JIRCAS Experience in Remote Sensing and GIS Training in Collaborative Research Programs

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Abstract

Since 1989, JIRCAS has implemented international collaborative research programs using remote sensing and more recently GIS techniques in developing regions. These programs include case studies in Syria, Pakistan, India, Mongolia, Thailand, China and Indonesia. In the process of development of a research environment, it is important to enhance the capability of data analysis of counterpart researchers in the field of remote sensing or GIS. Therefore JIRCAS has attempted to train scientists of the collaborating institutes for specific research objectives as illustrated in the text. Recently JIRCAS has initiated a visiting research fellowship program on a long-term basis in addition to an invitation program over a short period of time. This program includes the theme entitled "Development of Techniques for Environmental Resources Assessment Including Remote Sensing and GIS".

Introduction

GIS is a technique whereby various types of geographic data are processed in a unified geographic coordinate system using computerized equipment. This technique enables to delineate the actual state of land resources. Especially in the developing regions, where basic statistical data as well as precise thematic map data are lacking, GIS is considered to provide meaningful information on the area by the integration of a set of incompletely quantified data.

Agricultural activities are closely related to geographic information because information about land suitability conditions of specific crops is the basis of cultivation. It is necessary to evaluate the land conditions accurately for any region. Therefore agricultural institutes in many countries have recognized the need to promote research programs adopting GIS techniques. This trend has been enhanced even in developing countries since about 1990 due to the dissemination of satellite remote sensing data as well as the decrease in system preparation cost.

JIRCAS has also undertaken international collaborative research programs relating to GIS and implemented a series of programs since 1989. In most of the cases, counterpart institutes of JIRCAS faced the specific problem of management of land resources and sought appropriate measures to solve it. Fortunately, JIRCAS proposal of introducing GIS techniques to investigate the land resources issues was approved and specified in the work plan attached to the Memorandum of Understanding for collaborative research. Recently JIRCAS has been promoting comprehensive research programs, which attempt to adopt a multi-disciplinary approach to combine physical parameters with socio-economic conditions for evaluating land resources of the objective area. GIS is a useful tool and GIS specialists play a more important role than in unidisciplinary programs.

Collaborative research programs using remote sensing and GIS

Agro-environmental issues include the evaluation and management of land resources. Inappropriate land use

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or cropping systems in arable land could cause land degradation under various physiographic conditions. In order to analyze the mechanism of land degradation, it is necessary to obtain reliable data about the history of land use in the past in addition to morphological characteristics of land degradation. These data are still insufficient especially in the developing regions and remote sensing techniques are expected to compensate for the lack of information. GIS techniques enable to produce more comprehensive geographic information of the area by the integration of data from different origin including remote sensing data.

Research institutes located in the developing regions have sought effective measures to solve agro-environmental problems in the respective regions. Their common target is the development of sustainable agricultural production in harmony with environmental conditions. Remote sensing is a useful tool to monitor the changes of land surface characteristics which are associated with land degradation as well as agricultural activities. GIS enables to analyze the spatial pattern of land resources in relation to environmental conditions.

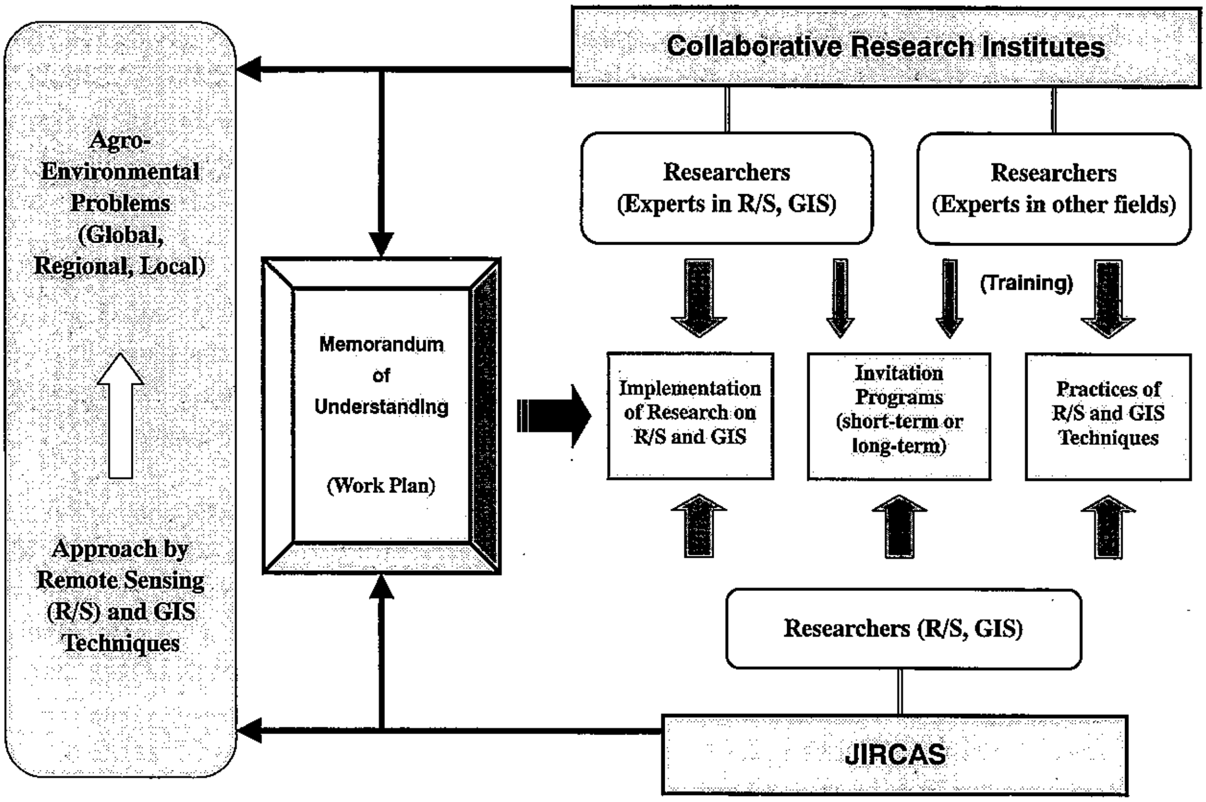


Fig. 1 Outline of collaborative research using remote sensing (R/S) and GIS

Fig. 1 illustrates the outline of collaborative research using remote sensing and GIS between institutes located in the developing regions and JIRCAS. At JIRCAS, researchers in remote sensing and GIS, can manipulate geographic data either by computer or manually. Research institutes, which are responsible for studying agro-environmental issues as regionally specific problems, can collaborate with JIRCAS based on common research themes. Collaborative research programs include the invitation of counterpart researchers to Japan in addition to the implementation of research outlined in the work plan. JIRCAS organizes two types of invitation programs: on a short-term basis and on a long-term basis. The latter program, which started in 1995, includes the theme entitled "Development of Techniques for Environmental Resources Assessment Including Remote Sensing and GIS".

Although JIRCAS is not an academic institution and does not have the capacity of organizing training courses, training of counterpart researchers in the field of remote sensing and GIS may sometimes be necessary for the successful implementation of collaborative research programs. In the process of setting up a new research group to implement GIS activities, education on the basic concept of remote sensing and GIS is required under the scheme of collaborative research.

JIRCAS has implemented research programs using remote sensing and GIS techniques in collaboration with institutes in 8 countries as indicated in Table 1. Table 2 shows the country, period and research title of invited

Table 1 International collaborative research programs implemented by JIRCAS

Country	Collaborative Institute	Period	Major Topics
Syria	International Center for Agricultural Research in the Dry Areas (ICARDA)	1989-95	1. Estimation of regional edible feed resources in rangeland. 2. Evaluation of land degradation hazard for mountainous area in the rangeland.
Pakistan	National Agricultural Research Centre	1990-96	1. Characterization of agricultural and vegetation activities on a national scale. 2. Analysis of soil erosion in the rainfed agricultural land in the North Punjab.
India	International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	1993-98	1. Extraction of the properties of representative soils in the semi-arid tropics. 2. Estimation of the spatial and temporal characteristics of agricultural land use.
Australia	Centre for Arid Zone Research, CSIRO	1994-98	1. Identification of the causes of desertification. 2. Development of assessment method for vegetation stability.
Mongolia	Institute of Meteorology and Hydrology	1994-	1. Estimation of water contents in snow-covered area. 2. Development of method to monitor the spatial distribution of water resources.
Thailand	Department of Land Development	1995-	1. Analysis of area with soil salinity in Northeast Thailand. 2. Evaluation of land suitability for sustainable agriculture.
China	Institute of Natural Resources and Regional Planning & Soil and Fertilizer Institute	1997-	1. Analysis of land use and soil environment changes for suburban and typical agricultural areas. 2. Development of method to estimate cultivation acreage of major crops.
Indonesia	Assessment Institute for Agricultural Technology & Center for Soil and Agroclimate Research	1998-	1. Analysis of conditions of location of existing farming systems in West Java. 2. Analysis of mechanism of land use change.

Table 2 List of invited counterpart researchers to JIRCAS for research on remote sensing and GIS technology

Type	Country	Period	Research Title
Short-term	Pakistan	Aug.25-Nov.15,1996	Analysis of land degradation in semi-arid area using remote sensing and GIS.
	Mongolia	Jan.9-Mar.27,1998	Heat and water exchange in atmosphere-vegetation-soil systems for the determination of evapotranspiration distribution.
	Indonesia	Jan.13-Mar.12,1998	Analysis of land use changes using remote sensing and GIS.
	Thailand	Feb.6-Mar.5,1999	Analysis of land use/cover distribution using remote sensing and GIS approaches.
	Mongolia	Feb.26-Mar.26,1999	Management of spatial data related to meteorology and hydrology in Mongolia.
	Indonesia	July 21-Oct.19,1999	Spatial analysis of farming systems using GIS.
	China	July 21-Oct.19,1999	Land use change analysis in suburban agricultural areas.
	China	July 21-Oct.19,1999	Spatial and temporal analysis of soil environment in suburban agricultural areas.
Long-term	Pakistan	Oct.1997-Sept.1999	Development of techniques for environmental and resources assessment in the semi-arid area using remote sensing and GIS.

counterpart researchers. As shown in the Table, JIRCAS has already received 9 researchers, including 1 on a long-term basis, from 5 countries since 1996. The Environmental Resources Division of JIRCAS is the host division, in which 3 scientists engaged in research relating to GIS and remote sensing can receive counterpart researchers. Research themes are generally discussed between institutes prior to the invitation and the materials for analysis are also prepared before the start of the training in Japan. As a result, the training in Japan should be consistent with the collaborative research program and it should contribute to the progress of the theme outlined in the plan of operation.

Examples

In this chapter the outline of collaborative research with institutes in Pakistan, India and China is presented. In each case the background situation was distinctively different in terms of definition of research objectives, experience in remote sensing and GIS technology of counterpart researchers and expectation of GIS activities in the collaborative institute. Pakistani case illustrates in short the successful establishment of a new laboratory including the employment of young experts at the institute. Indian case aimed at the application of remote sensing techniques at the International Crops Research Institute in the Semi-Arid Tropics (ICRISAT). In the case of China, two aspects are indicated; one is the existence of two counterpart institutes engaged in different basic disciplines, and the other is that a number of counterpart researchers had already been specialized in the field of GIS and remote sensing.

1 Case of Pakistan

1) Background of research and objectives

The Pothwar plateau located in the northern part of the Punjab province in Pakistan is dominated by rainfed agricultural land, where the climate is semi-arid and topography has changed extensively in association with water erosion. This area is highly productive in terms of wheat output in the post-rainy season, *Rabi*, whereas highly prone to land degradation due to the specific soil and climate conditions. National Agricultural Research Centre (NARC) affiliated to the Pakistan Agricultural Research Council (PARC) is a leading research institute in agricultural environment in the country and has implemented studies on the management of land conditions for this area.

NARC had implemented a project on the production of an agro-environmental atlas for the whole country on a 1:3,000,000-scale map, when collaborative research with JIRCAS started. NARC attempted to strengthen its capability of manipulating geographic data by introducing GIS techniques through the activities of this project as well as studies on soil erosion. Based on mutual consent between NARC and TARC (the predecessor of JIRCAS), objectives of collaborative research were set up as follows; 1) characterization of agro-environmental conditions on a national scale using coarse resolution remote sensing data and thematic map data, 2) development of a method to extract the conditions of soil erosion in the Pothwar plateau using high spatial resolution satellite data, and 3) development of a method to estimate and manage land degradation mainly associated with soil erosion.

2) Progress of research

In the fiscal year 1992/93, two TARC researchers visited NARC. They surveyed the availability of map and remote sensing data in Pakistan besides the observation of several experimental sites of NARC located in the Pothwar plateau. During the following two years, NARC established a new laboratory of GIS and employed 3 researchers as counterparts of TARC/JIRCAS. From 1992 to 1997, TARC/JIRCAS sent one or two researchers to NARC every year within the framework of the collaborative research program.

3) Results

* Land unit, which can be obtained by overlaying multiple thematic maps, showed the characteristic seasonal pattern of changes of the vegetation index calculated from coarse resolution satellite data.

Unit of land was obtained by overlaying six parameters of thematic maps, *i.e.* soil, land use, rainfall, elevation, landform and natural vegetation. All these maps were scaled at 1:3,000,000 and prepared for the agro-environmental atlas project of NARC. In the Pothwar plateau, two land units covered the dominant part of the area. Fig. 2 shows the changes of the Global Vegetation Index (GVI) in one land unit, where GVI data originating from NOAA/AVHRR data were modified to cover the range of latitudes from 75° North to 55° South by 2,500 columns and 904 lines.

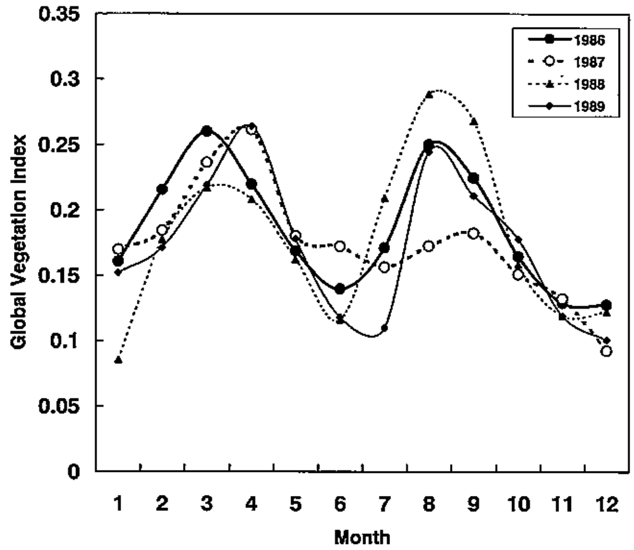


Fig. 2 Changes of GVI on a unit area basis in the Pothwar plateau extracted by overlaying 6 thematic maps

For training, the process of production of land units and delineation of temporal characteristics appearing in the units were useful for counterpart researchers to understand the standard flow of analysis in GIS. Furthermore, Fig.2 shows characteristics environmentally meaningful as follows. First, two distinct maxima corresponding to crop cultivation in the post-rainy season, Rabi, from March to April and in the rainy season, Kharif, in August were indicated. In the area of natural vegetation coverage, on the other hand, a unique maximum in the summer season was generally indicated. Second, in the Kharif season of 1987 and in the successive Rabi season of 1988, vegetation was less abundant than in other years presumably due to the shortage of rainfall. In the case of irrigated agriculture, a similar maximum was observed in the Kharif season of 1987.

The authors evaluated a method to distinguish extensively cultivated area from forest or rangeland including fallow area based on seasonal changes of GVI. This method led to the production of map data representing the agricultural activities on a national scale for every year when the source data were available. Fig. 3 shows the results of estimation of vegetation abundance, which corresponded to the density of green biomass, as well as the location of cultivated land in Pakistan. Rainfed agricultural land was generally located in the southern fringe mountainous area with abundant vegetation and there was a difference in the area of cultivated land between the years 1986 and 1987.

* Severely eroded area in the Pothwar plateau, where the topography had changed extensively, could be extracted and its severity could be evaluated by using high spatial resolution satellite data.

The various types of indices from remote sensing data utilized the information of not only spectral data, for example vegetation index, but also spatial or textural data. The study site was located in the southwestern district of Islamabad, the capital of Pakistan, in the center of the Pothwar plateau. SPOT panchromatic data and Landsat TM data were the source data of analysis.

Fig. 4 shows the false color composite image of the study site in the upper part and the estimated erodibility by pseudo-color representation in the lower part. Erodibility was estimated through the process of spatial filtering techniques and texture value calculation within a certain range of pixel distances. False color composite image shows that there are two types of modification of topography: one corresponding to the geological structure typically appeared on the lower left side, and the other consisting of developed dissected valleys appeared along the rivers and their tributary courses. The latter which was caused by water erosion was extracted in this study. The method developed by the authors could appropriately estimate erodibility as shown in the Figure.

The authors also observed that the erodibility was negatively correlated with the coverage index estimated from Landsat TM data. For the quantitative estimation of the soil loss rate in the area, two factors of coverage and control were derived from Landsat TM data and applied to USLE formula. Through the collaboration between NARC and JIRCAS, it was recognized that these results would be useful to develop management methods to mitigate the risk of soil erosion and to maintain the land resources for agricultural production.

These activities were described in JIRCAS publications (Uchida *et al.*, 1995). Some of the results were published in journal articles (Uchida, 1996; Ogawa *et al.*, 1998) and also presented at international conferences (Uchida *et al.*, 1994; Uchida, 1995; Yamamoto *et al.*, 1997; Ogawa *et al.*, 1997).

2 Case of India

1) Background of research and objectives

JIRCAS signed a Memorandum of Understanding with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India for collaborative research on the environmental changes using remote sensing techniques in 1994. ICRISAT is a crop research institute and its mission is to increase crop productivity and food security, reduce poverty, and protect the environment. ICRISAT focuses on five crops, *i.e.* sorghum, millet, groundnut, chickpea, and pigeonpea. This institute is located in the center of the Deccan plateau, where rainfed agriculture is unstable in terms of cropping area and production owing to the variation in rainfall.

In the semi-arid tropics of India, two major soils, *i.e.* Vertisols (black soils) and Alfisols (red soils), are extensively distributed and the campus of ICRISAT is located on the boundary of these soils. Cropping pattern in each soil type consists of cultivation once a year in the rainy season, *Kharif*, on red soils while in the post-rainy season, Rabi, cultivation predominates on black soils. The author attempted to utilize Indian Remote Sensing (IRS) data as a major source of analysis, due to easy accessibility from ICRISAT and availability of multi-temporal data within a limited budget range. The first objective of the research was to extract soil characteristics by using remote sensing data. The second was to develop a method to monitor agricultural land use.

2) Progress of research

In the fiscal year 1994/95, the preparation phase of collaborative research was conducted. After the installation of the equipment in September 1995, the author carried out mainly two activities: 1) retrieval and collection of geographic data including IRS and topographic maps and 2) measurement of spectral reflectance of various types of ground surface conditions. Simultaneously the position of the measurements was obtained by the GPS receiving system and the surface characteristics were recorded by a digital camera. The author trained one research associate employed at ICRISAT in the operation of these instruments, which were essential in field surveys of remote sensing and GIS studies. The training also involved the manipulation of topographic maps to produce DEM, for example.

In the fiscal year 1996/97, the author analyzed 15 IRS data taken at the time from 1989 to 1996 covering the area including ICRISAT campus. Analysis of soil characteristics combined with ground-measured spectral reflectivity data was implemented. A method to monitor agricultural land use using IRS data was also developed during this period.

3) Results

* In order to extract the characteristics of two major soils, Vertisols (black soils) and Alfisols (red soils) in relation to land suitability for agriculture, in the semi-arid area of India, two indices on redness and brightness calculated from remote sensing spectral band data were used.

The author along with the research associate measured the spectral reflectance of 10 samples for black soils and 12 samples for red soils on the ground of ICRISAT campus. For the application of IRS data, spectral reflectance data in the same range of wavelengths of the spectral band of IRS were used to characterize the two soils. It was observed that the two indices, redness index (*RI*) and brightness index (*BI*), expressed by the following formula were more suitable as discriminating indices for the two soils than intensity and hue, which were commonly used for the color representation of soils.

$$RI=(B3-B1)/(B3+B1), \qquad BI=\sqrt{\sum(Bi)},$$

where Bi is the digital number of band i of IRS data. $B1$ and $B3$ represent the value in the wavelength range of blue and red, respectively.

When *RI* and *BI* for IRS were plotted on the figure, the author noticed that the position in the scattergram could be related to the land suitability and soil moisture conditions. Table 3 shows the distribution of land use by classified soil types obtained from IRS data by the unsupervised method. If the land suitability could be estimated from the intensity of land use for agricultural purposes, the order of suitability would correspond to the indication below the table.

Table 3 Constitutional ratio (%) of land use in 1992/93 by classified soil type

Soil Type	Major Soil	Kharif & Rabi	Kharif	Rabi	Non-Cultivated Land	Water or Bare Land
1	Red Soil	5.1	44.3	3.8	41.7	5.1
2	Black Soil	13.1	46.4	10.5	27.6	2.4
3	Red Soil	1.1	27.8	1.1	59.8	10.2
4	Red Soil	0.2	17.1	0.7	63.4	18.6
5	Black Soil	25.3	44.6	10.2	18.5	1.3
6	Rock, Stony	0.0	10.5	0.3	57.7	31.5
7	Settlement	1.4	28.3	1.8	45.0	23.5
8	Black Soil	51.7	32.0	4.0	11.5	0.8
9	Black Soil	4.7	42.4	5.4	39.1	8.3

Suitability estimation : 8 > 5 > 2 > 9 (Black soils)
1 > 3 > 4 (Red soils)

Fig. 5 schematically illustrates the relation between the soil characteristics and indices derived from IRS multi-spectral data. This figure may be used to evaluate the land suitability as well as to enable a discrimination of black soils from red soils occurring over a considerable area in the semi-arid tropics of India.

* In order to estimate the intensity and stability of agricultural activities in the semi-arid tropics of India, a method to monitor the yearly distribution of cultivated area in Rabi was developed

One of the basic source data to evaluate the sustainability of agriculture at the site would be the spatial and temporal characteristics of actual cultivation of crops. For this purpose, statistical data, even if they were quantitatively reliable, would be insufficient in terms of information on spatial distribution. In this study the

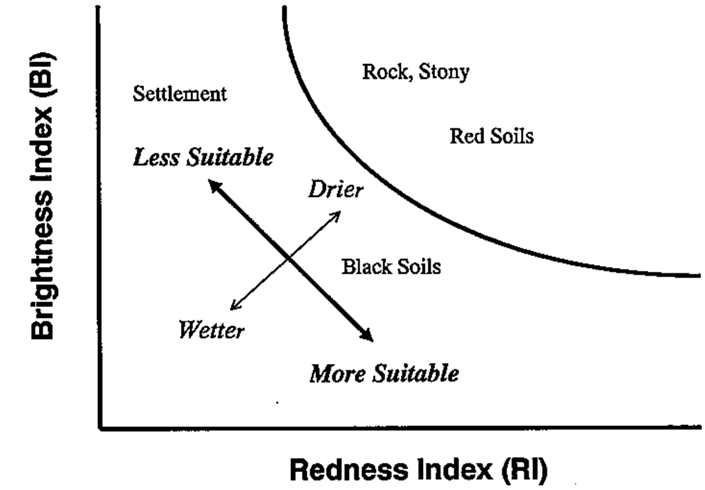


Fig. 5 Relation between land suitability and indices derived from IRS data

author attempted to develop a method to extract digitally the area under cultivation in the *Rabi* cropping season.

Supervised classification method is commonly adopted to discriminate between cultivated agricultural land from other land cover types. This method, however, does not enable to identify the most appropriate training sample data of classification. In this study, the cultivated area was discriminated by using an index, which could change according to the time. Fig. 6 shows the temporal changes of the Normalized Difference Vegetation Index (NDVI) averaged over each land use type indicated in the Figure for 15 data obtained from 1989 to 1996. This Figure shows that cultivated land could be discriminated by the threshold value of NDVI, which decreased almost linearly during the period from November to February.

The characteristics illustrated in Fig. 6 were applied to extract cultivated land for all the years, if data were available. The relation between the physical conditions and the distribution of cultivated land showed the following: 1) there was a positive correlation between the estimated cultivated area and the amount of rainfall during the period from October to December, which may contribute to the moisture content around the sowing stage. 2) The more suitable areas estimated by the scheme of Fig. 5 showed a higher percentage of cultivated area in the case of black soils. It should be noted that this activity was the first in which remote sensing was combined to GIS at ICRISAT.

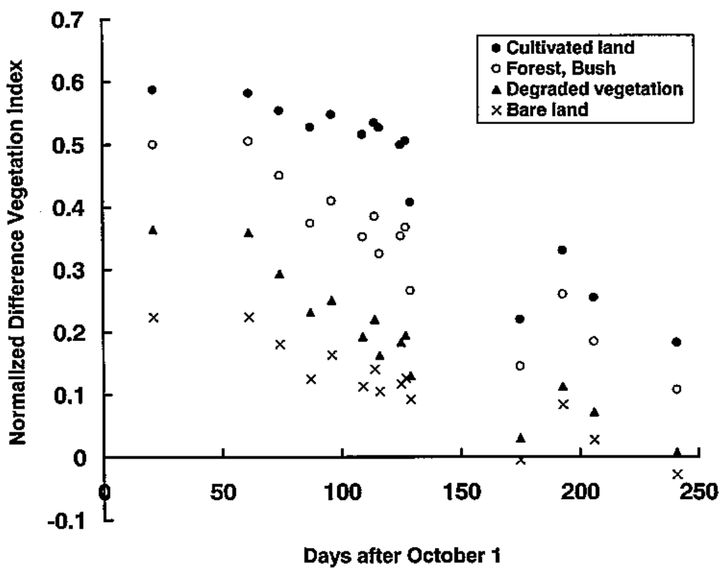


Fig. 6 Temporal changes of Normalized Difference Vegetation Index (NDVI) associated with land use type

These activities were introduced in journal articles (Uchida, 1998) and international conferences (Uchida, 1997). Some results are presented on the homepage of ICRISAT.

<http://www.cgiar.org/ICRISAT/text/research/networks/gnet4.html#top>

3 Case of China

1) Background of research and objectives

The comprehensive research project implemented by JIRCAS in collaboration with China started in 1997. The program of GIS and remote sensing was planned in collaboration with two institutes, Institute of Natural Resources and Regional Planning (INRRP) and Soil and Fertilizer Institute (SFI), under the Chinese Academy of Agricultural Sciences. INRRP established in 1995 the Department of Agricultural Application, National Remote Sensing Center of China, which is mainly concerned with the application of remote sensing and GIS techniques to agricultural resources survey, monitoring of agricultural resources dynamics and natural disasters. Therefore the staff members of INRRP had already acquired an expertise in the practice of remote sensing and GIS when the collaborative program started. At the SFI, on the other hand, the Department of Information Agriculture had been developing a GIS system for the evaluation of soil environment, but the staff members had just started to become acquainted with remote sensing and GIS technology through the development of their system. JIRCAS proposed to the two institutes to set up a common study area to analyze various aspects of agricultural environment. At the same time individual research topics were selected between JIRCAS and each institute in order to enhance the capability of application of these techniques.

The main theme of this comprehensive project is to contribute to an analysis of the state of food production and supply in China. The GIS group discussed and selected study sites where winter wheat predominates in Shandong province, the major grain production center, and in the suburban area of Beijing City. Objectives were as follows: 1) to improve the accuracy of extraction of the winter wheat cultivation area using remote sensing data, 2) to analyze land use changes along with the economic development recorded in the past decades, and 3) to analyze the changes in the soil environment with emphasis placed on the effects of fertilizer input. First and second objectives will be implemented in collaboration with mainly INRRP and the third with SFI. Besides these objectives, overall understanding of the changes in the agricultural environment including land use and fertilizer input would be set as objectives of collaboration with all partners.

2) Progress of research

The first mission from JIRCAS for discussing GIS research visited INRRP and SFI in March 1998. This mission presented the results of GIS and remote sensing research implemented by JIRCAS in collaboration with foreign institutes and also conducted a field observation of the winter wheat cultivation area including Shandong province. It learned from counterpart institutes that Chinese organizations had monitored the area and estimated the production of major crops such as winter wheat by satellite remote sensing data but the accuracy was a problem.

From 1998 to 1999, JIRCAS collected a time series of Landsat TM data over the same location, 18 scenes of Beijing area and 20 scenes of a part of Shandong province. Using these data the author examined various spatial and temporal characteristics of winter crop cultivation. Some of the results were explained for the counterpart researchers in China and presented at academic conferences in Japan. The reliability of these results, however, has not yet been verified in terms of land cover conditions compared with the actual conditions, because detailed field examination as well as statistical data had been limited. Presently the counterpart researchers are conducting these activities in addition to the development of methodology.

In addition, two counterpart researchers, one from each institute, INRRP and SFI, visited JIRCAS during the period from July to October 1999. The common study site was set at Shunyi county, Beijing, where agricultural productivity is high but recent land use changes from agricultural purposes to others are noticeable. The Chinese counterparts who brought maps and statistical data in a digital form had the opportunity to manipulate multi-temporal satellite data.

3) Results

* Land use changes during the period from 1984 to 1996 were analyzed based on multi-temporal Landsat TM data for the site located in the suburban area of Beijing.

First, the general trend of land use change in the suburban area of Beijing was delineated by overlaying the land cover classification data obtained from Landsat TM taken during 4 different years, 1984,1991,1992 and 1996. All of these data showed the land cover condition in mid-May, when the vegetation of winter wheat was most active. During this period, urbanization progressed as residential or industrial areas expanded around the existing urban areas or highways. Land use changes from arable land to fish ponds were observed especially in the lowland.

On the other hand, winter wheat cultivation had not been performed consistently for continuous years. This aspect is clearly indicated in Fig. 7 which shows a color composite image by representing NDVI in 1984 as red, in 1991 as green and in 1996 as blue. In the Figure, the white color portion indicates that wheat cultivation was practiced in all the three years, yellow in 1984 and 1991, magenta in 1984 and 1996, light blue in 1991 and 1996, and red, green and blue only in 1984, 1991 and 1996, respectively. Red and yellow portions also represent the part of land use conversion from agricultural to urban area. Using this figure, the authors attempted to analyze in more detail the characteristics of land use changes in this area.

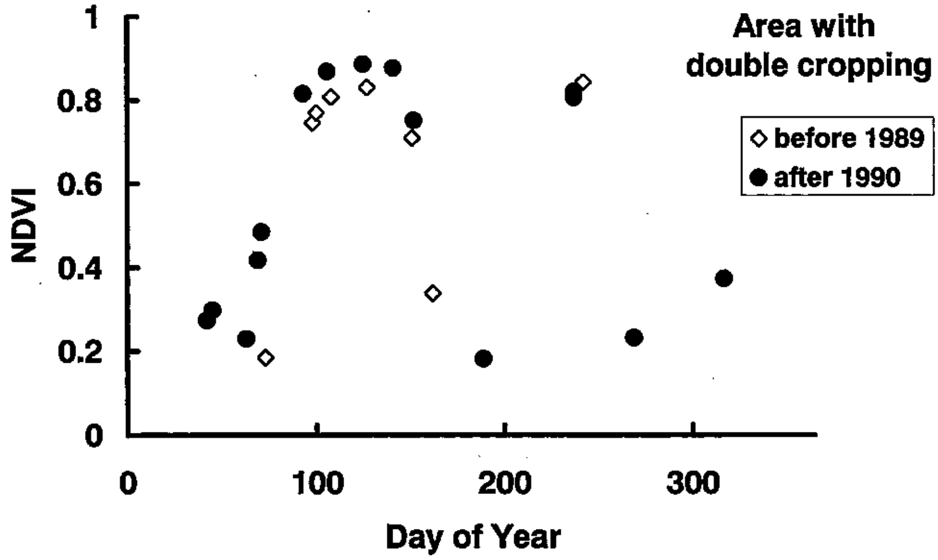
* Estimation method of winter wheat cultivation area was developed by using coarse spatial resolution satellite data but considering the mixture of various land cover types within one pixel.

Coarse spatial resolution satellite data could be useful to monitor crop growth due to the high frequency of repetitions of observations. However, spatial resolution of more than 1 km such as that of NOAA AVHRR would be too large as a unit of area for the estimation of winter cultivation, for example. In this study the seasonal patterns of NDVI derived from Landsat TM were examined and three general types were defined during the period from May to June, which appeared in the study area. The first type was represented by winter wheat, which indicated a high value around 0.7 in mid-May but low around 0.2 in mid-June. The second type was represented by mixed vegetation including rural settlements, which indicated an almost constant value around 0.3 to 0.4. The third type was represented by bare soils and urban areas, which indicated constantly a low value around 0.1 to 0.2.

Fig. 8 shows the results of estimation of each land use type based on NOAA AVHRR data, adopting a simple linear discrimination model, in comparison with land use data obtained from Landsat TM data. Only preliminary results were obtained and the model should be improved in future as there was an overestimation of the cultivated area in the lower part of the image. Since INRRP is one of the responsible institutes to analyze the yearly records of winter wheat cultivation by remote sensing and GIS, more advanced research on this topic will be implemented under the scheme of the collaborative program.

* Land data resulting from the intensification of agriculture recorded since 1980s were delineated by satellite remote sensing data.

SFI had implemented field surveys on groundwater quality in relation to fertilizer application and had attempted to input the data into a GIS to integrate remote sensing data. Huantai county in Shandong province is one of the study sites. The author collected and analyzed the multi-temporal Landsat TM data for this site. The statistical data on agricultural production and fertilizer consumption indicated that the high rate of grain yield increase recorded in the late 1980s was correlated with the increase of fertilizer consumption. Remote sensing



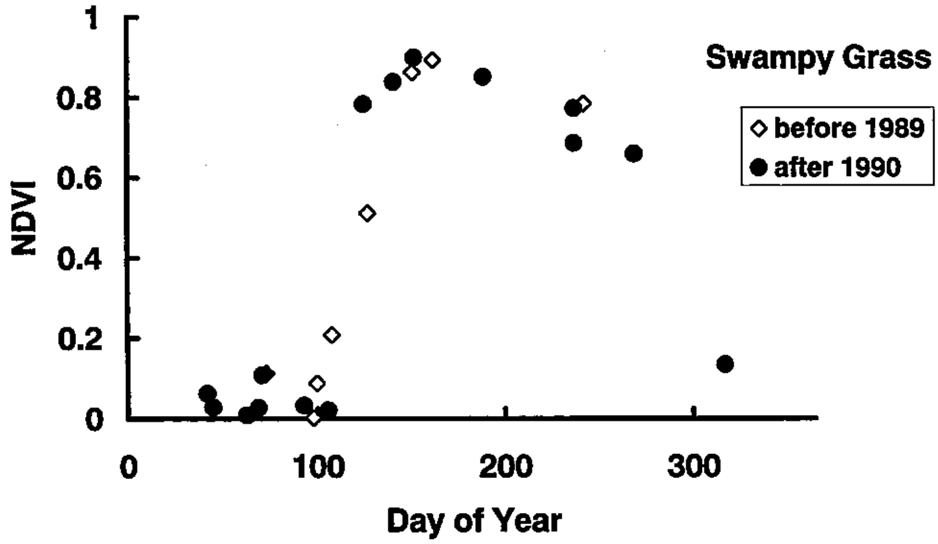


Fig. 9 Temporal changes of NDVI for cultivated area and swampy grass to compare the patterns in 1980s and 1990s

data also indicated differences in vegetation abundance in crop fields between 1980s and 1990s. Fig. 9 shows the NDVI of each period represented by different colors and plotted according to days in a year in the horizontal axis. This figure represents two land use types, *i.e.* cultivated area and swampy grass. In the cultivated area, each period shows a specific curve according to the growth of crop with different maximum levels, whereas swampy grass does not show any significant difference in the curve between the two periods. These results could be utilized for application in monitoring of the intensification process of agriculture and also estimating actual yield for yearly crop production.

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References

1) Ogawa, S., Saito, G., Mino, N., Uchida, S., Khan, N. and Shafiq, M. (1997): Estimation of soil erosion using USLE and Landsat TM in Pakistan, Proc.18th Asian Conference on Remote Sensing, R-15, 1-6.

2) Ogawa, S., Saito, G., Mino, N., Uchida, S., Khan, N. and Shafiq, M. (1998): Estimation of soil erosion in semi-arid area using USLE, Landsat TM and GIS, J. Japanese Agricultural Systems Society, Vol.14, No.2, 94-102. (in Japanese with English summary)

3) Uchida, S., Roohi, R. and Ahmad, S. (1994): Land degradation analysis of rainfed agricultural area in Pakistan using remote sensing data, Proc.15th Asian Conference on Remote Sensing, C-4, 1-5.

4) Uchida, S. (1995): Diagnosis of land degradation in the semi-arid area of Asia and Pacific region using remote sensing data -JIRCAS's case study-, Proc.16th Asian Conference on Remote Sensing, G-2, 1-6.

5) Uchida, S., Ahmad, S. and Roohi, R. (1995): Analysis of land degradation phenomena using remote sensing techniques -Extraction of geomorphological characteristics and land coverage in eroded areas-, JIRCAS Newsletter, No.4, 6.

6) Uchida, S. (1996): Evaluation of desertification using remote sensing and GIS, Farming Japan, Vol.30, No.1, 30-37.

7) Uchida, S. (1997): Temporal analysis of agricultural land use in the semi-srid tropics of India using IRS data, Proc.18th Asian Conference on Remote Sensing, A-7, 1-6.

8) Uchida, S. (1998): Extraction of soil characteristics and monitoring of agricultural land use in the semi-arid tropics of India using remote sensing, JIRCAS Journal, No.6, 39-52.

9) Yamamoto, Y., Uchida, S., Suyama, T. and Shoji, A. (1997): Land evaluation for sustainable land use by remote sensing and GIS; Case study: Assessment of soil erosion in Pakistan, Proc.18th International Grassland Congress, Vol.2, Session 24, 11-12.

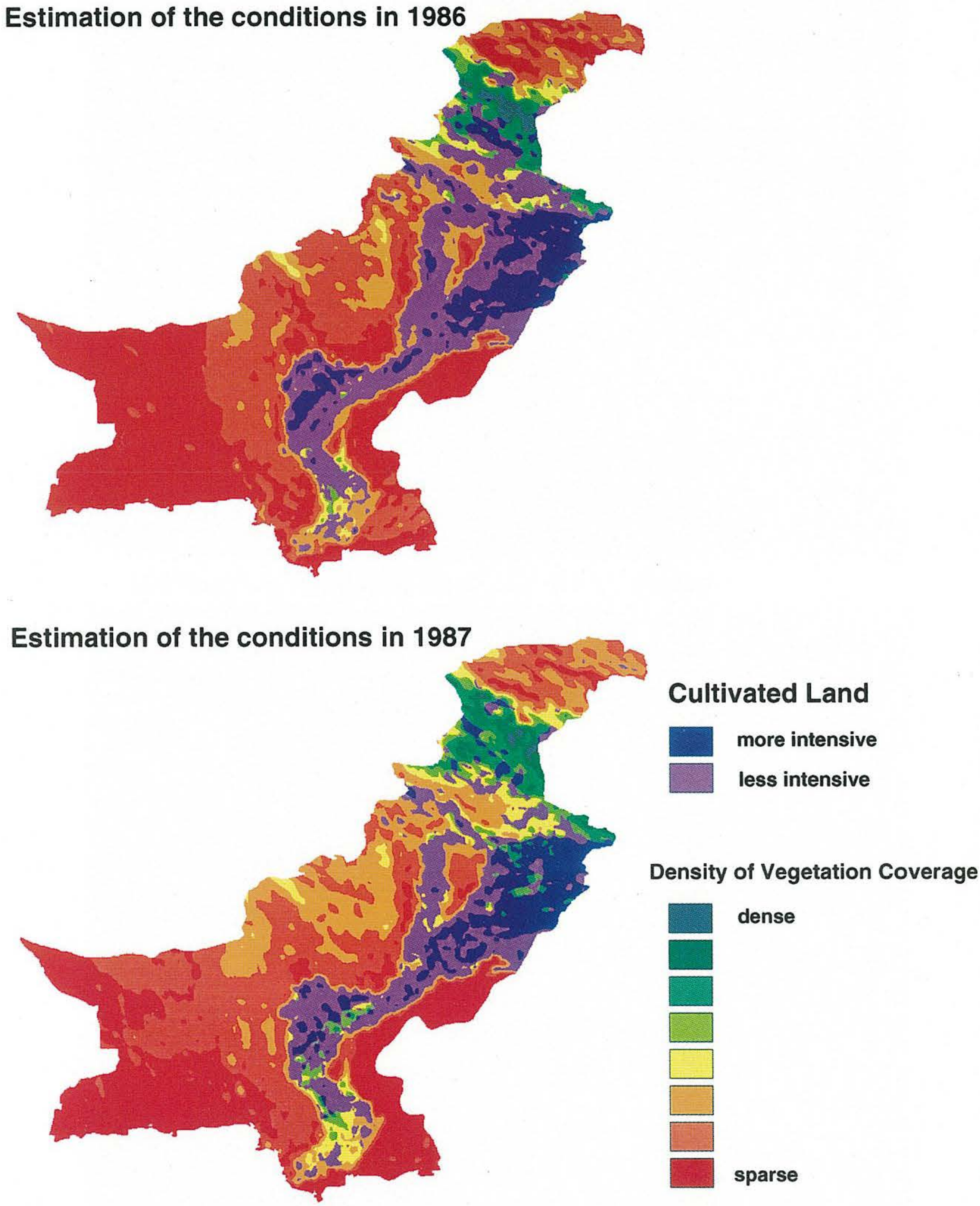

Fig. 3 Estimation of vegetation density and cultivated area in Pakistan using GVI data

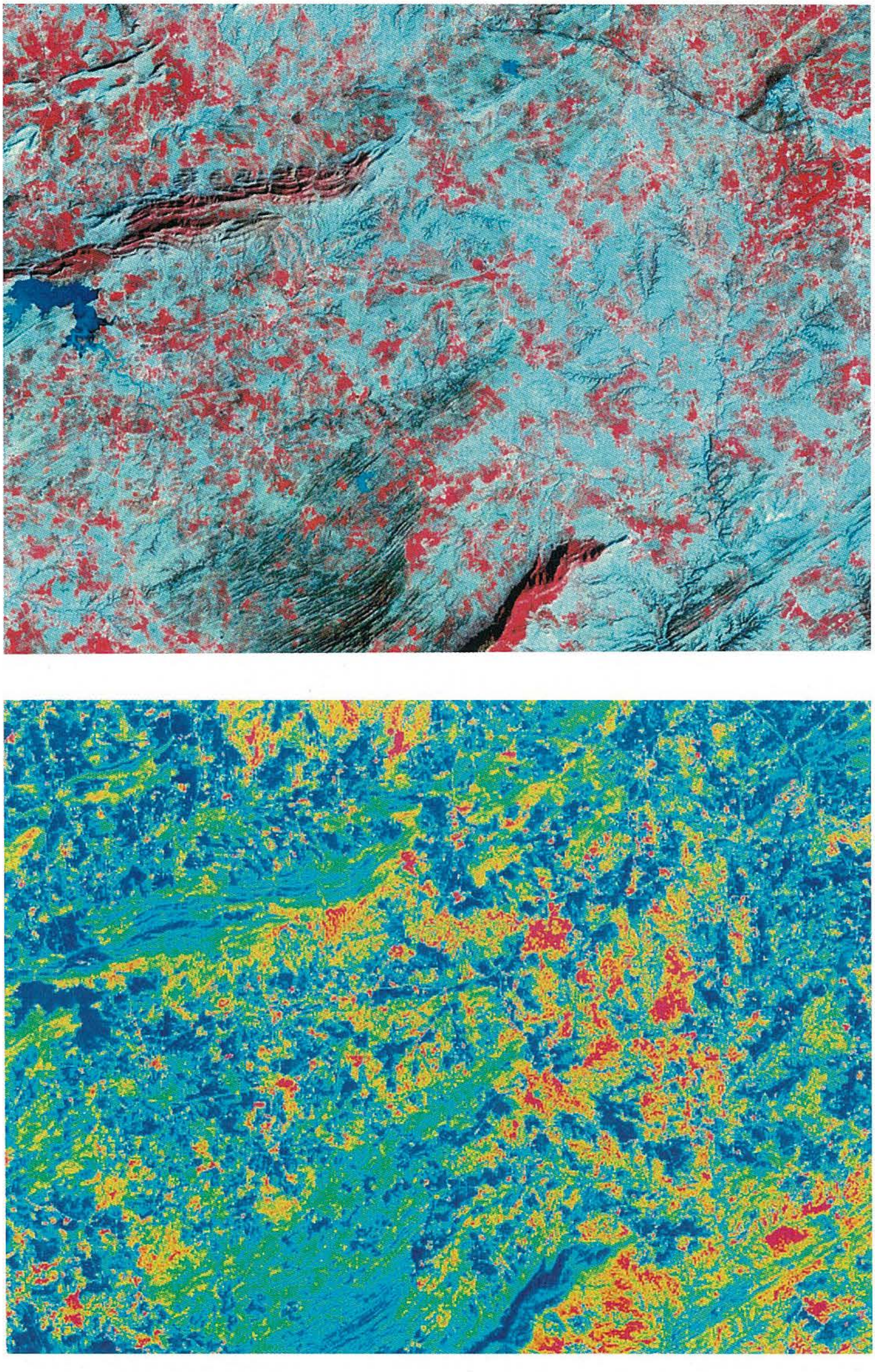

Fig. 4 False color composite image (upper) and estimated erodibility represented by pseudo- color (bottom) for the southwestern part of Islamabad in the Pothwar plateau

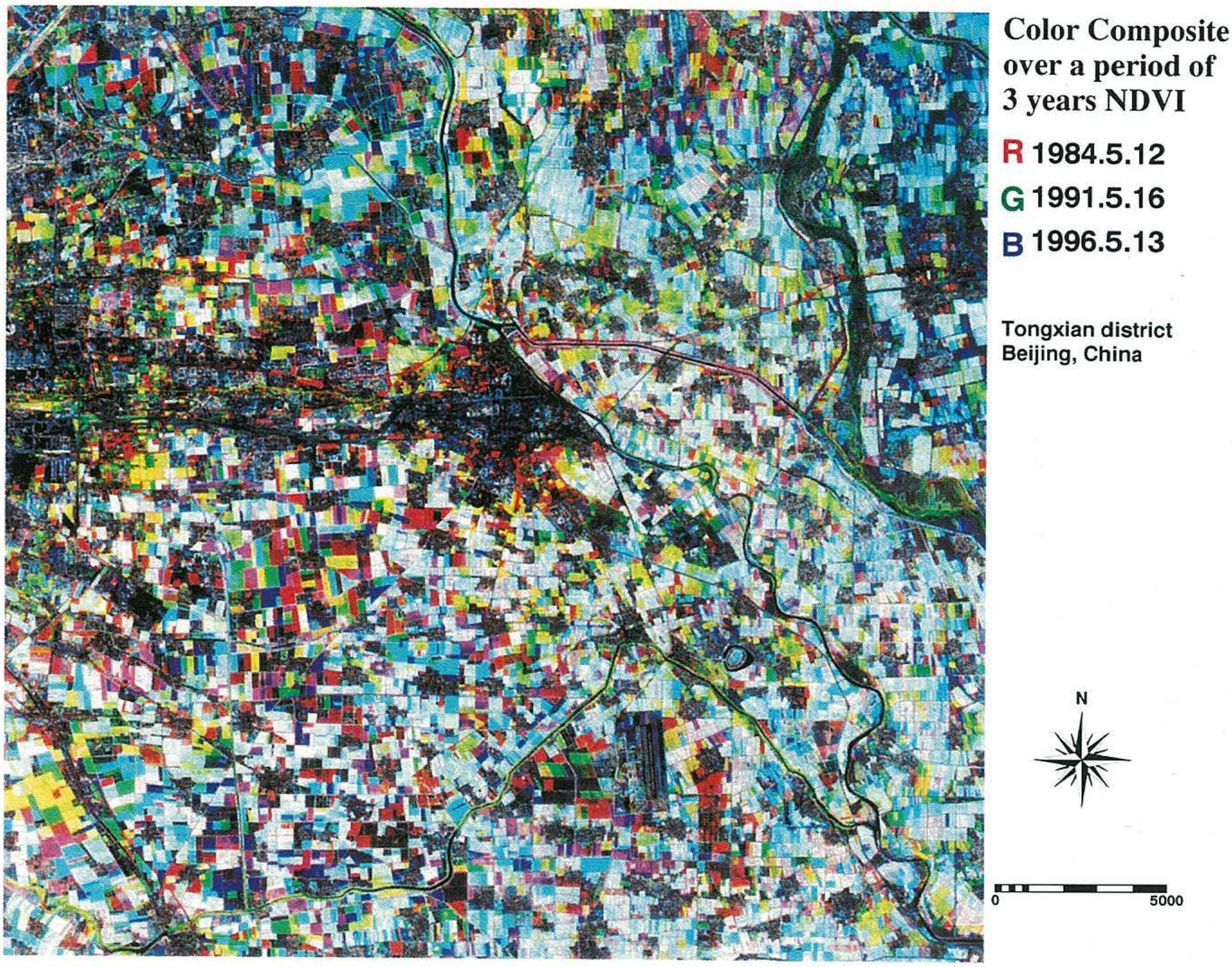

Fig. 7 Color composite image derived from NDVI value recorded for a 3-year period in Tongxian district of Beijing

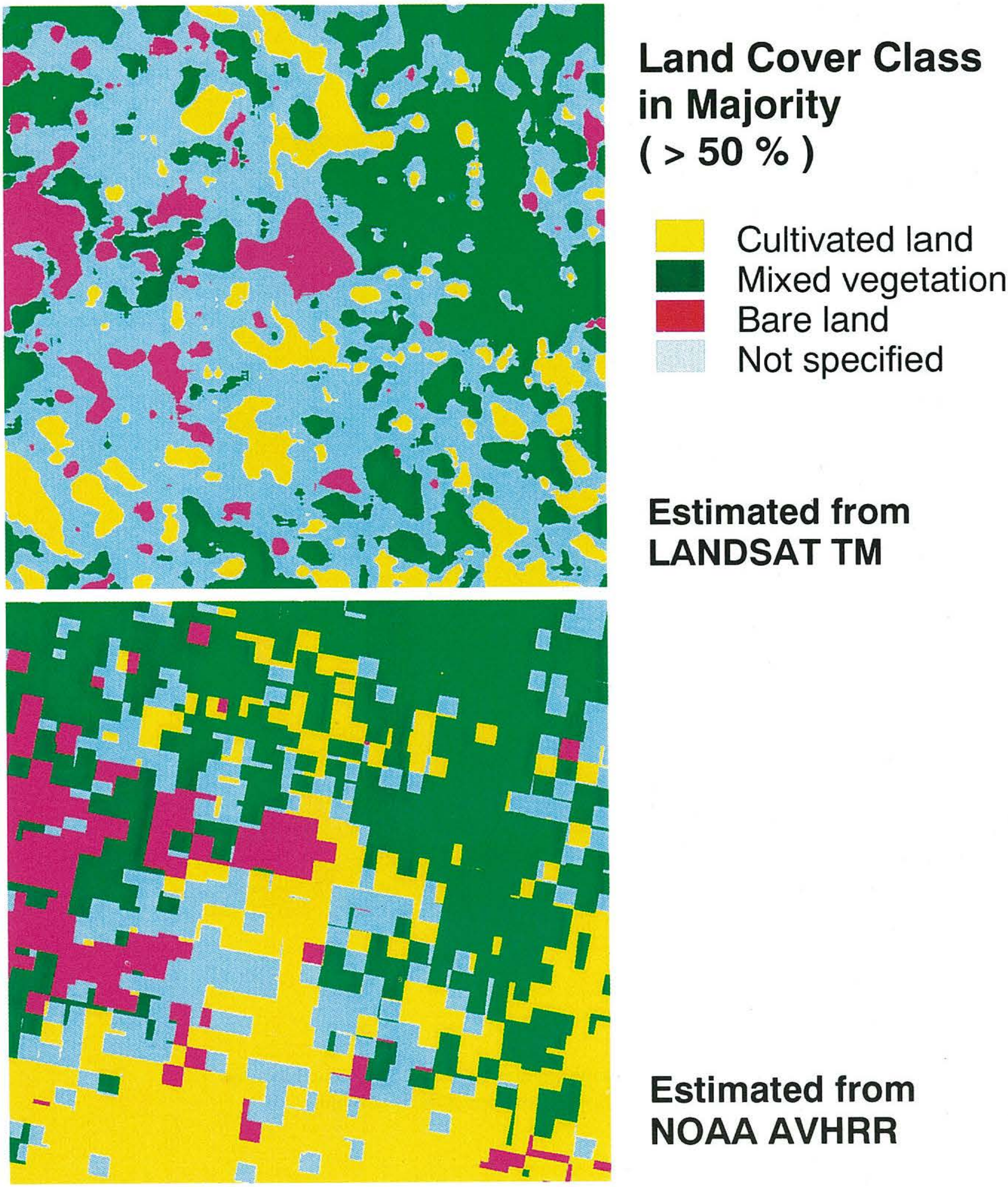

Fig. 8 Comparison of land cover classes (majority, more than 50 % in one pixel) between the results estimated from Landsat TM and NOAA AVHRR