A Feasibility Study about Extraction Method of Densely Crowded Areas with Wooden Buildings in the KOBE Government. Part II [1)]

Consideration of evaluation of urban fire hazard.

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ABSTRACT :

At 5:46 a.m. on January 17th, 1995, the worst disaster in postwar Japan changed Kobe. The ratio of the Kobe Government's houses destroyed by fire came to 98.9% in all of the burned out area. The reason for this is that it was a man-made disaster compared with the direst course of this great earthquake. As it turned out, the houses and other buildings densely packed in the narrow streets in the city center may have been the main factor of this Kobe urban disaster. Therefore, we feel that it would be good to improve the realizability of regional disaster prevention. This paper examines a report on districts suffering damage, and various analysis of building types derived from aerial photogrammetric surveying, urban geographic information system, and remote sensing in Kobe city, all of which must be taken into account in the determination of districts at risk.

1. In

This eas with wooden buildings in the KOBE government: consideration of evaluation of urban fire hazard. This research is a report which has the great Hanshin earthquake of southern part of Hyougo Pref. at 5:46 a.m. on January 17th, 1995, to the case and is developed. The purpose of the research is to derive the forecast of the spreading district of a fire through aerial photograph, geographic information system (GIS), and the remote sensing analysis beforehand. The houses burnt down in the Kobe city accounted for 98.9% of the whole, that si to say 7,377houses out of 7,456. Making of the wooden building in the overcrowded urban area and other factors such as narrow roads are thought to be the cause. Therefore, the research and development of the regional risk evaluation technology according to the enhancement of geography information on the city is requested. The land use situation has already been understood from the aerial photograph and the satellite image, and danger in the wooden overcrowded urban area in the urban disaster prevention plan has been pointed out.

Moreover, the possibility of the forecast of a district at risk for fire has already been examined from various fire hazard factors by GIS. Also, the fire hazard district forecast is made possible by the point of the bigness and smallness of the ratio in the overcrowded of the wooden building and the open-space in the urban area, which greatly influences a fire and spreading at the earthquake occurrence, and reading those factors has been understood. GIS was used, and districts where the even number eyes existed by 64 towns out of 197 in the entire investigation district, and the fire scale was comparatively large were 39 town even number eyes in the district which was able to be forecast dangerously, and the ratio of the forecast rate was 60.9% beforehand.

The improvement of the forecast accuracy of the fire spreading danger district by three analysis techniques of geographic information system analysis (GIS), the aerial photograph analysis, and the remote sensing analysis and which investigation items relate to the fire hazard forecast is a research purpose at this time.

2. Research development

When the research developed, it was assumed to be a research purpose to extract the fire spreading district again by using the following three analysis techniques, and to understand the accuracy improvement of each technique, the effectiveness, and the characteristic.

2.1 Analysis technique by aerial photograph

The building composition ratio on each town even number eyes was calculated from the building structural type classification chart by using the aerial photograph on an existing research, and the technique by which a fire breaking dangerous district was forecast was progressed.

2.2 Analysis technique by remote sensing

1. The forecast technique of a fire breaking dangerous district was progressed by using the building composition ratio on each town even number eyes from the coating classification of land by the remote sensing which used the satellite image data.
2. Because it was influenced by the amount of sunshine, a fire breaking dangerous district is forecast to the remote sensing analysis, and the data of the fire breaking dangerous element obtained from the GIS analysis was added.

2.3 Analysis technique by GIS

The investigation item of 32 was chosen from the damage investigation report as basic data, and the forecast of the fire hazard district was developed by the GIS analysis. (Table 1.)

3. Making of the fire rank chart

To judge the dangerous district forecast evaluation in each technique, a grasp of the situation of the fire hazard in this large earthquake, the fire situation chart is made from current state of damage chart. Next, the fire burnt-down rate was calculated from the fire area ratio of each town even number eyes based on this fire situation chart and the fire rank chart was made (Figure 1).

The fire rank division method was five capitations and calculated the difference between the upper bound and the lower bound of the fire burnt-down rate. It is shown that the one degree with high rank and the fire burnt down rate are high in the district. Thus, the fire situation of the respect extension from strength of the fire for each unit area burnt-down rate as a fire rank chart has been done.

This fire rank chart becomes fundamental analysis material which relates to either of the fire hazard district forecast obtained from the following three analysis techniques.

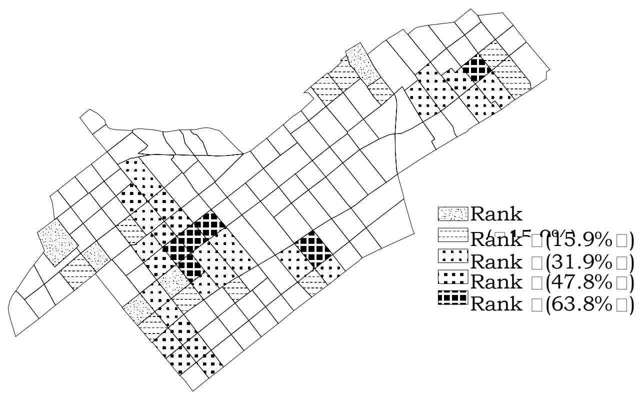


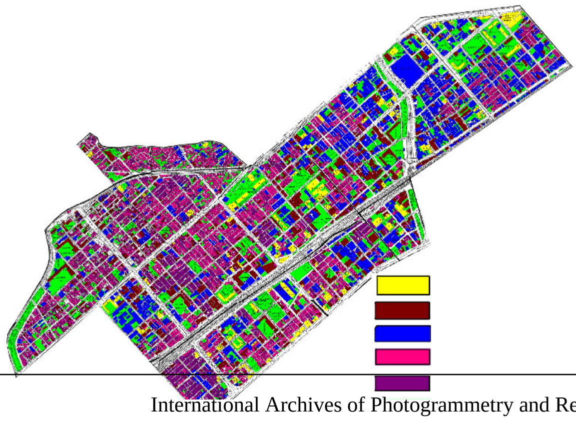
Figure 1. The Fire Rank Chart (Nagata and Suma district)

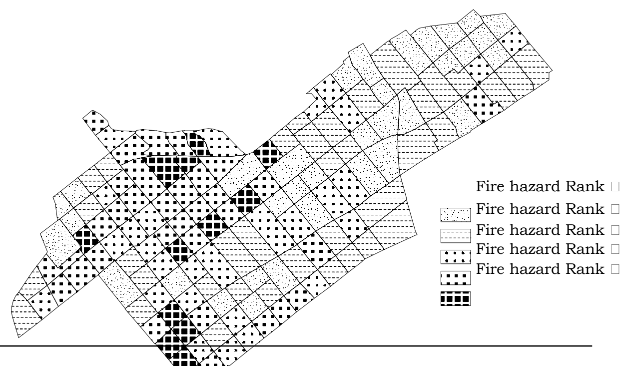
4. Fire hazard district forecast which uses aerial photograph

Data conversion on each town even number eyes was done by using the aerial photograph referring to the made building structural type classification chart (Figure 2), the building composition ratio on the town even number eyes was calculated, and the fire risk was calculated. A wooden rate, non-wooden rate, and the open-space rate were calculated from the building structural type classification chart, the rank division was done to five capitations, and the value was assumed to be a fire risk rank which used the aerial photograph.

As a result, fire breaking dangerous district forecast chart is shown in Figure 3. 32/73 town even number eyes were in the town where a fire occurred in the fire risk's having been forecast overlapping with the fire rank chart (Figure 1) and the comparison, and the forecast rate was 43.8%.

The cause of the fire spreading in an earthquake actual as for half of in the district where a fire had been forecast was understood at this stage in the forecast by the aerial photograph in this manner.





Non-wooden-framed bldgs.(5F□)
Non-wooden-framed bldgs.(3,4F)
Non-wooden-framed bldgs.(1,2F)
Wooden-framed houses(2F□)
Wooden-framed houses(1F)
Open space areas

5. Forecast of fire hazard district where GIS was used

5.1 Selection of dangerous factor investigation item

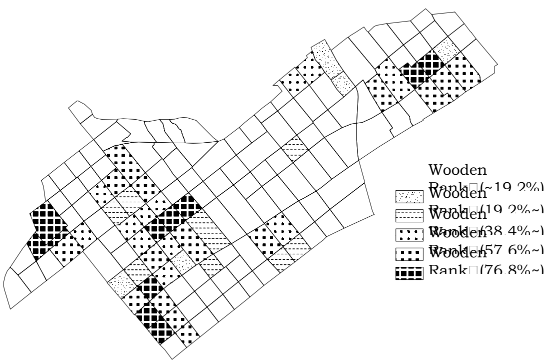
A variety of factor item which seemed to lead from the building structural type classification chart and damage investigation reports to a fire and the spreading danger forecast was selected, and made to the GIS data base by each town even number eyes . The selected investigation item is shown in Table 1.

5.2 Calculation of integrated risk and making of dangerous district forecast chart

Table 1 of the rank division was done respectively, and each investigation item by which was selected was assumed to be a comparison rank of the risk which led to the fire spreading forecast. In addition, when integrated risk was selected, the dangerous forecast chart was made from three items of these of a wooden rate (Figure4.), the open-space rate (Figure5.), and the spreading velocity of fire ratio (Figure6.) for GIS as integrated risk considering the result of the previous building structural type classification. (Figure7.)

Table 1. Investigation item

1	Density of population	17	Ratio of building(net)
2	Density of office	18	Rate of building(prewar)
3	Residential area rate	19	Total floor area(W)
4	Average gas use amount	20	Total floor area (LG)
5	Fire number	21	Total floor area (CB)
6	Burning area	22	Total floor area(RC)
7	Water begins drained off	23	Building number(W)
8	Number of the dead	24	Building number(LG)
9	Numbers of injured	25	Building number(CB)
10	Burning area/10 years	26	Building number(RC)
11	Material damage/10 years	27	Total buildings
12	Total damage/10 years	28	Housing lot area
13	Wooden rate	29	Area of land
14	Fire protection rate	30	Areas of town
15	Fire-resisting rate	31	Lot area/One house
16	Spreading of fire ratio	32	Open space rate



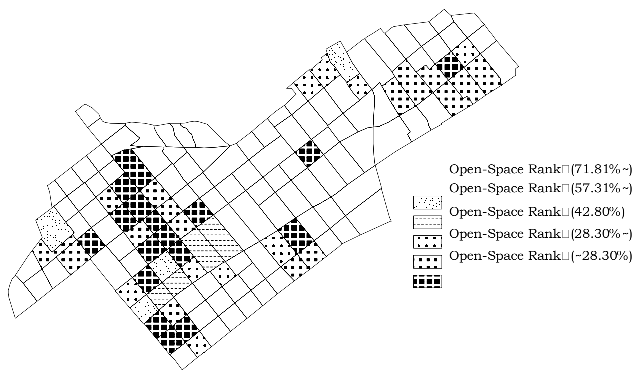


Figure 5. Risk comparison rank of open-space rate 3) by GIS

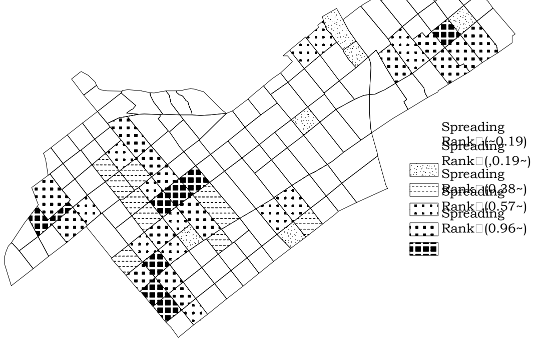


Figure 6. Risk comparison rank of spreading of fire ratio4) by GIS

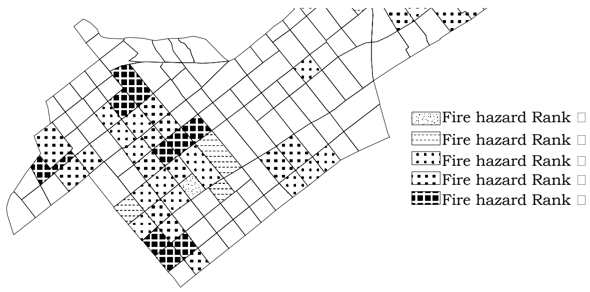


Figure 7. Fire hazard district forecast chart by GIS

As for the district where the risk displayed to compare Figure 1. and Figure 7. in the dangerous forecast chart is high, the district in the fire rank chart in which a large-scale fire breaks out is understood. 35/46 town even number eyes were in the district where a large-scale fire occurred in having been judged a fire was dangerous and it was high, and the forecast rate was 76.1%.

The overcrowded of the wooden building in the urban area and the ratio in the open-space greatly influences a fire and spreading in the earthquake is understood.

Moreover, fairly possible the fire hazard district forecast by reading those factors was understood.

However, if even □□□ does not read the integrated risk rank, not leading to the fire hazard forecast is a current state.

The improvement of accuracy by the geographic information system is necessary for forecasting the fire hazard as become possible in the future if the risk rank is read by two stages to □□.

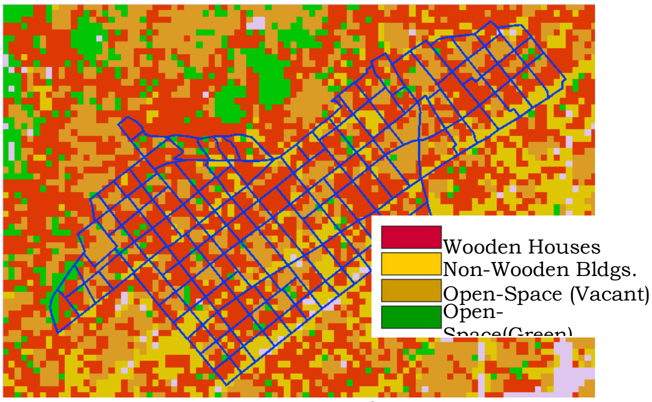


Figure 8. Land coating classification chart by supervised-classification(Nagata and Suma district)

6. Analysis by remote sensing

6.1 Fire hazard district forecast which uses supervised - classification

The thing to obtain latest information by using the remote sensing satellite image at shorter cycle than a aerial photograph and a regional data base (land use situation chart) can be done. It paid attention to the effect of the extraction of information on such a remote sensing and the land coating classification in the Kobe City before the disaster.

The use data is 1984.9.6 ahead of the large earthquake. It is Landsat TM image of taking a picture. The building structural type classification chart made by the aerial photograph and the site investigation was made groundtruth data, and the spectral value of each classification class was specified from the satellite image.

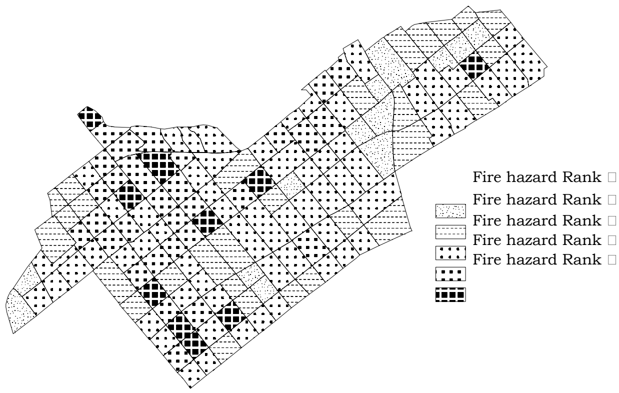


Figure 9. Fire hazard forecast chart by supervised classification (Nagata and Suma district)

In addition, reflectances of various land coating item materials in each wave-length zone region were understood with a spectroradio-meter for the improvement of accuracy.

The spectral value was corrected by comparing some data obtained from this and groundtruth data, and the land coating classification chart was made (Figure 8).

Next, the building composition ratio was calculated from the pixel number ratio included in each town even number eyes, and the fire hazard forecast chart (Figure 9) by the supervised-classification was made for the rank division and the fire risk.

In the fire hazard forecast by the supervised-classification by the remote sensing, 40 out of 102 town even number eyes were in generation about a fire, and the forecast rate was 39.2%.

The forecast rate was about 40% though the fire hazard forecast by the aerial photograph in a precise investigation was 43.8%, the forecast rate dropped somewhat in the analysis by the remote sensing as a handy technique.

6.2 Fire hazard district forecast by unsupervised-classification which uses NDVI & UI

In the supervised-classification by the previous remote sensing analysis, even if it was necessary to set the spectral value by using detailed regional information, and the spectral value by the reflection characteristic was set, the result controlled easily by the weather was obtained.

Therefore, a wooden rate and the open-space rate of each district which was the factor of the fire spreading were understood by using two indexes NDVI(Normalized Difference Vegetation Index) and UI (Urban Index) which was able to be calculated only by the operation processing in the satellite image.

6.2.1 NDVI(Normalized Difference Vegetation Index)

NDVI is an index to understand the distribution of global vegetation from the image data from the weather satellite and the earth observatory satellites.

NDVI can be obtained by the following expressions.

$$\mathrm{NDVI} = \frac{\mathrm{Band4} - \mathrm{Band3}}{\mathrm{Band4} + \mathrm{Band3}}$$

Band3: Visible light region (red region)

Band4: Near infrared

Band3 is observed value of the visible range of Landsat (red region) here, Band 4 is observed value of the near infrared.

A red region of Band 3 hits absorption band of the chlorophyll included in the leaf of the plant.

Band 4 shows the reflectance with a high one with remarkable vegetation according to a cell structural characteristic of the leaf.

Therefore, it can know the state of revitalization of the plant (state of vegetation) by comparing these Band 4 with Band 3.

6.2.2 UI(Urban Index)

UI can be obtained by the following expressions.

$$\mathrm{UI} = \frac{\mathrm{Band7} - \mathrm{Band4}}{\mathrm{Band7} + \mathrm{Band4}}$$

Band 4: Near infrared

Band 7: Small wavelength infrared region

Band 4 is a near infrared shown with NDVI Index.

Band 7 is observed value of the small wavelength infrared region.

The small wavelength infrared region of Band 7 shows the reflectance by the distribution of the state of changing in quality of the rock quality, that is, population structure.

In Band 4, the reflectance is shown by the state of revitalization of the plant. In the urban area therefore Band 7 indicates a high value Band 4 indicates a low value. It is an index to be able to see the state of the urbanization of the district by comparing this Band 7 with Band 4.

6.2.3 Fire Hazard forecast which uses NDVI & UI

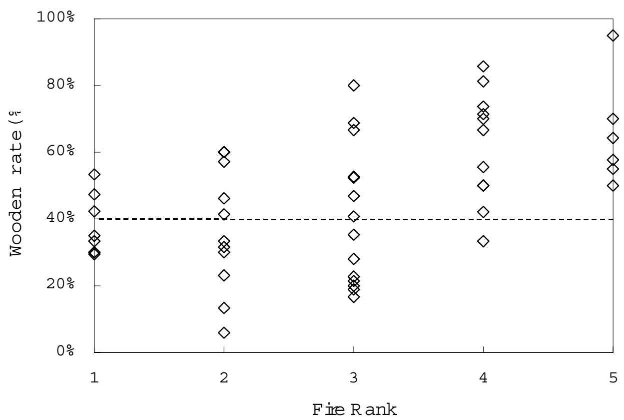


Figure 10. Relation between a fire rank and wooden rate

Figure 10. shows a big and small relation between a degree and a wooden rate of the fire rank. Moreover, a big and small relation between the degree and the open-space rate of the fire rank is shown in Figure 11.

As a result, it was understood that a large-scale fire occurred by the open-space rate 30% from the wooden rate 40% from these figures.

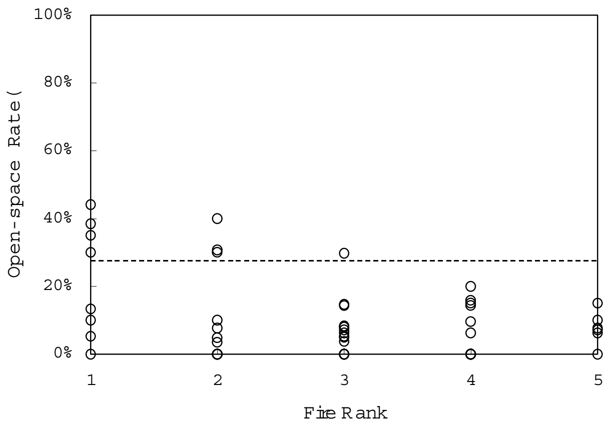
Therefore, attention to two points from this wooden rate 40% to the open-space rate 30%, and the scatter chart of the NDVI&UI value on each town even number eyes was made . (Figure 12.)

The classification chart where the fire hazard district forecast by the remote sensing analysis was able to be done was able to be obtained by beginning to pick up the district from the wooden rate 40% to the open-space rate 30% from the satellite image. (Figure 13.)

Next, proportions of the number of fire hazard pixels on each town even number eyes were calculated from Figure 13, the rank division was done, and the fire hazard forecast chart in unsupervised-classification by the remote sensing analysis was made. (Figure 14.)

22 out of 55 town even number eyes were in the district where a fire occurred in the fire hazard's having been forecast, and the fire hazard forecast rate was 40.0%.

Thus, in the analysis which used two values of NDVI as the unsupervised-classification and UI, the forecast rate was able to obtain the forecast result of 40% same as the supervised-classification.



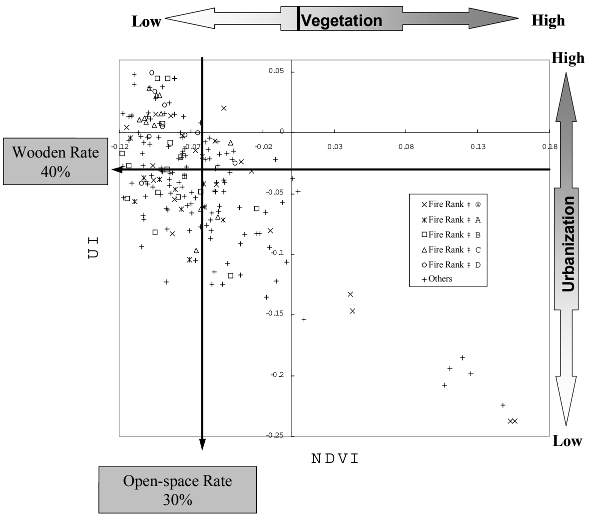


Figure 12. NDVI & UI scatter chart

district was done by understanding the generation factor of a fire of the forecast of the fire risk at the earthquake in the city by the site investigation and the aerial photograph decipherment, and using three analysis techniques of the aerial photograph analysis, the GIS analysis, and the remote sensing analysis next.

The fire hazard forecast rate in each analysis was 43.8% in the aerial photograph analysis. It was 76.1% in the GIS analysis. It is 39.2% in the remote sensing analysis in case of the supervised-classification. Moreover, it was 40.0% in case of the unsupervised-classification.

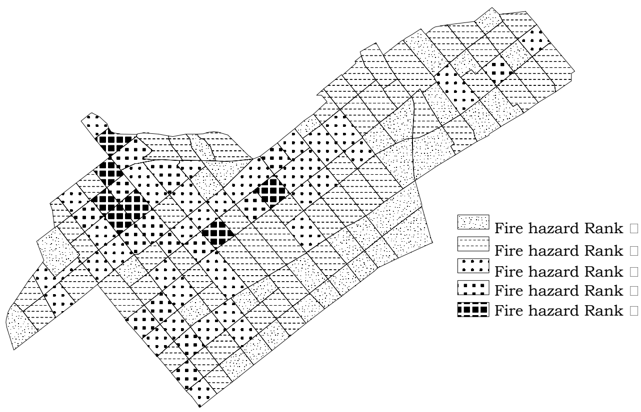


Figure 14. Fire hazard forecast chart by unsupervised-classification(Nagata and Suma district)

7.1□Fire hazard forecast by aerial photograph analysis

The forecast rate of about 45% was able to be obtained in the aerial photograph analysis.

As for the aerial photograph analysis with the stereoscope, there is an individual huge at the decipherment time, a decipherment error, and investigated difficulty and the difficulty are pointed out.

On one side, the update and the correction are in a difficult current state even if regional information used for GIS and the aerial photograph, etc. are long the cycle for the update, and acquire the data which leads to the fire risk forecast in the urban area which changes hourly.

Therefore, it is indispensable for the research to be able to do the update and the correction by data acquisition simply.

7.2□Fire hazard forecast by GIS analysis

High forecast rate (76.1%) was able to be obtained because it became an analysis which used detailed regional information in the GIS analysis. When actually thinking about the application in another city, the difficulty of the information collections whether the various place municipality has city information like this time is given.

It was possible to analyze in GIS data acquisition at this time because of the data obtained from the seismic damage investigation report etc.

However, the doubt remains when thinking about similar research development in another city.

7.3□Fire hazard forecast by remote sensing analysis

The decipherment accuracy decreased in the remote sensing analysis compared with the other two techniques, and the forecast rate when supervised-classification and unsupervised-classification was used was able almost to make out this level.

The supervised-classification was forecast rate 39.2%. It was forecast rate 40.0% of unsupervised-classification.

It was understood as the comparison of the technique of the unsupervised-classification which used NDVI and UI which had been proposed at this time with the supervised-classification which needed detailed regional information that they were handy, and very effective.

As for the supervised-classification, the complexity of the investigation of using a lot of data such as the current state of the land use in the various place district besides the remote sensing data, current states of a building structural type, and the residential quarter charts is pointed out. The analysis by the unsupervised- classification is recommended very much. That is, unsupervised-classification can be analyzed only according to the remote sensing data.

Therefore, the investigated simplicity is incomparable with the supervised-classification.

Then, if accuracy in the unsupervised-classification improves more than now, it can approach the other two detailed analysis techniques.

On the other hand, the remote sensing analysis data update period is two weeks from about one week. It is very suitable for the analysis in the urban area and the data update compared with two techniques of the aerial photograph analysis and GIS analysis.

The forecast rate is not enough in about 40% , however.

It is necessary to research the improvement of accuracy by a further unsupervised-classification.

7.4□Problem for accuracy improvement

It is thought that the decipherment and the forecast accuracy can be improved by improving the following points in doing the research development in the future by the remote sensing analysis based on the above mentioned result.

□ The characteristic grasp done by making the wave length and the reflectance graph by a spectrum value in each land coating classification with a spectro-radio meter and the classification spectral value should be likely to be corrected.

□ It is necessary to have seen from the point of fire prevention and extinction, and to improve a detailed grasp of unoccupied land, the open-space, and the road more than now.

□ The improvement of the decipherment accuracy of the roofing of a wooden house and the rooftop and the roofing of non-wooden structure is also important.

□ The coexistence rate grasp of wooden and non-wooden in 30m×30m a pixel in the transverse magnetic data is also important.

The improvement of the analysis accuracy by the unsupervised-classification which contains the above-mentioned four points is aimed at, and the problem by which the numerical value of the accuracy should be given from present 40% to about 60% is left.

8. Conclusion

Thus, it was understood that three of the spreading velocities of fire etc. were the overcrowded of wooden houses and the open-space comparatively related about the danger of a fire in the urban area. The effectiveness of making out these elements by using the remote sensing was able to be confirmed. Moreover, it is possible to evaluate as a technique of a handy fire hazard district forecast by which regularly latest information can be obtained though the forecast rate drops to the remote sensing analysis compared with the aerial photograph analysis and the GIS analysis.

Therefore, it was understood that it was effective as the outline and dangerous forecast means of a fire at the wide-ranging earthquake in the urban area. Moreover, when thinking about development with another city, it is necessary to improve further accuracy by the unsupervised-classification.

On the other hand, it is most important not to end in the forecast by the research but to advance the removal of dangerous articles, and to solve the work problem to the disaster prevention block of rebuilding in a fireproof building.

References:

1) Urban Disaster Prevention Project –A feasibility study of regional disaster prevention in the Kobe Government-,Toshio KOIZUMI, Ritsu KATAYAMA, X CONGRESS International Society for Photogrametory and Remote Sensing Session pp.365-371

2) $\text{Wooden rate} = \dfrac{\text{Wooden Building Number}}{\text{Number of Total Buildings}}$

3) $\text{Open-Space rate} = \dfrac{(\text{Town even number area} - \text{Housing lot area})}{\text{Town even number area}}$

4) $\text{Spreading of fire ratio} = \dfrac{(\text{Wooden rate} + \text{Fire preventional Wooden rate}) \times (1 - \text{Fireproof Construction rate})}{\left(\text{Wooden rate} + \dfrac{\text{Fire Preventinal rate}}{0.6}\right)}$