ICRISAT

CORNELL UNIVERSITY

GIS Application in Cropping System Analysis – Case Studies in Asia

Cornell University

International Crops Research Institute for the Semi-Arid Tropics

Citation: Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T. (eds.) 2000. GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 98 pp. ISBN 92-9066-423-1. Order code: CPE 127.

Abstract

"GIS Application in Cropping System Analysis - Case Studies in Asia" is a product of the hands-on training program for scientists from Asian national agricultural research systems (NARS) on the use of geographic information system (GIS) in analysis of cropping systems. The main objective of this training program was to pave a progressive path towards greater understanding and use of GIS for meaningful interpretation of various datasets. This publication contains an overview and methodologies of GIS software. Participants from Bangladesh, India, Nepal, and Sri Lanka analyzed datasets on rice-wheat and legumes using various GIS tools. The individual case studies showed changed scenario in crop productivity, diseases, and pests. A few case studies dealt with thematic mapping for constraints analysis.

Acknowledgments

The authors and editors are particularly indebted to the ICRISAT GIS faculty who supervised and developed all the maps and most of the graphics of this publication. These are M Irshad Ahmed and M Moinuddin of the GIS Laboratory, under the supervision of F T Bantilan Jr; K S Prasad and M Ashok Reddy of Agroclimatology, under the supervision of S M Virmani. The coordination process of this publication by C L L Gowda is gratefully acknowledged. Although many contributed to word processing of original manuscripts and subsequent corrections, the coordinating role played by J Nalini and I Radha is particularly appreciated. All contributors to this volume are appreciative of the competent technical editing of V K Sheila to enhance the final output. The coordination of the production process by T R Kapoor is gratefully acknowledged.

The research activities were supported by the Asian Development Bank and donors supporting ICRISAT's unrestricted core activities.

GIS Application in Cropping System Analysis - Case Studies in Asia

Proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region

18-29 August 1997, ICRISAT, Patancheru, India

Edited by

S Pande, A K Maji, C Johansen, and F T Bantilan Jr

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics

Patancheru 502 324, Andhra Pradesh, India

2000

Workshop Sponsors

Cornell University Soil Management CRSP

Rice-Wheat Consortium for the Indo-Gangetic Plain (RWC)

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

Workshop Organizing Committee

S Pande, Chairperson

Members

C Johansen	S M Virmani
N P Saxena	F T Bantilan Jr
I P Abrol	C L L Gowda
P K Joshi	B Diwakar
A Ramakrishna	

Contents

Part II: Case Studies

Preface

Geographic information system (GIS) has proved to be an important analytical tool in various fields of agricultural research and natural resource management. In view of recent progress in the use of this tool, it was thought oppurtune to provide a training program for scientists from Asian national agricultural research systems (NARS) on the "Use of GIS in analysis of cropping systems". This training course was designed to follow up a workshop on Harmonization of databases for GIS analysis of cropping systems in the Asia region held during 18-29 August 1997 at ICRISAT, Patancheru, India. The proceedings of this workshop was published in 1999 as "GIS analysis of cropping systems".

This publication "GIS Application in Cropping System Analysis - Case Studies in Asia" deals with GIS software overview and methodologies (Part I) and is supplemented with case studies in Asia (Part II). Participants from Bangladesh, India, Nepal, and Sri Lanka had hands-on training in different GIS software and the relevant features of the individual case studies are presented. Datasets on rice-wheat and legumes were assembled in the GIS core and analyzed using various GIS tools. Analysis using 'overlay', 'reclassification', and statistical analysis were major applications. Case studies showed temporal and spatial changes in crop productivity and pests. A few case studies attempted thematic mapping for constraints analysis.

Some advanced features of GIS have already been published in "GIS analysis of cropping systems". Some of the notable papers are on interfacing GIS and crop simulation modeling and application of statistics. GIS is fast progressing and many advanced features are now coming to light. This training program is a humble beginning and paves a progressive path towards use of GIS. It is anticipated that this program will ensure that the participants understand and use GIS for further objective specific interpretation of various datasets and improving knowledge in their respective field of research.

The Editors

PART I: GIS - Overview

Overview of GIS

S M Virmani, K S Prasad, and S Pande[1]

Introduction

Geographic information system (GIS) is a facility for diverse professionals such as geographers, foresters, environmentalists, planners, decision makers, and researchers. These professionals depend on the information related to an area or location for analyzing and implementing a developmental plan. Conventional data storage and management has failed to satisfy their needs. With the advent of computer technology, database management in terms of 'where' and 'what' has been classed through GIS.

What is GIS?

GIS has been variously defined as:

- A computer-assisted system for the capture, storage, retrieval, analysis, and display of spatial data within a particular organization (Clarke 1986).
- A set of tools for collecting, storing, retrieving, transforming, and displaying data from the real world for a particular set of purpose (Burrough 1986).
- An organized collection of hardware, software, geographic data, and personnel designed to efficiently capture, store, update, analyze, and display all forms of geographical referenced information (ESRI1994).
- A computer system capable of holding and using data describing a place on the earth's surface.

---

1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1403.

Virmani, S.M., Prasad, K.S., and Pande, S. 2000. Overview of GIS. Pages 3-6 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

The last definition is simple and needs little elaboration which highlights the components of a GIS.

Computer hardware

A GIS can be workstation (high end) or PC based and depends on the user's need. The minimum hardware requirement comprises a standard central processing unit (CPU) with adequate memory, color monitor, keyboard, mouse, printer or plotter, and a digitizer.

Software

Software perform the various functions in GIS. There are many software prevalent in the market. The software is chosen based on the need and investment required.

Spatial data and their attributes

GIS analyzes spatial data and their attributes. Spatial data represent the earth surface and the attributes are the characteristics of the spatial data.

Trained personnel

GIS does not function by itself and it must be emphasized that a group of well-trained persons skilled in the technology are crucial components and are termed as "humanware".

Uses of GIS

A GIS is not simply a computer for making maps, although it can create maps on different scales and in different projections. It is an analytical tool. The major advantage of a GIS is that it allows one to identify the spatial relationship between map features and the non-spatial data. Therefore, GIS can be used to answer the questions related to locations, conditions, and trends using temporal data and pattern. GIS can also provide answers to some assumptions and presumptions on "what will happen ... ?" and "what if...?" situations which are analyzed through 'modeling'. GIS can be used as a decision support tool in solving increasingly complex urban and environmental problems, forestry and wildlife tracking, wasteland developments, agriculture and groundwater resource exploration, and water resource management. Urban application includes utilities management, site suitability analysis, and demographic studies.

Types of GIS

GIS stores data in two types of data models. These are:

1. Raster Data Model
2. Vector Data Model

Based on the use of data model, GIS is called raster-based GIS or vector-based GIS. However, present-day GIS facilitates analysis on both data models.

GIS Software

Based on these two data models there are different GIS software packages available in the market. Among these, IDRISI, SPANS, ILWIS, MapInfo, and PC Arc/Info are most popular. IDRISI, ILWIS, and SPANS are raster-based and MapInfo, ISROGIS, and PC Arc/Info are vector-based GIS software.

Data Analysis Tool

- GIS is a powerful tool for map analysis.
- Spatial data stored in digital format in a GIS allows for rapid access for traditional as well as innovative purposes.
- Traditional impediments to the accurate and rapid measurement of area and to map overlay no longer exists.
- GIS has the ability to provide multiple and efficient cross-referencing and searching.

Data Display Tools

- Electronic display offers significant advantage over the paper map.
- Ability to browse across an area without interruption by mapsheet boundaries.
- Ability to zoom and change scale freely.
- Display in "3 dimensions" with "real time" rotation of view angle.

Advanced GIS

With passage of time, advancement in information technology and experiences in the domains are providing new dimensions in GIS application.

- Many new techniques in spatial modeling and decision-support systems are becoming available for complex and multi-dimensional analysis.
- Advancement in technology of GIS facilitates cross-cutting research activities.
- Modeling, programming, and interfacing models with GIS provide vital research tools.
- GIS triggers unification of technologists in natural resource management, cropping systems management, and environmental studies.
- GIS and global positioning system (GPS) integration have paved a path for more accurate mapping.
- Integration of GIS and remote sensing favor better resources and environmental management.

References

Burrough, P.A. 1986. Principles of geographic information system for land resource assessment. Oxford, UK: Clarendon Press.

Clarke, K.C. 1986. Recent trends in geographical information system. Geo-processing 3:1-15.

ESRI (Environmental Systems Research Institute). 1994. Understanding GIS - the Arc/Iinfo method. Redlands, California, USA: ESRI.

Fundamental Aspects of GIS

F T Bantilan Jr[1], A K Maji[2], and M I Ahmed[1]

Introduction

Recently there has been an increased need for timely response to promote effective administration, planning, decision making, and development processes. Coupled with the complexity and volume of today's data requirements, traditional paper-based data handling, spatial analysis, and display methods have proved inadequate.

The introduction of computers has offered a solution to these deficiencies. The application of "Database" and "Information System" technology has led to development of computerized geographic information system (GIS). The concept of GIS includes the collection, storage, analysis, and dissemination of integrated land-related information. GIS is defined as computerized database management system for capturing, storing, validating, maintaining, analyzing, displaying, and managing spatially referenced data for providing management information or for the development of better understanding of the environment.

1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

2. National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur 440 010, Maharashtra, India.

ICRISAT Conference Paper no. CP 1404.

Bantilan Jr., F.T., Maji, A.K., and Ahmed, M.I. 2000. Fundamental aspects of GIS. Pages 7-12 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Views of GIS

GIS can be viewed with different perspectives depending on the objectives of the users. However, in totality, GIS is viewed as given below (Maguire et al. 1991):

Views	Map perspective	Database management system	Spatial analysis tools
Features	Cartographic aspects	Well-designed and implemented database	Analysis and modeling
Functions	Map processing and display system	Used for analytical operation	Information system

Importance of GIS

GIS has become one of the essential tools in spatial analysis and provides excellent display. GIS is popularly used for various reasons as outlined by Rhind (1977):

- To make existing maps more quickly and more cheap.
- To make maps for specific user needs.
- To make map production possible in situations where skilled staff are unavailable.
- To allow experimentation with different graphical representations of the same data.
- To facilitate map making and updating when the data are already in digital form.
- To facilitate analyses of data that demand interaction between statistical analysis and mapping.
- To create maps that are difficult to make by hand, e.g., 3-dimensional maps or stereoscopic maps.
- To create maps in which selection and generalization procedures are explicitly defined and consistently executed.

Data in GIS

GIS stores two types of data: the location of geographic features and the attributes of those features. There are two main spatial data models in representing both types of geographic data: the vector model and the raster model. The vector data model represents geographic features the way paper maps do. An x,y (Cartesian) coordinate system references real-world locations. Points are recorded as a single coordinate. Lines are recorded as a series of ordered x,y coordinates. Areas are recorded as a series of x,y coordinates defining line segments that enclose an area. Each feature is assigned a unique id, number, or tag. The arc-node data structure in a vector model stores and references data so that nodes construct arcs and arcs construct polygons. Topology in a vector model explicitly defines spatial relationships, supporting the topological concepts of connectivity, area definition, and contiguity. In the vector data model, surfaces are represented as a series of isolines.

The raster data model is more like a photograph than a map. It has a regular grid or dots called cells or pixels, filled with values. A photo depicts a continuous surface. In the raster data model, the earth is treated as continuous surface. The numeric value of each cell or pixel may represent either a feature identifier, a qualitative attribute code, or a quantitative attribute value. The raster data model represents a discrete point as a value in a single cell, a linear feature as a series of connected cells that depict length, and an area feature as a group of connected cells depicting shape.

In both models, the attributes of geographic features are organized as records in attribute tables. Linking attributes to geographic features, the georelational model is by unique identifiers in both the geographic features list and in the attribute table.

It is possible to convert data from raster to vector and vice versa, and thereby take advantage of the strengths of both data models. Rasterization is the process of converting data from raster to rector. Vectorization is the reverse process of converting data from vector to raster.

GIS Software

The capability of a GIS package depends on the module (sub-program) it contains. These modules execute different functions in GIS. A modest GIS should support the following (Eastman 1990):

- Spatial and attribute database creation.
- Map digitization.
- Analysis/transformation/manipulation.

- Statistical analysis.
- Decision support system development.
- Data display and cartographic operations.

Steps for Creating a GIS Database

To create a vector polygon database in GIS core, three steps are followed:

1. Digitization of spatial data (map).
2. Creation of attribute database.
3. Linking steps 1 and 2.

The flow diagram (Fig. 1) shows the creation of a topologically correct vector database.

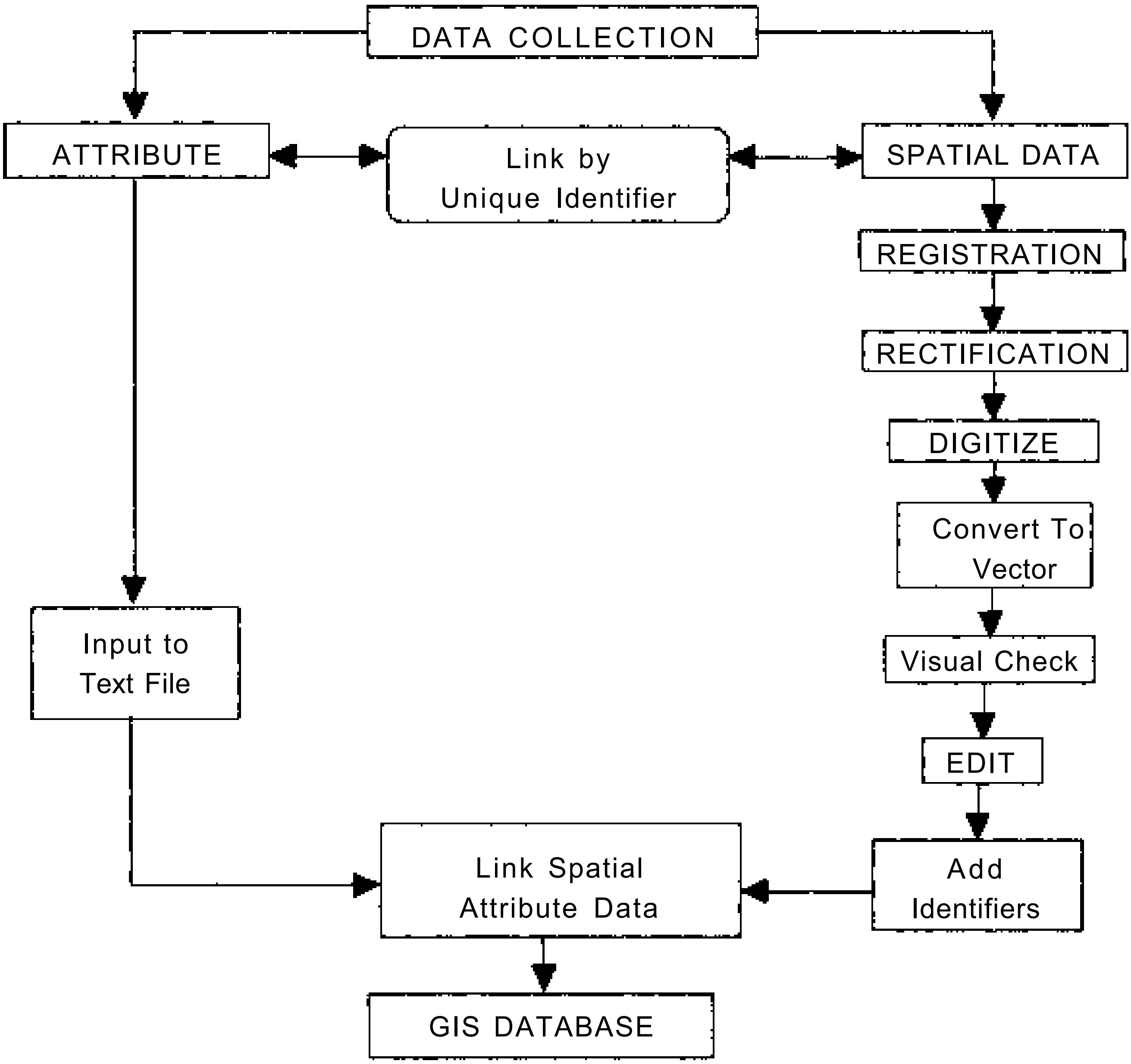


Figure 1. Steps in creating GIS database.

Common Operations in GIS

The most common operations carried out by GIS are database query, map algebra, and distance- and context-related analysis. These are described in 'spatial and attribute data and their processing in GIS'.

Spatial overlay. Two themes are combined to form a new spatial feature (both geometric and attribute features are combined) known as spatial overlay. Three types of overlay can be performed: polygon-polygon, line-polygon, and point-polygon.

Buffer zone creation. Distance operator in GIS is used for buffer zone creation. It shows the proximity or nearness from any point, line, or polygon.

Map generalization. Map generalization is a function to dissolve or merge adjacent polygon features.

Feature extraction. Feature extraction is subset selection of a map, e.g., district soil map from state soil map.

Other Features of GIS

Digital terrain modeling

Two-dimensional maps (chloropleth maps) cannot perceive the landform features which are having varying surface forms. Any digital representation of the continuous variation of relief over space is known as Digital Elevation Model (DEM) (Burrough 1986). The DEM is generated by the input data, data models, and related algorithms. Data from satellite images and contour lines denoting elevation are used to generate Digital Terrain Model (DTM).

In DEM the terrain features are represented through x, y, and z coordinates to depict a 3-dimensional view. The DEM is useful in slope analysis of a terrain, and combining thematic information with relief, laying railway lines, roads, etc.

Decision-support system

A decision-support system (DSS) is a computerized analytical tool to solve complex problems. This helps the decision makers to define their problems in GIS environment and get a solution using mathematical models and hybrid formulations. Spatial Decision Support System (SDSS) is explicitly designed to support a decision research process for complex spatial problems. SDSS provides a framework for integrating Database Management System (DBMS) with analytical models, graphic display, and tabular reporting capabilities and expert knowledge of decision makers (Densham 1991).

Conclusion

It is very difficult to provide details of GIS through a small write-up like this. Learners practicing the use of GIS will learn much more while interacting with GIS software. It is advisable that apart from the manuals of the software provided by the software manufacturers, the books authored by Maguire et al. (1991), Burrough (1986), and Aronoff (1989) may be referred.

References

Aronoff, S. 1989. Geographic information systems: A management perspective. Ottawa, USA: WDL Publication.

Burrough, P.A. 1986. Principles of geographical information system for land resource assessment. Oxford, UK: Clarendon Press.

Densham, P.J. 1991. Spatial decision support system in geographical information system. Pages 403-412 *in* Geographical information system: principles and applications (Maguire, D.J., Goodchild, M.F, and Rhind, D.W., eds.). New York, USA: Longman Scientific and Technical.

Eastman, J.R. 1990. IDRISI: A grid based geographic analysis system. Massachusetts, USA: Graduate School of Geography, Clark University.

Maguire, D.J., Goodchild, M.F., and Rhind, D.W. 1991. Geographical information system: principles and applications. New York, USA: Longman Scientific and Technical.

Rhind, D. 1977. Computer aided cartography. Transactions of the Institute of British Geographers 2:7-96.

Introduction to PC Arc/Info

K S Prasad and S Pande[1]

Introduction

Geographic information system (GIS) evolved as a means of assembling and analyzing spatial data. Many GIS software systems have been developed. PC Arc/Info software which is being used at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is described in brief (condensed from PC Arc/Info user's manual for training purposes). This software is made by the Environmental Systems Research Institute (ESRI), California, USA.

PC Arc/Info is a vector-based GIS software. In PC Arc/Info various maps are stored in layers called coverages. PC ArcEdit is one of the specialized PC Arc/Info modules designed to provide advanced capabilities for interactive, sophisticated graphic editing for coverage creation and update, and for final cartographic production. PC Arc/Info uses a command interface. An operation is performed by typing a command along with command arguments.

PC Arc/Info Modules

PC Arc/Info is available with its user guides for all its modules. It is necessary that a beginner must learn Disk operating system (DOS) and Windows operating system. PC Arc/Info includes Simple Macro Language (SML) to build macros. The different modules that are available in PC Arc/Info are: (1) Starter Kit, (2) ArcEdit, (3) ArcPlot, (4) Overlay, (5) Network, and (6) Data Conversion.

---

1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1405.

Prasad, K.S., and Pande, S. 2000. Introduction to PC Arc/Info. Pages 13-15 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C, and Bantilan Jr., FT., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Starter Kit

PC Arc/Info Starter Kit is the basic program module dealing with digitizing, attribute table creation, host communication, and plot system function.

PC ArcEdit

PC ArcEdit is used for more sophisticated interactive digitization and editing. It has all the capabilities of Arc Digitizing System and also allows to edit the attribute associated with graphic features while these features are displayed on screen. These editing capabilities include moving, adding, and deleting individual vertices in arcs and reshaping and splitting features. Annotation (text) can be positioned interactively to follow the orientation of features. Features for editing can be selected either with the cursor or by querying their attributes, thus allowing considerable flexibility in making precise changes.

PC ArcPlot

PC ArcPlot allows interactive map creation and display, graphic query, and plotting of maps.

PC Overlay

PC Overlay is the most important module for analysis such as all types of overlays and buffer generation. PC overlay features six overlay programs: CLIP, ERASECOU, IDENTITY, INTERSECT, UNION, and UPDATE.

PC Network

PC Network module is used in optimal routing, allocation, districting, and address matching/geocoding. PC Network analyzes networks, such as roads, rivers, and electric power grids, stored as Arc/Info coverages.

PC Data Conversion

PC Data Conversion module provides special functions permitting data exchange between PC Arc/Info coverages and a variety of other data exchange formats.

Spatial Terms

The various spatial terms applied in PC Arc/Info and used while map preparation are described below.

Map. A map is a combination of point, line, and closed polygon (area) features.

Arcs. Arcs represent line features, the borders of polygons, or both. One line feature may be made up of many arcs. Arcs are linked to their endpoints (nodes) and to the areas (polygons) on each side.

Nodes. Nodes represent endpoints of the arc and intersections of line features.

Polygon. A polygon is defined by the series of arcs which compose its border and by a label point positioned inside its border. The label point ID is used to assign the polygon a user-ID.

Label points. Label points represent point features. They are also used to assign user-IDs to polygons. The user-IDs are used to associate tabular attribute data with polygons.

Point features. Point features are locations defined by single x,y coordinate pairs. Each point feature is represented by a label point.

Tics. Tics are geographic registration or geographic control points for a coverage. They represent known locations on the earth's surface. They allow all coverage features to be registered to a common coordinate system. Before beginning digitization the tic registration points should be located and a unique number should be assigned.

Coverage extent or boundary (BND). Coverage extent represents map extent. It is a rectangle that defines the coordinate limits (extreme minimum and maximum coordinates) of coverage arcs and label points.

GIS Functional Elements

There are five essential elements that a GIS must contain: data acquisition, preprocessing data management, manipulation, analysis, and product generation. For any given application of a GIS it is important to learn these modules perfectly before planning to take up any GIS project.

ArcView GIS

M I Ahmed[4]

Introduction

ArcView is a powerful, easy-to-use tool that brings geographic information to the desktop. It gives the power to visualize, explore, query, and analyze data spatially. ArcView is made by the Environmental Systems Research Institute (ESRI), California, USA. Arc/Info (which is also made by ESRI) data can be used with ArcView to access vector coverages, map libraries, grids, images, and event data. This brief description of ArcView is based on ESRI (1996).

Working Spatially

ArcView can be used to work spatially. A key feature of ArcView is that it is easy to load tabular data, such as dBASE files and data from database servers, so that one can display, query, summarize, and organize this data geographically. While working with ArcView a completely new way of visualizing for seeing patterns, understanding geographic relationships, and achieving new results will be possible.

Arc View's User Interface

ArcView provides a simple user interface with views, tables, layouts, charts, and scripts stored in one file called a 'project', each component having a specific use and functionality. Not more than one project can be opened at a time in

1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1406.

Ahmed, M.I. 2000. ArcView GIS. Pages 16-19 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

ArcView. Projects enable one to keep together all the above components that are needed for a specific task or application.

The Project Window

A new project or an existing one lists all the components of the project and enables their management. A component can be opened by double-clicking it. A project component opens its own window. Any number of windows can be opened in ArcView, but at any one time there is only one 'active window' (the window currently being worked with). When an action in ArcView is performed, it applies to the active window. ArcView's user interface changes according to what is in the active window. For example, when the project window is active, the buttons, tools, and menus for working with projects can be seen.

Menu bar

The menu bar along the top of the ArcView window contains ArcView's pulldown menus. To choose a menu, the mouse or a keyboard shortcut can be used. Some keyboard shortcuts are listed in the menus. Others depend on the graphical user interface (GUI) system. The contents of the menu bar change according to what is in the active window.

Button bar

The button bar located beneath the menu bar in the ArcView window contains buttons which give quick access to various controls. The contents of the button bar change according to what is in the active window.

Toolbar

The toolbar located beneath the button bar in the ArcView window contains various tools to work with. However, while working on the project window or on a script, there is no toolbar. The tool remains selected until another is chosen.

The Table of Contents

Each view has a "Table of Contents" that lists the themes in the view and shows what symbols and colors they are drawn with.

Views

With ArcView, geographic data can be explored in interactive maps called views. Every view features ArcView's unique geographic "Table of Contents", making it easy to understand and control what is displayed.

Tables

Working with tabular data in ArcView's tables shows the records of a view and its attributes. The view shows the features of the selected records. ArcView's tables also have a full range of features for obtaining summary statistics, sorting, and querying.

Charts

ArcView's charts offer a powerful business graphics and data visualization capability that is fully integrated into ArcView's geographic environment. The user can simply click on features on a view to add them to the chart. ArcView allows the user to work simultaneously with geographic, tabular, and chart representations of data.

Layouts

ArcView's layouts allow creation of high quality, full color maps by first arranging the various graphic elements on-screen in the way desired. High quality results on a wide range of printers and plotters can be produced in ArcView. Layouts are smart because they have a live link to the data they represent. When a layout is printed, any changes to the data are automatically included, so that everything on the map can be updated.

Scripts

ArcView scripts are macros written in Avenue (ArcView's programming language and development environment). With Avenue it is possible to customize almost every aspect of ArcView, from adding a new button to running a written script, to creating an entire custom application.

Analysis of Cropping Systems

At the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), ArcView has been used as an exploratory tool in the analysis of cropping systems. It was primarily used to map out crop distribution (random) at the district level for the Indo-Gangetic Plain area. The dot density technique was used to depict distribution of crops across the Indo-Gangetic Plain districts. Other maps, such as the disease distribution and nutrient deficiency distribution, were also made. Resource inventory maps such as soil type, length of growing period, and precipitation were also used to analyze the cropping systems with ArcView analysis capabilities. Some examples are available in the case studies described later in this proceedings.

Reference

ESRI (Environmental Systems Research Institute). 1996. ArcView GIS user guide, Using ArcView GIS. Redlands, California, USA: ESRI.

Use of Raster GIS -- IDRISI

FT Bantilan Jr and M Srinivas[1]

Introduction

Geographic information system (GIS) software uses one of two main data models: vector and raster. The raster model is more convenient in handling and processing the data as the basic unit in this model is a cell or pixel. IDRISI for windows makes use of elements from both data models (Eastman 1990). Though it is primarily a raster-based software, IDRISI for windows uses vector data structures as a major form of display and exchange as well as essential aspects of vector database management.

Overview

The system of IDRISI for windows consists of several programs, a main interface program (with a menu and toolbar system), and a collection of over 150 program modules that provide facilities for the input, display, and analysis of both geographic and remotely sensed data. The spatial data in IDRISI are organized in map layers, each describing one single theme, such as roads, elevation, and soil type. Maps take on two basic forms: raster image layers and vector layers. Raster layers are excellent in representing spatially continuous data such as elevation, rainfall, etc. Vector layers describe distinct features with sharp boundaries on the earth's surface such as roads, land parcels, and political districts. In addition, IDRISI for windows has capabilities for the processing of remotely sensed image data, this performing as Image Analysis System (IAS) and GIS.

---

1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1407.

Bantilan Jr., F.T., and Srinivas, M. 2000. Use of Raster GIS - IDRISI. Pages 20-22 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

IDRISI for Windows Environment

The working environment of IDRISI is similar to any other kind of software where the user enters into different user-defined menus to execute functions.

Working with IDRISI

There are several functions existing with IDRISI. Some of the important functions of IDRISI in the form of menus are as follows:

- ENVIRON — Working directory is to be set. The files to work with and the output files are stored in this directory.
- FILE — File menu has a series of functions for file information and management.
- DIGITIZE — The digitize button provides for on-screen digitization with raster background and creation of vector files.
- DISPLAY — IDRISI has variety of options for displaying the data. This menu can be used to display raster, vector, and map composition data.
- REFORMAT — Reformat has functions to change the nature of geographic data files.
- ANALYSIS — Over 100 modules are devoted to the analysis of spatial data.
- DATA ENTRY — The data entry function integrates spatial and attribute data to get the required output with suitable legend.

Additional features of IDRISI

- Creation of digital elevation models.
- Image analysis including calculation of NDVI (Normalized Difference Vegetative Index).
- Statistical analysis of geographic data.
- Map analysis.

Database Query

The database query exercise explores the most fundamental operation in GIS; "what is at this location?" and "where are all locations that have this attribute?" The example deals with an area where local farmers practice what is known as "recessional agriculture" by planting sorghum (*Sorghum bicolor*) in the flooded areas after the waters recede. The conditions that make an area suitable for recessional sorghum agriculture in this location are: (1) the area should be flooded (elevations less than 9 m); and (2) it should be on clay soils. Each condition must be represented by an image, i.e., FLOOD and CLAYSOIL. BESTSORG, the name for suitable areas, is the result of combining these two images such that the areas left are those that satisfy both conditions. To do this, Boolean images are produced that contain only values of one and zero, where a value of one indicates that a pixel meets the condition and a value of zero indicates that a pixel does not. To produce the Boolean image FLOOD, the elevation model of the whole area called DELEV is generated using RECLASS module. To create Boolean image CLAYSOIL, the soil map named DSOIL, where the set of clay soils have a value of one and the rest have a value of zero, is chosen. ASSIGN module is used to perform to carry this out. Next, OVERLAY module is used to perform a multiplication operation between two Boolean images, FLOOD and CLAYSOIL, resulting in a logical end. The result is BESTSORG, where each pixel satisfies both conditions. The area in hectares is calculated using the AREA module.

Data Reformatting, Masking, and Image Group Files

The data needed to carry out a GIS task in IDRISI for windows usually come from various sources and in different formats. It is then necessary to reformat the various datasets to a common format before work can proceed. Moreover, the area of interest may only be a subset of the available image; thus the technique of masking is needed. Lastly, the use of image group files is illustrated in the interactive querying of attributes in DISPLAY. This exercise allows exploration of the use of the various modules in IDRISI in manipulating available data.

Reference

Eastman, J.R. 1990. IDRISI: A grid based geographic analysis system. Massachusetts, USA: Graduate School of Geography, Clark University.

Maps - Types, Layout, and Designing

F T Bantilan Jr and K S Prasad[1]

Introduction

Maps represent geographic features as points, lines, and areas. Points represent objects such as wells, telephone poles, buildings. Lines represent features such as rivers and roads. Areas represent the shape and location of geographic features considered homogeneous, such as states, soil types, or land use zones.

Maps present descriptive information about geographic features using symbols and labels. The map readers interpret the relationships between geographic features and locations and derive information from the position of mapped objects.

Maps use plane coordinate system, a framework for defining real-world location of geographic features on the map. The process of "flattening" the earth's surface to represent it on paper is called projection. A discussion on projection is presented later in this proceedings.

Types of Maps

Topographic map

A topographic map is a reference tool, showing the outlines of selected natural and man-made features of the earth. It often acts as a frame to other information.

---

1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1408.

Bantilan Jr., F.T., and Prasad, K.S. 2000. Maps - types, layout, and designing. Pages 23-26 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics

Thematic map

A thematic map is a tool to communicate the geographic concepts such as the distribution of population densities, climate, soils, and landmarks. Thematic maps are of two types: chloropleth and isopleth.

Chloropleth map. A chloropleth map uses reporting zones such as census tracts to show data; e.g., average incomes and soil geology.

Isopleth map. An isopleth map shows an imaginary surface by means of lines called isolines that join points of equal value (e.g., contours on a topographic map).

Characteristics of Maps

- Often stylish and generalized and require careful interpretation.
- Usually out of date.
- Show only static situation.
- Often highly elegant/artistic.
- Useful to answer certain types of questions.

GIS Features

A geographic information system (GIS) must provide the same capabilities as the paper maps provide, and more. The power of GIS lies not only in the ability to store geographic data, but also, the ability to analyze it more efficiently and more conveniently than is possible with paper maps.

PC ArcPlot provides full cartographic output capabilities from simple screen displays to high quality cartographic plots for reports and presentations. It facilitates interactive map creation and previewing maps on the monitor, sending maps to a printer or plotter, and using maps as graphic windows of the database for interactive query and updating of attribute information. It has also facilities for creating cartographic symbols and a macro language to create customized user applications.

Designing a Map

Map design means resolving a number of technical and graphic issues regarding map such as scale of the map, colors, and symbols to be used. Features for scaling and positioning maps, specifying symbols, selecting, drawing and labeling coverage features, adding titles, legends, neatlines, scale bars, north arrows, etc. are available in PC Arc/Info.

Map Layout

Considerations for the creation of a successful map include the layout of the map components in relation to each other, the characteristics of the symbols and labels used, and the size and scale of the entire map. It is advisable to design an intended layout on paper before preparing any final map in ArcPlot.

In addition to graphic considerations, there are technical factors which determine the amount, and detail of information that a map can display and still be easily understood. These include scale, resolution, and classification. In most cases, there is a trade-off between the amount of information that can be communicated and the complexity of that information.

Map Scale and Resolution

Map scale is the extent of reduction required to display a portion of the earth's surface on a map. It is expressed as a ratio of distance on the map page to distance on the ground. The appropriate scale at which any map is to be displayed depends on the information to convey. The use of terms 'small scale' and 'large scale' are often confusing. Large scale maps show features in greater detail but cover less area. Thus, important spatial relationships may not be shown. Small scale maps show a larger area but the information is in less detail, which may reduce the usefulness of the map for certain applications.

The resolution of a map determines how accurately both the location and shape of geographic features are represented. Unlike map scale, resolution is determined at the time a map is created on paper or digitized and cannot be changed in the display process.

The scale from which a map is digitized affects the resolution of that map. In a large scale map, the location features are depicted more closely and match the actual real-world coordinates because the extent of reduction from ground to map coordinates is less and spatial relationships between features are more closely preserved. Also, since more detail can be shown, less smoothing of features occurs. Thus, features shape will more accurately reflect the true shape of features represented.

Georeferencing and Map Projections

M I Ahmed[1]

Introduction

Spatial data has been presented on paper for long until recently when the computers took over the task of map making (digital cartography). Geographic information system (GIS) provides with the state-of-the-art technology in spatial analysis and is a very important tool for decision making in natural resources management and planning. There are many advantages of GIS such as customized display of map features, attachment of multiple attributes to the map features, and spatial analysis functions (e.g., buffers and overlay). However, the spatial representation of data in GIS remains tied to the mapping plane, i.e., a two-dimensional surface or paper. The only true representation of the earth, free of distortion, is a globe. The element of compromise is fundamental. A spherical surface cannot be produced on a flat paper; also the corresponding properties of positions and relative position which exist on that surface cannot be produced.

Georeferencing

Georeferencing refers to the manner in which locations in map (flat) are related to earth (curved or spherical) surface locations. This is possible by a process of transformation called map projections.

1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1409.

Ahmed, M.I. 2000. Georeferencing and map projections. Pages 27-32 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Map Projection

Map projection is a mathematical transformation that is used to create a flat map sheet from the spherical surface. It defines the mapping from geographic coordinates on a sphere or the geodetic coordinates on a spheroid to a plane surface. Projection formulae convert data from geographical location on a sphere or a spheroid to a representative location on a flat surface.

Parameters Required for the Projection of a Map

Reference surface (ellipsoid or sphere)

Reference surface is a mathematically (e.g., sphere or spheroid) or physically (geoid) defined surface to approximate the shape of the earth for referencing the horizontal and/or vertical position. Through a long history, the "shape of the earth" was refined from flat-earth models to spherical models of sufficient accuracy to allow global exploration, navigation, and accurate mapping.

Geodetic datum

A datum is a set of parameters defining a coordinate system, and a set of control points whose geometric relationships are known, either through measurement or calculation (Dewhurst 1990). A geodetic datum is defined by a spheroid, which approximates the shape of the earth, and the spheroid's position relative to the center of the earth. It is a reference object that describes the position, orientation, and scale relationships of a reference ellipsoid to the earth. Modern geodetic datum are defined with respect to the center of the earth, while historical geodetic datum are defined with respect to fundamental points on the surface of the earth.

Measurements on the globe. Although degrees of latitude and longitude can be used to locate exact positions on the surface of the globe, they are not uniform units of measure on the surface of the globe. Only along the equator does the distance represented by one degree of latitude approximate the distance represented by one degree of longitude. This is because the equator is the only parallel as large as the meridian. The degrees of latitudes and longitudes are not associated with a standard length because this reference system measures angles from the center of the earth, rather than distances on the earth's surface.

Planar measurements. Because it is difficult to make measurements in spherical coordinates, geographic data is projected into a planar coordinate system called Projection. Once it is projected onto a flat surface, the spherical values change. On a flat surface, locations are identified by x,y coordinates on a grid, with the origin at the center of the grid. Each position has two values, the x-coordinate and the y-coordinate. The advantage of the planar system is that the measures of length, angle, and area are constant across the two dimensions.

Map projections and parameters

Every flat map misrepresents the surface of the earth in some way. However, a map can show one or more but never all of the following: (1) True areas, (2) True shapes (conformality), (3) True directions, and (4) True distances.

Any representation of the earth's curved surface onto a two-dimensional surface involves distortion of at least one of the above parameters. Different projections produce different distortions. The characteristics of each projection make them useful for some applications and not for others. Of the four basic properties, correct representation of area over the whole map is the most easily achieved, since equivalent areas can be produced by an infinite variation of dimensions within the same shape or by employing different shapes.

A satisfactory balance of properties is not difficult to achieve over relatively small areas; it is when the area covered by the projection increases that difficulties arise, and most projections make poor show at their extremes when used to represent the whole globe.

Map projections fall into four general classes (Snyder 1987):

- Cylindrical projections result from projecting a spherical surface onto a cylinder.
  - Projection of a Sphere onto a Cylinder (Tangent Case): When the cylinder is tangent to the sphere, contact is along a great circle (the circle formed on the surface of the earth by a plane passing through the center of the earth).
  - Projection of a Sphere onto a Cylinder (Secant Case): In the Secant Case, the cylinder touches the sphere along two lines, both small circles (a circle formed on the surface of the earth by a plane not passing through the center of the earth).

- Transverse Projection of a Sphere onto a Cylinder (Tangent Case): When the cylinder upon which the sphere is projected is at right angles to the poles, the cylinder and resulting projection are transverse.
- Oblique Projection of a Sphere onto a Cylinder (Tangent Case): When the cylinder is at some other, non-orthogonal angle with respect to the poles, the cylinder and resulting projection is oblique.

- Conic projections result from projecting a spherical surface onto a cone.
  - Projection of a Sphere onto a Cone (Tangent Case): When the cone is tangent to the sphere, contact is along a small circle.
  - Projection of a Sphere onto a Cone (Secant Case): In the Secant Case, the cone touches the sphere along two lines, a great circle and a small circle.

- Azimuthal projections result from projecting a spherical surface onto a plane.
  - Projection of a Sphere onto a Plane (Tangent Case): When the plane is tangent to the sphere, contact is at a single point on the surface of the earth.
  - Projection of a Sphere onto a Plane (Secant Case): In the Secant Case, the plane touches the sphere along a small circle if the plane does not pass through the center of the earth.
- Miscellaneous projections include unprojected ones such as rectangular, latitude and longitude grids, and other examples that do not fall into the cylindrical, conic, or azimuthal categories.

Some Important Map Projections

Conic projections

Albers equal area conic. The Albers equal area conic is a conic projection that distorts scale and distance except along standard parallels. Areas are proportional and directions are true in limited areas. It is used in USA and other large countries with a larger east-west than north-south extent.

Equidistant conic. In the equidistant conic, the direction, area, and shape are distorted away from standard parallels. It is used for portrayals of areas near to, but on one side of, the equator.

Lambert conformal conic. In the Lambert conformal conic, the area and shape are distorted away from standard parallels and the directions are true in limited areas. It is used for maps of North America.

Polyconic. The polyconic projection was used for most of the earlier USGS (United States Geological Survey) topographic quadrangles, neither conformal nor equal area. The central meridian and the equator are straight; other meridians are complex curves. The parallels are non-concentric circles. The scale is true along each parallel and along the central meridian.

Azimuthal projections

Azimuthal equidistant. Azimuthal equidistant projections are sometimes used to show air-route distances. Distances measured from the center are true. Distortion of other properties increases away from the center point.

Lambert azimuthal equal area. The Lambert azimuthal equal area projection is sometimes used to map large ocean areas. The central meridian is a straight line whereas others are curved. A straight line drawn through the center point is on a great circle.

Orthographic. Orthographic projections are used for perspective views of hemispheres. The area and shape are distorted. Distances are true along the equator and other parallels.

Stereographic. Stereographic projections are used for navigation in polar regions. Directions are true from the center point and scale increases away from the center point as does distortion in area and shape.

Miscellaneous projections

Unprojected maps. Unprojected maps include those that are formed by considering longitude and latitude as a simple rectangular coordinate system. Scale, distance, area, and shape are all distorted with the distortion increasing toward the poles.

Space Oblique Mercator. The Space Oblique Mercator is a projection designed to show the curved ground-track of LANDSAT images. There is little distortion along the ground-track but only within the narrow band (about 15°) of the LANDSAT image.

References

Dewhurst, T. 1990. The application of minimum-curvature-derived surfaces in the transformation of positional data from the North American Datum of 1927 to the North American Datum of 1983. NOAA Technical Memorandum NOS NGS-50. Rockville, Maryland, USA: NOAA.

Snyder, J.P. 1987. Map projections: a working manual. USGS Professional Paper 1395. Washington, DC, USA: United States Government Printing Office.

Spatial and Attribute Data in GIS and their Processing

F T Bantilan Jr[1], M I Ahmed[1], and A K Maji[2]

Introduction

A map represents geographic features and related spatial phenomena conveying information about locations with their attributes graphically. Spatial information describes the position of a geographic feature on the earth's surface as well as the spatial relationships between features. Attribute (non-spatial) data describe characteristics of the geographic features represented such as the feature type, its name, abundance, and quantitative information [e.g., area (of a soil unit) and length (of a river)].

Geographic information system (GIS) uses raster and vector representations to model locations and provide linkages between spatial and non-spatial/attribute data. These linkages make GIS "intelligent" as the user can store and examine the information about 'where' and 'what' scenario. For example, a soil map with mapping units can have not only the soil type as the theme for map display but also other physical and chemical properties tied to it. The linkage between the feature and its attribute data is established by giving each feature one unique means of identification, which is usually a name or a number called its ID. Non-spatial attributes of the feature are then stored, usually in one or more separate files towards this ID number. In other words, locational information is linked with additional information from a database.

1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

2. National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur 440 010, Maharashtra, India.

ICRISAT Conference Paper no. CP 1410.

Bantilan Jr., F.T., Ahmed, M.I., and MajI, A.K. 2000. Spatial and attribute data in GIS and their processing. *Pages* 33-36 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Organization of Attribute Data

The attribute data is as important as the spatial data and needs to be organized and stored in different formats and files as required by the GIS software in use. The most generic form would be the ordinary delimited text format, which is accepted by software such as ArcView. Other methods are described below.

Flat files or spreadsheets

Flat files or spreadsheets is a simple method of storing data. All data of one geographic feature is stored in one row (record), with each attribute stored in each column. All records in the database have the same number of "fields" Individual records have different data in each field with one field serving as the key to locate a particular record. As the number of fields increase a flat file is cumbersome to search. Additionally, adding new records in it is time consuming. Other methods offer more flexibility and responsiveness.

Hierarchical files

Hierarchical files store data in more than one type of record. This method is usually described as a "parent-child" or "one-to-many" relationship. One field is key to all records, but data in one record does not have to be repeated in another. This system allows records with similar attributes to be associated together. The records are linked to each other by a key field. Each record, except for the master record, has a higher level record file linked by a key field "pointer". In other words, one record may lead to another and so on in a relatively descending pattern. An advantage is that when the relationship is clearly defined, and queries follow a standard routine, a very efficient data structure results. Access to different records is available, or easy to deny to the user by not furnishing that particular file of the database. One of the disadvantages of these files is one must access the master records, with the key field determinant, in order to link "downward" to other records.

Relational files

Relational files connect different files or tables without using internal pointers or keys. Instead, a common link of data is used to join or associate records. The link is not hierarchical. A "matrix of tables" is used to store the information. As long as the tables have a common link they may be combined by the user to form new inquiries and data output. This is the most flexible system and is suited to SQL (structured query language). Queries are not limited by a hierarchy of files, but instead are based on relationships from one type of record to another that the user establishes. Because of its flexibility, this system is the most popular database model for GIS.

Geo-relational structure

A geo-relational structure contains characteristics of both geographic and relational databases. Geographic coordinates are not required for every file, but each data element must relate to geographic coordinates through key variables.

Design of Attribute Database

Data stored in the database management system is by attribute name. The storage format is invisible. Thus, for data exchange, common formats are necessary. These should contain common attribute names or a common glossary of terms which must be maintained and updated. The same attribute name must be used for information of like kinds in all the files in the data management system. The attribute names should be as generic as possible and should represent only the substance and not the level of aggregation. Thus, for example, temperature should be called maximum temperature and minimum temperature, and not daily maximum and daily minimum. The names should be limited to eight characters. In addition to the names, the data management system should contain units; recommended levels of aggregation (e.g., geographic, temporal, taxonomic, etc.), a minimum level of significant digits, and a reference code for location of procedures and standards.

Judicious selection of file names can improve the management and processing capabilities of relational data management system. A unique ID, which identifies each record, is used to access a single record from all other records. When compiling a data management system, it is necessary to consider the data requirements that are needed to accomplish the intended objective and the above considerations should help in the achievement of the objective.

Attribution

Creating a spatial database requires careful planning and execution. This also involves decisions on the generation of unique identification codes for each feature so that the related attribute data can be linked. The task can be achieved during the initial stages of digitization of maps and/or after digitization. For example, a road map (line features) can have different types of roads such as national highway and state highway. These varieties of road features can be given unique identification (ID) while being digitized. Once the geographic features are coded, a separate table of non-spatial attributes can be prepared to add more data for analysis.

Database Query, Analysis, and Modeling

Analysis in GIS is basically a query on the spatial data. This may be a spatial query to find neighborhoods or adjacency of occurrence of an event or phenomenon. There can also be a query on non-spatial data linked to the spatial data to infer on the spatial pattern of the associated non-spatial attributes. Processes can be modeled after the data has been analyzed for a long period of time to obtain successful results.

Geo-processing

Geo-processing involves the processing of spatial and attribute data for special objectives. This includes map overlay, map merging, subset selection and buffering, each of which gives a specific output. Map overlay is the most important function of a GIS and also its strength. It facilitates the analysis of multiple layers at one time to find areas of homogeneous characteristics. 'Map merging' is used when smaller areas are to be appended to create a larger domain. Subset selection clips out features from a larger database to zoom into a selected window. Buffering is a neighborhood function to look into the possible area of expansion of the spatial phenomenon or the diffusion of an event.

For further reading, Burrough (1986) may be referred.

Reference

Burrough, P.A. 1986. Principles of geographical information systems for land resource assessment. Oxford, UK: Clarendon Press.

Digitization Using PC ArcEdit

K S Prasad, M Srinivas, and S Pande[1]

Introduction

One of the most important activities in geographic information system (GIS) is 'digitization'. In PC Arc/Info package, ArcEdit module is used for digitization and data input.

Digitization and Data Input

Data input is a process of converting analog data (map features) into a digital form to develop a spatial database for further analysis required for different applications. Data input is carried out through the process called digitization.

Input data to the GIS can come from several sources such as digitized maps from the output of the digitizing table; scanned maps from a scanner; ASCII files containing point data with associated coordinates from GPS (global positioning system) surveys; text data from published sources such as census departments; and thematic maps from satellite imagery. Before digitization is carried out one must know a few commonly used terms. These are:

Digitizer. Digitizer is the hardware device that is used to input coordinate data (e.g., hardcopy maps) into the computer. The map to be digitized is mounted on the digitizer (digitizing table) before digitizing.

Digitizing tablet (Cursor). Digitizing tablet is the hand-held device that is used to enter coordinate data on the digitizer. It usually consists of a number of

1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1411.

Prasad, K.S., Srinlvas, M., and Pande, S. 2000. Digitization using PC ArcEdit. Pages 37-44 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

buttons and a set of cross hairs used to pinpoint locations on maps mounted on the digitizer.

Serial port. Serial port is an interface connector used to connect the PC with devices such as digitizers, plotters, modems, or a host computer.

The steps involved in digitizing a map are:

- Procure the maps to be digitized.
- Mark clearly and number all tics (at least four known points covering the map) on the map to be digitized.
- Give a user-ID to each feature on the map to be digitized.
- Mark a starting point on all closed loops so that it is known where to begin and end while digitizing.

PC Digitizer Configuration

After the map area is prepared for digitizing, it has to be checked and ensured that the PC and digitizer area are correctly set up to communicate with each other. For this:

- The digitizer must be connected to one of the serial ports on the computer.
- The command CON-DIG should be typed before using the digitizer for coordinate input. This command identifies the digitizer and serial port to be used.

CON-DIG {DIGITIZER} {PORT} {BAUD-RATE} {PARITY} {DATA BITS} {STOP BITS}

To test the digitizer configuration, DIGTEST is typed and entered. A number of tests will be executed as follows:

- Description on how the digitizer was configured in PC Arc/Info.
- The message "Initializing Digitizer" will determine the digitizer and the PC are communicating. For each cursor button pushed, a line of data should appear at the bottom of the screen.
- The third test is to verify that stream mode digitizing is working. The cursor should be moved around the digitizing tablet and one of the cursor buttons held down. The screen should display changing x,y coordinates (as the cursor is being moved) and the cursor key number for each digitizer cursor button pushed.

- The next test involves entering cursor values in the order 0 through 9, A, and then B.
- Lastly, there will be a prompt to enter two points approximately 10 inches apart. This is to test the ability and the accuracy of the system to calculate the distance between the points.
- Disconnecting the digitizer with the host computer is done by typing CON-DIG NONE and enter.

After ensuring that the PC and the digitizer are configured (connected), the first step involved in digitizing a map is to mount it (prepared map) on the digitizer. While mounting the map it is necessary to ensure that the area to be digitized is contained within the active area of the digitizing board, i.e., avoiding the edges of the digitizer where the digitizing cursor is inoperable.

Digitizing

Digitization is the process of converting the spatial features, viz., point, line, and polygon features of a map in digital format. A point is represented by a single coordinate; and a line by a string of coordinates. One or more lines combined with a label point inside make a polygon. Thus digitizing is the procedure for capturing a series of points and lines. Points are used for two different purposes: to represent point features or to identify the presence of a polygon. To avoid confusion, both kinds of points in the same coverage should not be digitized.

There are two types of digitizing: discrete digitizing and spaghetti digitizing. Discrete digitizing refers to digitizing through several smaller arcs and creating a series of connected arcs by digitizing each intersection as a node. Spaghetti digitizing refers to digitizing through one long arc ignoring the intersections of arcs and digitizing the outline as one long arc.

Coverage Creation with PC Arc/Info

A coverage is a primary means for storing and representing map data in PC Arc/Info. It is a digital version of a map. In PC Arc/Info coverage, map features are stored as simple points, lines, or polygons. Thematic descriptors for each point, line, or polygon are stored in feature attribute tables.

There are six basic steps used for coverage automation with PC Arc/Info:

1. Digitize the map.
2. Identify and correct digitizing errors.
3. Define features and build topology.
4. Identify and correct topology errors.
5. Assign attributes to coverage features.
6. Identify and correct attribute-coding errors.

Firstly, an empty coverage containing only tic points is created (c:\yourname) [arc] create ticcov. This produces an empty coverage with a number of files including BND (boundary file) and TIC (tic files) on it. If there are several sheets of map of the same area with different information, the filename TICCOV will contain the common tic values of true coordinates of at least four control points from the map; these can later be used for generating other maps.

- TABLES and Enter are typed to start the tables for entering tic coordinates of the prepared map. (C:\yourname) [arc] Tables
- Select the ticcov.tic :sel ticcov.tic 0 records selected: (message appears).
- Type :add to start entering tic coordinate and Enter.

Idtic 1 appears on the screen; enter x tic value and y tic value, and repeat the same for other three tics. Values to be added are given below:

idtic:l	idtic:2	idtic:3	idtic:4
xtic:72	xtic:96	xtic:72	xtic:92
ytic:36	ytic:36	ytic:12	ytic:12

- Enter all four ID tics.
- Type LIST to see whether all tic values are registered correctly. For example, if one of the tic values is wrongly entered, proceed as follows to make correction.
- Use the Update command and enter as: UPDATE

Enter Record Number: (message appears) Type particular record number in which corrections are to be made and Enter. The following message appears:

IDTIC

XTIC

YTIC

EDIT?

Then make a correction on IDTIC, XTIC, or YTIC whichever is wrong by simply typing the correct value. Then press Enter and enter.

If a wrong tic point which has to be removed from the list is r, follow the procedure given below:

Select ticcov.tic

5 records selected (message appears).

Reselect $RECNO = 5

1 record selected (message appears).

Purge (to delete the particular selected record)

Record number 5 gets deleted. To check this, type list.

LIST

Only 4 tics appear on the screen.

- Type Q to exit TABLES.
- Use the command CREATE to copy the ticcov tics to India coverage.
- For example: (c:\yourname) [arc] create India ticcov

  The India coverage has all the coordinate values.

Coverage Management

- Use the Describe command to list the contents of the coverage.

  e.g., [ARC] Describe India
- Copy the coverage into a floppy disk.

  e.g., [ARC] copycov India a:India
- To change the name of our coverage.

  e.g., [ARC] renamecov India Indiast

BUILD THE COVERAGE

Type BUILD

Following syntax appears on the screen.

BUILD [cover] [poly/line/point]

BUILD INDIA POLY

To see the polygon attribute file, type:

List India.Pat

$RECNO	AREA	PERIMETER	INDIA	INDIA-ID
1	XXX	XXXX	0	0
2	XXX	XXXX	1	1
3	XXX	XXXX	2	2
4	XXX	XXXX	3	3
5	XXX	XXXX	4	4

The INDIA map attribute table is seen; each district will be identified with these ID numbers and each district here is referred as a polygon.

Digitizing Errors

"To err is human" is no exception in GIS and particularly in map digitization. While creating polygon coverage, a number of errors can occur which should be identified and corrected. Some common errors are undershoot and overshoot (geometric coordinate errors), too many label points, and no label points.

Identification of Errors

Pseudo node

Pseudo node is a node at which only two arcs intersect (or a single arc connects with itself). Another way to consider pseudo nodes is that they identify locations where an otherwise contiguous arc is actually 'split' into smaller discrete arcs. Pseudo node does not necessarily indicate an error or problem. Pseudo nodes can be displayed in ArcEdit, DIGITIZE, EDIT, and EDITPLOT. They are always drawn with a diamond symbol.

Dangling node

Dangling node is the dangling end point of a dangling arc. It can either be an undershoot or an overshoot. Dangling nodes can be displayed in ArcEdit, DIGITIZE, EDIT, and EDITPLOT. They are shown with a square box symbol. The NODEERRORS command can also list the dangling nodes present in the coverage.

Too many label points

If a polygon contains more than one label point it shows an error. A label error is also notified for that polygon if the labels have same ID. Multiple labels may also indicate unclosed polygons. This label error can be displayed in EDITPLOT. Multiple labels are always drawn with their polygon boundaries. The LABELERRORS command can be used to list the polygons, which contain too many label points.

No label points

A polygon which does not contain a label point will be given a user-ID of 0; and unless a polygon contains a label point, its user-ID can never be changed from 0. If a polygon does not have a user-ID, PAT (Point Attribute Table) attributes cannot be maintained for that polygon. Polygons with no label points can be displayed in EDITPLOT. Their boundaries are always drawn, and a star symbol is placed inside them. The LABELERRORS command can be used to list polygons that have no label points.

Note. There should always be a label error star in the center of the coverage. This star indicates that the universe polygon that surrounds the coverages has no label points. If the star fails to appear, it means that a point lies outside the boundary of the coverage. It is necessary to use CLEAN or BUILD to create polygon topology before potential label errors can be identified.

Sliver polygons

Sliver polygons are formed when the boundaries between two polygons overlap. They may form during coverage overlaying, and when the boundaries between two polygons are digitized twice. This can be seen in EDITPLOT command.

Gaps

Gaps are parts where the boundaries between two polygons do not meet. They are formed mainly during coverage overlaying. This can be seen in EDITPLOT command.

Weird polygon

Weird polygon is formed when two overshooting arcs meet at the end (overshooting), enclosing some small area. This can be seen in EDITPLOT command.

Creating Wheat Productivity Maps in ArcPlot

K S Prasad[1]

Introduction

During demonstration on various features of Arc/Info, a module named ArcPlot was explained in detail. PC ArcPlot provides for using maps as graphic windows to databases for interactive query and update of attribute information. It also provides facilities for interactively creating and previewing maps on the monitor screen, and sending maps to a printer or plotter.

Generation of Maps

The map coverage of India has been digitized and each district assigned with an ID (identification number). Stepwise activities for the generation of wheat *(Triticum aestivum)* productivity maps are illustrated below in a sequential order. For this, ARC prompt is first opened.

C:\[ARC] list India.PAT. This command is used to enter the data required in the table given below. It will show the polygon attribute table with 465 records.

Rec. no.	Area	Perimeter	India_	India-id
1	Xxxxx	xxxxxx	1	3801
2	Xxxxx	xxxxxx	2	3802
3	Xxxxx	xxxxxx	3	3803
4	Xxxxx	xxxxxx	4	3804

1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1412.

Prasad, K.S. 2000. Creating wheat productivity maps in ArcPlot. Pages 45-49 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

While preparing a wheat productivity map, a database is created in dBASE III+ on data of year-wise wheat yield assigning IDs of the districts of India. One has to know the database thoroughly. For example, if the database is from 1960 to 1995 the fields will be as given below:

Field 1	District	Name of district
Field 2	India-id	Code of the district
Field 3	Ar 60	Area under wheat in 1960
Field 4	Prod 60	Production of wheat in 1960
Field 5	Yld 60	Yield of wheat in 1960

Likewise, data of each year is entered continually until all data up to 1995 are entered. Then, India coverage for wheat productivity is copied with the following command.

C:\[ARC]Copycov India Wheatind (new coverage).

C:\[ARC]Additem

Then, a new syntax is seen as below:

Usage: Additem[in-file] [out-file] [pitem-name] [item-width] [output-width] [item-type] [decimal-places] [start-item]

Additem Wheatind _pat Wheatind_pat India-Id 6 6 N

India-id will be added to Wheatind.pat

C:\[ARC]Tables

This command enables to see the content of the table.

C:\[ARC]Select Wheatind.pat (wheatind.pat is the table name)

465 records will be selected (message is displayed after the command execution).

Then the following command is entered: Cal India-id = Wheatind-id

[Same IDs of India-id will be transferred to Wheatind-id also.]

In both Wheat.dbf file and wheatind coverage files, India-id is common.

In Wheatind coverage the following class items should be added:

Ar60	Ar65	Ar70	Ar75	Ar80	Ar85	Ar90	Ar95
Prod60	Prod65	Prod70	Prod75	Prod80	Prod85	Prod90	Prod95
Yld60	Yld65	Yld70	Yld75	Yld80	Yld85	Ydl90	Ydl95

The procedure for adding these items is:

C:\[ARC]Additem Wheatind.Pat Wheatind.Pat Yld60 3 3 N

For adding other items, this exercise is repeated until all data up to the final item Yld95 is added.

Then, in Wheatind coverage different classes are seen.

Linking the Coverage with dBASE Files

To link the coverage with dBASE files ARCPLOT is typed.

The next command is:

Join Wheatind.pat (coverage) Wheat (dbf file) India-id (relate item) Linear

Now the coverage is linearly linked with dBASE file (Wheat.dbf)

For selecting polygons the next command used is:

Asel Wheatind polys

Rsel Wheatind polys #ar60 le 1000

Nsel Wheatind polys

Areas of more than or equal to 1000 will be selected.

Classmanual Wheatind polys #yld60 5 Yld60 x

Four break points should be entered:

800 1000 2000 3000

To prepare a map composition (final map) of wheat yield for 1960 in ArcPlot, the following steps are followed:

Map WYLD60P

Mape Wheatind

Arclines Wheatind 1

Arclines of Wheatind appear on the screen.

Polygonsh Wheatind Yld60

Polygonshade with 5 classes appear on the screen.

Box (frame for the map) is inserted.

To write text the following commands are used:

Textsymbol 89

Move (position of text).

Wheat Productivity of India - 1960 to be typed and entered.

Box (frame for the title) is inserted.

Next, Mend to be typed and entered.

Mapend

Quit (to exit from ArcPlot).

Prepare a key file in ASCII:

Edit C:\Yld60.key (to be created in text editor)

.1

below .08 t ha^{-1}

.2

0.08-1.0 t ha^{-1}

.3

0.0-2.0 t ha^{-1}

.4

1.0-3.0 t ha^{-1}

C:\[ARC]ARC PLOT

DISP 4

MAP Yld60P

Again the entire map appears on the screen.

Add Legend.

Move

Keybox .3 .2

Keyspace .1 .1

Text symbol 3 3

Keyshade Yld.key

Legend will be placed where shown by the cursor.

MEND

MAPEND

AND QUIT

Thus the wheat productivity map of India for 1960 is produced. The same exercise can be repeated for other years.

PART II: Case Studies

Analysis of Constraints and Potential of the Soils of the Indo-Gangetic Plains of Punjab Using GIS

G S Sidhu[1], A K Maji[2], B K Khandpal[1], S Pande[3], and M Velayutham[2]

Introduction

Agricultural activities are related closely with climate, soil, water, and biotic factors. Soil survey provides an in-depth look into these properties for proper and alternative land use plan.

During a systematic soil survey, huge amount of data is collected on the site characteristics, soil morphology, physical and chemical properties of the soils, crop yields, cropping pattern, and other relevant socio-economic features. In the past such vast databases were managed manually to report the results through maps, charts, diagrams, and texts.

With the advent of advanced computerized technology, vast spatial databases have been best handled by geographic information system (GIS) which was first developed in the 1960s and has now further developed as a unique tool with huge potential. McCloy (1995) has defined GIS as a means of

1. Regional Centre, National Bureau of Soil Survey and Land Use Planning, New Delhi 110 012, India.

2. National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur 440 010, Maharashtra, India.

3. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1413.

Sidhu, G.S., Maji, A.K., Khandpal, B.K., Pande, S., and Velayutham, M. 2000. Analysis of constraints and potential of the soils of the Indo-Gangetic plains of Punjab using GIS. Pages 53-60 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

storing, restricting, analyzing, and display of spatially related sets of resource data so as to provide management information or to develop better understanding of environmental relationship.

Material and Methods

The data generation

Interpretation of satellite data (IRS LISS II), field surveys for site and soil morphological characteristics, and laboratory analysis for physical and chemical properties of the soils formed the primary database for the case study reported by Sidhu et al. (1995). The datasets were put into the GIS core to produce various thematic maps.

Creation of the database

The soil map polygons were digitized to form the spatial database using manual 'table digitization' in the Arc/Info GIS system. The attribute database using 27 soil, site, and chemical properties were generated in the dBASE IV environment.

Generation of thematic maps

The general procedure adopted for thematic map generation is the reclassification of basic soil map using appropriate dataset. A generalized flow diagram is shown in Figure 1 which was applied to generate maps of Punjab, India. The single area analysis of each theme was done to give the statistical information about these maps.

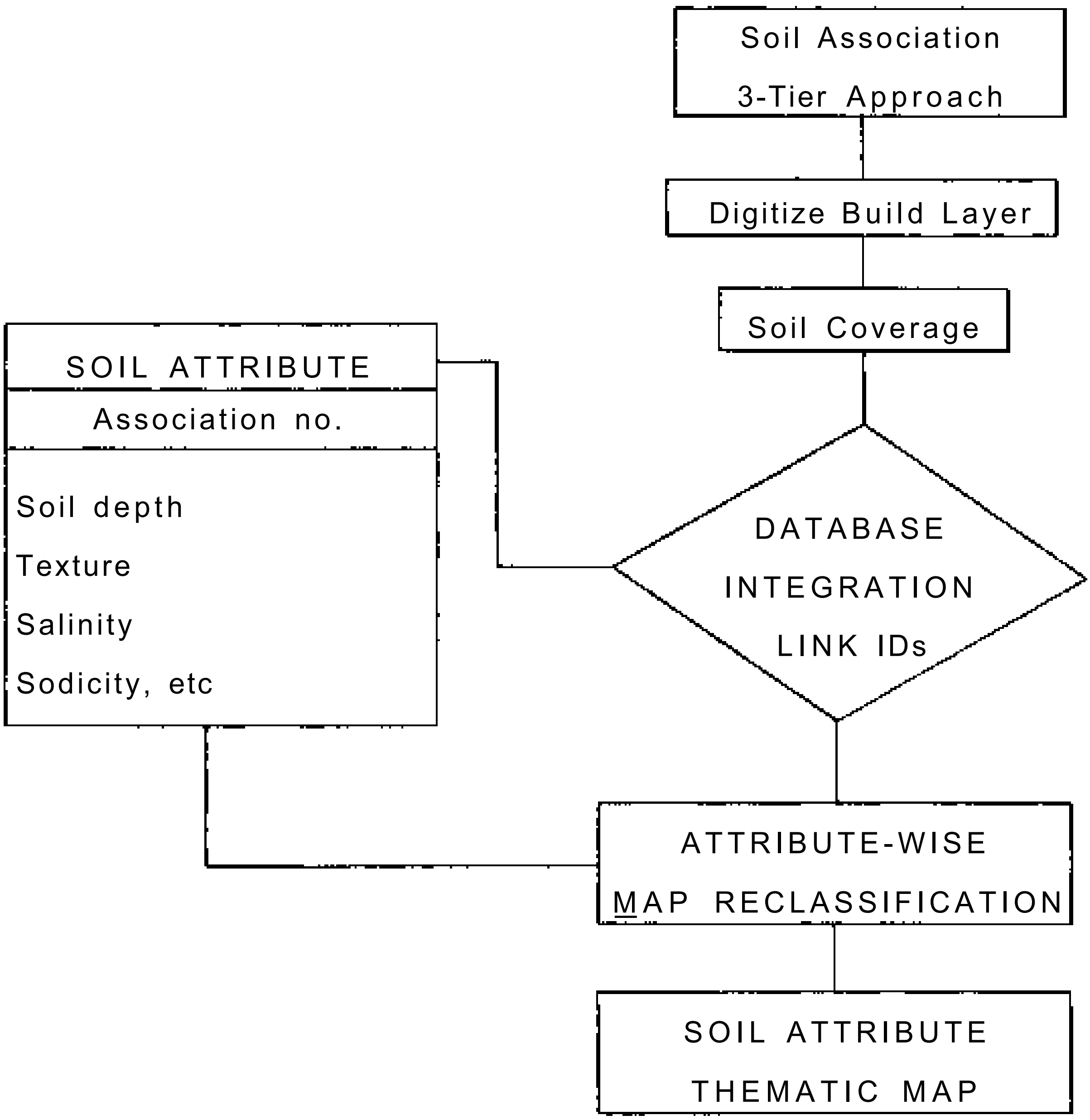


Figure 1. Flow diagram for generation of thematic map.

Results and Discussion

One of the most common and important activity in GIS is thematic map generation which helps in understanding various class/categorical aspects of the concerned theme with reference to their spatial distribution and extent. Out of many maps, those important for constraint analysis are depicted through Figure 2 (soils), Figure 3 (salinity), Figure 4 (calcareousness), Figure 5 (particle size distribution), and Figure 6 (erosion). Statistical information pertaining to area was produced using "single map analysis" and is depicted in Table 1. Soils distribution at subgroup level is depicted in Figure 2. Entisols, Inceptisols, and Alfisols are the predominant soils of the state of Punjab in India. Salinity status is represented through the extent in area and the severity in terms of electrical conductivity (EC) of the soils.

Extent.

Class	Class name	Coverage of map units
1	Limited	<l/3
m	Moderate	1/2-2/3
e	Extensive	>2/3

Severity.

Class	Class name	EC (dS m^{-1})
1	Nil	<0.8
2	Slight	0.8-1.6
3	Moderate	1.6-2.5
4	Strong	>2.5

The combination of these two forms the legend for salinity status (Figure 3). Map analysis shows that about 18% of area of Punjab is suffering from different classes of salinity. Calcareousness is moderate in 22.4 thousand km^2 area. Particle size analysis shows that majority of the soils have fine loamy texture, followed by sandy soils. About 12% area of the state is under threat of moderate soil erosion. It is obvious that such information gives a better understanding of the quality of the lands of the area.

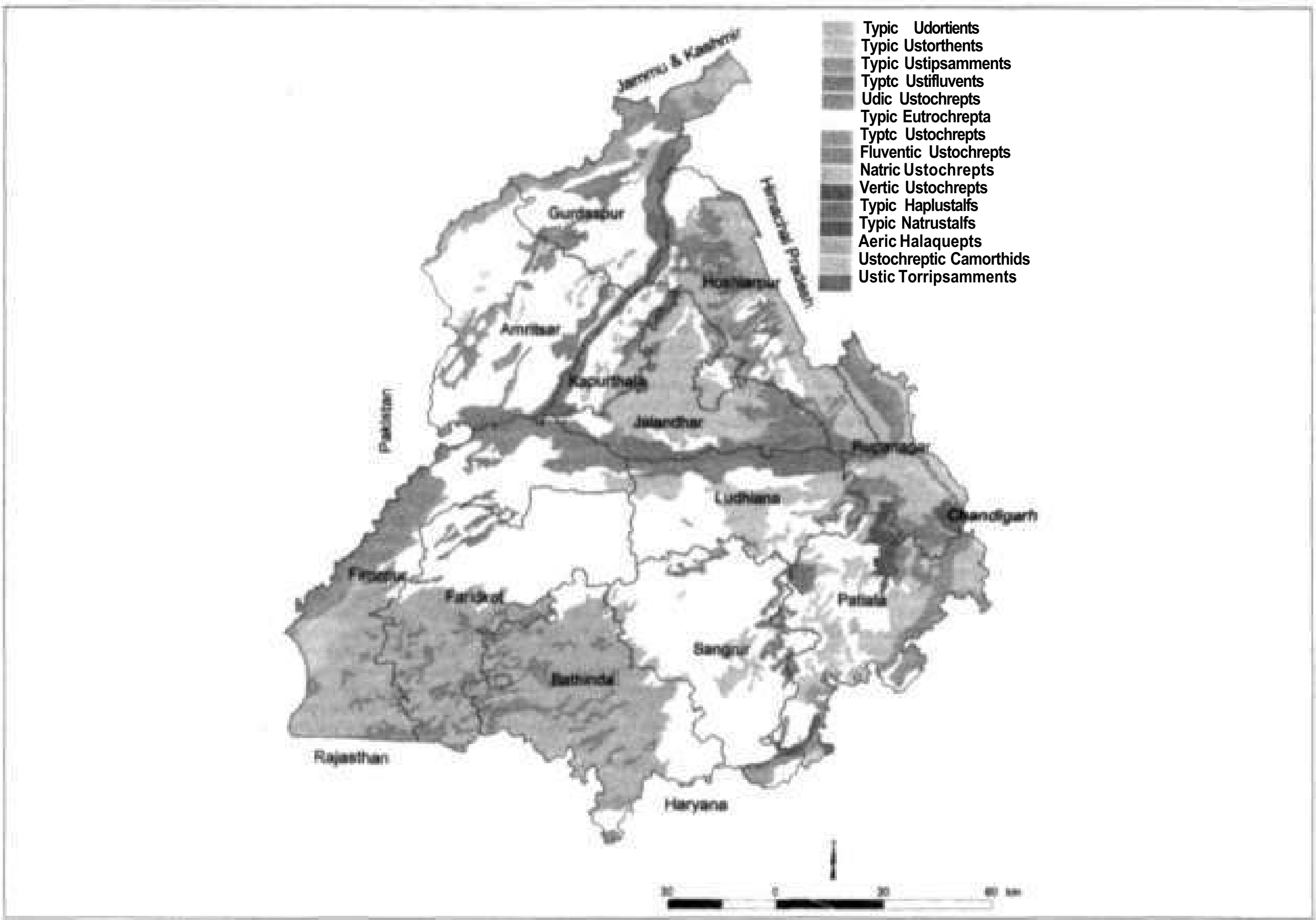


Figure 2. Soils map of Punjab, India.

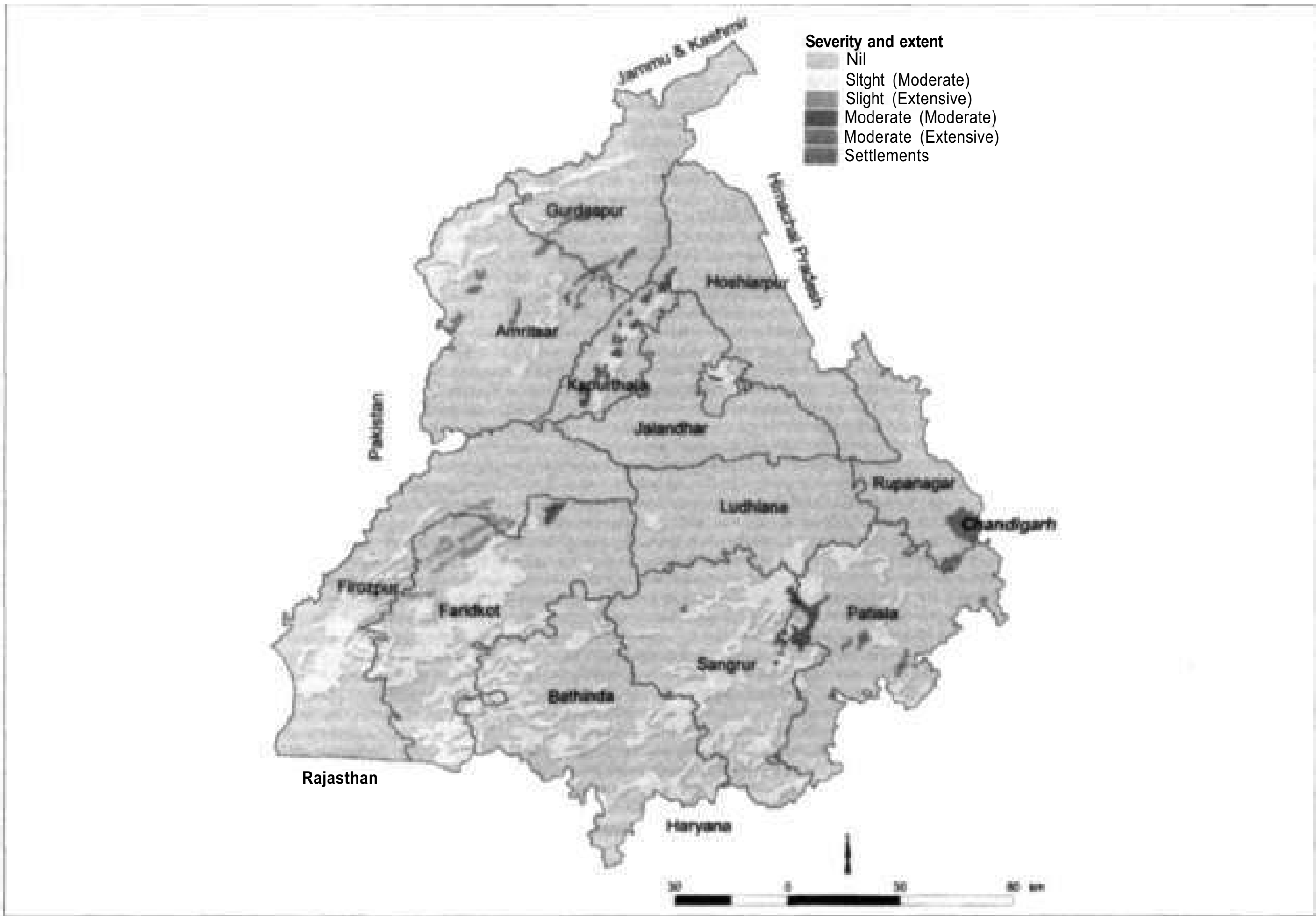


Figure 3. Severity (and extent) of soil salinity in Punjab, India.

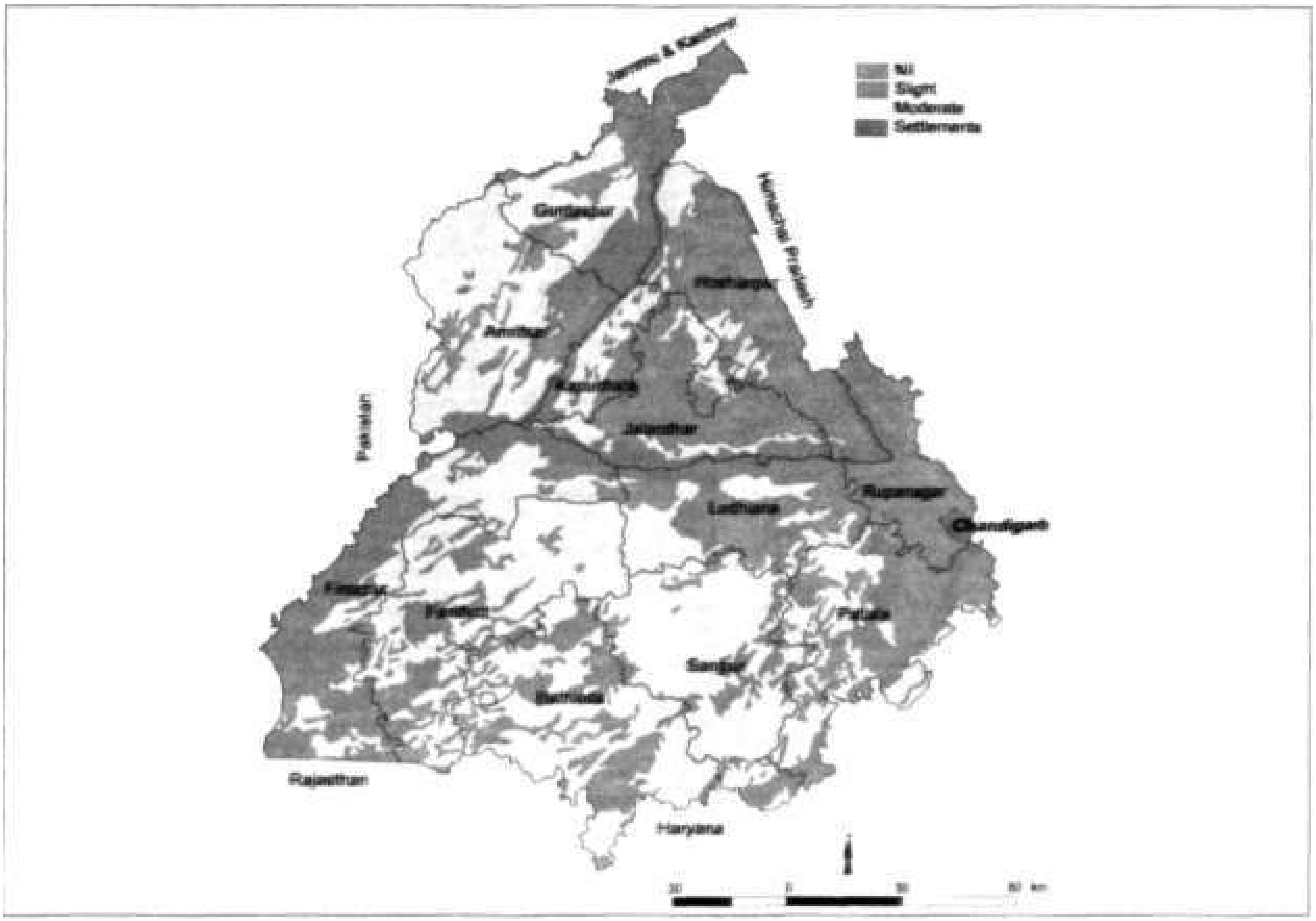


Figure 4. Calcareousness of soil in Punjab, India.

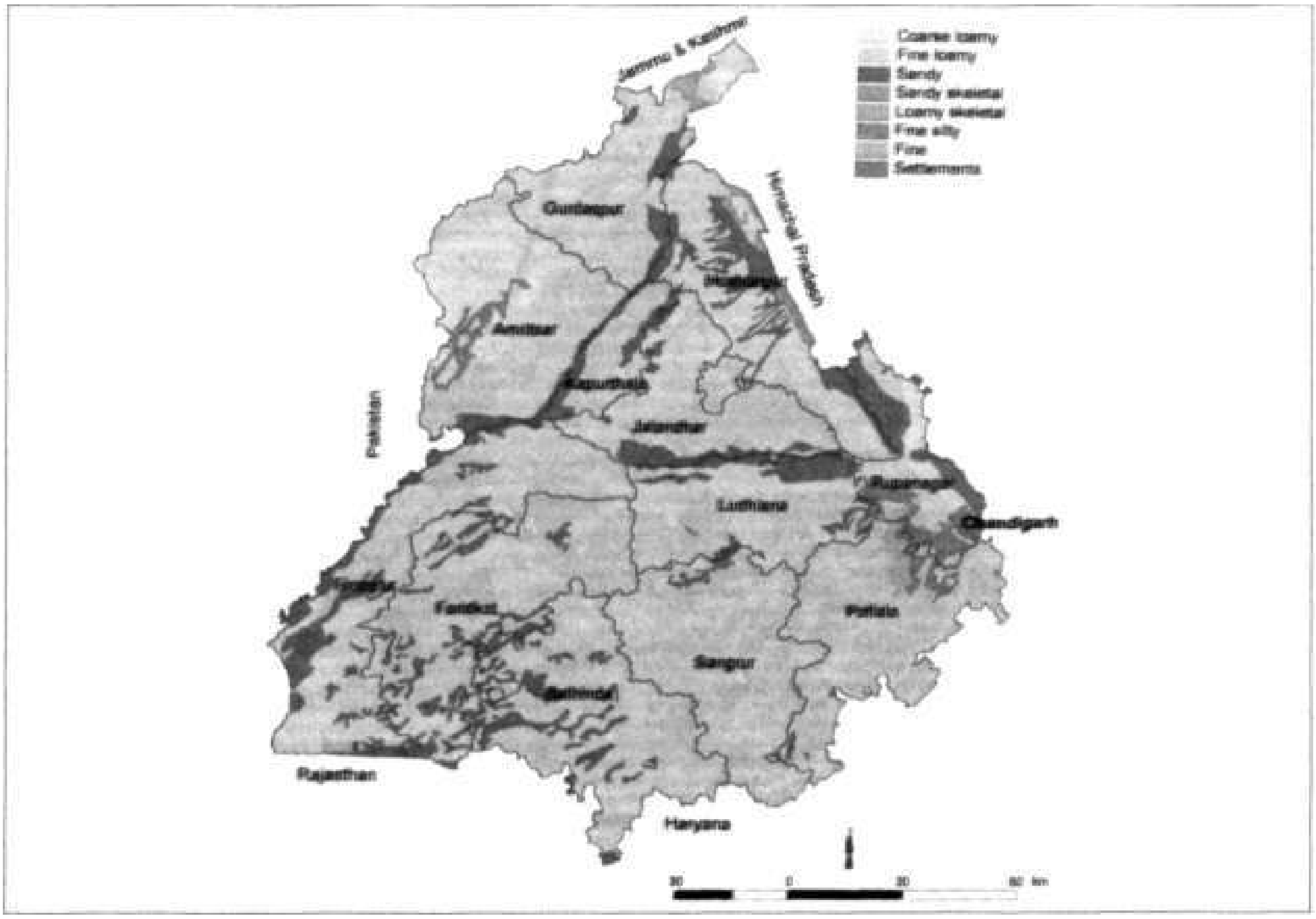


Figure 5. Distribution of various soils differing in particle size in Punjab, India.

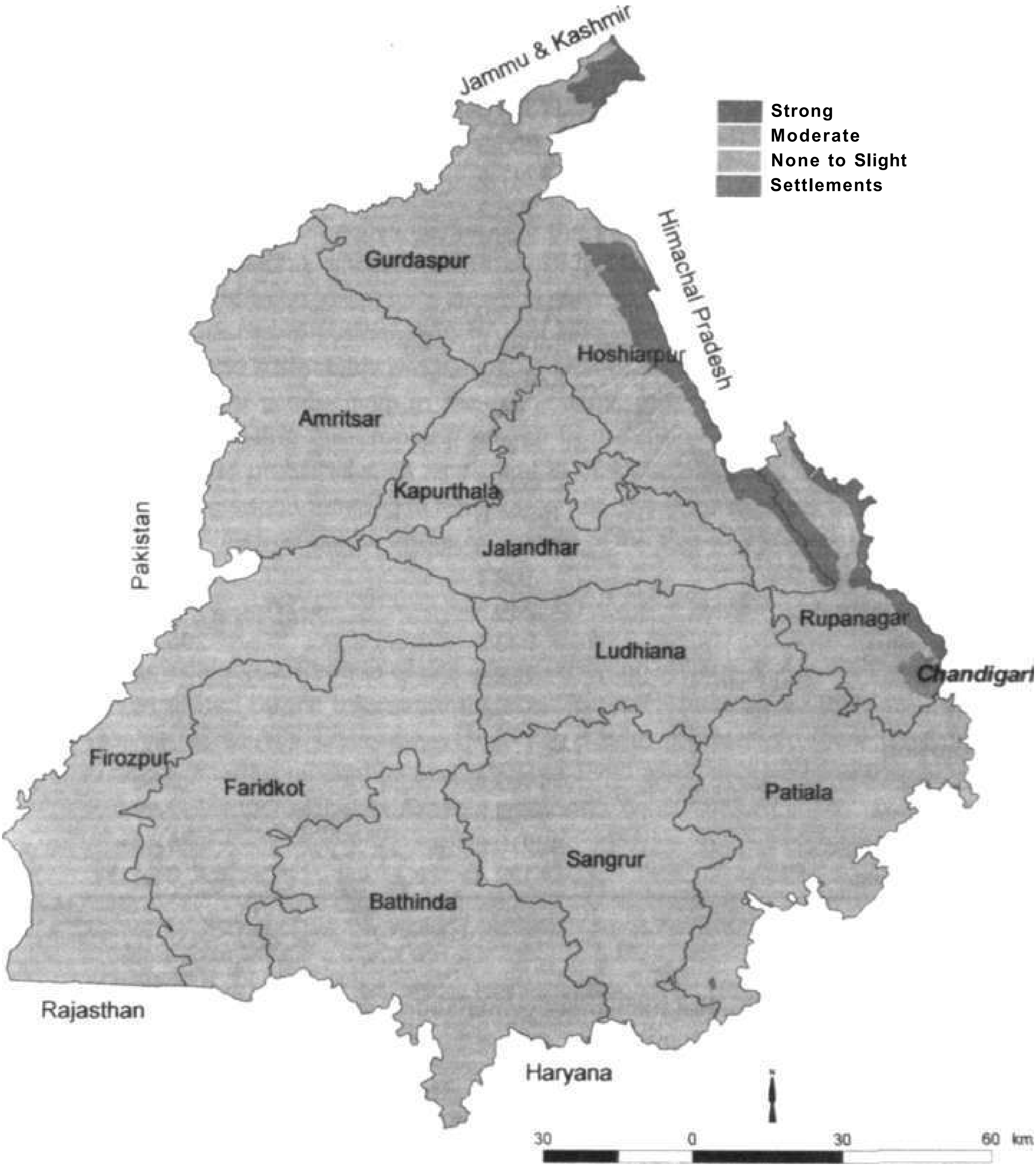


Figure 6. Severity of soil erosion in Punjab, India.

Table 1. Area analysis of thematic maps.

Class	Area (km^2)	Area (%)
Salinity status		
Others	37.2	0.07
1	41978.9	82.60
2e	250.3	0.49
2m	7727.6	15.21
3m	305.3	0.60
3e	400.7	0.79
Calcareousness		
Nil	12159.9	23.93
Slight	16032.6	31.55
Moderate	22470.1	122.40
Others	44.2	0.24
Particle size distribution		
Coarse loamy	25595.7	50.36
Fine loamy	16584.6	32.63
Sandy	6926.5	13.63
Sandy skeletal	108.1	0.21
Loamy skeletal	249.3	0.49
Fine silty	902.6	296.00
Fine	122.4	1.78
Others	0.58	0.24
Erosion		
Strong	1463.4	2.88
Moderate	6288.6	12.37
None to slight	42910.6	84.43
Settlements	122.4	0.24

References

McCloy, K.R. 1995. Resource management information system: process and practice. UK: Taylor & Francis.

Sidhu, G.S., Walia, C.S., Tarsem, Lal, Rana, K.P.C., and Sehgal, J. 1995. Soils of Punjab for optimising land use. NBSS Publication 45. Nagpur, India: National Bureau of Soil Survey and Land Use Planning.

Changes in Wheat Productivity in the Indo-Gangetic Plains of India

A K Maji[1], S Pande[2], M Velayutham[1], and M I Ahmed[2]

Introduction

The green revolution achieved through the interaction of improved cultivars, expanded irrigation, and increased use of fertilizer has prompted the farming community of India to opt for a cropping system, the rice *(Oryza* sativa)-wheat (*Triticum aestivum)* system, which until now proved to be one of the most successful and sustainable programs. Singh and Paroda (1994) have reviewed the rice-wheat productivity in the Asia-Pacific region. However, at the later stage of practicing this cropping system in the Indo-Gangetic Plain (IGP) of India, several problems such as decline in yield, salinity, and sodicity causing concern are encountered. Therefore, it is necessary for analysis of the factors controlling the production and productivity of the rice-wheat system.

The Uses of GIS

Primary database creation of rice-wheat cropping systems of the IGP has been accomplished by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Dataset pertaining to wheat productivity were used for analysis of temporal change from 1960 to 1990 using geographic information system (GIS) techniques in Arc/Info platform.

1. National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur 440 010, Maharashtra, India.

2. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1414.

Maji, A.K., Pande, S., Velayutham, M., and Ahmed, M.I. 2000. Changes in wheat productivity in the Indo-Gangetic plains of India. Pages 61-64 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

A district polygon coverage was digitized for the IGP region in India covering the states of Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal, and part of Himachal Pradesh in Arc/Info GIS system. Database of wheat crop consisting area, production, and yield (t ha^{-1}) were created in dBASE III format for all the districts falling under the IGP region over a period from 1960 to 1990. This database is linked to the base coverage using "Relate Function" based on the common IDs as district ID number. The coverage has been generalized based on the yield into several classes, i.e., <0.5 t ha^{-1}, 0.5-1.0 t ha^{-1},1.0-1.5t ha^{-1}, ... up to >4.0 t ha^{-1} depending upon the range of yield data. Using dissolve function, separate coverages were created for yield of 1960 and yield of 1990. "Vector overlay" was performed for these two coverages to indicate the areas of change from 1960 to 1990. These areas of change were aggregated to group into new classes.

Results and Discussion

The yield scenario of 1960 and 1990 and change in productivity are presented in Figure 1. The results show that there was a steady increase in wheat productivity over time in the entire IGP region in India with varying degree of enhancement in the yield. The areas having yield <0.5 t ha^{-1} had increased from 1.5% to 2.5%; similarly 6 classes (class 4-9) were observed in the production class of.0.5-1 t ha^{-1}, showing a change of productivity from 1 t ha^{-1} to 4 t ha^{-1}. The overall rate of change was also observed from 1.5 t to as high as 49.5%. The analysis also reveals that though lower IGP comprising of West Bengal, Bihar, and eastern Uttar Pradesh has lower productivity of wheat, in some areas increase (%) in productivity was fairly high. Highest rate of growth was recorded in Haryana, Punjab, and part of western Uttar Pradesh. However, in some of the districts negative growth trend has been observed because of very high productivity in one year, but rest of the years had a lower productivity resulting in overall negative growth.

Conclusion

GIS application has been used in bringing out the different aspects of the rice-wheat-based cropping system in the IGP of India. The GIS output can be utilized to identify the indicators for production, intervention needs, and

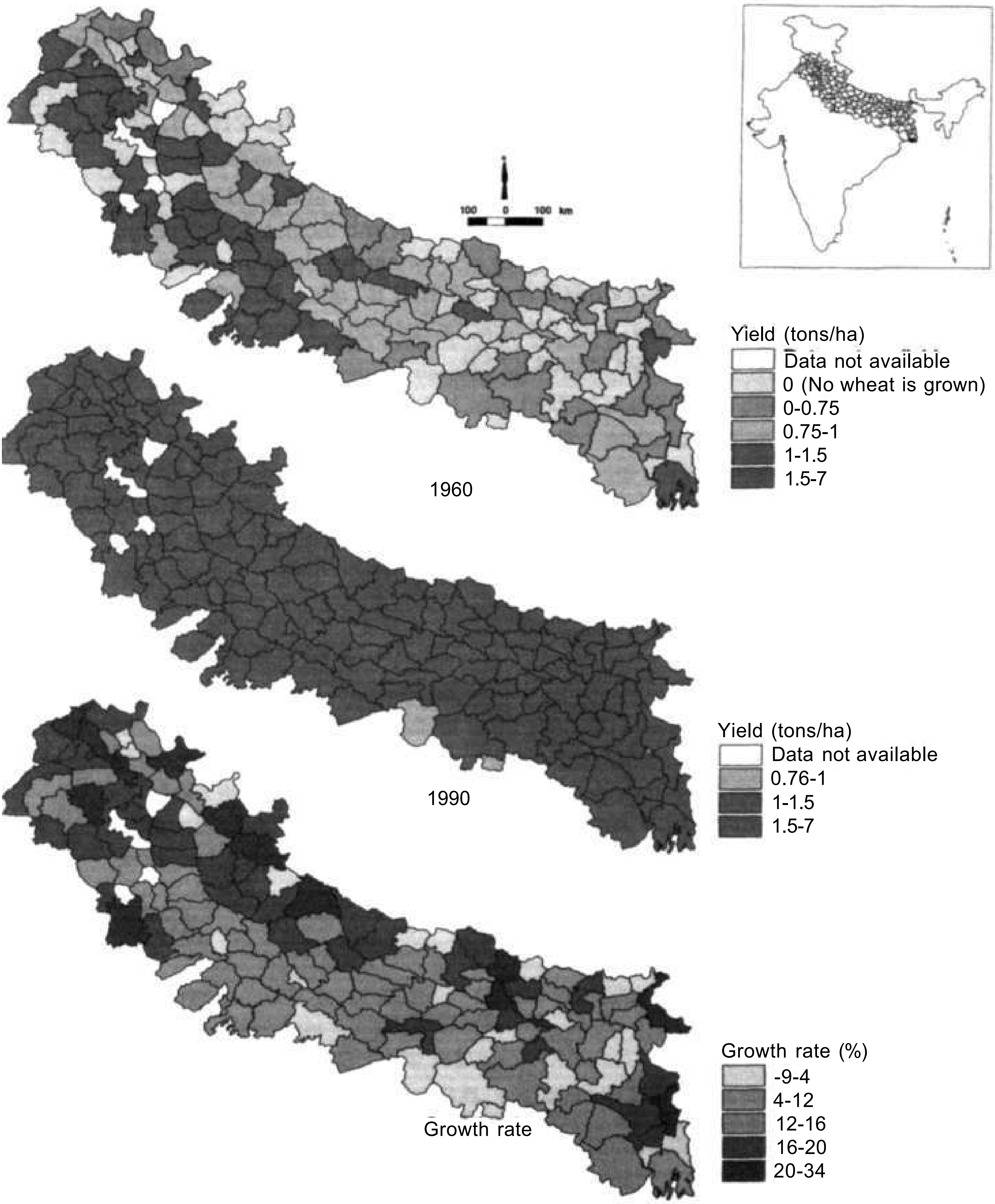


Figure 1. Temporal change in wheat productivity in the Indo-Gangetic plain of India during 1960-90 (Source: Agricultural Situation in India.

strategic planning procedure. However, GIS is a tool and the major success in bringing sustainability to rice-wheat system lies in interdisciplinary work.

Reference

Singh, R.B., and Paroda, R.S. 1994. Sustainability and productivity of rice-wheat system in the Asia-Pacific region: research and technology development needs. Pages 1-35 *in* Sustainability of rice wheat production system in Asia (Paroda, R.S., Terence Woodhead, and Singh, R.B., eds.). Bangkok, Thailand: Regional Office for Asia and the Pacific (RAPA), Food and Agriculture Organization of the United Nations (FAO).

Spatial Analysis of Incidence of Plant Parasitic Nematodes in Rice-Wheat-Legumes Cropping Systems of Uttar Pradesh, India

S Pande, M Asokan, S B Sharma, and P K Joshi[1]

Introduction

Geographic information system (GIS) is one of the most powerful tools, now widely used, to understand various agricultural problems. Use of GIS in plant parasitic nematode research is a new field of activity and database creation in GIS environment and their analysis on the nematode-plant relationship are scanty. The main objective of this paper is to map the incidence and distribution of nematodes using GIS and to see their presence in different cropping systems. A case study from Uttar Pradesh in India is presented here as an example of GIS application in nematode research.

GIS application

Spatial information on the occurrence of different plant parasitic nematodes was collected from 13 districts of Uttar Pradesh and used in GIS to build a layer of nematode incidence. Another layer showing different cropping systems practiced in the area was generated. For analysis of incidence of nematodes in different cropping systems, these two layers were overlayed. The maps produced are presented in Figure 1.

1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1415.

Pande, S., Asokan, M., Sharma, S.B., and Joshi, P.K. 2000. Spatial analysis of incidence of plant parasitic nematodes in rice-wheat-legumes cropping systems of Uttar Pradesh, India. Pages 65-67 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., E.T, eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

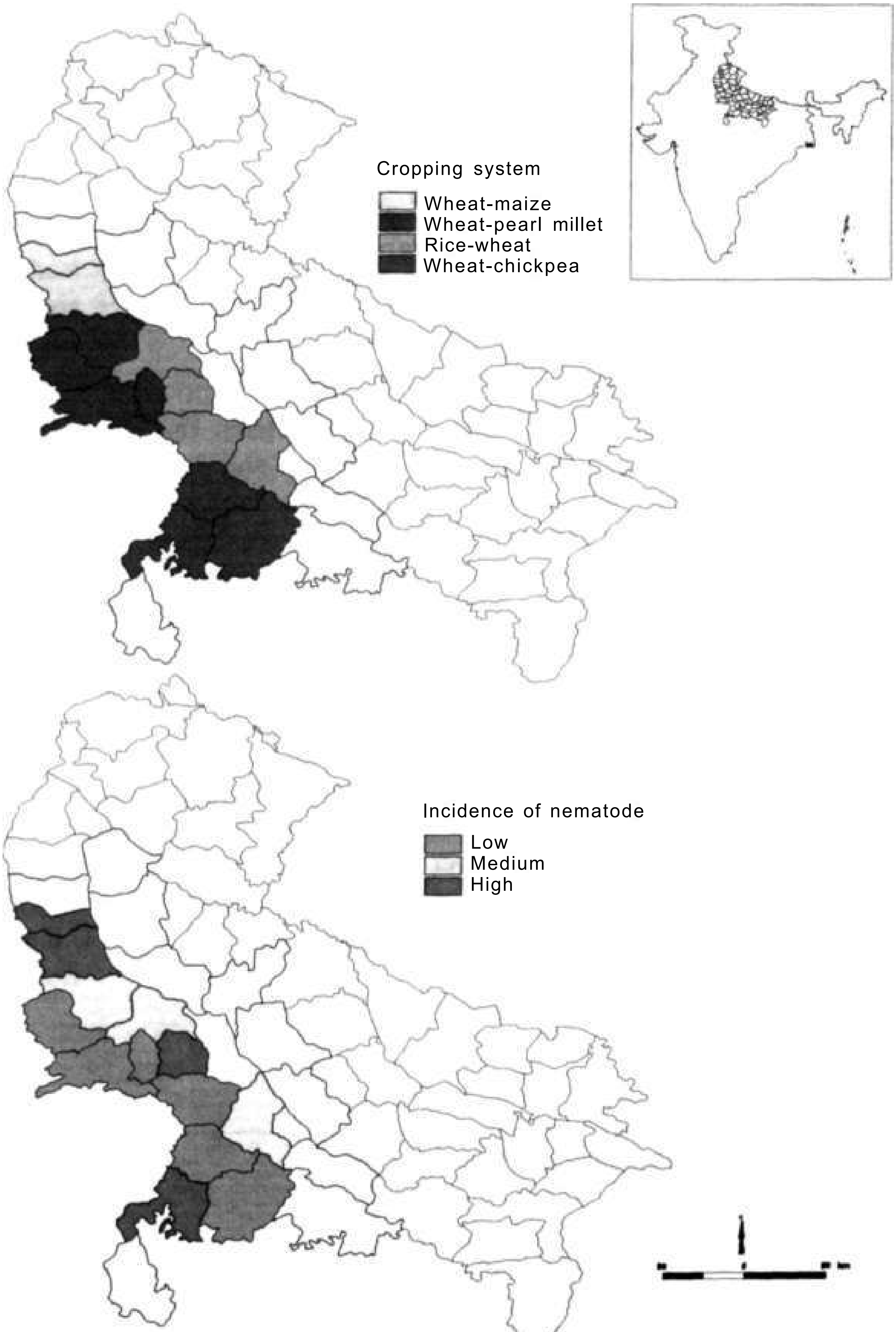


Figure 1. Nematode incidence in various cropping systems of Uttar Pradesh, India.

Results and Discussion

A large number of fungi, bacteria, viruses, plant parasitic nematodes, and mycoplasma-like organisms attack different crops (Sharma et al. 1996). However, there is a lack of data on the distribution of plant parasitic nematodes associated with cropping systems of the region. This investigation provides macro-scale data and important background information on the multi-locational incidence of parasitic nematodes. It is observed that high incidence of nematode attack is intensive in wheat (*Triticum aestivum*) -maize (*Zea mays)* and wheat-chickpea (*Cicer arietinum*) production systems. Rice (*Oryza sativa)*-wheat and wheat-pearl millet (*Pennisetum glaucum*) production systems have low incidence of nematode attack. Various types of nematodes attack these cropping systems. *Meloidogyne javanica, Ty/enchorhynchus spp, Pratylenchus* spp, *Hoplolaimus* spp, *Rotylenchulus reniformis, Heterodera cajani,* and *Helicotylenchus* spp are important nematodes that affect different cropping systems of Uttar Pradesh.

Reference

Sharma, S.B., Ali, S.S., Upadhyay, K.D., and Ahmed, F. 1996. Potential nematode constraints of pigeonpea in Uttar Pradesh in northern India. Afro-Asian Journal of Nematology 6(2): 151-155.

Production Trends of Legumes in Rice-based Cropping System of Sri Lanka

H B Nayakekorala[1], S Pande[2], K V Ravindra[2], Y S Chauhan[2], and R Padmaja[2]

Introduction

Rice (*Oryza sativa*) followed by rice is the major cropping system traditionally practiced in Sri Lanka, often on imperfectly- to poorly-drained soils. However, since the early 1930s, expansion of irrigated area resulted in inclusion of well-drained soils in this production system. Expansion of irrigated area, however, resulted in changed hydrology, leading to insufficient year-round water availability to reliably practice a rice-rice cropping system. In the Maha season (major rainy season from mid-Oct to mid-Jan) all lands in command areas of almost all irrigation schemes have enough water for the rice crop. But in the Yala season (minor rainy season from late Apr to Aug) only a portion of the command area can be cultivated with rice due to inadequate availability of water. Due to the low water requirement of legumes and other upland crops compared to rice, these have been introduced into the rice-rice cropping systems since the early 1960s. Comparatively higher returns from legumes and other field crops made the cropping system of Maha season rice followed by other field crops in the Yala season more popular.

1. Natural Resources Management Centre, Department of Agriculture, Peradeniya, Sri Lanka.

2. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1416.

Nayakekorala, H.B., Pande, S., Ravindra, K.V., Chauhan, Y.S., and Padmaja, R. 2000. Production trends of legumes in rice-based cropping system of Sri Lanka. Pages 68-72 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Rice-based Cropping Systems and Legumes

In rice-based cropping systems, rice is grown predominantly in the Maha season. Land preparation starts in late Oct to mid-Nov. Varieties of $3^1/_2$-4 months duration are generally grown in this system and harvested in Feb-Mar. The other field crops in rotation are grown during late Apr to Sep. The most popular crops are chili (Capsicum annuum), onion (Allium cepa), grain legumes, tobacco (Nicotiana tabacum), and vegetables. The highest returns are obtained from chili and onion. In rice-based cropping systems, the legumes grown include mainly mung bean (Vigna radiata), cowpea (Vigna unguiculata), soybean (Glycine max), groundnut (Arachis hypogaea), black gram (Vigna mungo), and pigeonpea (Cajanus cajan). Mung bean and cowpea are the main legumes grown because they have a higher demand, mainly for breakfast food. After the introduction of short-duration varieties, pigeonpea is being cultivated in many areas.

Studies using GIS

A spatial database was created in Arc/Info for Sri Lanka. The administrative map was used to examine the spatial distribution of paddy and legumes, and their changes over time and in relation to each other. Crop statistics from publications of the Government of Sri Lanka were used to analyze the spatial variation in the crop area and production. Statistics were compiled for each district and linked to the district map of Sri Lanka. The districts were classified into groups using ArcView and layouts prepared to print the maps.

GIS Outputs

Presently, legumes are grown in rice-based cropping systems in areas and locations where water demand for paddy cannot be met and soil drainage conditions are favorable. The extent of legumes grown in Sri Lanka over different periods shows that the major growing areas were confined to 4 districts in 1971-75, but increased to 8 districts in 1981-85 and to 11 during 1991-95 (Figure 1). The total extent of legumes in the island was 4037 ha in 1971-75, 12311 ha in 1981-85, and 15123 ha in 1991-95, on average per year. District-wise extent of legumes following rice (% area) and changes over time are presented in Table 1. Results show that a steady increase in legume area has taken place over time in Sri Lanka. Some districts (Mannar, Kurunegala, and Puttalam) show a declining trend for 1991-95. Twenty districts were in the 5%

Table 1. Extent of legumes following rice and change in extent over time in Sri Lanka.

	Extent of legumes after rice (%)		
District	1971-75	1981-85	1991-95
Ampara	0.26	1.81	4.17
Anuradhapura	3.20	7.52	13.35
Badulla	1.80	6.86	12.24
Batticaloa	0.43	0.86	1.02
Colombo	0.64	0.00	0.00
Galle	0.19	0.10	0.00
Gampaha	0.00	0.29	0.03
Hambantota	3.71	3.15	3.73
Jaffna	9.14	9.01	0.00
Kandy	0.68	0.98	0.82
Kegalla	0.41	1.59	0.14
Killinochi	0.00	4.66	5.53
Kalutara	0.05	0.00	0.00
Kurunegala	2.09	17.16	5.41
Mannar	1.56	6.61	3.36
Matale	1.72	15.52	11.33
Matara	0.11	0.09	0.01
Monaragala	14.92	24.64	40.41
Mullaittivu	0.00	12.42	20.21
Nuwaraeliya	2.00	3.48	1.47
Polonnaruwa	2.59	3.54	2.14
Puttalam	6.01	63.04	19.98
Ratnapura	0.54	2.70	14.72
Trincomalee	0.81	0.71	0.73
Vavuniya	21.70	14.27	21.20

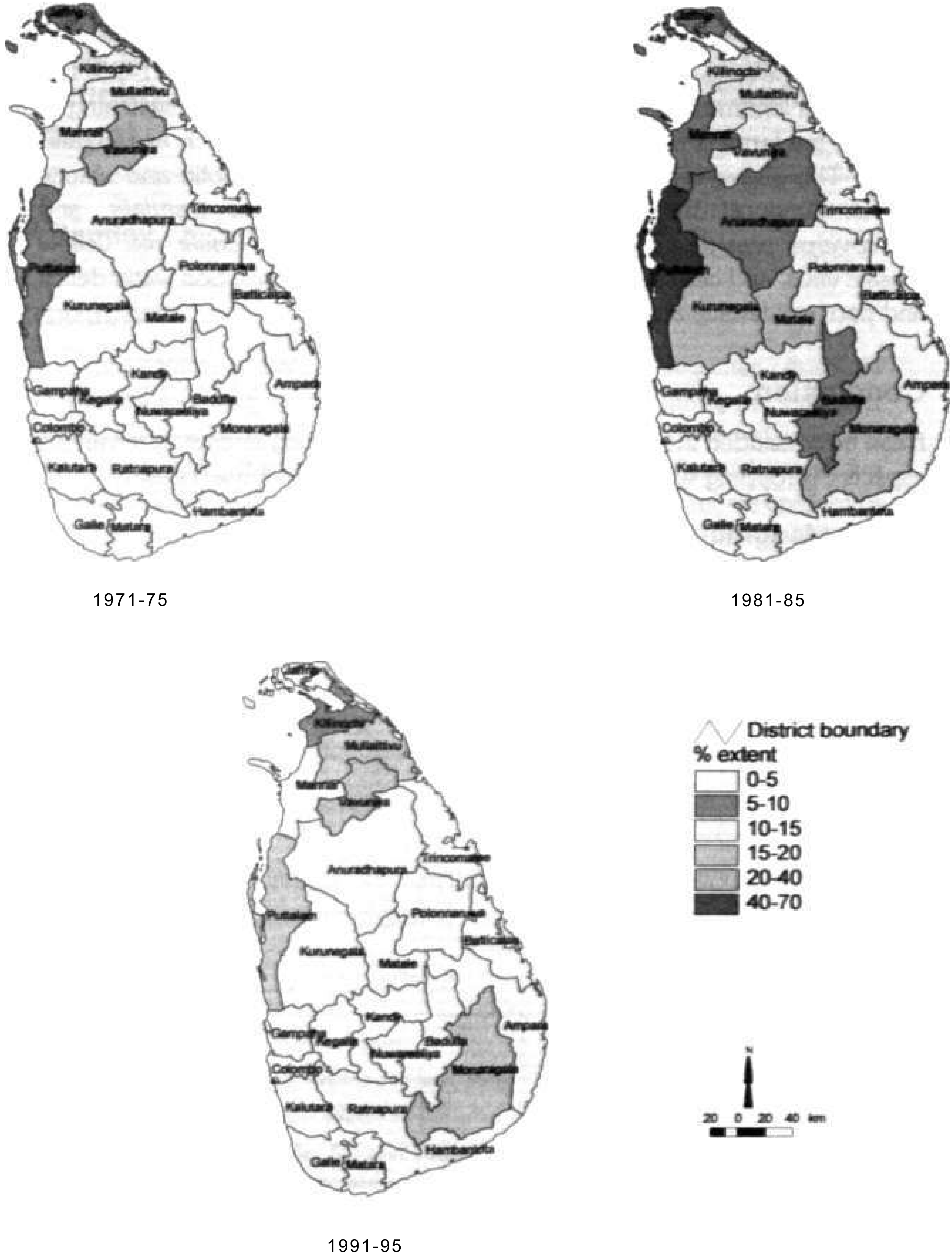


Figure 1. Extent of grain legumes following rice in Sri Lanka during different periods from 1971 to 1995.

range, 2 districts in the 5-10% range, 2 districts in the 10-25% range, 1 district in the 25-40% range, and 1 district was above the 40% range in 1991-95. The decrease in legume extent during the past decade can be due to switching of some of the farmers from legumes to more profitable crops such as chili and onion. The above scenario may be attributed to various biotic and abiotic factors. Amongst biotic factors, *Agromyza* sp, *Maruca testulalis,* and *Helicoverpa armigera* are the major insects of legumes. Collar rot, yellow mosaic virus, and cercospora leaf spot are the major diseases. Soil water deficit and poor soil fertility are the major abiotic constraints.

Conclusion

It can be concluded that G1S can be used as a tool to study and analyze various aspects of cropping systems using suitable spatial and attribute datasets.

Acknowledgment

The authors greatly acknowledge the contributions made by M/s M I Ahmed, K S Prasad, K Srinivas, M Srinivas, and M Moinuddin of ICRISAT in data processing and GIS analysis.

Use of GIS in Studying the Distribution Pattern of Chickpea in Rice and Wheat Cropping Systems in Nepal

S P Pandey[1], K Sah[1], S Pande[2], and K S Prasad[2]

Introduction

Rice (*Oryza sativa*), wheat (*Triticum aestivum*), and grain legumes constitute more than 80% of total food crops production in Nepal. Among the legumes, chickpea (*Cicer arietinum)* is an important crop grown in rice-based cropping systems. However, the area, production, and yield of chickpea have considerably declined during the past 10 years mainly due to severe epidemics of botrytis gray mold (caused by *Botrytis cinerea).* Chickpea, being a staple food as well as a potential export commodity of the country, deserves intensive research and development towards improvement in production of this crop.

Geographic information system (GIS) can be used to guide research and development efforts by clearly depicting spatial and temporal changes in chickpea area, production, and yield in relation to available information on relevant bio-physical factors controlling production.

GIS Application

GIS databases were created in Arc/Info environment following normal procedures. Base maps were digitized and polygons were assigned with

1. NARC, PO Box 5459, Kathmandu, Nepal.

2. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1418.

Pandey, S.P., Sah, K., Pande, S., and Prasad, K.S. 2000. Use of GIS in studying the distribution pattern of chickpea in rice and wheat cropping systems in Nepal. Pages 73-75 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

poly-IDs. Polygons were attributed with temporal series data of chickpea area on a district basis. As an example for this exercise two maps were generated to display changes in chickpea distribution over 10 years. These two maps were overlayed on the physiographic map of Nepal to analyze the distribution of chickpea in relation to different physiographic regions (Fig. 1).

Results and Discussion

Distribution of chickpea shows extensive spread in the Terai region (<300 m) followed by the Siwalik (300-700m), and Middle Mountain regions (700-2000 m), with little chickpea grown in the High Mountain and High Himalayan regions. The Terai region is an extension of the Indo-Gangetic Plain having favorable soil and climatic conditions and thus favors chickpea growth.

During the past 10 years chickpea cultivation has declined in many hill districts (Fig. 1). Also, a shift of chickpea cultivation has taken place from the eastern Terai to western Terai districts. This phenomenon relates to the greater incidence and severity of botrytis gray mold in the eastern part than the western part of the country.

Conclusion

Thus, GIS can be used to quickly and clearly identify changes in cropping pattern and infer possible constraints causing such changes. With GIS, it is possible to produce information in concise, attractive, and accessible form that would enable planners, decision makers, and other concerned users to understand cropping situations in a better way and in the shortest possible time.

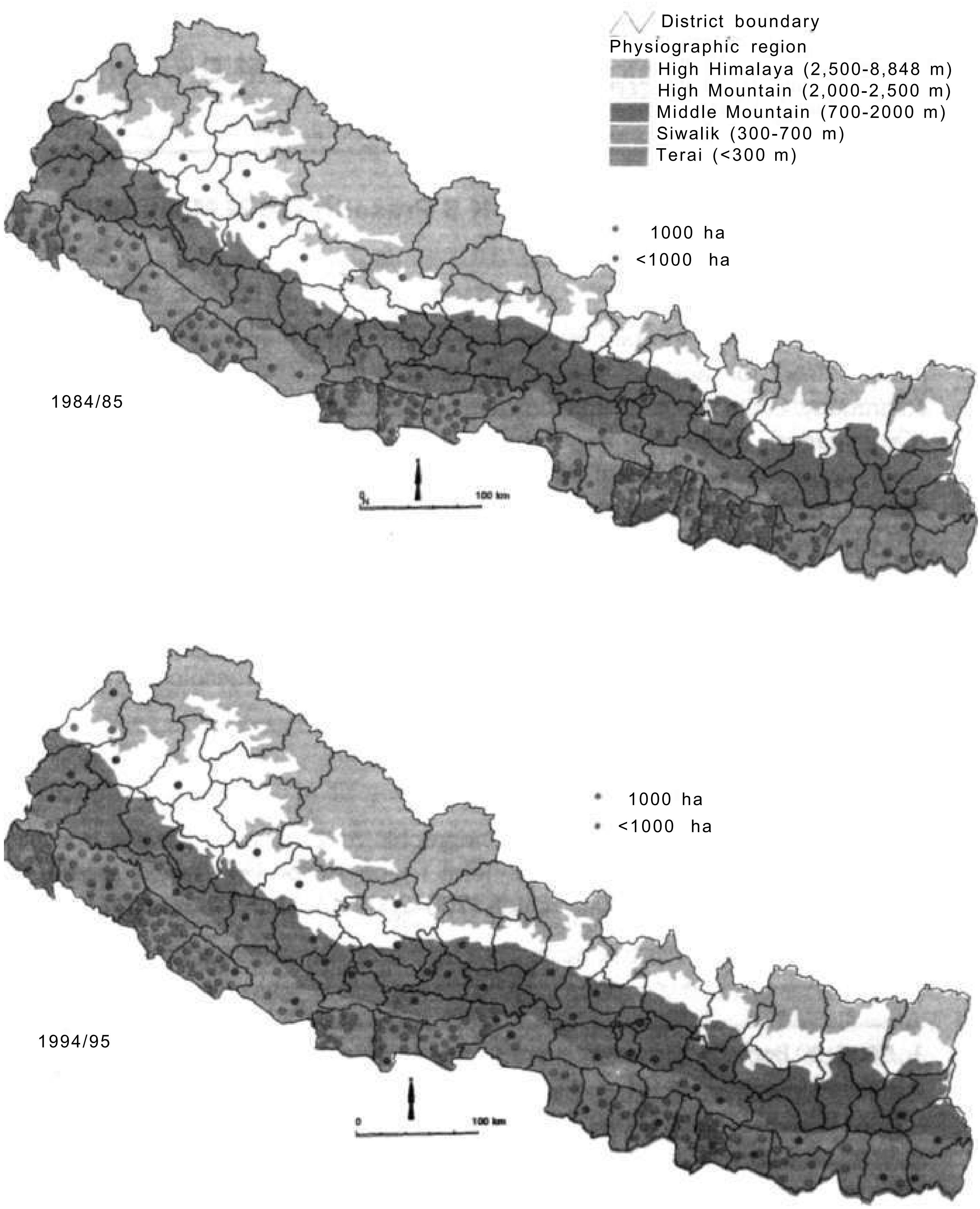


Figure 1. Temporal variation of chickpea distribution in relation to physiographic regions in Nepal, 1984/85-1994/95 (Source: Agricultural Statistics Division, Ministry of Agriculture, His Majesty's Government, Nepal).

Diseases of Chickpea in the Rice-Wheat Cropping System of Nepal

K Sah[1], S P Pandey[1], S Pande[2], K S Prasad[2], and M Moinuddin[2]

Introduction

Grain legumes are important in Nepal as a part of the human diet for cheap protein, feed for animals, restoration of soil fertility, and as an export commodity. Grain legumes rank fourth in area and fifth in production after rice (Oryza sativa), maize (Zea mays), and wheat (Triticum aestivum). The main grain legume crops of Nepal are lentil (Lens culinaris), grass pea (Lathyrus sativus), pigeonpea (Cajanus cajan), black gram (Vigna mungo), soybean (Glycine max), chickpea (Cicer arietinum), horse gram (Macrotyloma uniflorum), mung bean (Vigna radiata), and cowpea (Vigna unguicu/ata). Lentil alone covers more than 50% of the total legume crops area and contributes 55% to the total production of grain legumes. A large number of summer and winter grain legumes are grown in the varied agroecological zones of the country.

Physiographic Regions

Nepal is divided into five distinct physiographic zones running parallel from east to west with varying elevation. Terai region (<300 m), Siwalik region (300-700 m), Middle Mountain region (700-2000 m), High Mountain region

1. NARC, PO Box 5459, Kathmandu, Nepal.

2. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1417.

Sah, K., Pandey, S.P., Pande, S., Prasad, K.S., and Moinuddin, M. 2000. Diseases of chickpea in the rice-wheat cropping system of Nepal. Pages 76-79 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T, eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

(2000-2500 m), and High Himalayan region (2500-8848 m). Among these, the Terai region is cultivated to chickpea; Middle Mountain region also grows chickpea and other legumes.

Rainfall Distribution

The average precipitation is about 1015 mm per annum but actual amount of rainfall at different places varies greatly according to topographical variation. The highest annual precipitation 5177 mm occurs in Pokhara, Lumle area of Karki district. In general, the eastern part has more precipitation as compared to the western part of the country. About 85% of total rainfall occurs during Jun to Sep.

Case Study Using GIS

Arc/Info software was used to generate physiographic and rainfall distribution map of Nepal using normal procedure. Physiographic map was digitized as a separate theme and was superimposed on the district base theme. Rainfall distribution map was prepared using point data from meteorological observations. A separate layer showing location specific (point data) occurrence of different diseases of chickpea was prepared and overlayed on the above maps to study the relationship between occurrence of disease and rainfall and variation in altitude.

Results and Discussion

The occurrence of different diseases of chickpea in different physiographic regions and in different rainfall zones are presented in Figure 1. Map analysis shows that occurrence of diseases such as collar rot, dry root rot, and alternaria blight are more prevalent in the eastern Terai region and eastern Siwalik region as compared to the same physiographic region in the western side. These diseases are also found in the Middle Mountain region of eastern Nepal. Botrytis gray mold, stunt, black rot, and dry root rot have spread over the whole of Terai region. The rainfall distribution pattern map shows that the diseases are prevalent in the rainfall zone of 1200-2000 mm.

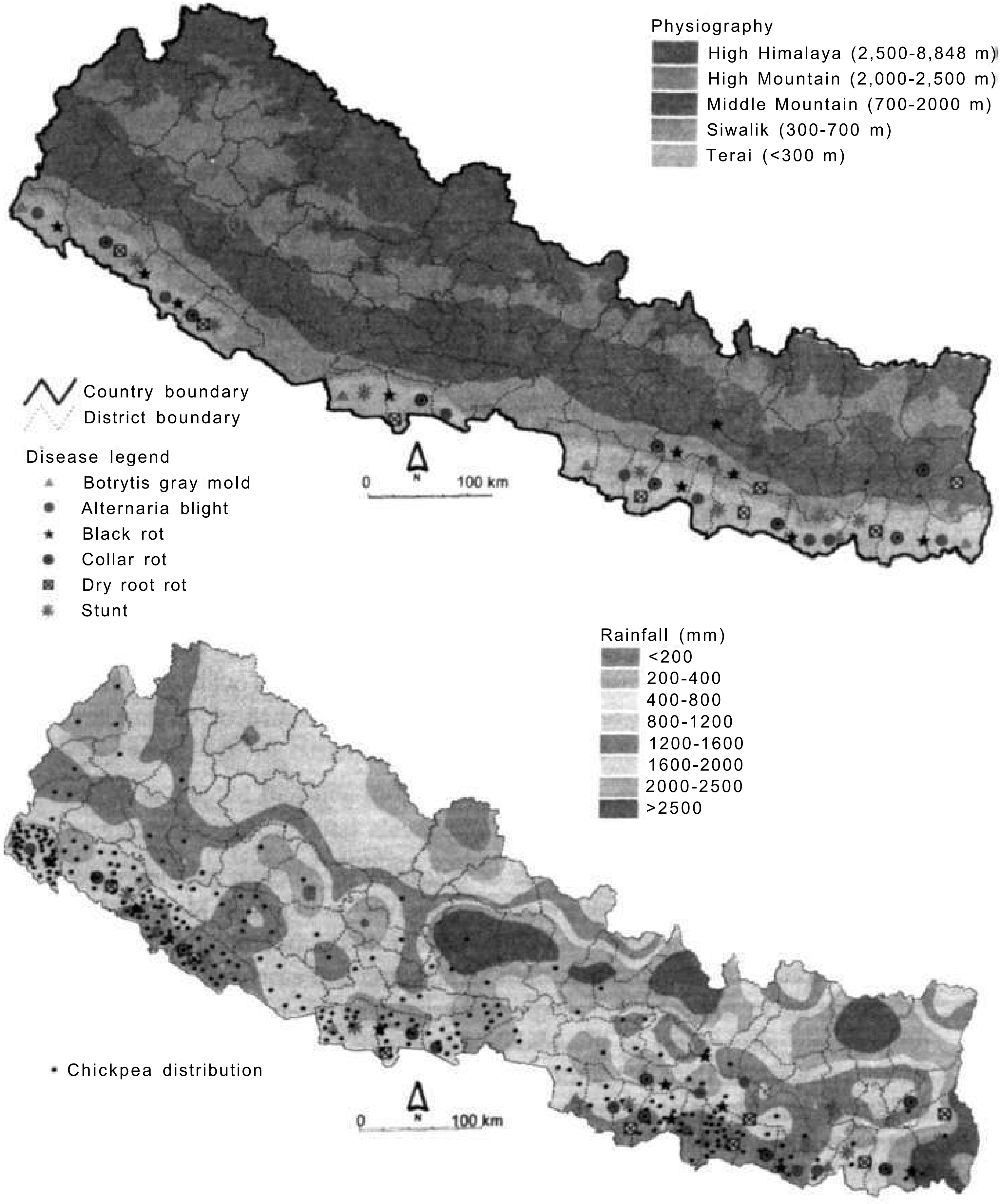


Figure 1. Diseases of chickpea in Nepal in different regions (top) and rainfall zones (bottom).

Conclusion

Geographic information system (GIS) helps in studying the interactive results of various themes through map overlay techniques. However, other layers of biotic and abiotic parameters may be considered for better interpretation on the incidence of diseases in different areas of Nepal.

Wheat Production Performance in Bangladesh: A GIS Analysis

D N R Paul[1], U K Deb[2], F T Bantilan Jr[2], M Moinuddin[2] and S Pande[2]

Introduction

Rice (*Oryza sativa*) and wheat (*Triticum aestivum*) are the two major cereal crops of Bangladesh. Information on production performance of wheat in Bangladesh is very important since the crop occupied about 708,000 ha and the production was 1.45 million t in 1997/98 (BBS 1998). The good performance of the crop is attributed to high-yielding varieties and improved management practices. The magnitude of growth and variability in wheat production has important implications for food security in Bangladesh. Two aspects of wheat production are important for policy purposes. These are growth in production and the situation of production risk (variability in production). This analysis has been focused on growth and variability in area, production, and yield of wheat in different regions of Bangladesh, for the pre-green revolution period (1951-66) (period I), green revolution period (1966-81) (period II), and post-green revolution period (1981-94) (period III).

Objectives

The objectives of this study are:

- To quantify the rate of growth in area, production, and yield of wheat for different periods in different regions of Bangladesh; and

1. Agricultural Statistics Division, BRRI, Gazipur 1701, Bangladesh.

2. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

ICRISAT Conference Paper no. CP 1419.

Paul, D.N.R., Deb, U.K., Bantilan Jr, F.T., Moinuddin, M., and Pande, S. 2000. Wheat production performance in Bangladesh: A GIS analysis. Pages 80-87 *in* GIS application in cropping system analysis - Case studies in Asia: proceedings of the International Workshop on Harmonization of Databases for GIS Analysis of Cropping Systems in the Asia Region, 18-29 August 1997, ICRISAT, Patancheru, India (Pande, S., Maji, A.K., Johansen, C., and Bantilan Jr., F.T., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

- To estimate the level of variability in wheat area, production, and yield for different periods in different regions of Bangladesh.

Data and Methodology

Secondary data were collected from the Bangladesh Bureau of Statistics. In this study, the country was delineated into 17 regions coinciding with the old 17 greater districts, viz., Dhaka, Mymensingh, Faridpur, Chittagong, Chittagong Hill Tracts, Noakhali, Comilla, Sylhet, Rajshahi, Dinajpur, Rangpur, Bogra, Pabna, Khulna, Barisal, Jessore, and Kushtia. Crop years 1971/72 and 1972/73 were excluded from this study due to abnormality in production in these two years.

Changes in area, production, and yield of wheat in Bangladesh were analyzed using statistical techniques and geographic information system (GIS) software. ArcView-GIS software was used to depict spatial changes in wheat productivity over time. With the help of this software, associations between growth rate in wheat area and yield were mapped for the three different periods focused in this study.

Results and Discussion

Analysis of contribution of different regions to total wheat area and production in the three different periods showed that average annual wheat area in Bangladesh was 50,000 ha while total production was 30,000 t in period I. During period II, both the average area and production of wheat increased to 187,000 ha and 288,000 t respectively. In period III, average wheat area and production increased to 581,000 ha and 1093,000 t respectively. Rajshahi, Rangpur, Dinajpur, Kushtia, Pabna, Mymensingh, Comilla, Jessore, and Faridpur are the major wheat-growing regions of Bangladesh. These regions contribute about 90% of the total wheat area and total wheat production in Bangladesh. Chittagong, Chittagong Hill Tracts, Noakhali, Sylhet, Khulna, and Barisal regions have a very small share in the total wheat area and production. The yields of wheat in Bangladesh during periods I, II, and III were 597,1542, and 1880 kg ha^{-1} respectively. Yield levels in all the regions increased during periods II and III (Fig. 1).

The estimated growth rates in area, production, and yield of wheat in different regions of Bangladesh are presented in Table 1. Based on the annual compound rate of growth, study regions were classified into four categories: Category A (high growth) includes regions, which achieved a growth rate of 5% or above; Category B (moderate growth) comprises regions, which achieved a growth rate of > 1 % but < 5 %; Category C (slow growth) includes regions, which achieved positive growth rate up to 1 %; and Category D (negative growth) encompasses regions that experienced negative growth rate in wheat area/production/yield in the reference period. During period I, 12 regions experienced high rate of growth in area and all these 12 regions except Khulna had a high growth rate in production. Khulna region experienced moderate growth in production during period I. A number of regions experienced negative growth in area (3 regions), production (2 regions), and yield (7 regions). Other regions had moderate growth in area, production, and yield of wheat in period I. In period II, 13 regions experienced high growth in area and all the regions experienced high growth in production. All the regions except Comilla, Barisal, and Sylhet experienced high growth in yield during this period. Faridpur region experienced negative growth in area while all the regions had positive growth in production and yield. During period III, Chittagong, Barisal, and Pabna regions had high growth in area while only Barisal region had high growth in production. Six regions faced negative growth in area while 8 regions had negative growth in production. Other regions experienced moderate growth in area and production. All the regions except Chittagong and Chittagong Hill Tracts had negative growth in yield during this period. These two regions had positive and moderate growth in yield.

Annual growth rate in area, production, and yield was computed for each of the three periods mentioned earlier. In all the three periods, Bangladesh as a whole had positive growth in wheat area. It had positive growth in production in periods I and II, but had a negative growth rate in period III. During periods I and II, annual compound rate of growth in wheat yield in Bangladesh was 0.57% and 9.19% respectively. On the other hand, yield declined at the rate of -1.5% per annum during period III. Thus, it appears that the growth in wheat production in Bangladesh in periods I and II was due to the expansion of area and increase in yield. Yield decline during the period III poses a serious threat to wheat production in Bangladesh, since there is unlikely to be an expansion in wheat area due to land scarcity.

For clear understanding of the growth scenario, the association between growth rate in wheat area and yield are discussed. All regions under study were classified into four types of associations:

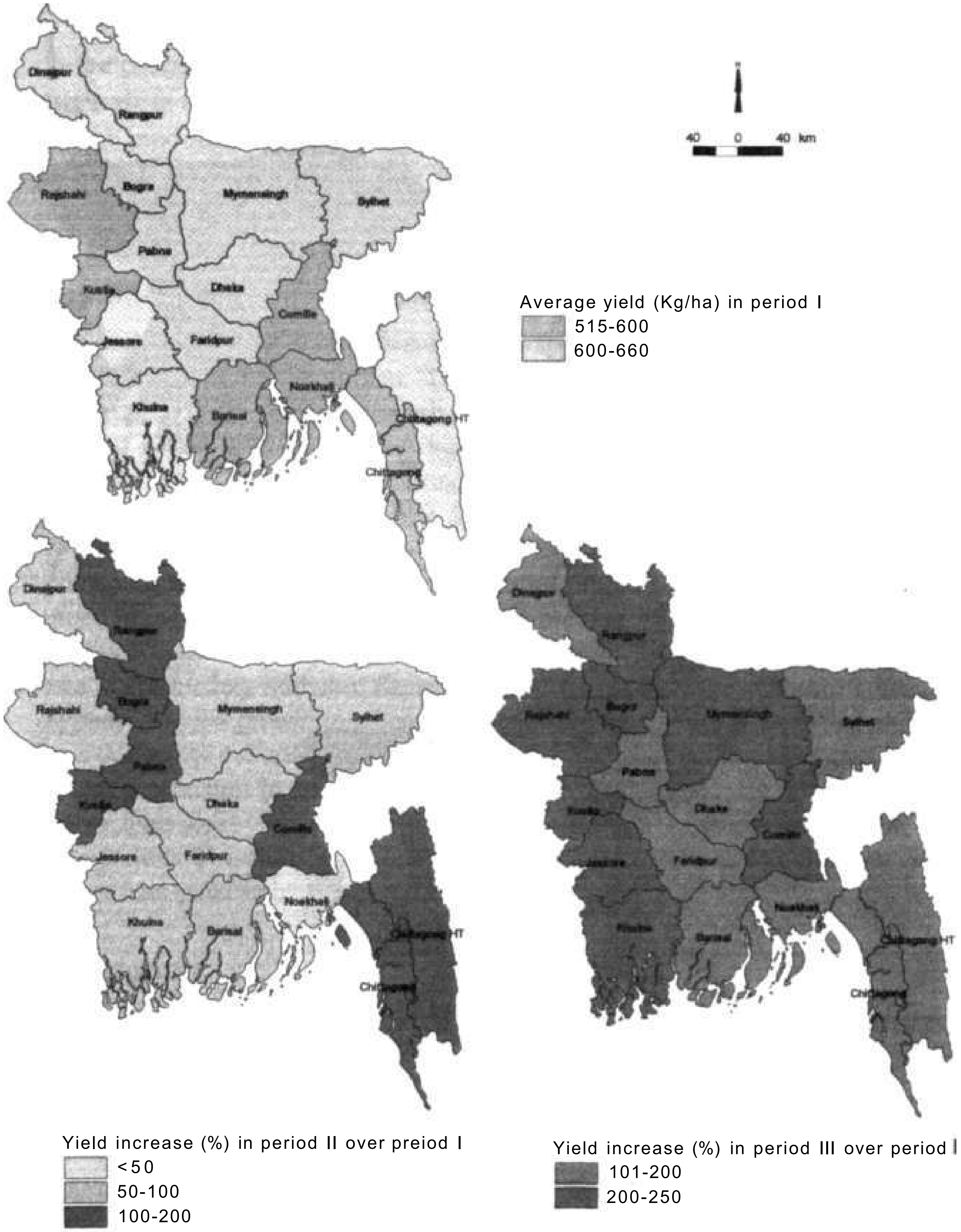
- AA - positive growth rate of area associated with positive growth rate of yield.
- AB - positive growth rate of area associated with negative growth rate of yield.
- BA - negative growth rate of area associated with positive growth rate of yield.
- BB - negative growth rate of area associated with negative growth rate of yield.

Association AA indicates that wheat is either replacing other crops or is grown in the newly cultivated area and the overall yield of wheat has increased. On the other hand, BA implies replacement of wheat by other crops or reduction in wheat cultivation and increase in yield in the remaining areas. Figure 2 shows the association between growth rate in area and yield. In period I, number of regions falling under category AA, AB, BA, and BB were 8, 6, 2, and 1 respectively; for period II, it was 16, 0, 1, and 0 respectively, while the corresponding numbers in period III were 2,6,3, and 6. Bangladesh as a whole had positive growth in area and yield during periods I and II. However, during period III, area growth has accompanied a negative rate of growth in yield.

Analysis of the magnitude of relative variability in wheat yield in different regions of Bangladesh showed that the coefficients of variation (CV) in wheat yield, after detrending, during periods I, II, and III were 10%, 20%, and 11% respectively. Mymensingh, Faridpur, Chittagong Hill Tracts, Noakhali, Rajshahi, Dinajpur, Rangpur, Pabna, Khulna, Jessore, and Kushtia had a significant increase (at 1% level of significance) in production variability. None of the regions except Chittagong had any statistically significant decrease (at 5% level of significance) in yield variability during period II compared to period I. In period III compared to period I, five regions (Chittagong Hill Tracts, Noakhali, Pabna, Barisal, and Jessore) had a statistically significant (at 1% level of significance) increase in CV of yield while eight regions (Dhaka, Mymensingh, Faridpur, Sylhet, Rajshahi, Dinajpur, Rangpur, and Bogra) experienced a statistically significant decrease in CV of yield. Other regions had no significant change in CV of yield. The regions that had an increase in CV of yield, contributed 18% in total wheat area and 17% of total wheat production

Table 1. Annual compound rate of growth (%) in area, production, and yield of wheat in different regions of Bangladesh for the periods 1951-66 (I), 1966-81 (II), and 1981-94(III).

	Growth rate (%) in periods								
	Area			Production			Yield		
Region	I	II	III	I	II	III	I	II	III
Dhaka	-0.65	4.97	1.74	0.90	10.60	1.12	1.55	5.63	-0.62
Mymensingh	13.12	15.90	4.69	12.23	24.85	2.93	-0.89	8.95	-1.76
Faridpur	15.87	-1.32	0.37	15.91	5.70	-3.16	0.04	7.01	-3.53
Chittagong	45.67	2.14	37.46	40.24	7.64	-27.57	-5.42	5.53	0.43
Chittagong Hill Tracts	-30.81	31.54	0.58	-27.15	33.84	2.61	-3.66	5.76	3.98
Noakhali	23.99	8.47	-4.42	23.14	13.79	-5.26	-0.85	5.31	-0.84
Comilla	31.62	21.44	-3.97	32.89	25.83	-4.67	1.26	4.39	-0.70
Sylhet	44.65	30.46	4.35	41.84	33.05	0.93	-2.82	2.59	-3.43
Rajshahi	1.54	8.43	0.89	1.71	14.80	0.52	0.18	6.38	-0.37
Dinajpur	5.95	24.17	3.13	7.58	30.32	2.59	1.62	6.15	-0.54
Rangpur	-3.78	16.78	-0.97	-3.63	23.65	-3.07	0.16	6.87	-2.04
Bogra	1.16	20.93	-5.27	2.97	27.36	-5.03	1.81	6.43	-0.05
Pabna	5.87	4.50	6.04	6.88	71.57	2.77	1.01	7.06	-3.27
Khulna	41.23	28.34	-2.66	3.88	35.62	-3.84	-37.35	7.28	-1.18
Barisal	37.43	15.23	7.05	33.93	18.54	8.51	-3.50	3.31	-1.45
Jessore	6.20	17.38	3.32	7.22	24.50	2.62	1.02	7.12	-0.70
Kushtia	0.72	11.05	-1.15	1.62	20.42	-2.97	0.90	9.37	-1.82
Bangladesh	3.61	14.59	1.10	4.18	23.78	-0.40	0.57	9.19	-1.50



Period I : Pre-green revolution period, 1951-66
Period II : Green revolution period, 1966-81
Period III: Post-green revolution period, 1981-94

Figure 1. Changes in wheat productivity in Bangladesh, 1951-94.

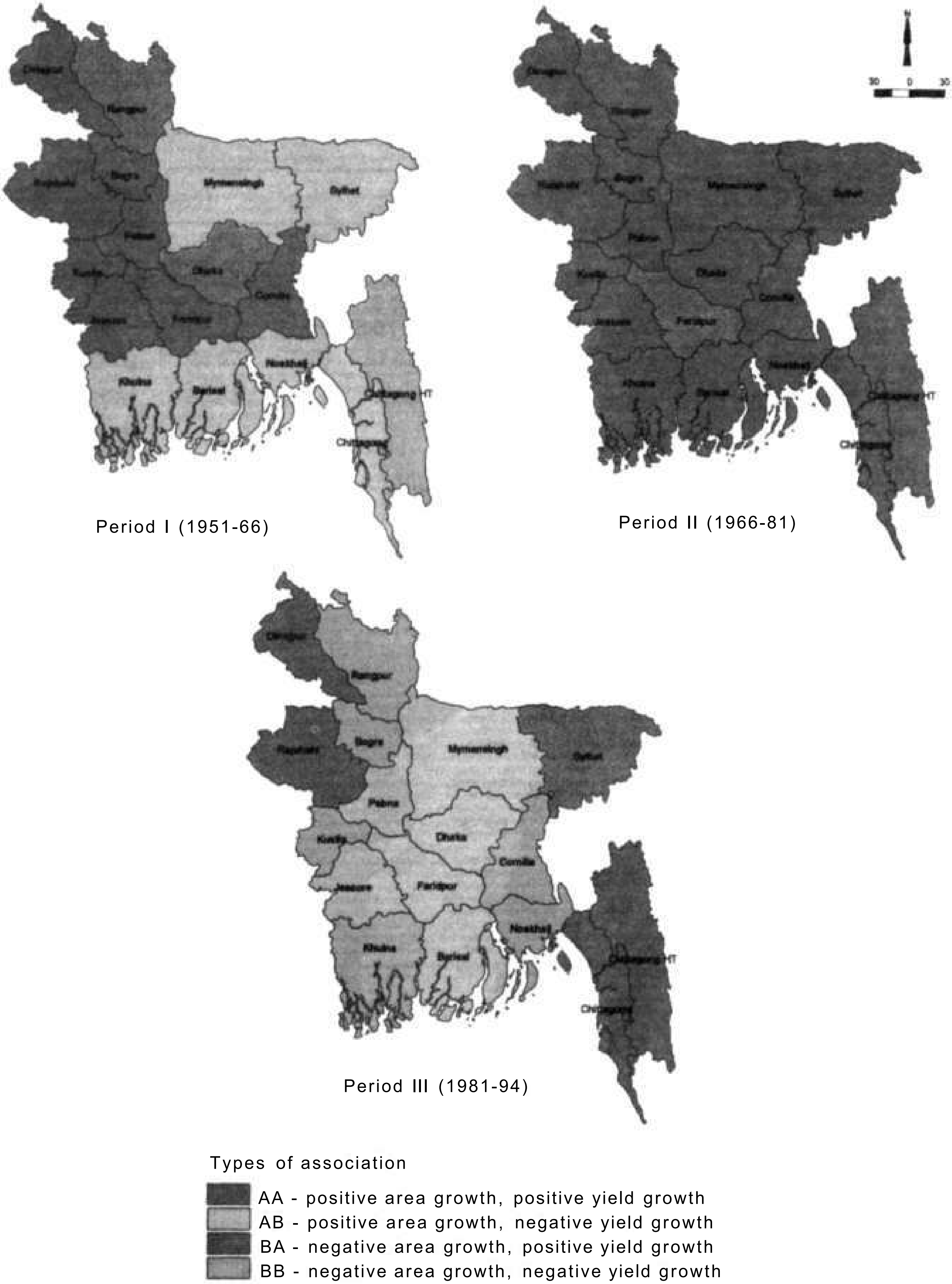


Figure 2. Association between growth rate of area and yield of wheat.

in the country during period III. On the other hand, those regions which had decrease in CV of yield, contributed 63% in total wheat area and 62% of total wheat production during period III. The implication of this finding is that reduction in yield fluctuation over time has increased the stability in wheat yield and thereby food security.

Summary and Conclusion

GIS can successfully be used to analyze the spatial and temporal changes in the production scenario of a crop. This study revealed that average area and production of wheat in Bangladesh has increased over time while contribution of total wheat area of different regions and production changed over time. Average yield of wheat in Bangladesh has progressively increased in succeeding periods as follows: 597,1542, and 1880 kg ha^{-1} in periods I, II, and III respectively. Yield in all the regions has increased in recent times as compared to the pre-green revolution period. In the pre-green revolution and green revolution periods, Bangladesh had positive growth in wheat area and production. But in the post-green revolution period, it had a negative growth rate in production, and yield declined at the rate of -1.5% per annum. Thus, it appears that the growth in wheat production in Bangladesh in periods I and II was due to the expansion of area and increase in yield but negative growth in wheat production in period III was due to declining yield. So, yield decline rather than yield variability possesses a serious threat to wheat production in Bangladesh. Therefore, emphasis should be on research for yield enhancement rather than yield stabilization.

Reference

BBS (Bangladesh Bureau of Statistics). 1998. Yearbook of agricultural statistics 1997. Dhaka, Bangladesh: BBS, Ministry of Planning.

Participants

B Bajracharya*
International Center for Integrated Mountain Development (ICIMOD)
P O Box 3226
Kathmandu
Nepal
Fax: +977 1 524509/536747
Phone: +977 1 525313
Telex: 2439 ICIMOD NP
Cable: ICIMOD, Kathmandu, Nepal

H Eswaran*
Director
International Programs Division
Natural Resources Conservation Services
United States Department of Agriculture
PO Box 2890
Washington, DC 20013
USA
Fax: +1 202 7204593
Phone: +1 202 690 0333
Email: Hari.Eswaran@ usda.gov

G Hyman*
Centro Internacional de Agricultura Tropical (CIAT)
Apdo, Aereo 6713
Cali
Colombia
Fax: +572 445 0073
Phone: +415 833 6625
Email: g.hyman @ cgnet.com

S P Kam*
Social Scientist Division
International Rice Research Institute (IRRI)
PO Box 933
1099, Manila
Philippines
Fax: +632 845 0606, 891 1292
Phone: +632 818 1926 Extn 592/387
Email: s.kam@cgnet.com
Telex: (ITT) 40890 RICE PM
Cable: RICEFOUND MANILA

Kamal Sah
Scientist
Planning and Coordination Division
Nepal Agricultural Research Council (NARC)
PO Box 5459
Kathmandu, Nepal
Fax: +977 1 521197/523653
Phone: +977 1 521149
Email: di@mos.com.np
Telex: 2262 Narani NP

B K Khandpal
Regional Centre
National Bureau of Soil Survey and Land Use Planning (NBSS&LUP)
New Delhi 110 012
India

* **Resource persons.**

A K Maji*
Senior Scientist
National Bureau of Soil Survey and Land Use Planning (NBSS&LUP)
Amravati Road
Nagpur 440 010
Maharashtra
India
Fax: +91 0712 522534
Phone: +91 0712 534664/534545/534615
Email: nbsslup@x400.nicQw.nic.in
Telex: 0715-7262 NBSL-IN
Cable: SOILANDBRU

Masood Ali
Head, Division of Agronomy
Indian Institute of Pulses Research (IIPR)
Kanpur 208 024, Uttar Pradesh
India
Fax: +91 512 250264
Phone: 252465/250264
Email: iipr@x400.nicqw.nic.in
Telex: 0325-471 IIPR IN
Cable: DALHANSODH

H B Nayakekorala
Research Officer/Deputy Director
Natural Resources Management Centre
Department of Agriculture
Peradeniya
Sri Lanka
Fax: + 94 8 388355
Phone: +94 8 388355
Email: dgaqri@sri.lanka.net

S P Pandey
Senior Soil Scientist
Soil Science Division
Nepal Agricultural Research Council (NARC)
PO Box 5459
Kathmandu
Nepal
Fax: +977 1 521197/523653
Phone: +9771521149
Email: di@mos,com.np
Telex: 2262 Narani NP

D N R Paul
Principal Scientific Officer
Agricultural Statistics Division
Bangladesh Rice Research Institute
Gazipur 1701
Bangladesh
Fax: +88 02 883416 (IRRI, Dhaka)
+88 02 883516 (CIMMYT, Dhaka)
Phone: 0681 2180 Extn 461
Email: irri.Dhaka@drik.bgd.toolnet.orq
cm@cimmyt.bdmail,net
Cable: RICERES

P Reich*
GIS Expert
Natural Resources Conservation Services
United States Department of Agriculture
PO Box 2890
Washington, DC 20013
USA

G S Sidhu
Soil Scientist
Regional Centre
National Bureau of Soil Survey and Land Use Planning (NBSS&LUP)
New Delhi 110 012
India

P Tulachan*
Farm Economist
International Centre for Integrated Mountain Development (ICIMOD)
PO Box 3226
Kathmandu
Nepal
Fax: +977 1 524509/536747
Phone: +977 1 525313
Telex: 2439 ICIMOD NP
Cable: ICIMOD, Kathmandu, Nepal

L Venkataratnam*
Group Head (Agriculture & Soils)
National Remote Sensing Agency (NRSA)
Balanagar
Hyderabad 500 037
Andhra Pradesh
India
Fax: +91 40 278648 or 279677
Phone: +91 40 279049
Telex: 0425 8039 NRSA IN
Cable REMOSEN

J White*
Centra International de Mejoramiento de Maíz y Trigo (CIMMYT)
Lisboa 27, PO Box 6-641
06600 Mexico
D.F. Mexico
Fax: + 52 595 41069
Phone: +52 5 726 9091 or +52 595 421 00
Email: i.white@cgnet.com
Telex: 1772023 CIMTME
Cable: CENCIMMYT

ICRISAT

Patancheru 502 324
Andhra Pradesh, India

I P Abrol*
Facilitator, Rice-Wheat Consortium
New Delhi, India

M I Ahmed*
Scientific Officer (GIS)

M Asokan
Scientific Officer (SEPP)

F T Bantilan Jr*
Senior Scientist (Environmental Physics)
Geographic Information Systems

F R Bidinger*
Regional Executive Director
ICRISAT Asia Region

S Chandra*
Senior Statistician

Y S Chauhan
Senior Scientist (Physiology)

U K Deb
Scientist (SEPP)

B Diwakar
Program Leader
Training & Fellowships Program

C L L Gowda
Coordinator
Cereals & Legumes Asia Network (CLAN)

C Johansen*
Project Team Leader, S4

P K Joshi
Senior Scientist (Economics)

J Kumar
Senior Scientist (Breeding)

M Moinuddin*
Associate (GIS)

R J K Myers
Project Team Leader, S2

R Padmaja
Scientific Officer (GIS)

K S Prasad*
Cartographer

A Ramakrishna
Scientist (Agronomy/CLAN)

K V Ravindra
Scientific Officer (Agronomy)

N P Saxena
Project Team Leader, Chickpea

S B Sharma
Senior Scientist (Nematology)

M Srinivas*
Scientific Officer (GIS)

Suresh Pande*
Senior Scientist (Pathology)

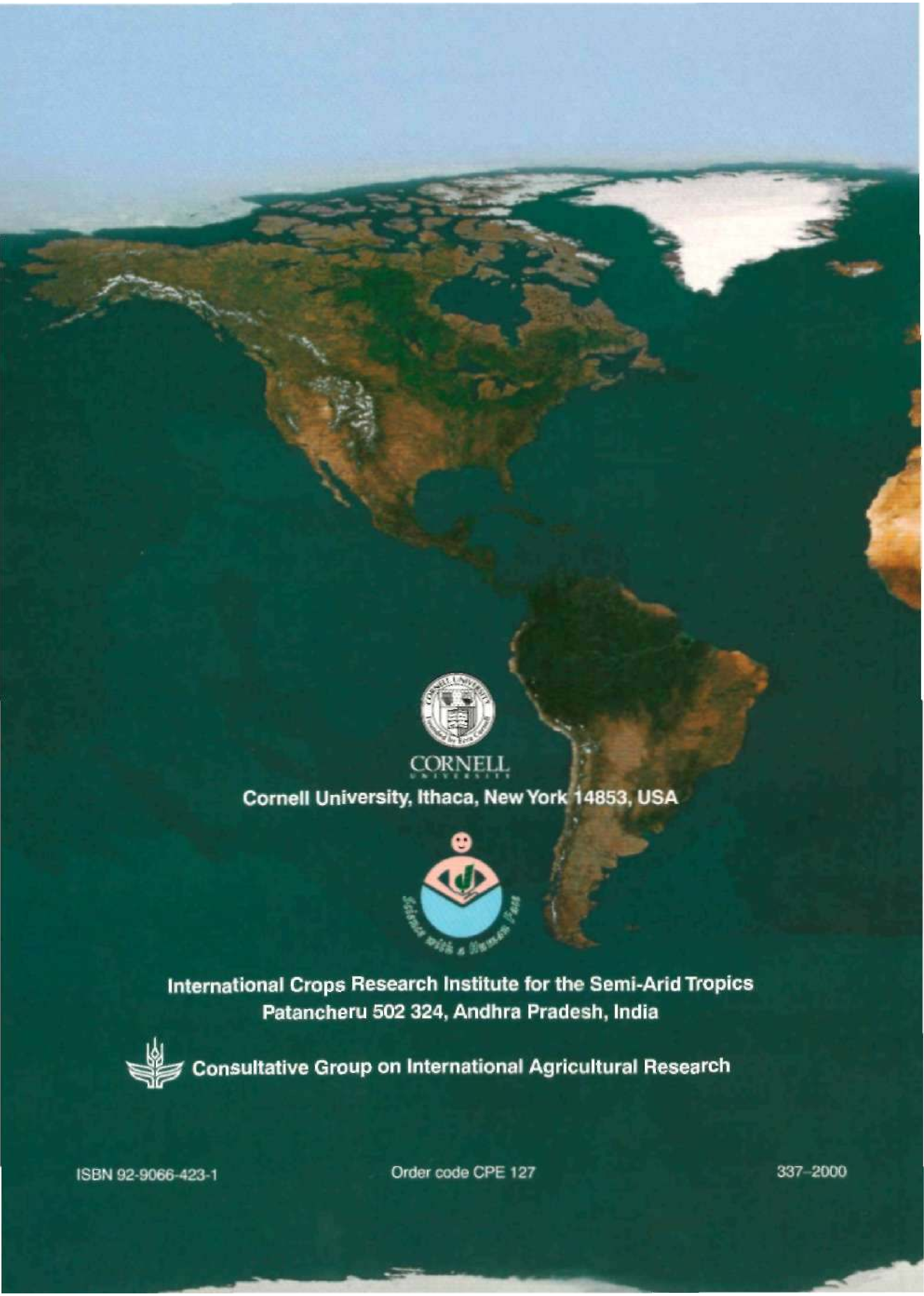
S M Virmani*
Project Team Leader, S3

About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the SAT. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.



Cornell University, Ithaca, New York 14853, USA

International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

Consultative Group on International Agricultural Research

ISBN 92-9066-423-1

Order code CPE 127

337–2000