Development of Spread Sheet-Based Supporting System for Land-Use Concept Planning

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Abstract: For better supporting in making the land-use plans, the *Sp*read sheet-based supporting system for the *L*and-*U*se *C*oncept planning (Sp-LUC) are newly designed and constructed. As the kernel system, the land-use capability classification model (Kojima and Obayashi, 1991) integrating the satellite remote sensing data jointly with the geographical information is introduced. The Sp-LUC consists of the following systems; i) Pre-processing system, ii) Analysis system, iii) Post-processing system, and iv) Information providing & management system. The pre-processing system and the post-processing system are operated under the internet-environment, while the analysis system could be executed in the spread-sheet environment. Furthermore, the analysis system is equipped with the following two sub-systems; i) the land use capability classification system, and ii) the mutual regulation supporting system based on the AHP(Analytic Hierarchy Processing) method. The system designs on the Sp-LUC might be a good guide for constructing the cooperating system on the spatial data integration and analysis under the spread sheet- and the internet-environment.

Keywords **:** *spread sheet environment, network environment, cooperating system, land use conception plan, satellite remote sensing data, spatial data integration and analysis, quantification method, Analytic Hierarchy Process(AHP)*

1. Introduction

An approach of integrating satellite remotely sensed data and various geographical information to be applied to the land use conception plans, and regional and district plans attracted attentions of the people concerned long time ago[1)]. Systems for processing and analysis of GIS (Geographical Information Systems) and satellite data can now be run with ease on the personal computers, and general public can access to the technologies for processing and analysis of industrial land information. For the decision making of the land use conception plans, the authors have developed the land use capability classification system (temed "LU-CAS") applying geographical information and the satellite data[2)-5)].

Furthermore, we have deployed applied researches relating to support for "mutual regulation" for establishment of plans, through utilization of the land use capability classification map, which is generated by the LU-CAS[6)-8)]. The usefulness of the LU-CAS has been proven by applying these researches to the various public projects. However, a huge amount of these researches and development of projects has been promoted under the UNIX environments. This means that unique analysis algorithms featuring LU-CAS can not be realized easily on the personal computers.

As for environments of the personal-computer utilization, due to completion of substantial network environments, scientific and technical computations can now be done readily. For example, promulgation of so-called SBS (Spread sheet-based System) as represented by Excel, SPSS, Lotus 1-2-3, Multiplan, VisiCalc, and SuperCalc is noteworthy[9)].

Along with fulfillment of the Internet environments, roles played by the ASP (Application Service Provider) have been remarkable also in the construction field[10)]. Successful application of coordination system that allows operation of the SBS under the Internet environments is highly expected. While, it is also true that problem areas relating to development and application of various technical processing and analysis requiring special knowledge, as well as integrated analysis model for spatial information that is dealt with in this study should be streamlined, and system design theory and concrete countermeasures should be thoroughly investigated.

Based on the above background, we have tackled to construct the Sp-LUC (Spread sheet-based supporting system for the Land-Use Concept planning) in which various processing functions share duties under the internet and spread sheet environments.

2. Features of this research

2.1 Problems in constructing spread sheet-based system

When "Integration and analysis model of spatial information" is used under the spread sheet environments in order to analyze the satellite data and various

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geographical information, the following problems are cited:

① Limits of spread sheet

If application is limited to education field, several systems are already available to be used on EXCEL for processing and analysis of the satellite data[4]. A spread sheet of EXCEL consists of a maximum of 256 cells (column) x 65,536 lines (row). This means that an image data in two-dimensional array can import an image data of only 256 x 256 pixels (maximum) per column. Further, restrictions on the number of explanatory variables (16 variables at the most for a regression analysis) for statistical analysis function also poses a problem. For multi-variate analysis in which satellite data and various geographical data are utilized comprehensively, there is naturally a limit for processing by EXCEL.

SPSS that has no limits on the sheet where multivariate data are processed then atracts a widespread attention. Although it has abundant statistical analysis functions, everybody knows that as far as processing performances and user-friendliness are concerned, EXCEL is superior to SPSS in computation processing which is an original function of the tabular form.

In constructing a spread base system aiming at assisting integration and analysis of the spatial information, it is important to realize a combination system in which advantages of each of spreadsheet software are utilized and duties are shared appropriately.

② Limits of SBS under Internet environments

An approach to use spread sheet base system under the Internet environments has been attracting attentions of the people concerned. At present, JAVA/ActiveX compatible development tools are on the market.

However, practical application of the system thus constructed suggests that any processing is not possible unless special file format or file structure is fully understood and that GUI (Graphical User Interface) for parameter entry is complicated depending on contents of processing.

In the construction consulting job, if various thematic maps involving the satellite data and digital geographical models should be generated and used, requirements here are such that as the pre-processing, data conversion and geometric correction should be done immediately, output results be analyzed and trial study be made, and the report should be summarized quickly. In many cases, instead of constructing and running purposely a system equipped with GUI, processing and analysis utilizing functions of the spread sheet software without any modification may be more effective.

Therefore, in promoting system design, entirely different viewpoints should be taken into considerations so that various functions share duties appropriately under the Internet and spread sheet environments.

Items as discussed above have surprisingly been remained as blind spots so far in constructing a spread sheet base system and resulted in the original idea of this research and development.

2.2 Features of Sp-LUC

Features of Sp-LUC are summarized by the following three items:

① Sharing of system functions and improvement of processing efficiency

As shown in **Figure 1**, the Sp-LUC consists of the following systems; i) Pre-processing system, ii) Analysis system, iii) Post-processing system, and iv) Information providing & management system.

Advantages of each system are sorted out as shown below, and basic investigation was made in many fields which resulted in such tentative conclusion that "Pre-processing system and post-processing system" should be run under the Internet environments and "Analysis system" should be executed under spread sheet environments. Sharing of processing functions under the Internet environments not only solves limitation problems of spread sheet designing, but also contributes to improvement of the processing efficiency.

② Efficiency of system development and expandability

If the pre-processing functions are shared under the Internet environments, it is not necessary to deploy all the function groups, which make up complicated processing algorithm, on the spread sheet.

This advantage allows small-sized JAVA module and improves the processing efficiency of each function. Consequently, turn-around time to obtain goods incorporating results of processing is improved. In other words, since processing function can be developed independently, the efficiency of system development is improved and the expansion of function is made easy.

③ Versatility of system utilization and efficiency of processing job

Recently, studies on design and development of spread sheet base system have been reported, which aims at executing image processing and analysis of the satellite data readily for resources investigation, environmental investigation, disaster prevention plan, and land use conception plan[11].

However, as mentioned previously, amount of the image

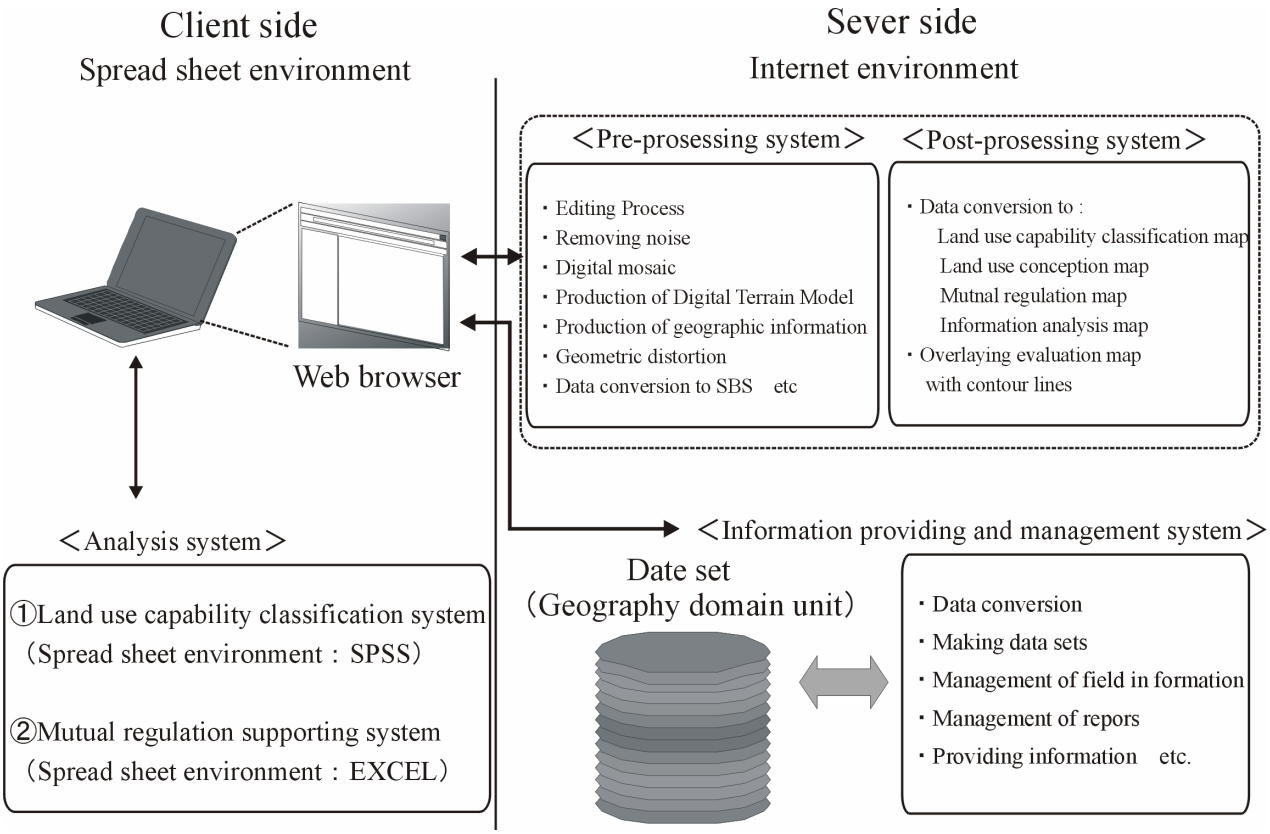

Figure 1 System structure of Sp-LUC.

data that can be imported into a spread sheet is limited. For this reason, the image should be divided into several segments in advance to be used as the processing data and this apparently poses a versatility related problem.

Besides, with spread sheet base system, a series of processing procedures are in many cases systemized using macro languages. However, users do not pick up macro processing if once experienced with the processing. This is because any processing that can be analyzed by data array of tabular form can be processed with ease thereafter. Namely, in many cases, construction of a spread sheet base system becomes a tentative object, while GUI to support processing on the spread sheet constructed purposely is wasted.

From the above, it is considered that discussion on "How should various speciality technical processing and analysis systems be developed and run under the spread sheet environments" is necessary, as well as support for the land use conception plans. This issue has been overlooked unexpectedly.

Sp-LUC is designed so that more than two engineers can use the system concurrently by issuing a brief command for shared processing of the job through uniformity of processing operations. It goes without saying that processing efficiency of the entire job is improved and this is delightful news for engineers who are engaged with concurrent processing of many jobs on daily basis.

3. Total design of system (Sp-LUC)

3.1 Basic requirements for Sp-LUC

The basic requirements for designing the system include the following three items:

① Environments of system operation

Taking ease of system maintenance into considerations, whole system is divided into pre-processing, analysis, post-processing, and information presentation and management systems, and detailed design is carried out according to this category.

Client and server system being connected through the Internet is used where the client side uses Sp-LUC. This system allows Internet environments (pre-processing, post-processing, information presentation and management), and spread sheet environments (analysis) where processing and analysis are done on job-sharing basis.

② Structure of sub-system

The analysis system is divided into "Land use capability classification system" and "Mutual regulation supporting system". This is to grasp and to execute whole aspects of a

Table 1 Functions of pre-processing system under the internet environment.

Functions for image correction	Functions for producing geographic information
・Image cutting ・Removing noise ・Digital Mosaic ・Geometric correction：Coordinates conversion ・Geometric correction：Resampling ・Data convertion(for Spread sheet-based supporting system)	＜Production from DTM＞ ・Slope map ・Elevation map ・Relief map ・Aspect map ・Drainage map ＜Productions from satellite remotly sensied data＞ ・Land cover classfication map ・Vegetation index map

series of processing algorithms for preparation of the land use capability classification map and mutual regulation map. Further, the land use capability classification system is designed and developed on SPSS, while the mutual regulation supporting system is designed and developed on EXCEL.

3.2 System management environments

It is possible to use Sp-LUC on the personal computer connectable to the Internet without any restrictions on time and place. No special peripheral device is required at all. This means that the system works under ordinary network environments, and operation is made being divided into "System utilization environment (client side)" and "System management environment (server side)" - one of distinctive advantages of this system.

① System utilization environment (Client side)

In the client side environment under Sp-LUC, A password is transmitted from system management side, and if accepted, one can use Sp-LUC under the Internet environments.

② System management environment (Server side)

In the server side, the data set and software library (SLMS: Software Library Management System) handled by Sp-LUC. Authorized system administrator alone can enter into this management environment. Genaeral users are not permitted to use the information management functions.

3.3 Style of system operation

During the course of designing of this system, we investigated four types of system operation styles from the relationship between "Place of execution of image processing and analysis" and "Place of storage of processing object data"[12].

Sp-LUC is based on one of these operation styles. The client side downloads the image processing and analysis program (Java applet), and processing and analysis can be performed at the user's location. To do this, the user side should possess the processing object data, as the satellite data and DTM (Digital Terrain Model).

It is of course necessary to check such a system operation style where the client side does not own the data and accesses the server side, in which the data set is accumulated in advance and executes processing. However, it should be noted that this idea involves problems with regard to maintenance of the data set and management costs, which will be investigated in the future.

4. Detailed system design of Sp-LUC

4.1 Pre-processing system

The functions of Sp-LUC the pre-processing sys As mentioned previously, the pre-processing system works under the internet environments and consists of "Image correction function" and "Production of geographical information" as shown in **Table 1**. These are essential for preparation of geographical information to be input prior to preparation of the land use capability classification map.

(1) Function of image correction

The image correction function is in charge of noise removal of the satellite data and correction for geometric distortion. The noise removal filter is designed to be capable of changing the level of weighting factor at user's discretion.

For correction of geometric distortion, the nearest neighbor interpolation or the cubic convolution interpolation[13] may be used. After these corrections are made for the satellite data, the land cover classification map or the vegetation index will be produced.

(2) Function for generating geographical information

Functions used for generation of five items of geographical information are produced from the Digital Elevation Model as shown in **Table 1**. To make the land cover classification map prepared from the satellite data, either "Supervised maximum likelihood classification[13)]" or "Unsupervised cluster analysis[13)]" can be selected. It is also possible to select more than two equations of vegetation index[13)].

The pre-processing system of Sp-LUC operated on job-sharing basis under the internet environments might be useful for the working level staff in terms of the following points:

①Suitability and efficiency of pre-processing

It is possible to prepare the causal factors to be input to the land use capability classification system appropriately and efficiently as needed.

②Continuity of GUI

The pre-processing system of Sp-LUC is equipped with processing functions essential for preparation of the geographical information, and alteration of GUI is not required. This means that user-friendliness is maintained and inherited, and the users concerned are not bothered with alterations of various functions.

③ Convenience of management and operation

Since the pre-processing system is made independent in Sp-LUC, no expense is incurred and no measures are needed for renewal due to addition of functions other than the pre-processing. Namely, user-friendliness will not be deteriorated, due to that functions used rarely are added or GUI is changed, whenever version upgrading is attempted.

4.2 Land use capability classification system

(1) Structure of analysis system of Sp-LUC

The analysis system of Sp-LUC consists of "Land use capability classification system" and "Mutual regulation supporting system" as shown in **Figure 1**. **Figure 2** shows the interrelation of sub-systems.

The geographical information prepared by the pre-processing system is used as the information to be input to the land use capability classification system under the SPSS environments. The land use capability classification map to be prepared also acts as the input information resulting in generation of the mutual regulation supporting system under the EXCEL environments.

Figure 3 shows a processing flow in the land use capability classification system consisting of processes of ① Causal factor conversion, ② Causal factor selection (Quantification method type III and II), ③Preparation of land use capability classification map (Quantification method type II and Mini-max discriminant method), and ④Production of the difference maps(termed "DIF map") as a final products.

Contents of the processing will be explained one by one in the following description.

(2) Format conversion of causal factors

This function is capable of converting the judgment criteria (i.e., the "training data") for the capability classification and causal factor data in the form of a data set. Upon starting the system, a menu as shown in **Figure 4** appears on the WEB browser. In "causal factor conversion" processing at the right of the figure, more than two causal factors are input and designated, and are converted into data sets.

Furthermore, in "dummy variables conversion" processing, these causal factors are converted to dummy variables which are used in the quantification theory. The foregoing processing can be executed easily without worrying about special file structure.

Although these functions correspond to "pre-processing" in the analysis system, these are distinguished from "pre-processing" shown in **Table 1** in order to avoid system design related confusions.

(3) Selection of causal factors

The data set that completed causal factor conversion has such an array that allows importing to SPSS. **Figure 5** shows a style after importing. The name of causal factor is shown in the uppermost row to assist analyses using quantification method[9)].

With Sp-LUC, after correlation analysis is made by quantification method type III, any combination that exhibits high correlation is sought. Causal factors with higher partial correlation coefficient based on quantification method type II are adopted to prepare the land use capability classification map.

(4) Discriminate analysis

An analysis based on quantification method type II is executed using causal factors selected. As shown in **Figure 6**, after the dependent variable (i.e., training data) and the explanatory variable (i.e., causal factors) are designated, "weighting factor" to be affixed to categories constituting a causal factor will be calculated automatically.

Using linear functions based on this weighting factor, evaluation values are calculated by pixel unit. Furthermore, for pixels to which this evaluation value is affixed, preparation of the land use capability classification map is made through min-max discriminate method.

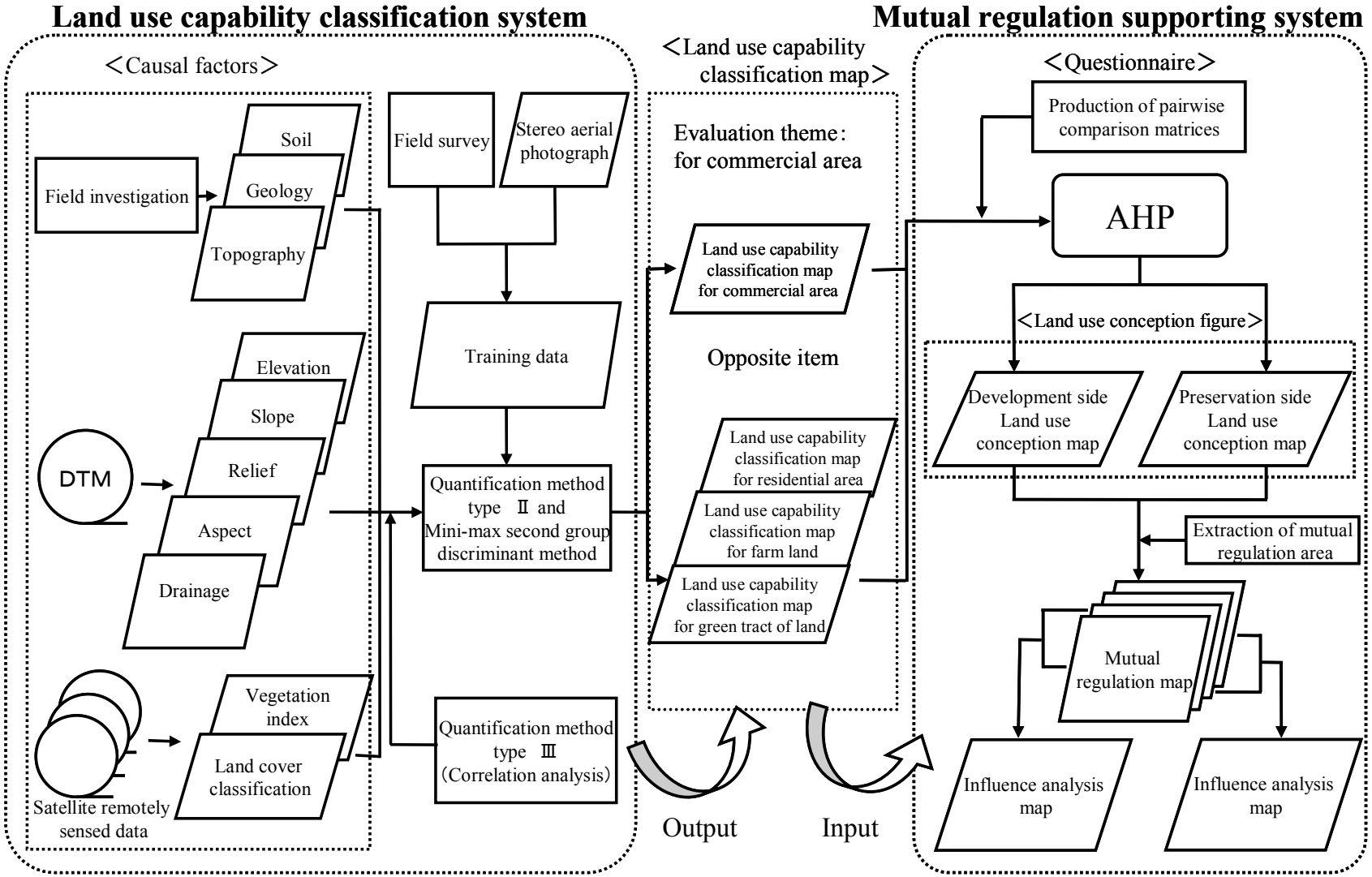

Figure 2 Analysis system of Sp-LUC

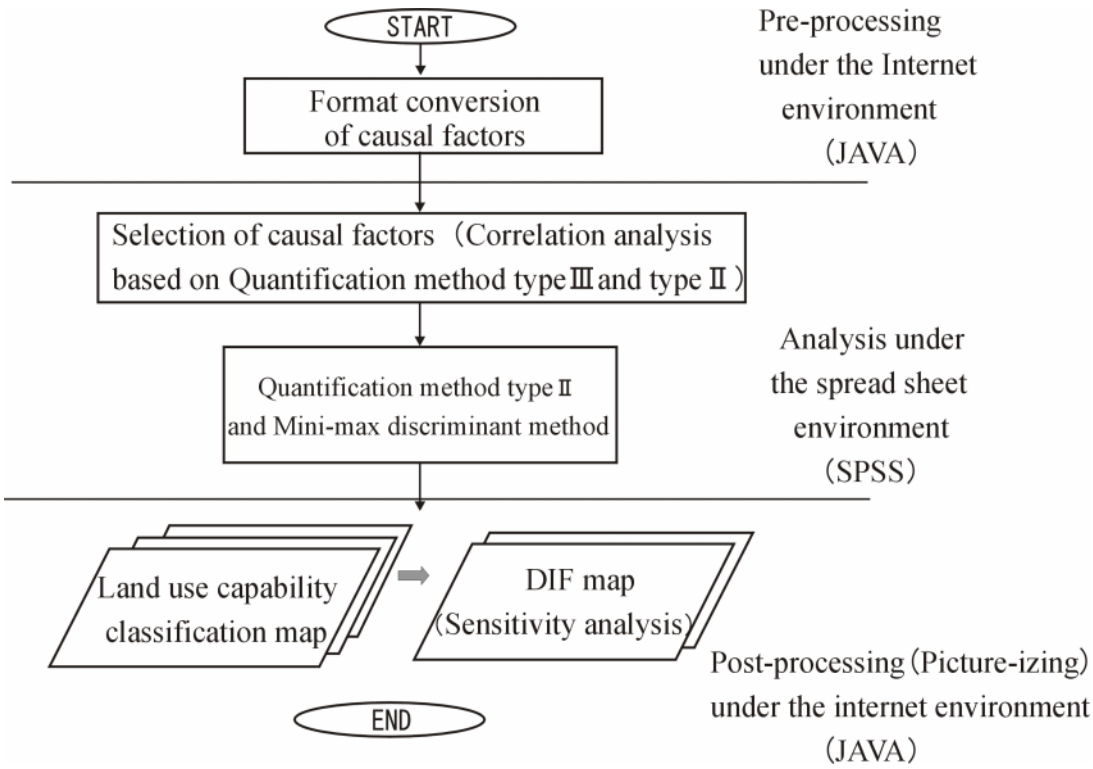

Figure 3 Processing flow of land use capability classification system.

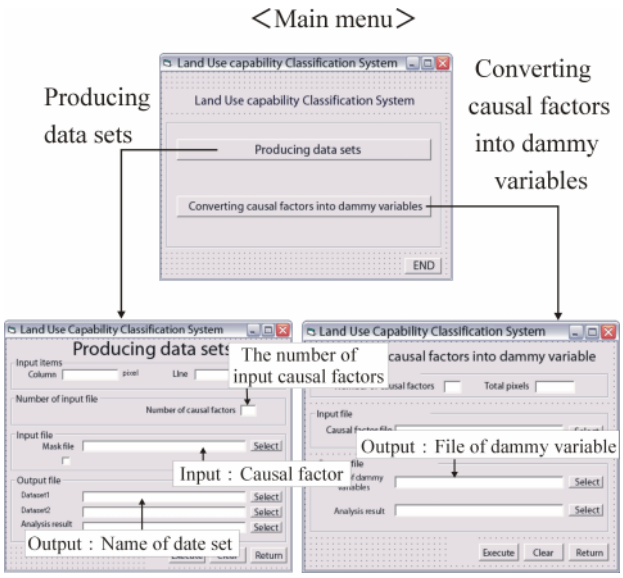

Figure 4 Control panel for converting the causal factors into dummy valuables.

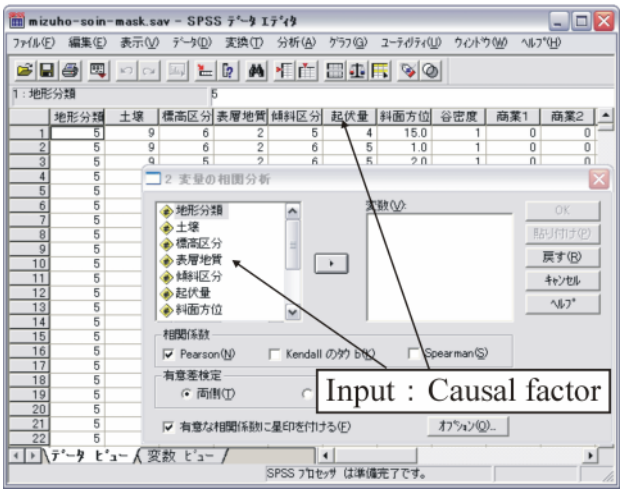

Figure 5 Import of data sets on causal factors.

(5) Sensitivity analysis

As shown in **Figure 2**, it is possible to create various capability classification maps by changing the training data. Comparison of these differences (i.e., sensitivity analysis) will be an essential factor from viewpoints of analysis of land use suitability. With Sp-LUC, sensitivity analysis can be made via a "difference map (termed DIF map)" in which differences of more than two capability classification map are extracted. These processing are made under the spread sheet environments.

In order to assist a series of processing, manuals complying with the format shown in **Figure 7** are streamlined[14]. Considerations are given so that processing may be promoted one by one in inductive fashion while state of the screen is shown on the left, and contents of the operation are shown on the right[2)-5)].

4.3 Mutual regulation support system

(1) Flow of processing

Figure 8 shows a flow of processing in the mutual

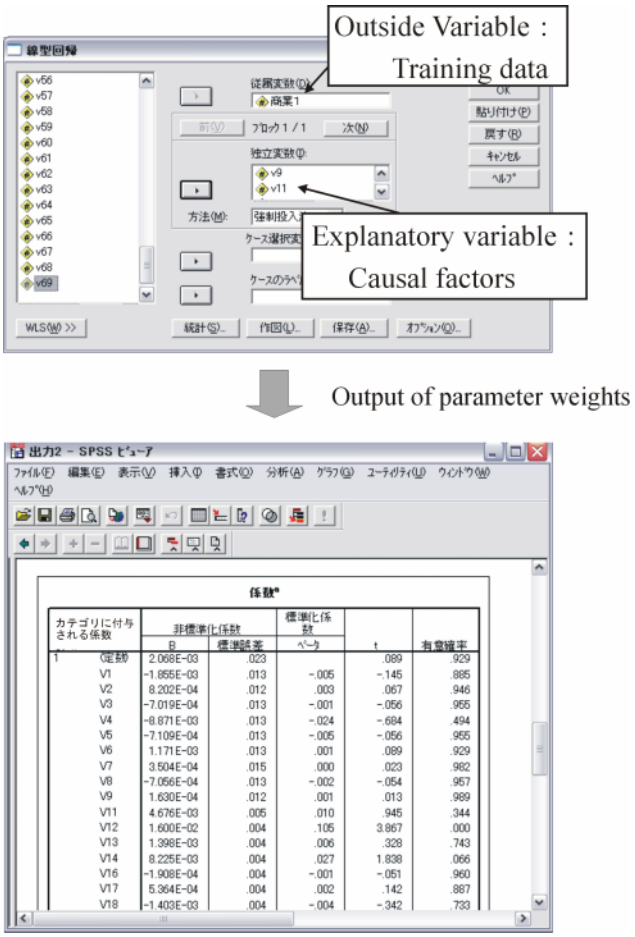

Figure 6 Calculation of parameter weights of categories based on SPSS.

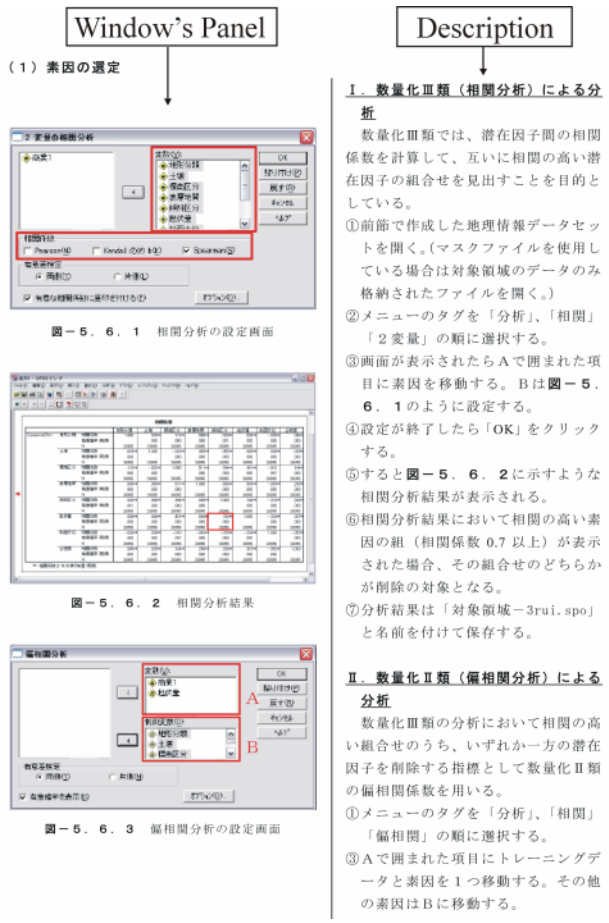

Figure 7 Example of operation manual.

regulation support system. It is divided into "preparation of the land use conception map" and "preparation of mutual regulation map"[6)-8)].

The land use capability classification map prepared through the land use capability classification system as mentioned above is used as the input information, and the land use conception maps of the "development side" or "preservation side" and the mutual regulation map are prepared in this order.

As one example, if thematic subject of classification is set to the "commercial area selection," while suitability of "residential area, farmland, green tract of land, etc." are cited as the "opposing factor" from land use planning viewpoints. The conception plan will be generated if the intention of the development side and preservation side is expressed on the map, while taking these opposing factors into account.

The mutual regulation map will be generated if "concession region" is extracted from the conception maps of the development and preservation side[6)-8)].

(2) Calculation of importance level

With regard to the capability classification map corresponding to the thematic subject of classification and the opposing item, based on the hierarchical structure as shown in **Figure 9**, pairwise comparison matrices questionnaire survey is carried out to calculate the importance level for each classification criteria. Calculation of summing up importance level can be done easily, which is an important requirement in the system.

With Sp-LUC, by inputting a pairwise comparison matrix one by one into the color highlighted cell on the spread sheet (EXCEL) of the prescribed format as shown in **Figure 10**, calculation of the importance level will be made.

This sheet is designed in such that when the calculation is made on sheet No.1 up to overall importance degree, degree of adjustment and adjustment ratio will be calculated on sheet No.2, and many considerations are being given for data link design between sheets.

(3) Procedure of mutual regulation

Upon completion of calculation of the importance level, it is possible to calculate the evaluation value by pixel unit at development and preservation side. The concession region (neutral zone) is determined based on the evaluated value. Specifically, as shown in **Figure 11**, evaluated values at development and preservation sides are plotted on

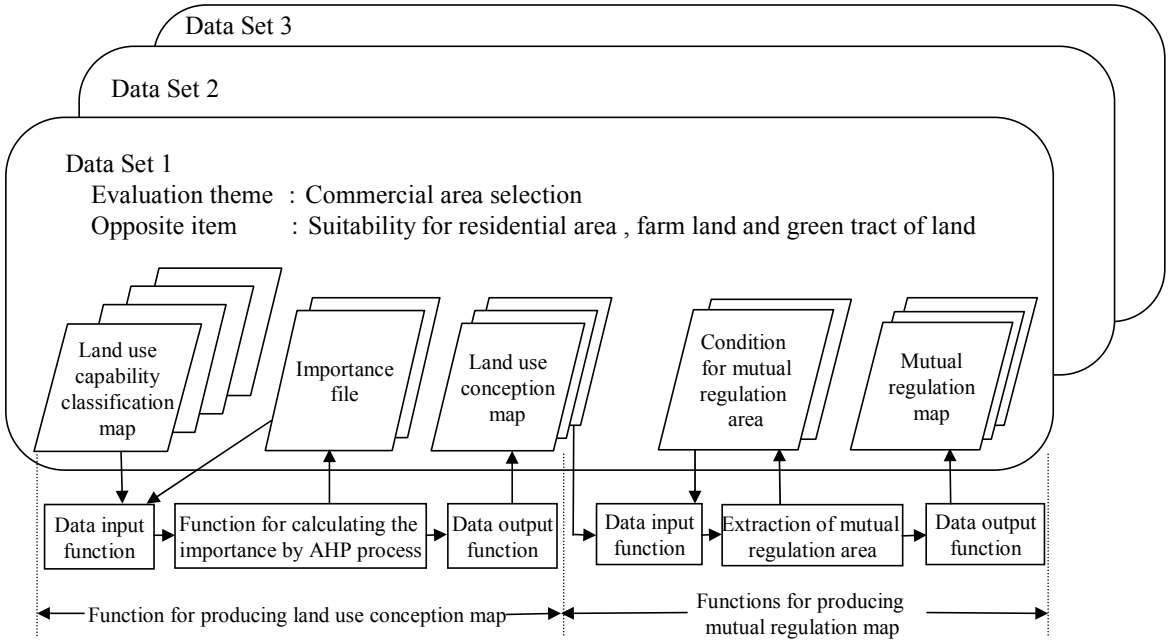

Figure 8 Relationship between and functions.

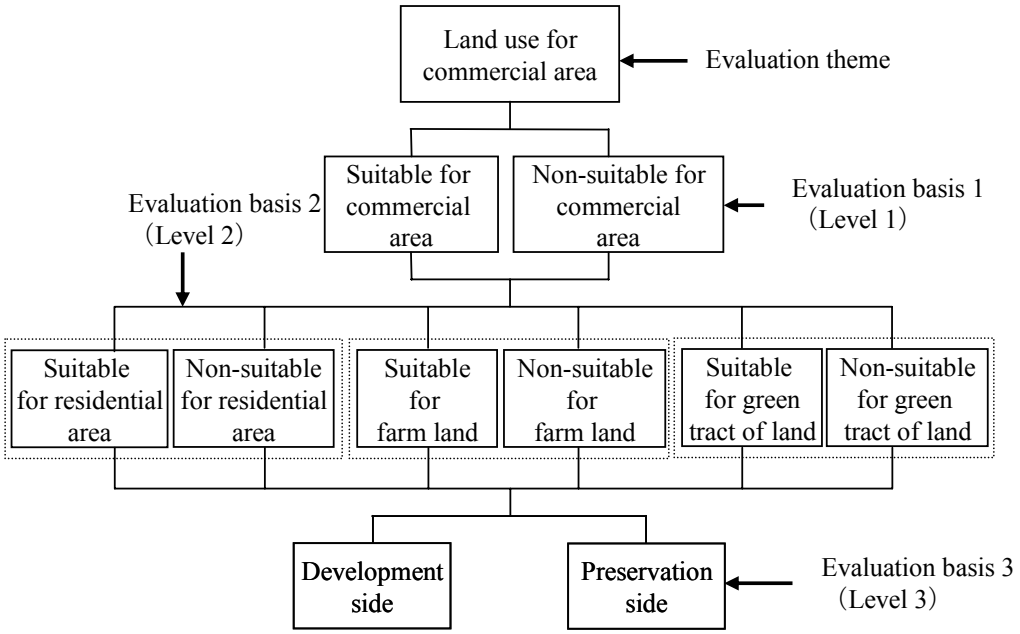

Figure 9 Hierarchy for AHP-based analysis.

x-axis, and a cumulative frequency is drawn from the right and the left to generate a graph.

The concession region is then set based on this graph, and the upper limit and the lower limits are output as an intermediate file.

(4) Production of mutual regulation map

Using the importance level as mentioned above and the information file of the concession region as the input information, preparation of the land use conception map and mutual regulation map is initiated. This processing is to output the land use conception map and mutual regulation map at development and preservation sides and is executed under the internet environments.

Figure 12 shows a menu for preparation of the land use conception map and the mutual regulation map. After the input file is designated, file name of the land use conception map and mutual regulation map is input and the execute button is simply clicked.

Examples of output of the conception map and the mutual regulation map at development and maintenance sides are shown in section 4.5.

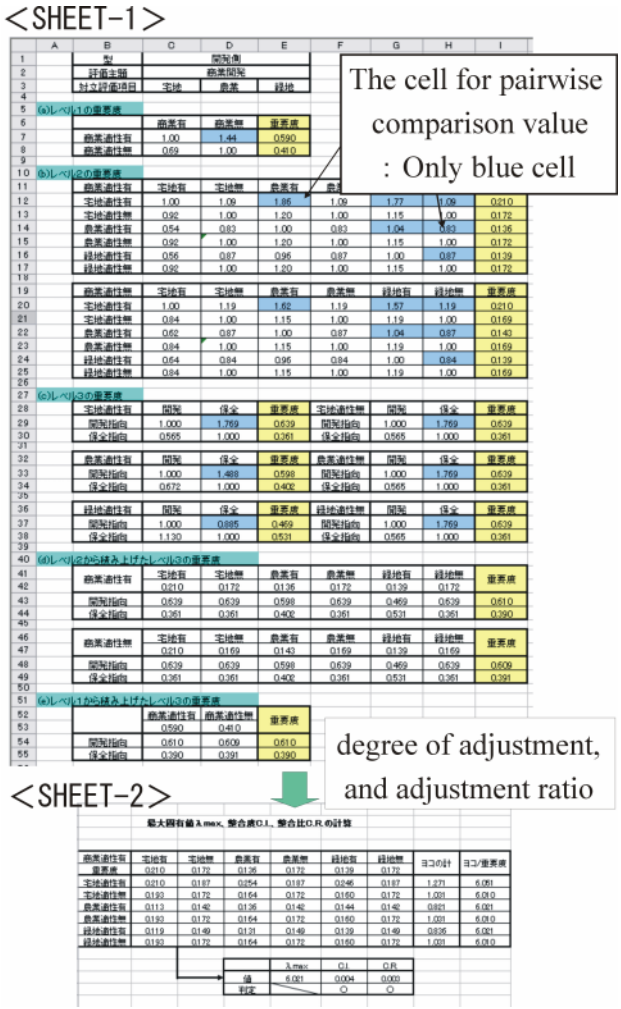

Figure 10 Example of spread sheet design for inputting the pairwise comparison values and calculating the degree of importance.

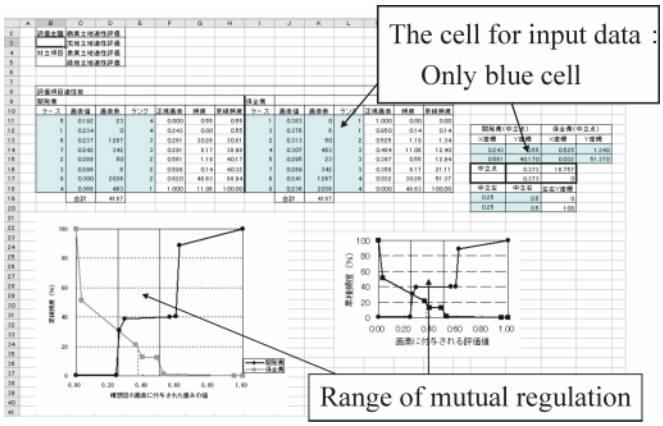

Figure 11 Example of spread sheet design in calculating mutual regulation area.

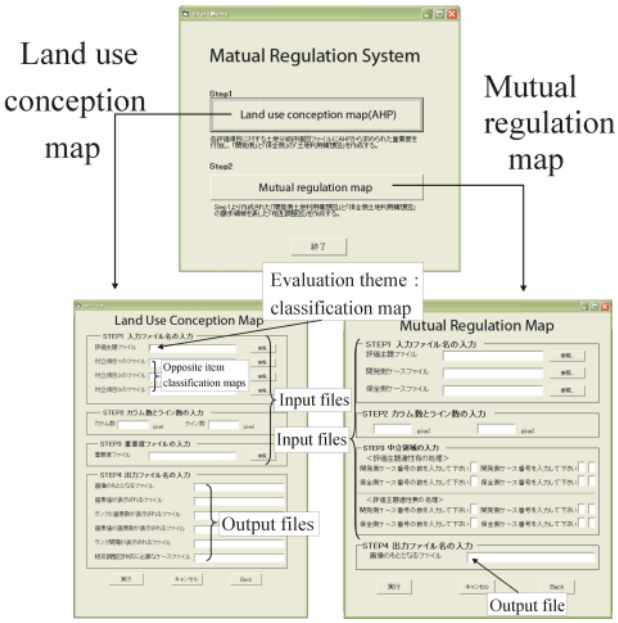

Figure 12 Control panel to make the land use conception map and mutual regulation map.

4.4 Post-processing system

In the post-processing system, superposition of various thematic maps and topographical maps and unification of display style are performed to shape results of the processing into achievements. The post-processing system also includes preparations of reconnaissance survey ledgers, reports, and data for presentation (e.g., generation of 3D viewing image). These are identical with ordinary functions which GIS available in the market is equipped with.

4.5 Information providing and management system

Through a series of processing as mentioned, it is possible to obtain a variety of information including causal factors (satellite data and geographic information), land use capability classification map, conception figure at development and preservation sides, mutual regulation map, reconnaissance survey information (moving and still pictures), reconnaissance survey ledgers, and reports. These information should not be scattered and lost, and be accumulated and managed continuously whenever the processing is made. This is an indispensable system requirement.

With information presentation and management system of Sp-LUC, these information are consolidated as the data set by geographic information unit, and accumulation and "retrieval/reference" of the information are possible under the internet environments.

(1) Data set specification

Figure 13 shows an example of data set specification displayed on the WEB browser. The specification is divided into ① Causal factors, ② Land use capability classification map, ③ Land use conception figure, ④ Mutual regulation map, ⑤Reconnaissance survey ledger, and ⑥ Related information. It is of course possible to accumulate effectively various kinds of information according to these information items.

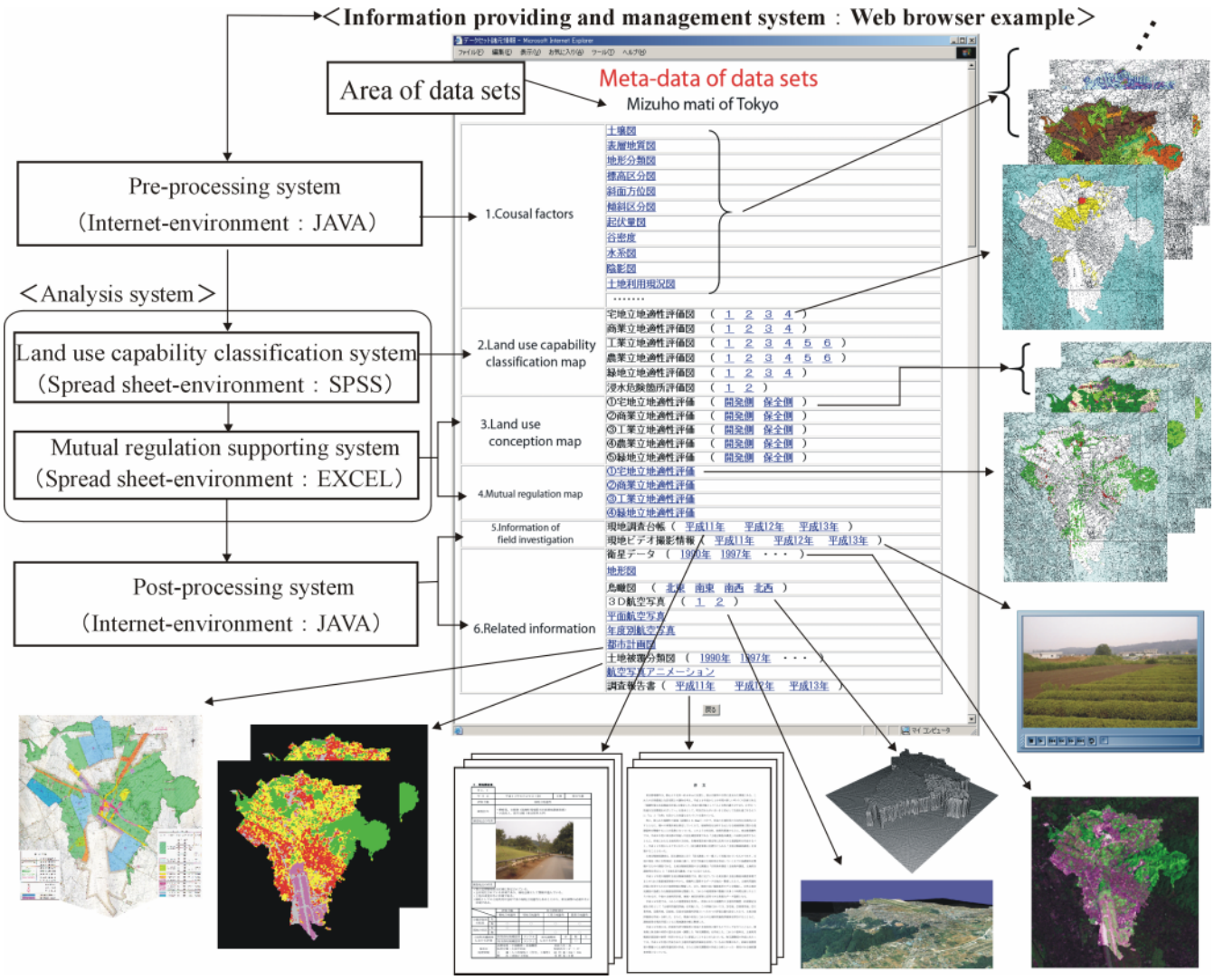

Figure 13 Data sets providing and management system of Sp-LUC.

At the right of **Figure 13**, coordination between Sp-LUC system and processing flow is shown. In addition, considerations are given so that coordination between the information handled in each system and the data set specification can be grasped at a glance.

(2) Retrieval and reference of data sets

① Area selection

Upon requesting HTTP from the WEB browser, a base map, on which prefectural and city government border lines are shown (**Figure 14**), appears as the initial screen. If the prefecture containing the information to be referred to is designated by a mouse, it moves to the screen showing a zone on the topographical map (scale: 1/50,000).

② Selection of zone

By further clicking the zone to be referred to, a list of data set specification is displayed.

③ Reference to link information

By clicking the highlighted character, it is possible to refer to image information and numerical value information concerned. It is designed in such that as noticed from the link portion, the data can be added easily whenever any processing is executed. All the information handled by Sp-LUC can be referred to via the data set specification.

Image information and numerical value and text information can be disclosed easily on the internet environments. While it may be pointed out that discussions about continuity of data maintenance, and expansion of information providing and management system, including the framework required for accumulation and management of the information obtained from the system processing expertise technical field, made so far are not enough.

We consider that the contents of development of this research will be of some help as one example relating to “How should the data be shared and controlled” in constructing a coordination system operating under the internet and the spread sheet environments.

6. Concluding remarks

For better supporting in making the land-use plans, the Spread sheet-based supporting system for the Land-Use Concept planning (Sp-LUC) are newly designed and constructed. Contents of the research and development can be summarized into the following three points:

- As the kernel system in Sp-LUC, the land-use capability classification model[2)] integrating the satellite remote sensing data jointly with the geographical information is introduced. The Sp-LUC consists of the following systems; i) Pre-processing system, ii) Analysis system, iii) Post-processing system, and iv) Information providing and management system.
- The pre-processing system and the post-processing system are operated under the internet-environment, while the analysis system could be executed in the spread-sheet environment. Furthermore, the analysis system is equipped with the following two sub-systems; i) the land use capability classification system, and ii) the mutual regulation supporting system based on the AHP(Analytic Hierarchy Processing) method.
- The system designs on the Sp-LUC might be a good guide for constructing the cooperating system on the spatial data integration and analysis under the spread sheet- and the internet-environment.

In the research and development field handing satellite data or various geographic information, keywords as typically represented by IT (Information Technology) and environmental technology have been cited frequently.

Although it is necessary to execute job analyses based on the technological contents of the field of the expertise all the time, combination with development tools and coordination with the system should be taken into considerations at designing phase when development environments have been diversified as frequently noticed today.

The authors will be grateful if the contents of this research and development could raise problems for not only system development aiming at consolidated use and the spatial data analysis, but also development relating to construction of various technological processing and analysis system working under the spread sheet and the internet environments.

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