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Spatial Information System (SIS) & Sustainable Development

Sustainable Development of Wet Land through Using GPS and SIS

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List of Acronyms

GPS	Global Positioning System
GIS	Geographic Information System
SA	Selective Availability
SIT	Spatial Information Technology
SIS	Spatial Information System
RS	Remote Sensing
GMS	Ground Monitoring System
DCS	Data Collect System
GCP	Ground Control Point
RSO	Rectified Skew Ortomorphic
SDIS	Sustainable Development Information System

1- Introduction

The last decade GPS has appeared as a powerful instrument for radio navigation technology for military, transportation, engineering, geosciences and GIS applications. GPS has a variety of applications on land, at sea and in the air. Basically, GPS is usable everywhere except where it's impossible to receive the signal such as inside most buildings, in caves and other subterranean locations, and underwater. Many different types of GPS are now in the market. The contribution of GPS technology in sustainable development is what we called to answer in this paper. The sustainable development is an environmental issue of our days. We believe that all the GPS types can provide a sustainable development in a different way each one of them.

There are two main types of GPS, the GPS with a reference antenna and the handhold GPS. Using these two GPS types, on a mountainous area, it was found that there are different position results and there was not accurate with the real ones which were measured by surveying methods.

The Methodology which was followed based on the knowledge of Selective Availability (SA) implementation, due the Gulf War in Iraq, by the time of the fieldwork. The Selective Availability was a method for reducing the accuracy for civilian users of the system. After the fieldwork the results of GPS's were compared and the results of surveying methods and a comparative table were made in order to point out the inaccurate points. Based on this GPS fieldwork we will discuss about the possibilities of contributing these types of radio navigation systems in sustainable development on mountainous areas.

The GIS data collection is directly connected with the located position. A big rate of GIS applications is based on data which can be covered from only one receiver. The handhold GPS provides more facilities in use than the GPS with reference antenna, although that both them collect data for GIS applications, which can be used for making a sustainable development plan for a mountainous area.

2- Description

The industrialization and modern science and technology achievements in the past several decades have made economy develop very fast in the world. At the same time, however, many global issues have emerged. The results of human over-exploit for natural resources such as land, water, mineral, etc., have decreased the functions of earth systems. Most part of natural environment on the globe has been destroyed through industrialization by the developed countries. Moreover, this mode is still been followed by many developing countries. At present, we are confronted with a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill health and illiteracy, and the continuing deterioration of the ecosystems on which we depend for our well-being.

In order to meet the challenges of environment and development, the United Nations Conference on Environment and Development was held in Rio de Janeiro, Brazil from 3-

14 June 1992, and several important resolutions such as the *Rio Declaration on Environment and Development*, *Agenda 21*, etc., were approved by the participants from different countries. It reflected the new sustainable development standpoint of human beings, and the global sympathetic highest level promise.

In sustainable development, everyone is a user and provider of information considered in the broad sense. That includes data, information, appropriately packaged experience and knowledge (UNCED, 1992). The need for information arises at all levels, from that of senior decision makers at the national and international levels to the grass-roots and individual levels. In Agenda 21, the roles of Spatial Information Technology (SIT) in resolving global issues were given special attention. Both for developed and developing countries, great benefits can be obtained from the applications of spatial information techniques in different fields such as natural resources investigation, ecosystems and environmental monitoring, development planning in different levels, etc.,

In order to promote the contributions of spatial information technology in realizing regional sustainable development through bilateral and multilateral cooperation between countries in Asia and the Pacific region, ESCAP organized a ministerial conference on space technology and applications for sustainable development in 1994 in Beijing, China. An important document, *the Beijing Declaration on Space Technology and Applications for Sustainable Development*, was adopted and approved by participants of officials, scientists and researchers from member countries of ESCAP. Therefore, it is desirable to fully use space technology, especially remote sensing, geographical information systems, global positioning systems, ground monitoring systems, etc., in a global partnership for sustainable development.

3- General Analysis

3.1 The Concept of Spatial Information Systems (SIS)

The collection and management of data about the spatial distribution of significant properties of the earth's surface and of people, animal, and plants have long been an important part of the activities of geo-scientists, researchers and officers. Until relatively recently, however, most of these data were keep in the form of paper documents and maps from which they can be read off easily, but only with difficulty could they be used to analyze the patterns of distribution of attributes over the earth's surface and the processes that had given rise to them. The development in both computer technology and mathematical tools for spatial analysis that have taken place in the second half of the twentieth century have made many things possible, among them the ability to restore, retrieve at will, singly or in combination, and to display data about all aspects of the earth surface, which are basic functions of spatial information systems. As this kind of technique and its applications have been developed so rapidly that many systems have been developed and applied in different fields though there have not been an authoritative definition for spatial information systems.

There are different meanings for spatial information systems in different fields or different regions, even different experts. In our point of view, the Spatial Information Systems (SIS) are technical systems based on computer, with functions of collecting, managing, analyzing and applying of spatial distributed data, it should include Remote Sensing (RS), Geographical Information Systems (GIS), Ground Monitoring Systems (GMS), Global Positioning Systems (GPS), etc. Furthermore, the result of simply getting G*P*S, *R*S, G*I*S and G*M*S together is just *PRIM* rather than SIS. As showing a *PRI**S**M* (colorful) world, SIS is developed by integrating those technique approaches to form an integrated system (see Figure 1 and Figure 2).

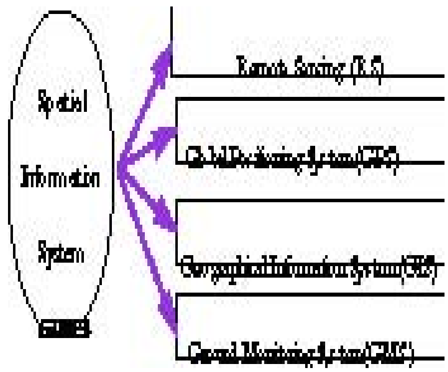

Figure 1. The main components of SIS

Figure 2. The meanings of SIS.

3.2 The Concept of Sustainable Development

Sustainable development is a broad concept that seeks to provide a development path that meets the requirements of present and future generations (WCED, 1987). Social development, economic development and environmental sustainability must all be explicitly addressed in developing sustainable development strategies. Their mix depends on the economic, social, cultural and environmental situations of individual countries. The eradication of poverty is an overriding priority for achieving sustainable development. It should both contribute to and result from the achievement of sustainable development. The activities of the United Nations as a whole are aimed at achieving sustainable development worldwide.

Within the concept of sustainable development, the United Nations Conference on Environment and Development (UNCED) emphasized the relationship between the economic and social aspects of development and the use of resources, considering the environment as a "sink", absorbing negative impacts of human activities, and as a "source", providing resource inputs into productive processes or providing final environmental services directly.

3.3 The Role of SIS for Sustainable Development

The implementation of sustainable development strategies should base on the scientific policy making, which demands great deal of information and real-time information. Therefore it is one essential step to obtain real-time information and construct information systems for sustainable development. Moreover, as the key problems for sustainable development are resources and environment, in other words, the goal of the activities for sustainable development is reasonable utilization of natural resources and effective ecosystems and environmental protection, so the information of resources and ecosystems and environment is essential for sustainable development decision-making.

The development of SIS can provide a reliable technique support for real-time information acquisition and effective information processing. RS technique is of many advantages such as vast field of vision, and rapid, economic and dynamic characteristics, etc., it may regularly (satellites) and irregularly (airplanes) obtain ground truth and the dynamic information of natural resources and environment. The well-known Data Collect Systems (DCS), which is a typical kind of GMS, may automatically obtain different information such as meteorological data, water and soil data, etc., in areas with odious conditions and a sparse population, and transmit these data to the data processing center of ground station by satellites. GPS is of such advantages as all weather monitoring, high-accuracy positioning, and fast, simple and convenient operating, it can provide 7-dimensional information including 3-dimensional position, 3-dimensional velocity, and time. GIS can efficaciously analyze and manage all information required by sustainable development decision making especially manage spatial data, develop traditional point data operation into 3-dimensional spatial data operation. With these unique advantages, the SIS may play an important role in sustainable development (Figure 3)

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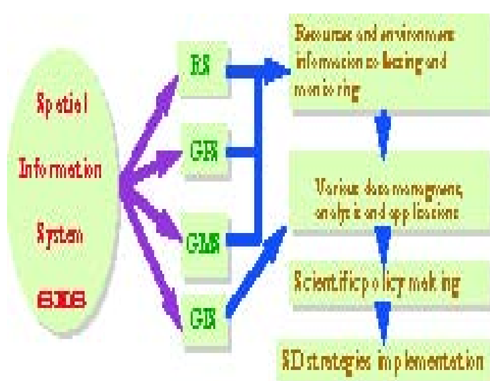


Fig. 3 the roles of SIS in sustainable development

3.4 Study Areas of SIS Applications for Sustainable Development

The study of SIS applications for sustainable development is a new and broad field that is relevant with many areas. The main study areas are composed of three aspects as follows.

A- *SIS Technical study and development*

The study and development for SIS techniques is an important component of sustainable development actions, its objectives are to improve SIS techniques and develop practical technical systems by fully using the achievements of RS, GIS, GPS, GMS, etc.

B- *Theoretical study on sustainable development*

Promoting sustainable development is a new task for human beings, it needs public especially planners and decision makers' awareness and participation from different regions, sectors and fields. In particular, it is essential to study and discuss the theories of sustainable development by actively participating and cooperating of scientists, researchers and technicians from different disciplines.

C- *SIS applications for sustainable development*

SIS technology has many advantages in acquiring, managing and applying of data needed by regional planning and decision making. The basic and critical task, for both officials and scientists, is to strengthen the applications of SIS in regional planning and decision making so as to promote scientific policies to be formulated and realize regional sustainable development.

4- Actualization- Case Study

Wetlands Mapping in Kuala Trengganu-Malaysia

Mapping wetland vegetation over larger regions has commonly been done using digital imagery obtained from satellites, and may be referred to as land cover mapping. Wetland cover mapping is actually providing critical information about the distributions of the species and vegetation types and "human land uses" surrounding it, thus, possible for biodiversity conservation planning, as the wetland cover classifications may link to a particular species composition and habitat types. In this case, wetland cover maps produced may provide the baseline measurements that allow the study of changes in a particular land cover over time and further discover the impacts of such changes on the biodiversity. Maps arranged according to their dates may reveal the patterns (Mitchell, 1999) and help the interpreters to infer the relationship (Turner *et al*., 1994) between the maps studied. Meanwhile, statistics in table forms summarize the findings to specifically display the increment and reduction of total areas that changed over time.

In addition, most maps used by the ecologists are land cover maps (Burel and Baudry, 2003), created from the analysis of the satellite imageries, together with aerial photographs, and through field observations that has been done by the scientists from remote sensing fields. Often, landscape ecologists use the final products of GIS processing or the interpretation of spectral data to conduct their study, as many of them are not technically proficient in all the intricacies on spatial extents that are much larger than those traditionally studied in ecology (Turner *et al.*, 2001). Therefore, the objectives of this study are two-folds, namely (i) to map the wetland cover of Kuala Terengganu district and to determine its rate of change between 1998 and 2005, and (ii) to produce final wetland cover maps of Kuala Terengganu for each year of study.

4.1 Methodology

The selected area of study was Kuala Terengganu district of Terengganu state, as shown in Fig.1. Kuala Terengganu is located between latitudes of 5° 27’ 58.31” N and 5° 11’ 42.36” N and longitude of 102° 57’ 06.10” E and 103° 13’ 18.69” E. The capital city of Terengganu state is located in this district. The total study area is approximately 60,528 ha, which covers 4.67 percent of the Terengganu district. Three sheets of 1:50,000 scaled topography maps were used as a reference to conduct the ground truthing process. Two softwares were used in this study. Erdas Imagine 8.7 was used in the digital image processing, while ArcView 3.2 was used for the GIS analysis.

Landsat^{TM} was acquired from scene 126/56 (path/row), with spatial resolution of 30 m. Images were obtained from Malaysian Center for Remote Sensing (MACRES). These images were taken on 15th October 1998, 14th July 2002 and 15th August 2005. The raw images of the study areas were shown in Fig.2 by using the band combination of RGB 4, 5, 2.

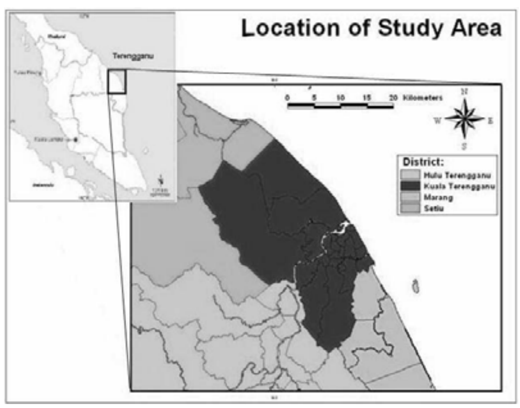


Fig.1 Location of the study

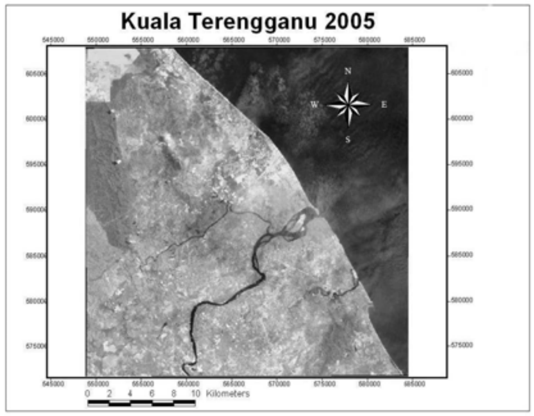


Fig. 2 Raw image of Kuala Terengganu August 15, 2005

Multi-dates images of Kuala Terengganu district were used to initiate this task, which involved images of 1998, 2002 and 2005. A uniform interval was expected in order to determine the land cover changes rate, but unfortunately, a uniform three or four year's intervals are not available in the archive. The seven bands of each image were layer stacked to merge them together, before producing a single image. Geometric correction process was done based on the Ground Control Points (GCP) taken during the ground truthing. A total of 50 GCPs were registered for each image; they were resampled to produce the corrected imaged. All corrected images were justified based on Root Mean Square Error (RMS Error) of less than half a pixel (Lillesand *et al.*, 2004) by using the First Polynomial Order. The images used Rectified Skew Ortomorphic (RSO) Projection with Spheroid of Modified Everest and Kertau 1948 as the Datum. In unsupervised classification process, Iterative Self Organizing Data Analysis Technique (ISODATA) was applied to the 100 classes of unknown land covers with 30 iterations. This process is then followed by redefining the criteria for each class and classifying them again before producing the last output images of the unsupervised classification process. Wetland class was identified roughly based on the analyst's prior knowledge and from analyzing the topographical maps.

During the ground truthings, the actual wetland cover class involved was checked and identified. Global Positioning System (GPS) Garmin GPS 12 with accuracy 15m RMS was used to acquire the exact coordinates of study areas (GCP), while photographs of the wetland cover class was captured together with their details recorded. The images were then classified into wetland cover types. The analysis was done using data collected during the ground truthings with the aid of topographic maps to produce the output images of supervised classification. Next, they were filtered through the Statistical Filtering by using 7x7 modes. Mean Filter was applied for all these output images before recoding them according to the wetland class, in order to measure the areal extent of the wetland rate of change per the years studied. The output images for supervised classification process were assessed to determine the classification accuracy. Stratified Random Sampling was applied to each supervised classification images, where 30 random reference pixels were taken into account. The accuracy report was generated later that comprised the summary statistics of overall agreement percentage, together with user's and producer's accuracy. All the output images from the supervised classification were used in the GIS Analysis to determine the changes occurred amongst the temporal years under study. Each image was independently classified and registered before undergone the post-classification comparison. The rate of change was determined after calculating the total areas of wetland cover class. The changes in distributions of wetlands were shown in the generated wetland cover maps.

4.2 Results and discussions

Unsupervised classification was done to assist the ground truthing. Besides the wetland there were eleven other classes of land cover with uncertainties of the actual locations predicted during this process. The eleven classes are barren land, cloud, cloud shadow, forest land, oil palm, orchard, paddy, rubber, urban or built-up land, and water. They were nine classes categorized including the wetlands which were confirmed using ground verifications. Land cover classes for supervised classification images include the cloud and cloud shadow, which appeared in the images. Fig. 3 shows the images that have undergone the supervised classification that was further subset to highlight only the study area, which is the Kuala Terengganu district. A summary of the total area for each land cover classes, especially the wetlands in every image were demonstrated in Table 2 according to their respective year of study to measure the rate of change for the three temporal years.

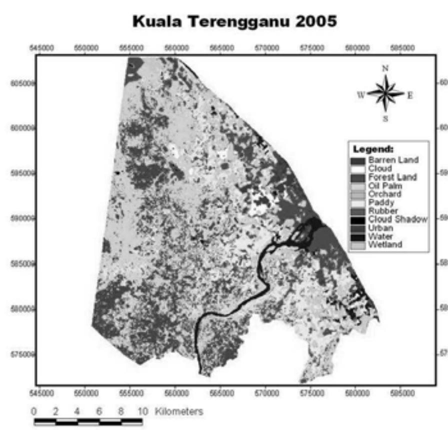


Fig. 3 Supervised classification image of K. Terengganu for 1998, 2002 and 2005

Classes	1998		2002		2005	
	Ha	%	ha	%	ha	%
Barren Land	92.22	1.97	39.46	0.84	63.135	1.35
Cloud	204.96	4.37	140.87	3.00	66.321	1.41
Cloud Shadow	185.86	3.96	76.04	1.62	9.639	0.21
Forest Land	264.40	5.64	77.39	1.65	49.437	1.05
Oil Palm	58.46	1.25	238.19	5.08	382.329	8.15
Orchard	1612.14	34.39	1841.40	39.26	1274.049	27.16
Paddy	405.06	8.64	362.27	7.72	772.182	16.46
Rubber	534.94	11.41	478.84	10.21	1017.756	21.70

Urban or Built-up Land	1109.52	23.67	1214.33	25.89	500.328	10.67
Water	118.19	2.52	121.14	2.58	174.132	3.71
Wetlands	**102.34**	**2.18**	**100.68**	**2.15**	**381.348**	**8.13**
Total	4688.13	100	4690.65	100	4690.65	100

Table 2: Total areas of land cover and land use for 1998, 2002 and 2005 image of K. Terengganu

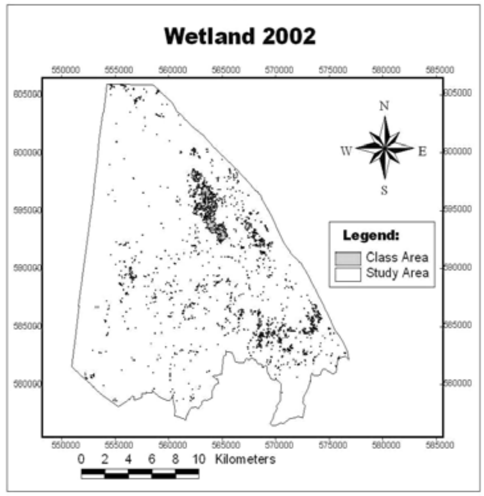
Based on the results, all Root Mean Square Error (RMS Error) obtained are less than a pixel. In this study, the spatial resolution of each data used is 30 m, which represented by a pixel. Therefore, the errors obtained should not be more than the image resolution, which means not more than 30 m. Furthermore, for the change detection analysis, a requirement of accurate spatial registration during geometric correction could bring an effective result for each dates of imagery. Ideally, the RMS Error should not be more than half a pixel.

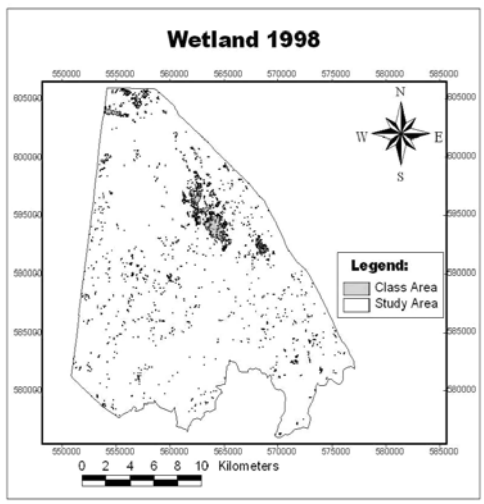
4.2.1 Accuracy assessment

In accuracy assessment, a total of 330 stratified random sampling points was used to determine the accuracy for each output images of the supervised classification. The overall classification accuracy obtained for 2005 image is the best, which is 90.91%. The overall accuracy for 1998 and 2002 images can be considered as moderate, where the accuracies are 74.55 % and 82.42 %, respectively.

4.2.2 Geographical Information System (GIS) analysis

Arc View 3.2 software was used in the GIS analysis to enable determination of the total changes of areas for each class, when the images were compared. The arrangement of the classes was done by putting the priority, based on the highest to lowest increment of total area that changed from 1998 to 2005, and further followed by the highest to lowest changes reduction of the total area. For wetland class, distribution of the particular land cover is shown in Figure 4. In 1998, the total area is 2.18 %or 102.348 ha. The value decreased slightly in 2002 to be 2.15 % or 100.683 ha. Surprisingly, the value of total area of this class expanded in 2005 to be 8.13 % or 381.348 ha.





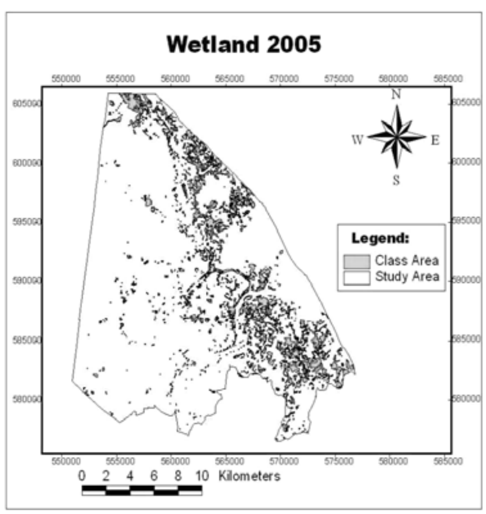


Fig. 4 Wetland covers type maps of K. Terengganu for 1998, 2002 and 2005

The total area of wetlands has increased to 5.95 % or 279 ha from 1998 to 2005. In 2005, the total area for wetlands was observed to be higher compared to the earlier years of study. This might be due to the inexperienced analyst, where the spectral reflectance of other land use cover such as rice paddy areas was misinterpreted as wetlands. Meanwhile, in 2005, the areas of Wetland class were observed in more detailed, as the ground truthings enable determination of the exact wetland cover involved in the area. Furthermore, seasonal peat swamps are included in this class, where this class is influenced by the water table to be mistakenly interpreted as the rice paddies class. Basically, the weakness in interpretation of this class is due to the lack of knowledge of the study area in the earlier years of study.

With the aid of ground truthing and further analysis of the ancillary data, it is observed that the wetlands of K. Terengganu district were found in Kampung Mengabang Panjang in Batu Rakit, Kuala Nerus subdistrict, Gong Badak industrial areas and Gelugur Raja, mainly associated with wetland floras of sea hibiscus (*Hibiscus tiliaceus*), nipah palm (*Nypa fruticans*) and mangrove fern (*Acrostichum aureum*). Forested wetland is dominant in Kuala Terengganu and most of the mangrove trees observed were Avicennia, Sonneratia, Rhizophora and Melaleuca genera.

Wetland areas have their own international importance, as they provide the natural protection to the coastal areas from the strong storms, as well as the sand erosion. They have a high biological diversity and traditionally utilized for food resources, firewood, charcoal and timber (Yousif *et al.*, 1999). Wetland has been recognized to be the breeding areas and refuges for many marine species, including prawns. Mangrove is also capable in preserving water quality and reducing the water pollutions by filtering suspended materials and assimilating dissolved nutrients. Since wetland areas protect the human and the human settlements, they are eventually have become our responsibility to take care of them, so that people do not have to worry too much about the disasters that might occur if these areas are eliminated.

5- Discussion –Sustainable Development Using SIS

Promoting regional sustainable development is a widespread, comprehensive and difficult task that involves in the relationships among society, economy, population, resources, environment, industrial structure, etc., and the changes of these elements. It is necessary to coordinate the activities on natural resources development and the relation between environment and social factors in the region, so as to provide scientific base for sustainable development planning and decision making. The study of SIS applications and related actions should be carried out to achieve these goals.

5.1 DATA COLLECTION

SIS has provided new approaches to monitor global environment change, investigate renewable resources and underground resources, and so on. The successful launch and operation of a lot of satellites such as LANDSAT series, SPOT series, MOS series, IRS series, NOAA series, etc., has improved the earth observation capacity of human beings who can easily obtain the real scenes of ecosystems deterioration, population increase, industrial and domestic wastes and pollutants, etc. Furthermore, there are still many application programs for launched satellites, and satellite launch plans in the world. For example, China has successfully launched 35 satellites of different types, including scientific, recoverable, communication and meteorological satellites (Zhang Guofu, 1996). It is also developing FY-2 geostationary meteorological satellite, CBERS earth resources satellite that is a joint program between China and Brazil for remote sensing of natural resources and environmental monitoring, DFH-3 communication satellite, etc., and proposing a series application satellite programs including geostationary orbit platform DJS-1 and DJS-2, sun-synchronous orbit earth observation platform TTS-1 and TTS-2, recoverable satellite platform, etc.

Based on those satellites and worldwide data receiving station network, a new kind of data collect integration systems will be established in the near future by using the comprehensive techniques of RS, GIS, GPS, GMS and satellite communication. The establishment of information systems and industrialization will make it possible that SIS contributes much more and more for regional sustainable development.

5.2 Data Management and Analysis

The information needed by sustainable development study, planning and decision-making are characterized by many data types, large quantity, etc. It is essential to carry out scientific management, processing and analysis for all kinds of data so that the data can be fully used. With such capacity as input, storage, retrieval, processing, analysis, update, output, etc., for spatial information, GIS is a reasonable approach to support the comprehensive analysis, assessment and decision making for sustainable development. Therefore, it is necessary to establish sustainable development information systems (SDIS) and network by using SIS.

The main difference of SDIS from other kinds of information systems is that specific attentions are paid to the acquirement and management of information about sustainable development, including current status and related activities, especially information about the states of global and regional natural resources exhausting and environment worsening. Consequently, SDIS systems and network, in which GIS is an important component, give directly service for sustainable development managing and decision making.

5.3 Sustainable Development Planning and Decision-making based on SIS

Regional sustainable development planning is the planning to be aimed at realizing regional sustainable development. The goal of regional sustainable development planning is to meet the requirements of coordinate development of society, economy, population, resources and environment in different levels (global, national, regional, etc). Specifically, it should satisfy the needs of:

(a) To ensure economic development in reasonable growth;
(b) To improve the quality of economic development;
(c) To meet the basic needs of people in planning region;
(d) To protect and strengthen resources foundation;
(e) To improve technical development directions;
(f) To ensure stable population level;
(g) To raise population quality and improve population structure;

(h To coordinate the relationship of economic development and ecosystems, to protect integrated life-support systems and ecosystems, to conserve biodiversity and natural resources, to reduce loss of hazards damage; etc.,

Sustainable development planning and decision making based on SIS can be implemented through establishing thematic information systems by using SIS techniques, developing regional sustainable development planning models, formulating sustainable development schemes, and setting up sustainable development decision making support systems, which can provide reasonable base for regional sustainable development decision making (Figure 4).

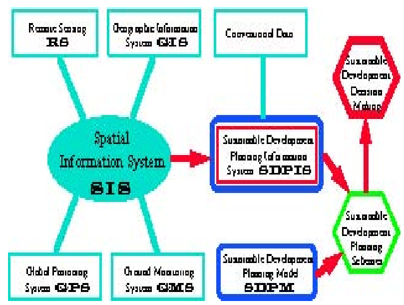


Fig. 4 Sustainable development planning and decision making based on SIS

6- General Recommendation

Sustainable development is a way that will meet current needs without compromising the ability of future generations to meet their needs. It needs read-time dynamic information in various fields especially in natural resources and environment for planning and decision-making. The application of Spatial Information Systems (SIS) including Remote Sensing (RS), Geographical Information Systems (GIS), Global Positioning Systems (GPS) and Ground Monitoring Systems(GMS), etc., can obtain the dynamic information of regional resource, environment, disaster, etc. It also plays important roles in information restoring, inquiring, analyzing, and decision making. On the other hand, the social and economical development will provide farther supports for SIS technique development and applications

7- Conclusion

The final goal of regional sustainable development activities is to realize coordinate development of society, economy, population, resources and environment. This is a very important and very difficult task for human beings. The applications of SIS can provide real-time information about resources and ecosystems and environment for planners and decision makers, and dynamically monitoring their changes as well as managing and analyzing data from different approaches.
As a new topic, however, SIS technologies and applications are confronting many challenges as well as good opportunities from the sustainable development actions in the world. There are so many works need doing that it is very essential for all scientists and researchers in the world to carry out extensive cooperation in this field to share their experiences, information, opinions, etc.

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