Establishment of Spatial Land and Water Resources Database Using GIS and Remotely Sensed Data

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Abstract

With the image processing system and GIS capabilities, together with the Institutional Linkage Programme Project (McGill and KKU), Khon Kaen University could establish a spatial land and water database of the Northeast both regional and detailed scales. These data include soil types, rainfall isohytes, terrain, water and forest resources with an objective of supporting the natural resource development plans in the Northeast. More than 120 map sheets of spatial land and water resource database have been complete. Directly linked to this is research into the application of remote sensing and GIS to integrated mapping, temporal land cover change, and modelling of potential soil salinity. The result obtained can help supports the sustainable development plan of natural resources in the Northeast.

INTRODUCTION

In the late 1980s, the Canadian International Development Agency offered its support for the development of remote sensing and geographic information system capabilities at Khon Kaen University in Northeast Thailand. This was accomplished through agreements leading to two grants which were implemented at approximately the same time.

The first grant provides financial support for the Institutional Linkages Program Project entitled "Remote Sensing, Soil and Water Management in Northeast Thailand" between McGill University and Khon Kaen University. The two broad objectives of this project are:

- to develop expertise in remote sensing and land and water resource management through staff training at Khon Kaen University and
- to put this training to work through the development of a physical resources database of direct use to soil and water management in the region.

In the summer of 1989, Khon Kaen University received material aid under the second of these grants which forms part of an overall strategy to make use of satellite technology in furthering the objectives of the Greening of the Northeast Plan. The grant covered the delivery and installation of the Meridian Image Processing System and a Micro Vax II computer and operating system as well as the PAMAP Geographic Information System (GIS).

To meet the aims of these grants, Khon Kaen University contributions comprise staff and infrastructure support; the latter as facilities and the usage of equipment at the University Computer Center.

The rationale behind this aid program is to address some of the critical land and water resource-related problems of the Northeast. The Northeast suffers from limited resource sustenance capabilities which are coming under increasing population and development pressures. Salient aspects of these problems include :

Climate — The predominant agriculture of the Region, rainfed rice production, is reliant on rains which occur through the period May-September. Irrigation has been successful only in limited areas due to the nature of the landscape. A detailed understanding of the rain cycle and more specifically, its relation to the spatial mosaic of crops, needs further study.

Water resources — Given the precarious nature of rainfall in the Northeast and, more important, seasonal water availability, there is a need for accurate, up-to-date information on water resources.

Deforestation — Decades of logging and clearing of forests to create new agricultural land have decimated the Region's forests. 1988 estimates of remaining reserves range as low as 13% of total land area. Major efforts are underway to recover some of the previously-forested lands through programs of community education and involvement and agroforestry.

Edaphic constraints

- **soil fertility/texture** Over 80% of the soils in the Northeast have low nutrient status and/or are acidic. Moreover, the most extensive soils have high proportions of fine sand and a consequent low cation exchange capacity. Laterization, or the formation of skeletal structure, also affects many soil types.
- **soil salinity** Many areas of the Northeast suffer from a seasonal problem of elevated levels of salt at or near the soil surface, owing to the presence of the widespread salt-bearing Mahasarakham Formation. Locally, this can impose serious constraints on agricultural productivity. The mechanisms of soil salinization are not fully understood and precise methods of mapping/predicting the extent of salt-affected soils remain a challenge.
- **soil erosion** Soil erosion in the Northeast is a secondary effect linked to agricultural practices, to deforestation and locally, to salinity. The problem can be acute on upland soils and could be reduced in extent with improved soil and water management practices.

In order to mitigate the severity of future problems in these areas, there is an acute need for careful resource planning based on an institutionalized system of informed decision-making. The computerized system at Khon Kaen University and the developing expertise of the group there is beginning to meet these goals.

SYSTEM CONFIGURATION

Figure 1 provides the layout of the image interpretation/GIS now operating at the Khon Kaen University Computer Center. The system has a standard configuration with expansion options. It includes the Micro Vax II (Central Processing Unit), a Meridian image-station, a PAMAP workstation, input peripherals (tape drive, table digitizer), high

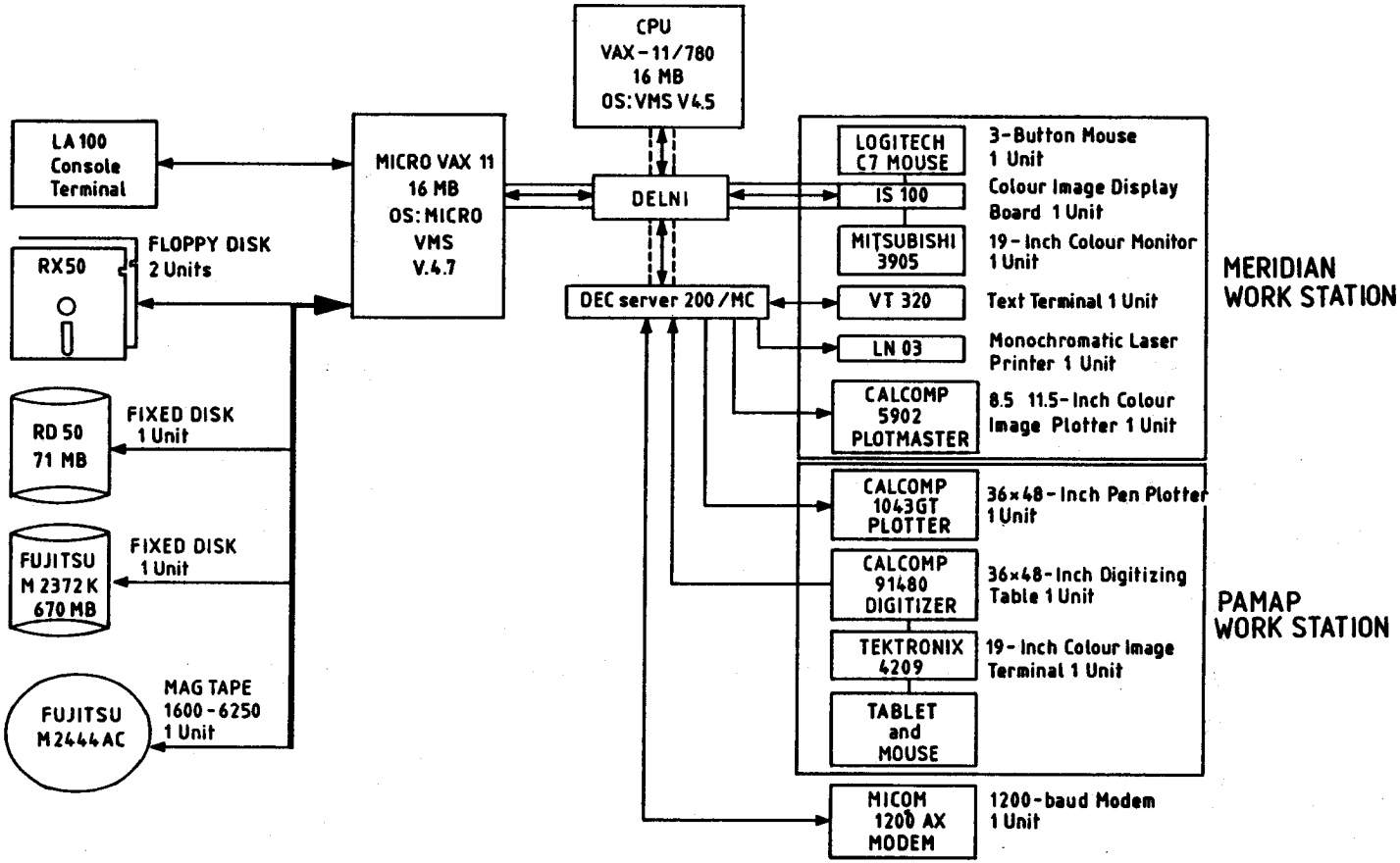


Figure 1. Satellite image processor and geographic information system configuration (1989).

capacity disk drives, output peripherals and an Ethernet interface. The software consists of the Meridian Core Package, Meridian Image Package and PAMAP GIS. The Meridian system contains functions which permit integration with PAMAP GIS.

APPROACH TO DATABASE DEVELOPMENT

Prior to the advent of GIS technology, the computer encoding of spatial land and water resource information remained non-systematic. While it was possible to acquire information from remote sensing,i.e., aerial photography or satellite imagery, and to digitize and display information on specific ecosystem components (e.g., geology, terrain/soil type, drainage, vegetation, etc), combining these data by computer required software designed specifically for this purpose. Until recently, the process was conducted manually, using transparent overlays.

Using information extracted from satellite imagery in combination with other map-based information (e.g., topography, soils), the Remote Sensing soil and Water Management in Northeast Thailand project has undertaken to assemble a spatial land and water resource database using the Meridian and PAMAP systems. Satellite imagery covering the entire Northeast has been provided to the project by the National Research Council of Thailand, Remote Sensing Division. The essential goal of this database is to provide a single, comprehensive basis on which to manage the Region's land and water resources.

In the first of two encoding sub-projects, up-to-date water resource mapping has begun by combining digitized 1:50,000 topographic map sheets of Khon Kaen (28 sheets) and Ubon Ratchathani (42 sheets) Provinces with water resource information derived from the visual interpretation of Thematic Mapper Band 5 black and white print. Water boundaries, rivers, lakes and small water channels were traced from December 1988 and January 1990 (dry season images). Mapping of these two Provinces is now complete.

These data can be used :

- to locate areas that may be suitable for development of second crops in the dry season;

- to find areas where there are potential sites for small reservoir construction
- by provincial authorities to detect channel areas that need to be reclaimed from sedimentation;
- to link water resource maps with other databases such as land information, climate, economics or census, in order to assess water use on a regional scale. This will be useful for watershed management and land use planning.

A second sub-project comprised the digitized of regional scale information from the most up-to-date existing sources. These include maps covering the following parameters:

- soil type;
- rainfall isohytes;
- terrain units;
- forest resources.

These data on water resources and land attributes now form part of the Northeast database and are available in computer-compatible tape or hardcopy format, at any scale, either as individual ecosystem components or in specified combinations, through the Khon Kaen University Remote Sensing and Geographic Information Center.

RESEARCH DEVELOPMENT

CLIMATIC DYNAMICS

As the first step towards compiling a water resource database for the Northeast, the spatial and temporal patterns of wet season (April-October) rainfall were analyzed using thirty years of continuous daily rainfall data collected from forty stations located throughout the Region. The analysis divided the wet season into four periods : the onset of rains, two peak rainfall intensity periods and the termination. Summaries of daily rainfall data were analyzed in terms of rainfall effectiveness classes based on general crop growth needs. The frequency of occurrence of these classes were mapped along with a measure of their variability.

The analysis confirmed that wet season rainfall increases in quantity from southwest to northeast across the Region and that more rain falls during the latter half

of the wet season. Variability in rainfall is greatest in the southwestern section of northeast Thailand and the analysis revealed four drought-prone areas which straddle several provinces (Changwat) in the west and central parts of the region. This potential shortage in rainfall has repercussions for agriculture in these areas.

The results underlined the utility of detailed analysis of medium-term daily rainfall data as a tool in developing the water resource database for the Northeast.

INTEGRATED MAPPING

Research into applications of satellite remote sensing data to thematic mapping of earth resources has developed rapidly in the past twenty years. More recently, thematic mapping has benefited from the analytical capabilities offered by GIS. One of the major challenges facing practitioners of these two technologies is to produce planimetrically-accurate thematic maps by integrating satellite image data with data from other sources.

In a case study, the Project developed a methodology for integrating a classified subscene of a December 1986, SPOT satellite image of part of Namphong Basin with other spatial information (polygonal and linear) contained in PAMAP GIS files. The aim was to verify the accuracy of a resultant land ecosystem map assembled from information derived from diverse sources and to determine a practical scale of perception for such a map.

The key elements of the study were geometric correction and supervised classification of the SPOT image subscene and fitting of PAMAP map files to the classified image by scaling or shifting map elements. The resultant land ecosystem map was generated on the Meridian image processing system and is being used at a reconnaissance scale (1:500,000) to further characterize terrain and land use in the Northeast. The exercise underlined the importance of image geocoding and the planimetric accuracy of data digitized from maps or hardcopy images.

LANDCOVER CHANGE DETECTION

The multitemporal nature of satellite imagery had made it a preferred source of information for the detections and mapping of all types of change in landscapes.

The speed with which processes such as deforestation and land use change are taking place in Northeast Thailand make it an ideal location for the development of a change detection methodology.

A land cover change detection technique was designed by which two images of the same geographical area, acquired at different times, could be digitally combined to produce a single, residual image of change. Two geocoded Thematic Mapper (TM) subscene of Yasothon Province, acquired during the wet and the dry seasons, were selected as test images. These were coregistered to a 25 metre UTM grid and a supervised classification was performed on each, yielding ranges of digital numbers from 1 to 14 for the dry season image and 1 to 11 for the wet season image. The images were digitally combined by applying a formula which produces a unique digital number for each possible combination of classes.

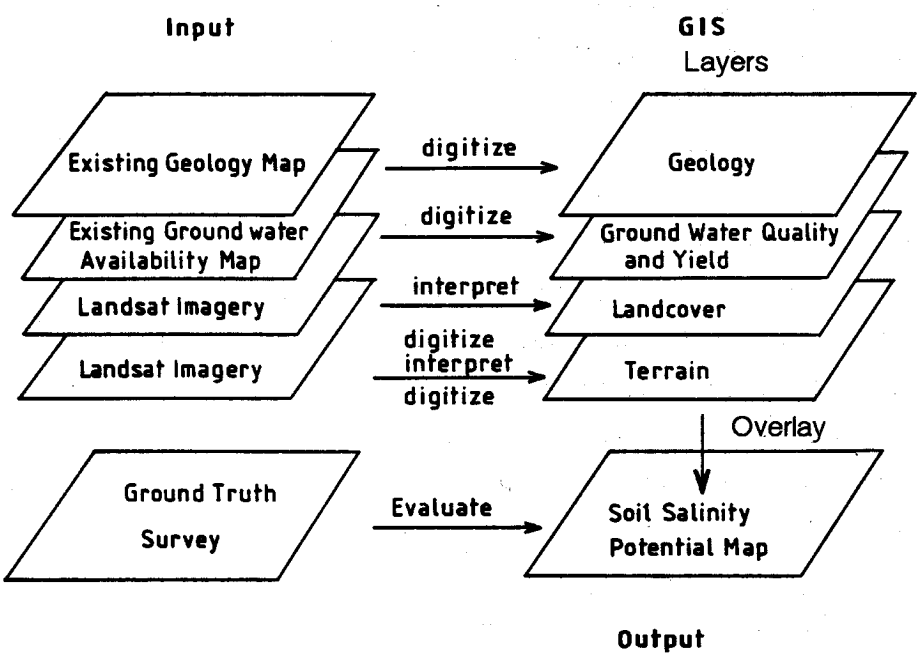
The dominant character of growing rice and stagnant water on the September landscape and the widespread reflectance of bare ground in April are two land cover changes which were highlighted by generation of the residual image.

The changes detected by this methodology are meaningful, in that they compare already-classified images which are based on ground truth information as well as radiometric data. Refinements of the technique will focus upon improving discrimination between landcovers with similar reflectance values.

MODELLING CAPABILITIES

Given an adequate database on land and water resources, a geographic information system (GIS) can enable the modelling or prediction of certain conditions at specified geographical locations through the superposition of spatial data layers. These conditions are functions of particular combinations of parameters, each of which is usually contained in the GIS as one data layer.

The Project has compiled data on four parameters to enable the spatial modelling of potential soil salinity, as shown below.



Schematic of GIS model for mapping soil salinity potential

The particular combination of these four parameters which could produce areas of salt-affected soils is as follows :

- **geology** : are a must be underlain by the Mahasarakham Formation (salt-bearing);
- **groundwater** : there must be a high yield of groundwater with high chloride content;
- **land cover** : vegetation in the area must be sparse ;
- **terrain** : the area is restricted to the "lower terrace" geomorphic unit.

The map of soil salinity potential generated by the overlay process was divided into four classes, in which one class corresponded to zones where the conditions for salt potential were not met (non-saline) and three others corresponded to varying degrees (low, moderate, high) of potential. Field checks and comparisons with existing soils maps showed the results to be highly reliable in identifying areas susceptible to soil salinity.

FUTURE PROSPECTS

The products of the Remote Sensing, Soil and Water Management in Northeast Thailand project which have been described above and the developing expertise of Khon Kaen University staff at the Center are receiving wide recognition in Thailand. A sustained effort since mid-1988 and the cooperation of many individuals and agencies both in Thailand and in Canada have enabled the Center to establish a firm beginning and make considerable progress toward what will hopefully become a long-term programme.

The future tasks of the Remote Sensing and Geographic Information Center are readily defined :

- completion of the encoding of available land and water resource data;
- updating, on a regular basis, those data acquired from satellite imagery;
- updating information acquired from other sources as they become available;
- refining the database by enlarging the scales of input data wherever possible;
- generating analytical output in whatever form requested by users such as local government, agricultural extension officers, university, departments, etc.;
- conducting research into the applications of the system.

Clearly, accomplishing the above will require the establishment of an institution capable of maintaining the level of effort needed to meet the goals along with the concomitant level of funding. In this regard, it has been announced that the Center will be included in Thailand's Seventh National Social and Economic Development Plan.

CONCLUSION

Many of the problems are simultaneously affected by a number of economic activities and natural processes. In terms of sustainable development of natural resources, studies of individual causes and effects are inadequate for policymakers who confront the increasingly complex ecosystems. GIS can look at entire ecosystem as all potential. GIS is a powerful tool for handling spatial data and data are maintained in a digital form. The major part of GIS's capabilities involves the analysis of complex

spatial and non-spatial data set in an integrated manner. Directly added to this is up-to-date temporal and spatial information acquired by remote sensing. The system capabilities in the integration of remotely sensed data enhance up-to-date information into GIS database that leads to more reliable results.

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