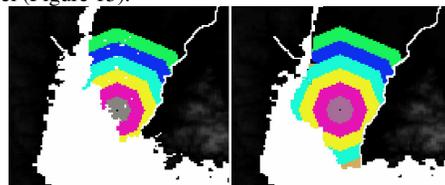


Figure 15. Change of the coast line and its distance from the Karekinomiya settlement

The catchment analysis shows the regression of coast line to near the border of the 50 minutes threshold. Simply the time cost has doubled for the people to reach the coast.

Visualization was implemented to support the understanding of the change (Figure 16 and Figure 17).



Figure 16. CG shows the landscape of the Karekinomiya settlement in first half of Latest stage of Jomon period.



Figure 17. CG shows the landscape of Karekinomiya settlement after the mid half of Latest stage of Jomon period.

Their daily life may have been affected by not only the disadvantage of a distanced shoreline but also an increase in the deposition which harmed the habitat of shellfish. The change of coastline has disabled the people from relying on ocean resources, which meant that the site was no longer a suitable location for their way of living. The declining of the settlement must have been caused by the lack of principal food, which urged their moving to another location. On the other hand, Shingu settlement has survived the period and the location of the settlement was used continuously from then. Shingu settlement may have been superior in environmental endurance because of diversified environments, and was able to survive by diversified food resources.

## 4. DISCUSSION

### 4.1 Discussion

The study overviewed the prehistorical interaction of human activity and environments. The environmental change and its spatial structure were estimated by calculation using GIS, and its result was depicted as a realistic CG. Consideration toward the interaction and the relation was deepened and partly quantified by integrating spatial analysis results and archaeological knowledge. The difference of environmental endurance was pointed out by comparing two contemporary settlements. Comparison implied that the difference of endurance was attributable to the diversity of food gathering activity and surrounding environments. From the view point of coexistence with nature and sustainable resource utilization, both settlements were making satisfying life styles. Even though, big differences were observed in the chance of surviving when people meets a major environmental change. Not only the magnificent monumental ruins but also these records

of local living of people are informative and have great importance as a “cultural heritage”.

Geo-informatics technologies were highly useful for prehistorical study in aspects of modelling, spatial analysis, and visualization. Utilization of GIS can be understood as an abstraction of the real world into the virtual world. This simplification enables the quantification of the matter, but on the other hand, simplification sacrifices the sense of reality. Representation by CG can be an effective method to translate the abstracted results (e.g. GIS layer) into representational drawing. This is especially significant in the historical field, which is no longer able to see the real scenery again.

The further development of quantification (or modelling) method of the prehistorical living to establish a tangible and comparable criterion with the subsequent society will be the future work.

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