Geographic Information Systems and Environmental Problems

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武部　隆「地理情報システムと環境」　本稿では、地理情報システムに関して、その適用事例を中心に具体的な考察を加え、とくに、環境分野における地理情報システムの今後の利活用の方向性について検討を試みる。

すなわち、まず、第２節で、地理情報システムの発展段階を、①当該経済主体の施設管理のための地理情報システムの段階、②施設管理をも包含した当該経済主体の経営管理の手法としての地理情報システムの段階、③地域インフラとしての地理情報システムの段階、そして、④社会インフラとしての地理情報システムの段階の４つの段階に区分して考察する。次いで、第３節で、地理情報システムの適用事例について、①エイセルメイ社の公共サービス配給情報システムのケース、②フロリダ州リー郡の土地情報管理システムのケース、そして、③ＷＲＴ社が参加するプロジェクトにおける地理情報システム適用のケースを取り上げ、それぞれ具体的に検討する。続いて、第４節で、いわゆる地理情報システムテクノロジーの具体的応用事例について触れる。すなわち、①地図データ検索機能活用の場合、②半径探索集計機能活用の場合、③地図の重ね合わせ機能活用の場合、それに、④マーケティング分析における市場分析での活用の事例と立地分析での活用の事例である。そして、最後に、第５節で、環境分野における地理情報システムの今後の利活用の方向性について、イギリスで試みられている農村計画・農村環境管理のための地理情報システムという方向を取り上げ検討する。

本稿でみるように、環境分野における地理情報システムの利活用は、随所にその応用事例がみられるものの、まだ緒についたばかりである。しかし、その利活用の可能性は、限りなく広くまた大きいといえる。地理情報システムの開発と発展を視野に入れながら、とくに農村部における環境分野に地理情報システムを導入して、農村部における環境問題に一定の解答を与えるということは、われわれ農業経済研究者に課せられた重要な責務だということができよう。

1. Introduction

Geographic information appears in the forms of images, statistics, or text information. In recent years, computer technology has greatly advanced in both hard- and software, and so-called GIS, Geographic Information System, is now drawing much attention of the whole world; it satisfies users' intention by converting geographic information as above into numerical (digital) information, saving it as databases, putting it instantly into diagrams and maps, and furthermore, making spatial analytic models and analyzing the simulation.

Geographic information means here the information which can be expressed on maps by means of location identifying codes (that is, 'geocodes'), like longitude and latitude, mesh code, administrative regional code, or zip code. It consists of some kinds of information: image information is either what is obtained by remote sensing methods such as satellite pictures and air photos or what is expressed in maps; statistic information is what is implied in various statistical charts based on various statistical researches; and text information is what is stated and expressed as text in topographies, dictionaries, and cyclopedias[1].

A geographic information system, as seen above, was formerly grasped in general as "a computer-assisted technological system for collecting, diagramming, numerically expressing, storing, processing, and displaying geographic information". The present contents of it are, however, not just confined thereto. It is now under reconstruction to be a more refined technological system which contains analytic tools adequate to users' purpose; this is so-called Spatial Information System[2]. The technology is also widely applied to various fields such as (1) information collecting (remote sensing, monitoring, etc.), (2) planning and maintenance (city planning support, local planning support, facility maintenance, etc.), (3) environment (natural environment, conservation environment, etc.), (4) landscape (urban landscape, historical landscape, etc.), (5) disaster prevention (collection of disaster information, research of disaster suffering area, etc.), (6) business (marketing, facility siting, estate maintenance, etc.), so that the range where utilization of geographic information systems are expected is steadily spreading[3].

The first geographic information system is thought to have been the "Canadian Geographic Information System (CGIS)", which Canadian Government designed in 1964 especially for their agricultural reconstruction and development plan[4]. Thereafter, especially since 1970's, various countries, led by USA, have achieved their own individual technological development both on hard- and software sides, and tried to answer users' purpose. While a lot of results have been brought about, the technology for its particular users has advanced to be the technology of general purpose, and its practicality is now being more and more highly appreciated.

Intention to use a geographic information system differs greatly depending on whether its users are public bodies like central and local governments, etc. or private bodies like electric power companies, gas companies, banks, real estate companies, etc. The public ones use it for public interest and benefit, while the private ones use it for their private benefit. Central and local governments use geographic information systems for (1) city plan settling, (2) real property taxation, (3) public facility maintenance, (4) anti-disaster policy, (5) land conservation policy, and (6) forestry resource conservation policy, etc. Electric companies, gas companies, banks, real estate companies, etc., on the other hand, use them definitely for their private interests[5].

This paper is intended to examine concretely how and where geographic information systems are applied and to consider what direction their usage is going to, especially on the branch of environment. The stages of development of geographic information systems are summarized in the following chapter, and some examples of the usage of geographic information systems are shown in the concrete in Chapter 3. Then some examples of the definite applications of so-called geographic information system technology will be investigated in Chapter 4. And in the last Chapter 5, there will be considered the possibility and the direction for introducing geographic information systems into the field of the environment.

2. Stages of development of geographic information systems

Generally speaking, the geographic information system begins its first stage as a geographic information system for (A) maintaining the facilities of the economic body concerned[6]. For instance, public bodies like local governments begin to apply it to maintaining public facilities such as constructions of water and sewage works or roads; private bodies like gas or electric companies begin to apply it for managing their facilities like gas pipes, electric cables, or communication wires. The characteristic point of this stage is that the systems are developed originally and independently in both hard- and software, mainly conducted under the economic body concerned to answer the purpose of the body itself.

The next stage is an advanced one where the systems begin not only to carry out facility maintenance, but also to be (B) a method of administrative management, including the facility maintenance, of the economic body concerned. Let us take some illustrations. A gas company will unify their account database and their facility maintenance geographic information system, and reconstructs the existing geographic information system into an industrial information system in order to estimate the demand of gas appliances and to promote sales. A local government will make up the previous system into a more useful one that can plan and settle the renovation of facilities like water and sewage works systematically in accordance with the water charges and the source of revenue.

Needless to say, both the hard- and software of the geographic information system in this stage will be, in the main, what are developed originally for the sake of the economic body concerned.

The further it goes on, the more possibly will geographic information systems advance to take a task of (C) a local infrastructure. Particularly in the urban area, a number of institutions and facilities of public and private bodies stand very close together and each of them has their own databases independently concerning their institutions and facilities. To exchange those databases with each other will pave the way for the mutual use of them. The city planning division of a local government, for instance, may expect very much such a geographic information system as a local infrastructure to be constructed. On this stage, even if the hard- and software may be developed individually for the sake of the economic body concerned, it will be essential for the software, especially for the technique to manage data, to have some certain mutual interchangeability and commonality.

Finally, it can be assumed that the stage will come of geographic information systems as (D) a social infrastructure. On this advanced stage, by paying a certain fee, people will be able to access the databases concerning those institutions and facilities that the economic bodies serve or share, and people can purchase map information (digital maps) put on the market as a CD ROM, etc. Then both hardware and software will get greater interchangeability and everyone will be able to purchase them at comparatively low prices. Central and local governments will use geographic information systems without hesitation for (1) city plan settling, (2) real property taxation, (3) public facility maintenance, (4) anti-disaster policy, (5) land conservation policy, (6) forestry resource conservation policy, etc. Private enterprises, not only electric or gas companies that have already been using them but other kinds of economic bodies, will begin to introduce them. Using a geographic information system, newspaper delivery shops will make their daily work more efficient, pizza deliverers will ascertain the order addresses; and car drivers will easily know the way to their destination. Present geographic information systems may be, seen on a worldwide scale, at the beginning of this stage, the leading center of which is Europe and America. In the near future, the day will come of the full-scale "geographic information system as a social infrastructure", not only in the Western world but also in Japan.

In the following chapter, let us consider in the concrete some examples of present use of geographic information systems and we will see the age of real "GIS as a social infrastructure" is drawing near.

3. Usage examples of geographic information systems

(1) Public service distribution information system of Ijsselmij Utilities Company

Ijsselmij Utilities Company is one of the leading public service companies in Holland that aims at distributing energy, and supplies electricity, gas, water, cable TV, and local heating services, etc[7]. Ijsselmij Utilities Company introduced in 1991 a geographic information system as Public Service Distribution Information System (DISIS).

Their Public Service Distribution Information System is a geographic information system with the object of managing and analyzing the geographic information. The information includes both image and non-image data concerning the networks for distributing public services such as power lines over 40,000km, pipes, cables, and thousands of attached switches, valves, meters, boxes, amplifiers, etc. It consists of five subsystems. (1) "The text information system" manages technical data concerning the components of networks both on the ground and embedded under ground. (2) "The logical map and geographic rough map system" shows wide area network maps on the display or on the planning sheet. (3) "The utility map system" manages detailed image information of large-scale maps. (4) "The connection data system" manages technical data and distribution data of individual households and big consumers. And (5) "the standard package system" calculates model cases and analyzes local troubles.

Before introduction of the Public Service Distribution Information System, Ijsselmij Utilities Company found neither unification nor consistency in their data sent from the areas under their control or from local offices. Some data was left unrenewed and some was utterly unavailable. But after introducing this system, such problems are gone; available information is input and output efficiently, and controlling quality has improved remarkably.

The Public Service Distribution Information System of Ijsselmij Utilities Company is an independent organization within the company and belongs to no department. It is, therefore, characteristic of the system that any department in the company is able to utilize it. The fact suggests the possibility that the same kind of utilities companies distributing public services as Ijsselmij does can cooperate in building a common system to share with each other, and the construction of a more efficient Public Service Distribution Information System can be expected in the future.

As is shown above, it is obvious that Ijsselmij's Public Service Distribution Information System has gone beyond the stage (A) "a geographic information system for maintaining the facilities of the economic body concerned". We can say it has reached the stage (B) "a geographic information system for administrative management, including facility maintenance, of the economic body concerned".

(2) Land Information Management System of Lee County, Florida

Lee County is located in the southwestern part of Florida Beach in the U.S.A. The climate is mild and it is favored with good coastline. It is so attractive a place as a resort that it has grown rapidly since 1980[8]. Lee County has had increasingly so much work like property evaluation, settling of city plans and land use plan, etc., that in response to its expanding city function the officials of the county government have been suffering from the heavy load of works. In order to tide over the situation, they adopted the idea that it should be solved not through increasing budget and officials but through improving the way to manage. The result was that in 1991 they began operating a geographic information system as Land Information Management System.

In this Land Information Management System, not only works like property evaluation and land use are supported, but many functions like water and sewage maintenance, road maintenance, zone management, disaster prevention and police support, some kinds of area measurement, are also incorporated and make the system very profitable. In this system, the newest data of the geographic information is supplied and cooperatively used, and every department is in charge of inputting and maintaining the graphic and text data of the geographic information it is concerned with. Any one of officials of the county government can retrieve and analyze the common geographic information by virtue of his proper authority[9].

By introducing Land Information Management System, property evaluation cost per one block in Lee County has become the lowest one in the State of Florida. Any user of Land Information Management System can easily get concise information among lots of databases maintained by various departments of the county, whichever database it may be from and whichever department may be in charge of it. The efficiency has thus extraordinarily increased. In addition, one can use the newest information in automatic procedure with few errors, and do ones work more efficiently and effectively. The effect on this side cannot be disregarded, either.

Such a geographic information system as Land Information Management System in Lee County seems to have passed the development stage (C) "a geographic information system as local infrastructure" and now to be entering the stage (D) "a geographic information system as a social infrastructure".

(3) An Application example of geographic information system in the project Wallace Roberts & Todd Corp. participated in

WRT (Wallace Roberts & Todd. Corp.) is one of America's leading companies that assist planning and designing[10). The head office is located in Philadelphia in the U.S. WRT organized a cooperative team with environmental scientists, and carried out an extensive land use study in the coastal area of Cumberland County in the State of New Jersey, in connection with the inhabiting conditions of wild animals and plants scarce and in danger of extinction. WRT utilized geographic information systems effectively and fully for this land use study.

In the beginning, WRT used the digital maps produced by the U.S. Geological Survey and made a land use base map, consisting of landscape, geology, soil, weather, administrative border, zoning, rivers, lakes and marshes, roads, railways, facilities, landmarks, etc. Then observation records of those animals and plants that are (or were) very rare and in danger of extinction—after being studied and analyzed on the basis of the results of the cooperative survey with environmental scientists—were kept and stored on the base map. The data obtained from the survey was also composed in the existing land use map by the use of computer mapping technique.

Cumberland County has had coordination problems of land use due to its extending economic size and urbanization on the one hand, and environmental conservation problems in Delaware Valley Protected Region on the other hand. The result of this land use survey by WRT using geographic information systems is expected much to function effectively to reconsider the master plan about the land use in this county.

WRT, in cooperation with Rutger's University, etc., has also made the Economic Assessment of what is to be brought about by "New Jersey State Plan", using geographic information systems. The plan is going to be carried out by the year 2010 and the assessment evaluated what effects the plan will have on the economic developments and the inhabitant's life in the state of New Jersey. The effects were grouped as follows: (1) effects on industry and population such as commercial or industrial location, decrease of agricultural and forest area, increase of employment, and home lots development; and (2) effects on living environments such as air pollution, water foulness, and increase of urban facilities and cultural facilities. They estimated and evaluated those effects, but it didn't stop here: they made a total and systematical evaluation as well, taking note of (3) effects on state's and local government's grand total of tax, and effects on enlargement of expenses on keeping infrastructure or local service increase.

4. Application examples of geographic information system technology

(1) Utility example of geographic information system technology

We have considered in the concrete some examples of geographic information systems in the previous chapter. Here we are to examine how and where the technology of geographic information system (that is, GIS technology) is applied.

By the way, this GIS technology is, according to Hiroyuki Kohsaka, interpreted as data processing function and analyzing function of geographic information systems, and these functions are understood to be unique to geographic information systems derived from the characteristics of using digital maps. He says its data processing and analyzing functions consist of 9 principal functions: (1) data retrieval, (2) map generalization, (3) map abstraction, (4) map sheet operation, (5) buffer generation, (6) polygon overlay/dissolution, (7) measurement, (8) grid cell analysis, and (9) digital topographical analysis[11].

In the following, we will pick up among others (1)map data retrieval, (2) radius search and totalization, and (3) map overlay, and see and brief how they are utilized.

Now let us see examples of map data retrieval function. In Milwaukee city in the U.S.A., it is extremely important among the officials' daily works to respond quickly to the inquiries from citizens and traders about legal restriction about city planning such as regulations on land use purposes or buildings[12].

So the city introduced a geographic information system and started making purpose-distinct area maps classified by purpose, size, and altitude, in order to show the legal restriction circumstances at a glance. The city planning department and the building inspection department began to use it. At the same time, using the system enabled them to respond quickly the inquiries in relation to applications for building permission from citizens and traders. It is the basic function of map data retrieval of GIS technology that made it possible to manage those inquiries about building permission application in Milwaukee.

The second example is that of radius search and totalization function. In San Diego City in the USA, the police use geographic information systems in order to save and analyze criminal data[13]. Radius search function illustrates the crime occurrence circumstances within a certain extent around the point in question, and is broadly utilized as a criminal analysis map drawing system.

In this system, by selecting a center point (address, etc.) and radius, a criminal distribution map within the radius around the center is output. Characteristically, it enables them to see the criminal occurrence circumstances in relation to roads, land use, or population. Thus, San Diego's crime analysis map drawing system has got effect by making use of the basic function of radius search and totalization in geographic information system.

The last example is of map overlay function. Selection of area suitable for development (siting), for instance, is a typical application of map overlay function[14]. Such a technique of overlaying polygons as is used to choose development suitable areas is generally called thematic composition (layer composition). One layer shows suitable and unsuitable areas concerning one element of condition; if there are some conditions to be considered, the same number of layers are drawn for each element; then they are overlain—or composed—and the most suitable area possible to develop can be selected.

(2) Utility example in marketing analysis

The subjects of marketing analyses using geographic information systems are roughly divided into two groups: (1) analysis of market itself, and (2) analysis of location. The former group can be subdivided into what aims to visualize the market and what clarifies the market's characteristics. The latter group can also be subdivided into analysis of overlapping trading areas and that of non-overlapping trading areas[15].

First, among the groups of market analysis, those that aim "market visualization" are trying to express markets visually—to visualize markets—on the three phases: (1) expressing trading areas, (2) expressing competition of trading areas, and (3) expressing movement of trading areas.

Here, "expressing trading areas" means to express, for example, the service areas of three different fitness clubs visually and three-dimensionally, using a geographic information system[16]. "Expressing competition of trading areas" is to express competing trading areas visually and three-dimensionally and make it possible to see the situation where they are competing and sharing the place. And "expressing movement of trading areas" is to express visually and three-dimensionally how the trading areas change as time pass or in response to advertisements or events. For instance, it compares customer-collecting conditions at different two times in a certain shopping center and analyzes the difference between them[17].

The next is the second group of market analysis: "what clarifies market's characteristics". This includes (1) market segmentation and (2) market area segmentation.

"Market segmentation" is chosen, for instance, when a certain enterprise, in order to carry out a minute manufacture policy (sales policy), classifies the area in question into some groups according to market characteristics—generally according to such indexes as age, sex, income, vocation etc.—and adopts respective manufacture policy (sales policy) in each classified region[18]. "Market area segmentation" is also called geodemographics and the characteristic of it is to divide residential areas into some types and to subdivide each type into smaller segments[19].

Market analysis that aims location analysis, as above mentioned, consists of two types: analysis of overlapping trading areas and that of non-overlapping trading areas. In this classification, it can be said that the former is a location problem of a private facility, and the latter of an official facility—a common facility. Such a location analysis is characterized by its way of solving questions by interlocking various mathematical models.

"Overlapping trading area analysis" can give us a certain solution, for instance, by using the maximum inclination method—one of the optimization methods—and the impact analysis method[20]. "Non-overlapping trading area analysis" has two types: (1) location analysis of a single facility and (2) location analysis of plural facilities. And this non-overlapping analysis has two ways of solution according whether it deals with a location problem in a serial space or in separate spaces (a location problem at the joint-point on the network). Other types of methods have also been devised and used: some are, for instance, methods by seeing from the side of facility users: (1) users total moving distance minimization method, (2) users longest moving distance minimization method, an so on; other methods are by seeing from the side of facility providers: (1) facility number minimization method (in case of plural facilities), (2) existing facility maximum utilization method, and so on[21].

5. Direction in geographic information system applied to the environmental field

In this chapter, we will consider the possibility or direction of introducing geographic information systems into environmental field. The two largest fields where introduction of geographic information systems are hoped for are "administration" and "business". But environmental problems concern mainly on the administration parts—whether national or local. Here we are, therefore, going to examine the field of administration exclusively.

By the way, administrative offices have been the largest user of geographic information systems up to the present. They have been using them, for instance, for the following purposes: (1) information collecting (remote sensing, monitoring, etc.); (2) planning and maintenance (city planning support, land use planning support, facilities maintenance, real estate taxation, etc.); (3) resource conservation (land conservation, forestry resource conservation, etc.); (4) environment protection (natural environment protection, environmental preservation, etc.); (5) landscape protection (urban landscape protection, historical landscape protection, etc.); (6) disaster prevention (disaster information collection, research of disaster area, etc.). This is—and is going to be—the fact not only in foreign countries but in Japan.

In this situation, especially seen from the point of environmental problems, a geographic information system is expected to function effectively and properly as an environmental monitoring system by the administration. Among environmental problems, there are (1) problems caused as "nature destruction"—to destroy the function the environment has as a resource supplier, (2) problems caused as "nature pollution"—to destroy the function the environment has as an assimilator, and (3) problems caused as "amenity destruction"—to destroy the function the environment has as an amenity supplier. And these problems sometimes occur separately and sometimes as a compound[22). The types of environment monitoring are (1) what needs periodic monitoring f. ex. of water, land subsidence, (2) what needs constant monitoring f. ex. of air pollution and noise, and (3) what needs to estimate the environmental influence before carrying out various planning such as environmental assessments[23).

The objects of monitoring are also varied and wide-ranged in relation to the type of destruction; some deal with mainly maintenance and protection—or in some cases control and prevention of environmental pollution—against the changing ecosystem and the living conditions of rare animals and plants, greenhouse effect and desertification of the earth and so on; others mainly aim to grasp the change of social environment, including maintenance and protection of natural environments and control and prevention of environmental pollution, such as change of location condition of roads, railways, buildings and facilities, change of purpose-designation of area, or change of land use, etc. In addition, if we count amenity control and protection of city landscape, historical landscape, or cultural heritage like terraced rice field, there is possibly no end to the range of monitoring contents.

In the following we will focus the administrative—in this case, local administrative—monitoring on rural district and examine the direction of introducing a geographic information system especially into environmental field in relation to the planning of rural land use.

The typical direction of it can be seen in the geographic information system for "rural planning and rural environment maintenance" tried in England[24). In England, they have "Urban and Rural Planning Act". According to it, when they make a plan of rural land use, a basic plan is to be made in a comparatively wide range in the first place. On the basis of it, a detail plan is made for each small area. The basic plan shows the main frame, and its contents are about roads, wide-range development plan, or green belt designated area, etc. On the other hand, in area's detail plan, pastoral areas, landscape conservation areas, and environmentally sensitive areas (ESA) are prescribed concretely and in detail. Environmentally sensitive areas (ESA) are in relation to Common Agricultural Policy (CAP) by European Union (EU), and in that area they try to maintain rural environments by restricting intensive agriculture.

Now, when a local government plans such a basic plan and area's detail plan in relation to the plan of rural land use, they utilize geographic information systems effectively. For instance, when they select environmentally sensitive areas in the area's detail plan, they don't only estimate for the area the degree of possibility in agricultural land use or the degree of possibility in various development plans on the basis of various social-economic indexes. But they also take into consideration even those elements that you might think to be difficult to index, such as ranking of nature and landscape beauty, characteristics of phase of living things, characteristics of topography, geology, and soil, or archeological, architectural or historical value. Thereafter, by overlaying these layers, they try to estimate totally and select environmentally sensitive areas. After selecting, the monitoring of the environmentally sensitive areas by the local government belongs to the field over which geographic information systems have advantage, so far as its monitor system runs effectively.

Geographic information systems work for making area's detail plan as well, when they select landscape conservation areas from the vast fields and forests in the concerning region. Geographic information systems also make it more effective to monitor the selected landscape protection area.

The direction of introducing geographic information systems into rural environmental field by the government is summarized to be a kind of use of geographic information systems for rural planning and rural environmental control by the government[25]. To speak concretely and technically, three types of data are synthesized: (1) face information (raster type data) concerning the present land use by satellite pictures and aerial pictures, etc., (2) polygon information (vector type data) concerning topography, geology, soil, and climate, water resource, and underground water, etc., and (3) point and line information (vector type data) concerning water quality test, environmental test, or existence of agricultural undertakers. Then they are constructed, as one total spatial analytical information, into a geographic information system for rural planning and rural environmental maintenance. Thus geographic information systems will come to be more often used; it will be used not only when we need output of rural land use plan, but also as an assisting tool for the deciding process of rural land use plan. Apart from environmental problems, geographic information systems are greatly expected as a method of proper use and management of resources in agricultural/rural areas, and moreover, of maintenance of facilities, etc., owing to their merits of visualization and manipulation.

6. Conclusion

We have investigated geographic information systems concretely in some of their utility examples, and especially put focus on direction of their future utility in the field of environment.

In Chapter 2, four stages of development of geographic information systems are considered: (1) stage of maintaining the facilities of the economic body concerned, (2) stage of administrative management including its facility maintenance, (3) stage as a local infrastructure, and (4) stage as a social infrastructure.

In Chapter 3, among the ways of usage of geographic information systems, a few cases were chosen and investigated in the concrete: (1) the case of distribution information system of public services by Ijsselmij company; (2) the case of land information management system in Lee county, Florida; (3) the case of geographic information system in the project WRT company participates in. And in Chapter 4, definite application examples of geographic information system technology are considered: (1) map data retrieval function, (2) radius search and totalization function, (3) map overlay function, and (4) market analysis and location analysis in marketing analysis function.

Finally, in Chapter 5, the direction of utilization of geographic information systems in the environmental field was investigated, seeing an example in England, where they try to make rural plans and maintain rural environment by using them.

As is seen above, applied usage of geographic information systems is found in several cases of environmental field, but it is just in the beginning. The possibility of usage seems endlessly wide and large. It can be said that we, agricultural economists, are in charge of giving a certain answer to environmental problems in rural areas, by taking a good view of development and progress of geographic information systems, and introducing them into the environmental field of rural areas.

Notes:

1) Planning and Coordination Bureau of National Land Agency, ed., *National Land Information—Domestic and Overseas Tendency*, Printing Bureau of Ministry of Finance, 1986.
2) See e.g. Hiroyuki Kohsaka, *GIS for Administration and Business*, Kokon-Shoin, 1994. He also says in "Marketing and Geographic Information Science", *Theory and Applications of GIS*, Vol.3, No.2, Geographic Information Systems Association, 1995, that GIS is a system which saves, displays, and analyzes spatial data (geographic information), and spatial data is data which has spatial reference code (geocode).
3) Detailed in e.g. George B. Korte, *The GIS Book—Geographic Information System for practical business*, transl. by Toshiharu Murai and Mitsuru Nasu, International Thomson Publishing Japan, 1994.
4) Jeffrey Star and John Estes, *Geographic Information Systems – An Introduction*, transl. by Atsuyuki Okabe, Yukio Sadahiro, and Osamu Imai, (Kyoritsu Publishing, 1992).
5) Information about the purposes of using GIS includes: Planning and Coordination Bureau of National Land Agency, ed., *National Land Information—Domestic and Overseas Tendency*.
6) References about Stages of GIS includes: Sachio Kubo, *The New Geographic Information Technique*, Kokon-Shoin, 1996.
7) References about Ijsselmij's public service distribution information system includes: Ijsselmij Utilities Company, "Ijsselmij Utilities Company (Holland)", *GIS Readings*, Informatix, 1995.
8) Land information managing system of Lee County, Florida is described in Frank Jacquez, "Administration Reconstruction and GIS in Lee County in Florida (1)", *GIS Readings*, and Ginger M. Juhl, "Administration Reconstruction and GIS in Lee County in Florida (2)", *GIS Readings*.
9) Shared geographic information is divided into types: (1) classification, (2) management, (3) building environment, (4) land record, (5) natural environment, (6) administrative region, and (7) facility.
10) Detailed information of application examples of GIS in the project WRT participates in includes: WRT Corp.; "CDS Project Examples in WRT (USA)" in *GIS Readings*.
11) References for data processing function and analyzing function of GIS includes: H. Kohsaka, *GIS for Administration and Business*, pp.54-58.
12) For the map data retrieval function of GIS in Milwaukee city, see H. Kohsaka, *GIS*

for Administration and Business, chap.6.

13) For the radius search totalization function of GIS of San Diego city police, see H. Kohsaka, *GIS for Administration and Business*, chap.7. As an example in Japan, we have case studies in Ichiro Tamura, Hidenori Tamagawa, and Shuzo Kitamura, "An Analysis of the Relation between Crimes and Social or Spatial Structure in West Part of Niigata City", *Papers and Proceedings of the GISA*, vol.1, 1992.

14) For selection of area suitable for development, using map overlaying function, see H. Kohsaka, *GIS for Administration and Business*, chap.8. In Masahiko Murata, "Suitability Analysis Supporting System – An Application of GIS – ", *Papers and Proceedings of the GISA*, vol.2, 1993, we also find some interesting description.

15) H. Kohsaka, "Marketing and Geographic Information Science".

16) For "expressing trading areas" and "expressing competition of trading areas", see Toshio Yamazaki and H. Kohsaka, "An Application of GIS to the Trading Area Analysis for Private Sports Clubs", *Papers and Proceedings of the GISA*, vol.3, 1994.

17) For "Expressing movement of commercial zone", see Hideki Yanagi and H. Kohsaka, "An Analysis of Retail Trade Area Using Card Information", *Papers and Proceedings of the GISA*, vol.3, 1994.

18) For examples thereof, see H. Kohsaka, "Geographic Information Systems and Area-marketing Analysis", *Papers and Proceedings of the GISA*, vol.1, 1992.

19) References includes: H. Kohsaka, *GIS for Administration and Business*, chap.12.

20) For examples of the arithmetic model analysis, T. Yamazaki and H. Kohsaka, "An Analysis for Service Area of Sport Clubs Using GIS", *Theory and Applications of GIS*, vol.4, book 1, 1996, H. Kohsaka, *GIS for Administration and Business*, chap.12, and Masayuki Kitamura, "A GIS-aided Method for Analyzing Locational Factor of Retail Stores on a Road Network", *Theory and Applications of GIS*, vol.2, 1994, are available.

21) Those examples of the arithmetic model analysis are detailed in e.g. H. Kohsaka, *GIS for Administration and Business*, chap.9, H. Kohsaka, "Geographic Information Systems and Area-marketing Analysis". Area marketing on the basis of the number and distribution of facility users is detailed in Tetsuya Furihata and Koji Matsuoka, "An Analysis for Spatial Spread and Local Availability of Facilities using Geographical Information System which Contains Town Map Data", *Papers and Proceedings of the GISA*, vol.1, 1992, and his "A Facility Location Analysis Considering Spatial Patterns of Distributed Users", *Papers and Proceedings of the GISA*, vol.2, 1993. See also Y. Sadahiro, "Analysis on the Spatial Competition and Avoidance of Store Chains Using GIS", *Theory and Applications of GIS*, vol.2, 1994.

22) This understanding of environmental problems is based on Kazuhiro Ueda, *Invitation to Environmental Economics*, Maruzen 1998, pp.191-192.

23) Reference includes: Minoru Akiyama, *Procedures of Geographic Information*, chap.4, Sankaido 1996.

24) Reference includes: Eiji Yamaji, "GIS Application to Rural Land Use Planning In Britain", *Papers and Proceedings of the GISA,* vol.1, 1992.

25) Reference includes: Kenji Ishida, "Geographic Information Science for Agriculture and Rural Planning", *Theory and Applications of GIS,* vol.3, book 2, 1995.