

### H-3.1 Geographically Explicit Long-term Projection of Land-use Change in China

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**Total Budget for FY 1998-FY2000:** 58,573,000Yen (FY2000: 17,386,000Yen)

**Abstract** We produced many 20-km grid maps of China about natural and socioeconomic factors related to land use/cover change. We have also produced 2-km grid maps of land use for the Yangtze River Delta and Northern and Northeastern Parts of China. The 20-km China maps were used for identifying vulnerable areas against agricultural development and discussing national self-sufficiency issue of food. The 2-km maps were used for studying land use change, especially urbanization this time, for typical areas.

According to our analysis using 20-km grid maps, China has enjoyed self-sufficiency of food as of 1995s and will enjoy even at 2025. About this result, we recognize the need of more reliable data for current and future food demand in China. In terms of case studies of Yangtze River Delta, through field surveys and interviews and the analysis of statistics and the 2-km grid maps, we have found that each town in the delta targeted to expand its town center first for its development and identified eight driving factors for the rapid expansion. The eight factors have interacted each other and formed a good chain of development in each town. We also have analyzed land-use changes in the southern part of Beijing City and determined the factors underlying those changes. The underlying factors are: policy, population, urbanization, technology and resources. The land-use changes under socialistic economy were based on the linkage of policy, technology, resources and urbanization; and under the present socialistic market economy, on the linkage of policy, technology, resources, urbanization and population.

**Key words:** China, Land Use/Cover Change, Geo Referenced, Digital Map, Food Balance

#### 1. Introduction

To study past, current and future land use/cover, it is very important to identify where, what, which, when, why and how such changes have occurred, occur, or will occur. For this purpose, geo-reference data, especially digital maps, provide us with very powerful information. This report consists of three studies with the help of 20-km grid maps and 2-km grid maps, respectively.

Self-sufficiency of food for whole China has been a big issue for last ten years. We have tried to analyze this issue as more quantitatively as possible by producing many 20-km grid maps related to this issue. Some of 20-km grid maps also provide us with useful information on vulnerable areas for agricultural development. This information supports our assumption in selecting the case study areas this time.

Two case studies reported here are about urban expansions in China. Roughly speaking, there are two patterns of urban expansion in China; one is that driven by central government, another, driven by local government. Expansion of big cities, such as Beijing, Shanghai and state capital cities, is mainly initiated by central government and induced by investing public capitals (such as national and local governments) on national lands or by private investment supported by the governments. In case of urbanization of local towns, such support is not available, therefore, each town must raise business fund by own resource and effort for its development. The case study of Xishan city in Yangtze River Delta deals with the latter case<sup>1)</sup>, and that of Beijing city deals with the former case<sup>2)</sup>.

## 2. Research Objectives

### I. GIS Aided Study on Food Balance in China at 20-km Grid Resolution

The objectives of this study are to discuss the current and future food balances for whole China at 20-km grid resolution. To conduct this geo-referenced study, we have produced maps related to food yield and demand in 1995 and 2025.

### II. Geo-referenced Study of Future Land Use for Typical Areas at 2-km Grid Resolution

#### (1) Expansion of town center of local towns in Yangtze River Delta

The objectives of this study are to analyze the expansion process of town center in local towns in Yangtze River Delta as of middle 1980s and its mechanisms.

#### (2) Mechanisms of land use change in and around mega city

The objectives of this study are to analyze land-use changes during 1982–1995 in the southern part of Beijing city and to determine the factors underlying those changes.

## 3. Research Method

### I. GIS Aided Study on Food Balance in China at 20-km Grid Resolution

We have discussed food balance issue for whole China by producing 20-km grid scale (precisely speaking, 10'×15' latitude-longitude grid scale) maps of yield and demand for rice, wheat and maize (corn) at 1990s and 2025. In terms of resolution of the maps, we compared the area of arable land in China determined by a 1-km grid map with that determined by a 20-km grid map. As a result, we concluded that a 20-km grid resolution was small enough to discuss the food balance for whole China. Those maps are based on agricultural census of China at county administrative level. When allocating those census data to each grid cell, we adopted a population weighting interpolative method. Therefore, we have also produced 20-km grid scale maps of population at 1990 and 2025 by distributing current and predicted populations of country level to each cell with the help of improved DMSP/OLS Stable Light Images (SLI)<sup>3)</sup>.

To draw a future grain yield map, we need the productivity of land as basic information. Therefore, we have produced a 20-km grid scale map of possible arable land determined by natural conditions, and that of potential productivities depending on limiting factors, such as light, temperature, soil moisture and soil fertility. While, to draw a future grain demand map at 2025, we need distribution maps of population and demand rate per capita at the target year. These values are so much dependent on socio economic factors and policies that scenario approach is only feasible for us at present.

## II. Geo-referenced Study of Future Land Use for Typical Areas at 2-km Grid Resolution

### (1) Expansion of town center of local towns in Yangtze River Delta

In the study, satellite images in 5-year intervals from 1980 to 1999 were used as the basic data to clear the problem of marked inadequacy of time-series data. For verification of the results of reading satellite images, they were collated with the land-use maps in 1984 and in 1996 available and accurate classification of land uses was attempted. Furthermore, field survey and hearing from the related organizations were carried out 3 times in the autumn of 1998 and spring and autumn of 1999<sup>13)</sup>. We tried to profile the whole picture of town center expansion as much as possible by feeding back the above philological analysis, image analysis and field surveys. Then, we discussed the mechanism of expansion in 6. In the study, we also attempted to extract the conditions peculiar to Xishan city as well as analyzing common factors seen generally in the southern Jiangsu.

### (2) Mechanisms of land use change in and around mega city

Land-use changes in China were analyzed by comparing land use maps of different periods. These land-use changes were historically, politically and socio-economically divided into the socialistic economy and the socialistic market economy<sup>4), 5)</sup>. Maps covering these three periods were based on the Chinese Land-Use Maps of 1982<sup>6)</sup> and field surveys and remote sensing satellite photos of 1995<sup>7)</sup>. Before the comparison, each map was divided into 800 grids of two square kilometers, and the percentage of all kinds of land use in each grid was measured in accordance with the dot-sampling method. Then the author applied the modified Weaver's method to the percentage of respective land use in each grid<sup>8), 9)</sup>, and individually obtained the combination pattern of land use with respect to that grid. Furthermore, the author paid attention to elements of this combination pattern, and analyzed historical and spatial changes in these elements among the three periods. According to a series of analyses, the authors clarified typical land-use changes and their driving forces in the southern part of the Beijing metropolitan area.

## 4. Results and Discussion

### I. GIS Aided Study on Food Balance in China at 20-km Grid Resolution

A possible arable land map determined by natural conditions gives us basic information to draw future grain yield. Potential land for grain yield was determined by light, temperate, slope and precipitation; therefore, distributions of potential land are different among grains depending on natural condition for the growth of each grain. Combining potential land area maps for rice, wheat, corn, and bean yields into one and overlaying it on a map of actual arable land, we can identify the areas to be cultivated and vulnerable areas for cultivation (see

The 20-km grid maps of yield and demand for rice, wheat and corn at 1995 were produced, respectively. The food balance map at 1995 was made by use of those maps. There are very few statistics in grain demand at both provincial and country levels. Thus, we had to make several daring assumptions to make demand maps. We also produced the 20-km grid balance map of grain yield and demand at 2025, by giving future scenarios of grain yield and demand. In terms of future grain yield, the basic information (Ex. Fig.-1) was referred. The current and projected food balance maps say that food will be in surplus totally even at 2025 as well as is at present, which means China will afford herself in future in spite of expected population growth. However, we should not forget that the projection

depends on very much on future demand rate per capita in China. We need more detailed study on future diet pattern for whole China.

## II. Geo-referenced Study of Future Land Use for Typical Areas at 2-km Grid Resolution

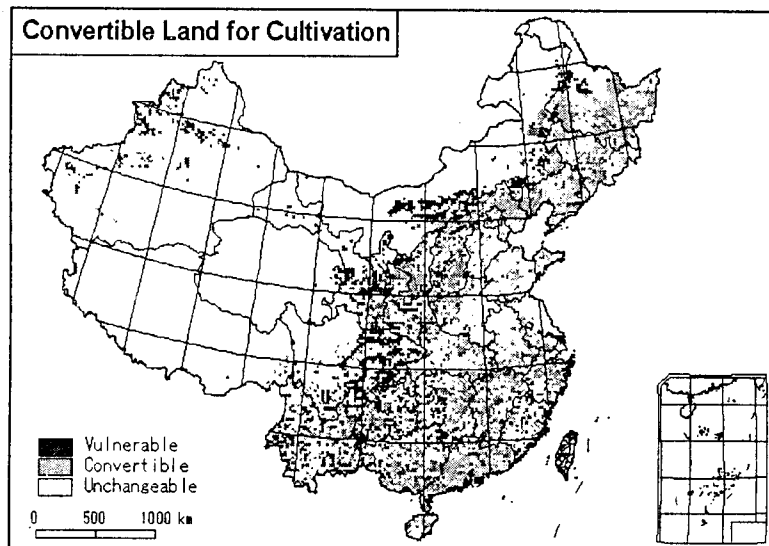


Fig.-1 20-km grid map of land to be cultivated (green) or to be deteriorated by cultivation (red)

(1) Expansion of town center of local towns in Yangtze River Delta

1) Driving forces and mechanisms of expansion of town center

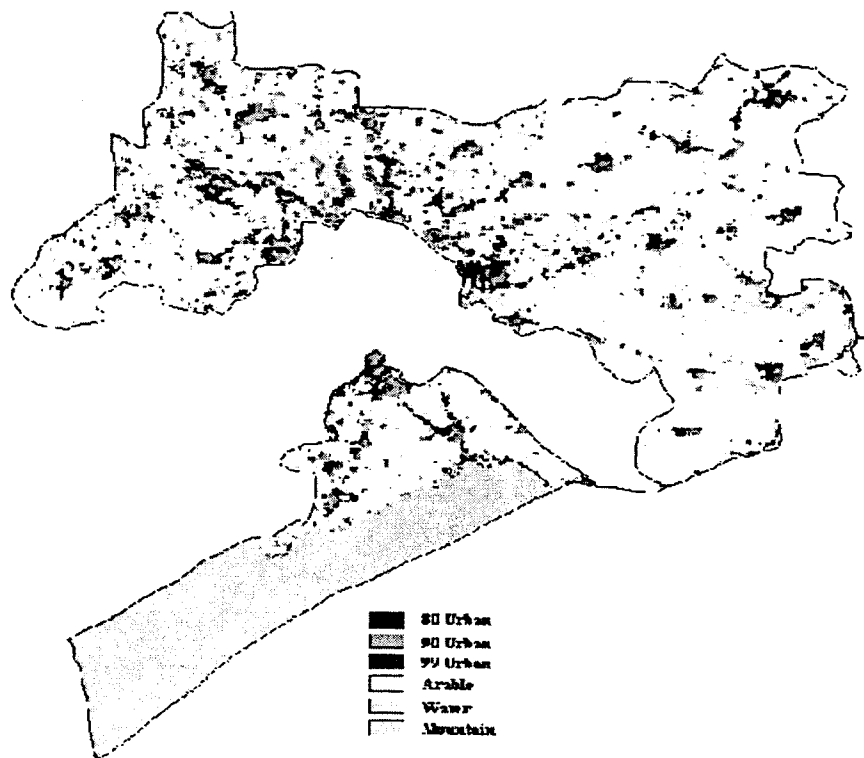


Fig.-2 Expansion of urban land in Xishan city from 1980 to 1999 (Grid size: 100 x 100)

Fig.-2 shows the areas of the city center in 1980, 1990 and 1999 in colors reflecting the time-series changes in the urban area in three stages before 1980, in 1980s and 1990s. We have summarized the whole picture of urbanization of Xishan city as follows.

- i) The population pressure against land in this area was high in the history and the rural region had the problem of surplus working power. The most fundamental driving force of urbanization in Xishan city is the constant demand for upgrading of land uses due to such population pressure. However, apart from basic reasons seen anywhere in the southeast coast of China, there were backgrounds peculiar to the region including presence of fertile Taihu Plain, favored water and land traffic conditions, close distance to big cities such as Shanghai and Wuxi, long history of engagement in dual industries and commerce, accumulation of funds in stock in the era of "commune" to start local industries, precedent development of local industries, high education level, close territorial bond with Shanghai, flexible management of policies from 1950s and "the age of shortage of things" in 1970s when "anything can be sold if it is made".
- ii) While self-helped promotion of urbanization was sought for, local industries not only grew up as a driving force of local economy but also played an important role in local management through payment of profits and taxes to town finance. Therefore, expansion of a town center was regulated by the growth of local industries and their rise and fall was reflected immediately to expansion or reduction of the town center area. On the other hand, accumulation of various functions such as circulation and finance in turn supported local industries. In addition, one cannot ignore presence of a strong driving force produced by Trinitarian unification of the party, administration and business controlling administration, economy, land and personnel completely.
- iii) With the accumulation of local industries to town centers, a chain reaction was produced as the employees (village populations) also moved and the increase in the permanent population in the town center urged development of housing lands and accumulation of commerce, transport, communication, finance and service industries resulting in expansion of town center. Depending on the progress of urbanization, the nature of the town center changed from a distribution center of the primary industry to the place accepting industries and, further, to incubator of the tertiary industry.
- iv) In Xishan city, adjustment of land uses with emphasis on rearrangement of town center shall be promoted from now on aiming at continuous and profitable land uses.

## 2) Future perspectives

In the prospective survey of the town center expansion in future, Xishan city plans to move 975,000 persons corresponding to 65% of its population to town centers by 2010. Following the regulation of Jiangsu Province to restrict the area occupied by one person to 100 m<sup>2</sup> or less and the urban area shall expanded to 97.5 km<sup>2</sup>. It can be assumed that expansion of town center shall slow down gradually due to enforcement of a new "Land Control Law" and strict instruction from the upper-rank organization such as province related to preservation of agricultural area. Fig.-3 shows a projection of urban expansion. This projection is based on the past trend of the expansion and land use plans of population density, roads, houses and income by local governments

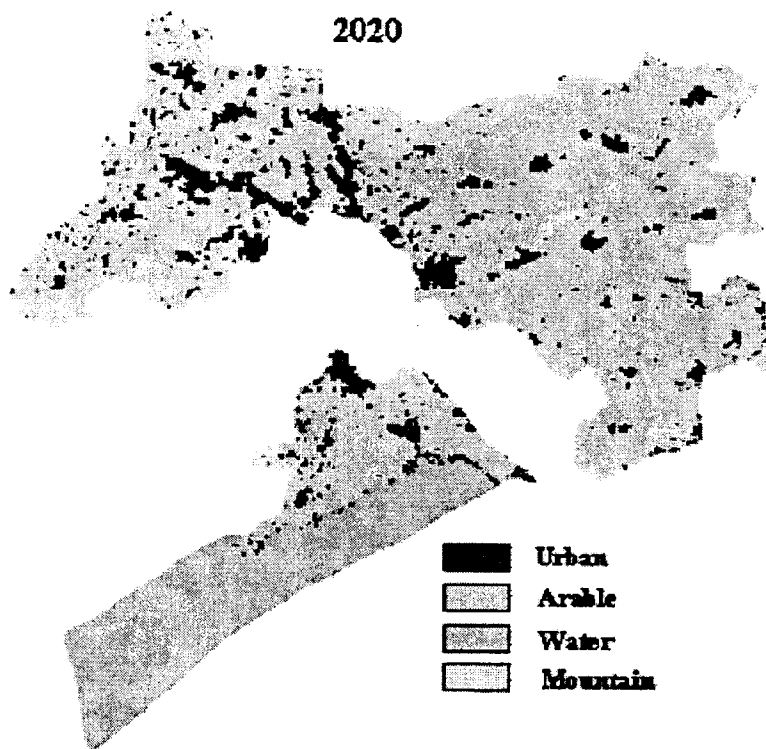


Fig.-3 Projected expansion of urban land of Xishan city in 2010 and 2020  
(Based on past trend and population density, Grid size: 100m×100m)

## (2) Mechanisms of land use change in and around mega city

### 1) Land use in 1982

We have prepared the map to illustrate the distribution and characteristics of land use in 1982. According to the map, the castle walls that once enclosed the city center had been destroyed, and circular beltways were constructed along the site of the old ramparts. Urban land use was continuously expanded from the city center to its outskirts by removing the castle walls, so that the expansion of urban land use has been more remarkable than any other land use in the suburbs. Especially within the Third Ring Road, built-up areas were extended by conversion from non-urban to urban land use, and urban land use began to on both sides of that road. Although many dispersed constellation communities were constructed by city planners with a view of dispersing urban functions to the suburbs, such communities not only caused urban sprawl but also accelerated the expansion of continuous urban land use form the city center.

Generally speaking, since the establishment of the socialistic economy, farmland has been developed by the conversion of lowlands and swampy hinterlands into paddy fields, together with the conversion of the mountainous slopes and lower hills into upland fields. Taking the opportunity of the founding of the People's Republic of China, the Chinese Communist Party attached importance to an agricultural policy that designed to increase food yield and to stabilize the food yield. Therefore, there was increased agricultural investment to enlarge farmland and develop rice cultivation. According to these agricultural policies, farmland was enlarged through leveling and terracing mountainous slopes and lower hills, and the productivity of farmland was increased by irrigation and land improvement in the

alluvial lowlands. On the other hand, wasteland was converted into grassland and forest for protection against soil erosion in the highlands, indicating an enormous investment in environmental conservation.

## 2) Land use in 1995

We have also prepared the map which shows the distribution of land use and its characteristics in 1995. From the map, we have found that urban land use has been accelerated, and built-up areas have expanded between the Third and Fourth Ring Roads. In the suburbs, built-up areas of some constellation communities have also expanded and are now connected with the city center. Some such constellations are being independently constructed in the outer suburbs of Beijing City. In terms of the current trend of urbanization, urban land use has developed mainly on the eastern and western sides of the city center. These directional trends are reflected in the construction of large-scale industrial districts and public facilities such as research institutes and universities. With such construction as a focal point, urban land use has been expanded into the suburbs and outer suburbs.

On the whole, agriculture under the socialistic market economy has changed from local food yield to commercial yield, so that agricultural land use has been diversified into various patterns based on rent and profitability. Because each farmer is free to use and cultivate individual farmland since the introduction of the agricultural yield responsibility system, farm management in this area has gradually evolved into three types: cooperative farming, contract farming, and small-scale family peasant farming. Cooperative farming combines the advantages of both a people's commune and enterprise farming, by which farmers intensively cultivate highly profitable crops such as vegetables. As the rural population moves from the peripheries of Beijing City into the urban and urbanized areas, farmers migrating from the outer suburbs and peripheries play an important role in contract farming, and cultivate traditional food crops such as wheat, rice and maize abandoned by local farmers. In family peasant farming, plots of about 40 acres per farm household are used to cultivate various food crops and vegetables on a small scale.

Particularly in contract farming, which is a more typical management mode than others, local farmers work in township enterprises and thus derive large incomes from both wages and farm rents. While this contract farming contributes to maintaining agricultural land use continuously, cooperative farming contributes to intensified agricultural land use in terms of cash-crop yield. In contrast to both contract and cooperative farming, the increase in family peasant farms is one of the factors that promote urban land use instead of agricultural land use, and that tend to undermine the framework of agricultural land use in the suburbs of Beijing City.

## 3) Land-use changes in the southern part of Beijing City

We considered the trends in land-use change between 1982 and 1995 on the basis of their spatial distribution. As is evident from Fig.-3, there were three main trends during this period: the conversion from grassland into forest land, the conversion from upland fields into urban land use, and the conversion from paddy fields into upland fields. Comparing land use maps between 1982 and 1995, it was clear that the trend toward urban land use was dominant in the suburbs, particularly in both the western and eastern sectors extending out from the city center. The distribution of this trend corresponded to the location of industrial districts and dispersed constellation communities, the arrangement of high-speed transportation networks,

and the expansion of built-up areas to accommodate internal migration. These conditions followed from the economic policy that gave priority to industry over agriculture.

As for the trend toward agricultural land use, while the conversion to both upland fields and orchards accelerated, the conversion to paddy fields ceased. These conversions from paddy fields into upland fields were directly due to the shortage of water for irrigation, and were indirectly caused by the development of cash crop cultivation, innovations in farming technology, and the changing eating habits of Beijing urban dwellers. The trend toward reforestation to prevent soil erosion also continued to be dominant in the highland regions of Beijing City, so that the conversion from grassland into forest land could be distinguished from the others. On the other hand, a trend toward abandoning wastelands appeared around built-up areas of the city center. These wastelands were characterized as socially underutilized land.

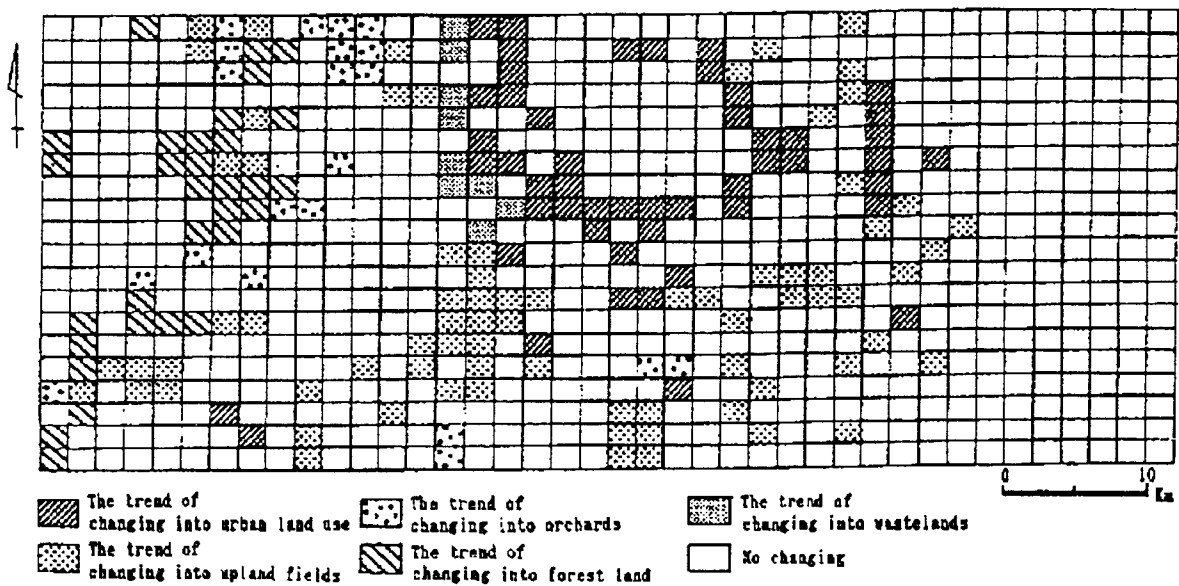


Fig. 4 Land use changes in the southern part of Beijing City between 1982 and 1995  
Data sources: Mesh maps of land use in 1982 and 1995

## 5. Conclusion

### I. GIS Aided Study on Food Balance in China at 20-km Grid Resolution

Many 20-km grid maps related to yield and demand for rice, wheat and corn at 1995 and 2025 were produced, respectively. The food balance maps at 1995 and 2025 were made by use of those maps. The current and projected food balance maps say that China has enjoyed self-sufficiency of food as of 1995s and will enjoy even at 2025. However, we should not forget that the projection depends on very much on food demand per capita in China. We should collect more detailed and reliable data on food demand.

### II. Geo-referenced Study of Future Land Use for Typical Areas at 2-km Grid Resolution

#### (1) Expansion of town center of local towns in Yangtze River Delta

We have identified eight driving factors for the rapid expansion of town center in each local town. The eight factors are development of local industries, multiple routes of



funding, change of working structure, Trinitarian system of communist party - local government - enterprises for development, promotion to administrative town, appointment as a model town, adjacency to a big city, and, no substantial area as local capital city in Xishan city. These eight factors have interacted each other and formed a good chain of development in each town. We need more study whether this good chain will be formed at other areas in China, or not.

## (2) Mechanisms of land use change in and around mega city

In consideration of the trends and characteristics of land-use changes in the southern part of Beijing city, we could identify five major driving factors: policy, population, urbanization, technology and resources. The various types of land-use change have been based on the systematic linkage of these elements.

The linkage of such elements was summarized as follows. Firstly, land-use changes under the pre-socialistic economy were based on the systematic linkage policy, technology and resources. Secondly, land-use changes under the socialistic economy were based on the systematic linkage of policy, technology, resources and urbanization. Finally, such changes under the socialistic market economy were based on the systematic linkage of policy, technology, resources, urbanization and population. With the evolution toward a market economy, therefore, the system of driving forces has tended to be complicated because the numbers of its elements and linkages have increased.

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