UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

INTERAGENCY REPORT USGS-250

THE APPLICATION OF REMOTE SENSING TECHNIQUES TO INTER AND INTRA URBAN ANALYSIS

by

Frank E. Horton
Institute of Urban and Regional Research
University of Iowa
Iowa City, Iowa

May 1972

Work performed by the University of Iowa for the USGS Geographic Applications Program under USGS Contract No. 14-08-0001-12505, and for the National Aeronautics and Space Administration (NASA) under NASA Contract No. W-13165, Task No. 160-75-01-35-10.

[redacted]

STANDARD TITLE PAGE FOR TECHNICAL REPORTS	1. Report No. USGS-DO-73-ØØ2	2. Govt. Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle

The Application of Remote Sensing Techniques to Inter and Intra Urban Analysis

5. Report Date: May 1972

6. Performing Organization Code

7. Author(s): Frank E. Horton, University of Iowa

8. Performing Organization Rept. No.: IR-USGS-25Ø

9. Performing Organization Name and Address
U. S. Geological Survey
Geographic Applications Program
Washington, D. C. 2Ø242

10. Project/Task Work Unit No.

11. Contract/Grant No.
NASA W-13165
USGS 14-Ø8-ØØØ1-125Ø5

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, D. C. 2Ø546

13. Type of Report & Period Covered: Final Report

14. Sponsoring Agency Code

15. Supplementary Notes
Prepared by University of Iowa for USGS Geographic Applications Program under USGS Contract No. 14-Ø8-ØØØ1-125Ø5

16. Abstracts
This is an effort to assess the applicability of air and spaceborne photography toward providing data inputs to urban and regional planning, management and research. Through evaluation of remote sensing inputs to urban change detection systems, analysing an effort to replicate an existing urban land use data file using remotely sensed data, estimating population and dwelling units from imagery, and by identifying and evaluating a system of urban places utilizing space photography, it is determined that remote sensing can provide data concerning land use, changes in commercial structure, data for transportation planning, housing quality, residential dynamics and population density.

17. Key Words and Document Analysis. (a). Descriptors

Urban analysis, Urban planning, Housing quality, Land use mapping, Remote sensing, Aerial photography, Spaceborne photography

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 13 B

18. Distribution Statement	19. Security Class (This Report)	21. No. of Pages
Unclassified - Unlimited	UNCLASSIFIED	254
	20. Security Class. (This Page)	22. Price
	UNCLASSIFIED	

FORM NBS-867(1-70)

TABLE OF CONTENTS

Chapter | Page

Chapter | Page

LIST OF TABLES

LIST OF FIGURES

I. REMOTE SENSING APPLICATIONS TO INTER AND INTRA URBAN SYSTEMS: AN INTRODUCTION

Metropolitan areas and city systems undergo continual change brought on by forces from the broad political, economic, technologic, and social environment. Urban geographers have focused their research, in large part, toward understanding relationships among elements of intra and inter urban spatial structure. Two facts are apparent: (a) geographers can benefit from the data derived from remote sensing projects, and (b) past geographic research, as for example the derivation of spatial regularities concerning the relative location of people and objects (cities), can be utilized to refine and assist remote sensing methodology.

Cities may be viewed from a variety of perspectives. Perhaps the most advantageous view reflects the assumption that cities are "urban systems" which at any one point in time reflect a multitude of interacting social, economic, and physical processes. In order to understand this complex system called a city, and the processes which lead to its growth and development, data concerning an enormous number of subsystems and element relationships must be available to scientific researchers. On the other hand, effective urban planning and urban management, the use of urban process knowledge, requires information as to the state of the urban system within specific but different time frames.

A system of cities at any one point in time may also be viewed as the result of the processes listed above. The geographic literature is rich in studies, both theoretical and empirical, which focus on locational and functional facets of systems of cities. While sets of data necessary for the definition and evaluation of regional systems of cities is generally available in the U.S., different sets are collected within different time frames. Secondly, for foreign areas, particularly underdeveloped countries, information necessary for both regional and national planning and evaluation of the state of the city system is not readily available.

Monitoring macro and micro urban elements serves to describe the current status of urban activities and permit the measurement of change. While the monitoring function can take place in a variety of time cycles, continuous monitoring would, of course, give the greatest capability for understanding the cyclical nature of the processes being examined. Ultimately this means the recording and tabulating of urban transactions as they occur, always keeping current accounts of those phenomena of importance. The systems required to monitor total intra and inter-urban change would be enormously complex and fantastically expensive. To be sure, geographers, planners, operations-research investigators, and others are working on components of this problem, and, in some cases, subsystems of the intra-urban change detection system are being developed. Considerable experience and knowledge has been gained from basic and applied research into the nature of urban systems - to the point that some important elements can be delineated.

This report focuses on components of two theoretically different, but operationally similar, aspects of urban geography: (1) definition and analysis of central place systems, and (2) urban change analysis and detection. Both of the research areas overlap in a methodological sense and, therefore, are not so diverse as to preclude their examination within the context of a single work program.

Remote Sensing Potential

The day-to-day recording of a variety of urban transactions, such as new buildings, new street openings, population movements, the entrance, exit, and movements of commercial and industrial enterprises, urban flows, etc. combine to make it difficult to develop an operable urban change detection system. Employing conventional modes of monitoring these activities most often result in costs which are prohibitive. However not having information about the various subsystems in metropolitan areas, and the non-optimal decision making resulting therefrom is likewise costly. Presently, attempts at urban change detection systems rely heavily on data from conventional sources. Urban planning studies have also placed some reliance upon aerial photography to identify some elements of change, primarily that associated with land use.

In a system of cities context, remote sensing is seen as a data acquisition device which can provide timely and definitive data with respect to the makeup of regional systems of cities and their functional relatedness. Given the capability to define these systematic relationships and the data necessary for the monitoring and evaluation of change, information of value to geographers, regional and national planners, and decision-makers can be made available through computerized information systems.

It is the contention of the investigators of the Institute of Urban and Regional Research, both geographers and planners, that remote sensing can be applied to maintain current inventories of selected urban activities and thus has utility for urban change research. However, remote sensing cannot be considered a general solution for all urban information needs.

Inter Urban Studies: Systems Context

The location and functional makeup of cities and the spatial and economic relationships between cities has long been of concern to geographers, economists, and regional planners. As mentioned previously, the theoretical and empirical geographic literature focuses on the locational and functional aspects of regional systems of cities. Urban places act as nodes for the production and distribution of goods. In theory, their location and the goods which they distribute are inexorably interrelated. Theories put forth by Lösch and Christaller have provided the basis for extensive empirical research centering on defining urban locational processes.

In a more applied sense, understanding the economic interrelationships among cities and between cities and their hinterland yields valuable information to geographers attempting to deal with a wide range of processes and to regional planners attempting to plan for orderly economic growth and development. Regional and national planners, especially in economically developing countries, are faced with the tasks of providing a range of services to the central population, and facilitating economic growth. This two-fold task requires information concerning the existing system of production and distribution nodes, as well as information concerning the change in inter-urban relationships over time. Monitoring the outcomes of the implementation of public policy with respect to national and regional development is an important input to decision-making concerning the application or withdrawal of alternative policies whose purpose is to facilitate orderly development of the country's resources.

Intra Urban Change Detection: Systems Context

Remote sensing research within urban areas currently includes housing quality studies and the identification of land use, with preliminary investigations beginning in commercial structure and urban transportation. Extending experiments in remote sensing of urban environments to provide a data base for the maintenance of an urban change detection system also seems feasible. It is clear that we cannot provide, given the present state of the arts, a variety of social or economic information concerning households and firms, although we believe that functional relationships between the physical environment and the social and economic environment can be formulated.

Report Outline

The remainder of this report consists of five chapters dealing with remote sensing inputs to the general problem of obtaining data of utility for urban planning, management and research. Chapter II presents a conceptual structure and outline of an urban information system and provides a perspective for the empirical research of Chapters III, IV, V, and VI. A final chapter summarizes the work presented in the report and comments on general problems associated with research of this nature.

The overall conceptual structure provided in Chapter II is a result of collaboration by Drs. Kenneth J. Dueker and Frank E. Horton. The latter author served as principal investigator for the entire project. The problem addressed in the chapter is how to integrate remote sensing data with conventionally collected information in a system that describes and reports urban change. User requirements, data compatibility, spatial referencing, and imagery utilization problems are discussed, among others.

Chapter III describes research which compares imagery derived land use information with conventionally collected data. The study area is Washington, D.C. and the comparison data was provided by the Metropolitan Washington Council of Governments (COG) for two dates, 1968 and 1970. The imagery was available at three scales, approximately 1:50,000, 1:100,000, and 1:382,000. The major methodological problem was that the COG data is derived from "parcel" ownership records so that streets and quasi-public space is omitted from areal totals. A corrective adjustment for this problem is explored for the residential component. The results are quite positive in many respects. The responsibility for this work was that of the principal investigator.

The next chapter also deals with the Washington, D.C. region. Prof. Dueker contributed to this analysis. The primary purpose of the research was to explore the nature of the relationships among imagery derived data and variables tabulated by the U.S. Bureau of the Census for the 1970 Population and Housing First Count Summary Tapes. A correlation and multiple regression design attempts to determine the feasibility of replicating "census like" variables from high altitude imagery. The basic hypothesis must be considered tenable but very systematic research will be needed to establish operational procedures which have a high degree of reliability.

Chapter V discusses work done in collaboration with the USGS "Census Cities" project through the assistance of James Wray. Dr. John Mercer coordinated the research which involved imagery interpretation, field work, and local agency evaluation of products. The study area was Cedar Rapids, Iowa and the cooperation of the Linn County Regional Planning Commission, particularly Mr. Robert M. Donnelly, is acknowledged. The research utilized a nine category land use code adapted from the "Census Cities" project. Census tracts were the areal unit of observation and imagery was at a scale of 1:100,000 with 1:50,000 photography used as a check or interpretation. Tabular and graphic output, including First Count census variables, was provided to the planning commission for evaluation. The agency critique stressed the disparity between their normal working unit, traffic zones (100 in number), and census tracts (30 in number).

The sixth chapter was completed under the direction of Dr. Gerard Rushton. The focus of this research is on a regional system of cities, that is inter urban analysis. A space photograph of Atlanta, Georgia and the surrounding region taken by Apollo IX astronauts from 106 miles in altitude served as imagery for this work. Urban places were delineated and area measurements made, transportation routes counted, and other pertinent attributes of the system of cities recorded. A mathematical model and computer algorithm were developed and tested for the ultimate purposes of aiding in imagery interpretation and utilizing such inputs for regional studies.

The research presented in this report could not have been completed without the able assistance of research assistants from the Department of Geography and the Program in Urban and Regional Planning at the University of Iowa. Research assistants included Mr. Robert Ellinger, Mr. Fred Ermuth, Mrs. Nancy Hultquist, and Mr. Robert Schmitt, Ph.D. candidates in the Department of Geography and Mr. Joel Biggs and Mr. Brad Pearson students in the Program in Urban and Regional Planning. Drafting for the report was undertaken by Bill Stanley, Department of Geography.

We also owe thanks to Dr. Borden D. Dent, Georgia State University, Department of Geography for providing the base maps of Georgia appearing in Chapter VI. That department also provided a place from which the activites of the Atlanta field investigation could be coordinated. That assistance is greatfully acknowledged.

II. URBAN CHANGE DETECTION SYSTEMS: REMOTE SENSING INPUTS

The expected increase in the availability of data from satellite and aircraft imagery provides the impetus for greater concern with the development of geographic information systems for urban analysis. This chapter explores the possibility of remote sensing technology providing inputs to geographic information systems for urban change detection. Urban change detection refers to the general problem of monitoring the urban system and discerning changes that are occurring within that system that are of interest to urban planners, managers, and researchers. The geographic information system problem is one of extracting point, line, and area information from maps or imagery; interpreting the phenomena to be associated with those points, lines, and areas or patterns thereof; providing data file structures and storage techniques; setting up input mechanisms; providing for comparative analyses between data files; and producing output upon user demand in graphic, printed, or machine readable form.

Administrative recordkeeping systems such as building permits, and survey data such as census and origin-destination data have in the past proved to be useful information for detecting changes within cities. However, these kinds of information are expensive to collect and process; good studies are undertaken only infrequently. Further, the lag time between collection and data delivery is often excessive. Conventional aerial photography and more recently, color infrared imagery have proved extremely useful in providing inventories of changes in various urban subsystems at more frequent time intervals than conventionally collected data. The problem addressed here is to integrate remote sensing data with conventionally collected data in a system that describes and reports urban change.[1]

In order to successfully integrate remote sensing data with functioning urban change detection systems it is also necessary to describe a conceptual framework for encoding spatial data, particularly data that exhaustively partitions a region into polygons. Thus, this chapter also addresses alternative encoding schemes.

In the sections that follow an attempt is made to set forth the status and prospects for urban change detection systems and remote sensing inputs to these systems. Although there is a vast amount of technology available the system designer must select and assemble elements that can be integrated into a feasible and operational system capable of serving the needs and objectives of the user. Given that explicit objectives for urban change detection systems cannot be expressed very precisely without a city specific context, it is apparent that a vast number of alternative systems are possible.

Problem

Urban change may be partitioned into changes in the physical, social, and economic subsystems of the city. Remote sensing provides a means of discerning physical changes in the distribution of activities which in turn are related to social and economic changes within the system. Clearly an important problem area for research is the functional relationships between land use and other elements of the urban environment. Chapter IV, for example, explores the structural form of equations relating small area populations of urban areas to imagery derived variables. It is recognized that for many practical purposes imagery from remote sensors will only partially supplant conventional inputs to an overall change detection system. Other data such as from surveys or administrative recordkeeping systems will remain important inputs. The initial research task is to evaluate all data sources related to change and to identify those indicators which describe change in a way that it is useful to those who need information. Subsequently construction of systems which monitor those variables and reports data in final form to the users is necessary.

Different users have different requirements. Depending on the class of user, whether he be local, state or federal, the urban change detection system may or may not have to be linked to local or metropolitan recordkeeping functions. Thus total system design recommendations can be quite different depending upon the expected use and scope. If the use is primarily for intra urban area surveillance, it is imperative that the system be tied into an administrative recordkeeping function. If the purpose is for comparative analysis between areas or for analysis of regional systems of cities, then imagery alone may provide the necessary information. A later chapter (V) explores the problem of utilizing space photography for inter-urban analysis and although the present discussion does not directly address that topic much of the material is isomorphic.

Urban and regional planners have a long standing and for the most part unmet need, for small-area data on population, employment, and other activity data. The principal need of the urban planner and manager is current information on facilities and service demand and on the facilities and services which supply those needs within small areas. Although traffic zones and census tracts have proved useful in the past, experience has proved that basic land use data are often aggregated in several different and frequently incompatible ways (i.e., school districts, police districts). Therefore a smaller observational entity, say a city block or block face, provides the most desirable areal unit with respect to flexibility. Table 1 is a preliminary estimate of user requirements for land use data at various levels -- local, state, and national. Table 1 also classifies users in the broad functional categories and attempts to determine their need for land use data in terms of areal units and classification of land.

Population and employment are probably the most needed small area data, yet these data are least visible from imagery. It is extremely important that better accounting methods for population and employment changes be devised. This means that an effective recordkeeping system must be implemented in spite of fragmented jurisdictions and other problems or an appropriate method must be found for estimating population and employment by measuring variables that are visible from imagery, such as housing units and activity intensity. However, care must be exercised as

TABLE I.

User Requirements for Land Use Data
User Type vs. Area Size and Classification

USER TYPE	FUNCTIONAL TYPE	AREAL UNIT	L.U. CLASSIFICATION
NATIONAL			
	Community Development	Cities over 2500 pop. Counties	one-digit*
	Economic Development	Cities over 2500 pop. Counties	one-digit
	Human Resources	Cities over 2500 pop. Counties	one-digit
	Natural Resources	Counties	one-digit urban two-digit non-urban
STATE			
	Community Development	Townships	two-digit urban one-digit non-urban
	Economic Development	Cities over 100 pop.	two-digit
	Human Resources	Census tracts for cities over 25000 pop.	two-digit urban one-digit non-urban
	Natural Resources	40 acre parcels (1/16 section)	one-digit urban two-digit non-urban
LOCAL			
	Community Development	City block	4 digit urban 2 digit rural
	Economic Development	40 acre parcel (1/16 section)	4 digit
	Human Resources	City block	4 digit residential 2 digit other
	Natural Resources	40 acre parcel (1/16 section)	2 digit urban 4 digit non-residential

*One-digit classification of land use into general categories, such as residential, industrial, commercial, agriculture, etc.
Two-digit classification of land use breaks each general category into subdivisions such as single family residence, two-family structures, multi-family structures, etc.
Four-digit classification provides an extremely detailed breakdown such as distinguishing between retail uses.

relationships change. For example, Des Moines, Iowa increased its housing stock by 150 units but lost 10,555 persons in the period between 1960 and 1970. This exemplifies the potential need for well designed and detailed studies of urban areas from the structural standpoint which can feed relationships to highly automated change detection systems relying essentially on imagery input.

Systems for Urban Change Detection

Urban change detection, as discussed here, focuses on the measurement of changes in the urban environment and their relationships to increased demand for urban services. This is a legitimate focus in light of the primary objectives of user groups.

The purpose of this section is to evaluate the requirements for surveillance or monitoring of urban subsystems and relate those requirements to urban information system efforts which are underway or being planned in many metropolitan areas. Thus, the emphasis is upon the surveillance component of urban information systems useful to planners, operational decision-makers, and researchers concerned with urban and regional analysis.

Monitoring Urban Systems

Monitoring urban change provides a basis for the description and maintenance of the current status of urban activities. The monitoring function can take place in annually, semi-annually, monthly, daily, or continuous time cycles. Continuous monitoring of course, would provide the greatest capability for understanding the important cyclical nature of the urban processes under examination. In general, to monitor the current status of urban activities, ultimately means the recording and tabulating of urban transactions as they occur, always keeping current accounts of those phenomena of importance to urban analysts and decision-makers in cities. Monitoring urban systems by keeping current accounts of urban activities requires a broader administrative and functional framework for metropolitan recordkeeping than now exists.

Figure 1 illustrates, in terms of a generalized flow chart, an information system having the potential to provide information concerning urban change. A basic hardware-software system is identified, an input mechanism, data files, and an output system. It also attempts to illustrate the user environment which consists of a user system, data sources and data users. The primary basis of the input system is geocoding which includes all forms of geographic identification of data, entity transformation, image processing, and of course, conversion to machine-readable form. Similarly, the software system is broken into elements of retrieval, utility and statistical subsystems. The data file system separates data into disaggregate data, areal units summaries and time cycle summaries. The output system identifies forms of output such as a report generator, graphic display subsystems, mapping and derivative machine records. Finally, potential data sources and users are identified. As indicated the system should allow for adequate information flow to a broad spectrum of planning processes.

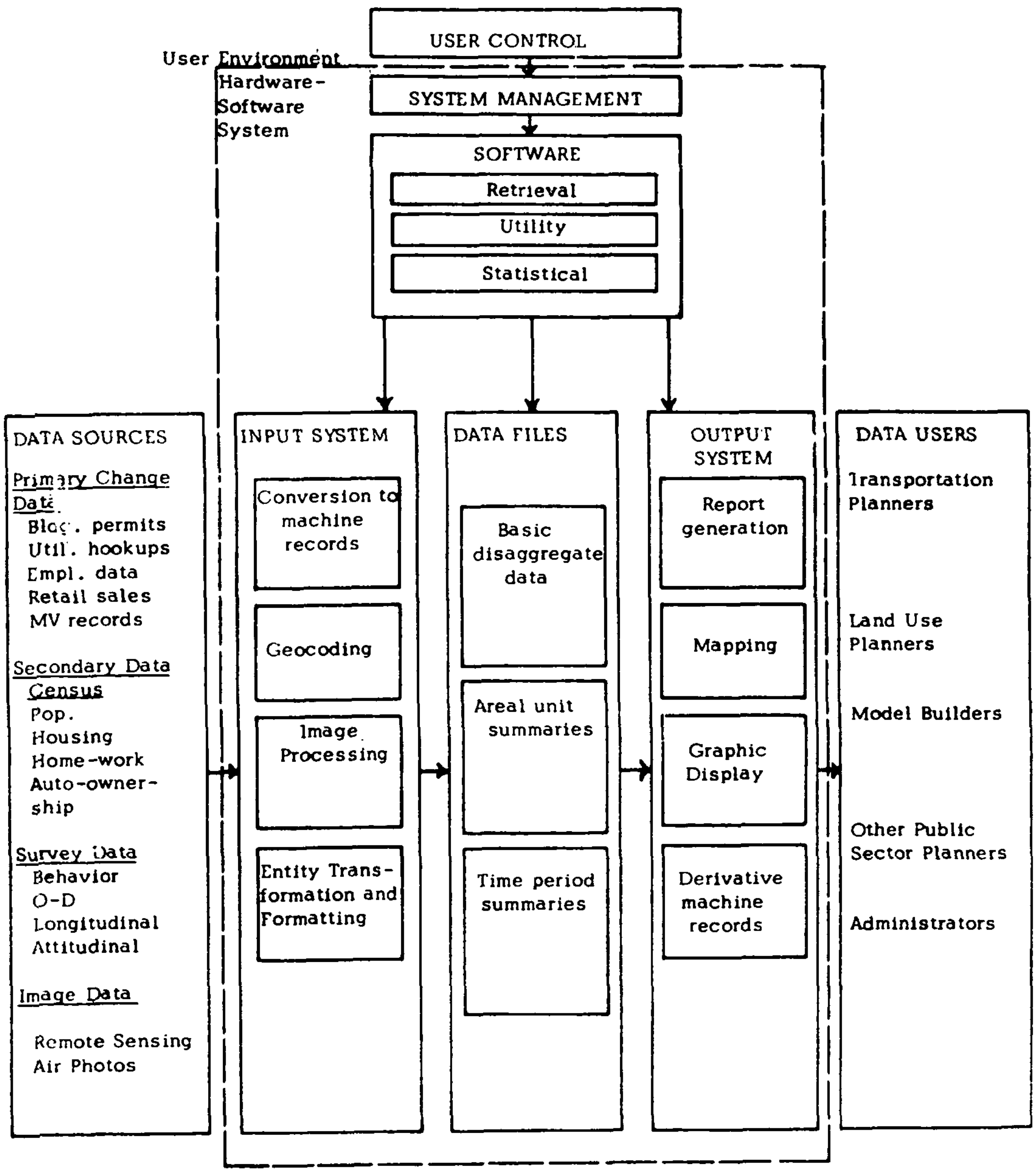


Figure 1. Urban Planning Information System Elements with an Emphasis on Urban Change Detection

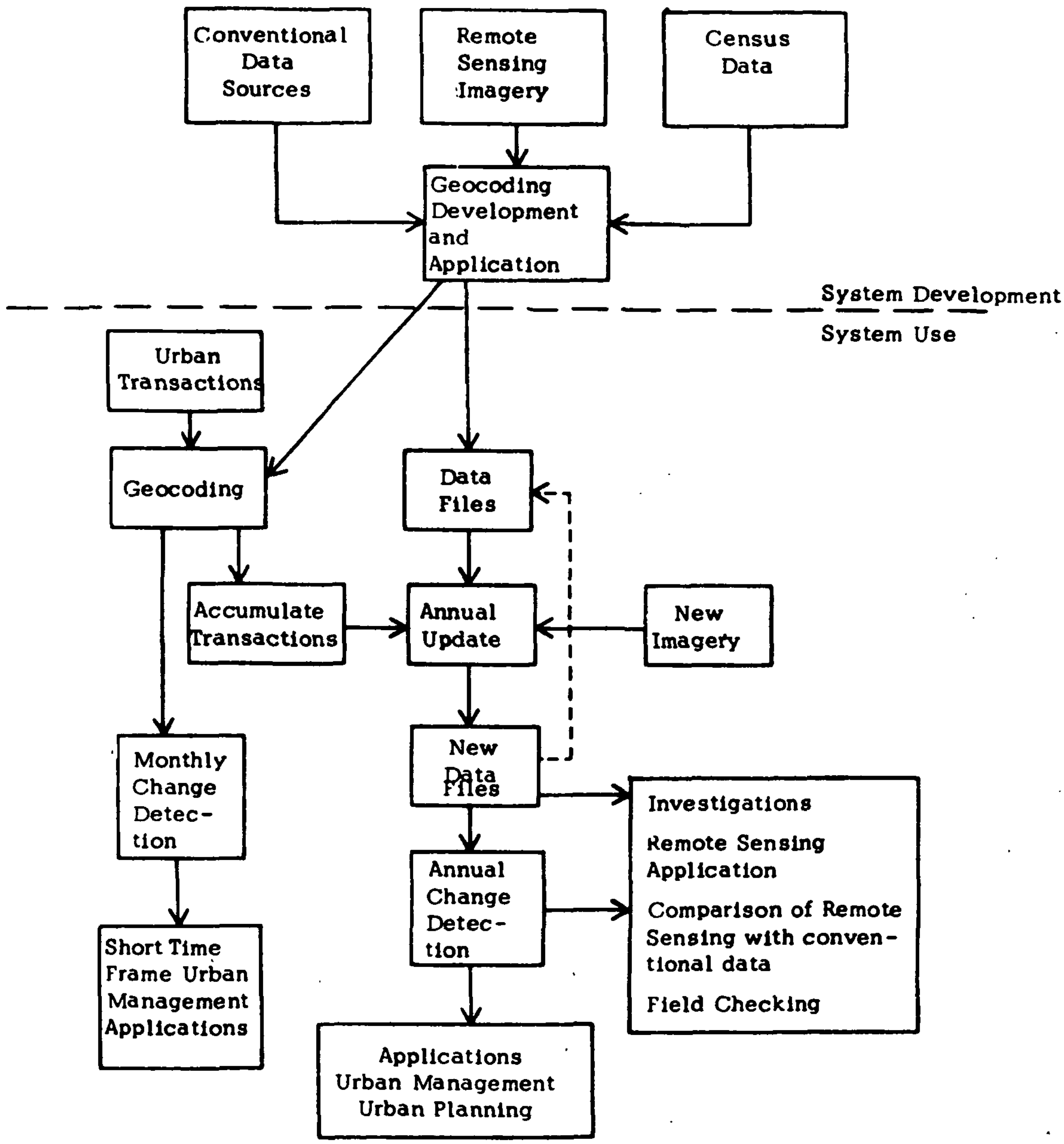


Figure 2 - Flow Diagram of Operational Urban Change Detection System

Four major data sources can provide inputs to operating urban information systems. These data sources consist of primary data from operating agencies, secondary data collected and usually aggregated by others, survey data placed directly into the system, and graphic data and other data items potentially available from remote sensors.

Imagery data are of two forms: 1) maps or other forms of graphics, and 2) imagery produced by remote sensing techniques. Phenomena and their attributes which can be observed directly or indirectly from imagery are numerous. The potential identification of a myriad of urban phenomenon could easily tax our ability to store such information. Translating direct observation of phenomenon from imagery into machine-readable form currently requires tedious coding and the definition of taxonomies necessary to define particular phenomenon as well as attributes of that phenomenon. Further coding is required in order to identify locational attributes of the data items.

In many instances, imagery will provide appropriate data for describing physical aspects of the urban system. However, in many instances data concerning a variety of socio-economic processes are also needed. For such items a source of significance is the use of surveys, either complete inventories or sample surveys. A complete inventory such as the United States Census of Housing and Population or urban land use inventories provide an exhaustive data set which requires considerable monetary resources to manipulate, update, and utilize effectively. On the other hand, application of scientific sampling methodologies normally can provide reasonably accurate data about many of the phenomenon of interest to urban analysts and planners. Sample surveys are particularly useful in identifying attitudes and preferences of urban inhabitants and in specifying the revealed behaviors of urban inhabitants. Attitudinal surveys attempt to anticipate people's behavior whereas behavioral surveys such as the Origin-Destination study, record the actual behavior of the respondent. Data from these types of surveys are or should be essential inputs into operating urban information systems, although further research could well indicate that such data might also be provided efficiently through remote sensing. While it has been demonstrated that evaluation of variables describing the physical aspects of urban systems can provide clues about socio-economic aspects of the system, current technology is relatively meager. Extensive financial inputs for further research into the acquisition of information related to socio-economic processes should be given top priority.

The administrative recordkeeping functions of local public agencies provide a wealth of data for use in a broader planning and management context. For example, building permit applications are used to ensure that new construction is inspected and meets the building code provisions. Similarly, building permit applications can be used to determine areas of growth within the community and the intensity of that growth. Although it seems intuitively obvious that administrative recordkeeping functions can provide useful data to planners and managers within the urban sector, these data have not been utilized effectively because of difficulty in translating administrative forms into machine-readable information and in relating street addresses to analysis areas. A major difficulty has been a lack of coordination and cooperating between various local and state agencies to develop metropolitan-wide systems. Remote sensing applications, if carried beyond segmented and individualized efforts to a developed and operational technology, would effectively bypass many of these considerable handicaps.

System Elements

There are three important dimensions or elements associated with urban information systems. The first is a methodology for specifying a spatial location, the second deals with temporal questions, and the third is related to the kind of phenomena being observed.

Methods of spatial location, often termed geocoding, refers to means of specifying location in a machine-readable form. Essentially there are three alternative methods for identifying location: 1) direct digitizing, 2) area unit codes, and 3) unique addresses such as street addresses which then must be translated to geographic coordinates or areal unit codes. Direct digitizing of observations to x-y coordinates is the usual method chosen when the data source consists of imagery, maps or other graphics. Assignments of areal unit codes to observations is a usual procedure when conducting surveys. Depending on the type of survey and the sample size, areal units will vary from individual blocks to aggregations of census tracts. Finally, a procedure which is gaining greater acceptance is the machine translation of street addresses to either geographic coordinates or to areal unit codes. The street address translation process requires a Geographic Base File, specifying a directory of street address ranges for each areal unit. The street address translation process obviously allows greater utilization of administrative recordkeeping files for use in urban planning and management. Whatever its nature an operational urban information system must have the capability to translate data from imagery, surveys, and administrative recordkeeping functions and relating those data to a common geographic base.

The frequency with which the data base is updated depends upon the use of the data and the rate at which specific phenomena change status. Determination of the appropriate frequency for acquiring new imagery, surveys, or evaluating data from recordkeeping functions must be determined. Definitive decisions regarding daily, weekly, monthly, annual or bi-annual updating of specific data elements is a necessity. Clearly, data items requiring constant updating and maintenance should not be obtained by re-inventory methods, but by imagery analysis or continuous monitoring of administrative recordkeeping. Surveys and inventories should be confined to that data which cannot be obtained by any other method.

The third information system element deals with the kind of phenomena to be measured. This element has continually plagued urban analysts, managers and planners. While it is easy to point out that social, economic, and physical phenomena should be measured and integrated into information system files, specific identification of needed data items and their attributes varies from place to place and system to system. A case in point involves the concept of population density. Low income families, regardless of the density, require many more and different public services than do middle and upper income groups. A high density of children implies quite different service demands from the same density of adults. Further, the level of areal reporting, that is the size of the tract or zones utilized in the system, can make some measures quite insensitive to real changes in the situation being described. Consider, for example a twenty-five story high rise with four apartments per floor and having a base of one/fourth acre (a square with edge of about 104 feet). Assume each apartment contains three people and that the complex is located on a wooded twenty-five acre tract. In comparison, consider a similar twenty-five acre tract subdivided into one/fourth acre lots, each with a single dwelling unit with three occupants. A few simple calculations will show that population per unit area is equal for the two tracts; yet no one would deny that two very dissimilar residential situations exist. Combined with demographic and economic elements such situations produce quite complex patterns that require careful scrutiny before decisions are made as to the variables included in an urban information system.

In the above example, 'open space per person' might be a relevant variable or perhaps even 'open space per unit'. While it is apparent remote sensing can provide some of the data items desirable for urban change detection the overall capability of the technique for this purpose is yet unknown. As refinements in methodology and advances in technology are made a continuing research program can be utilized, through feedback mechanisms, to expand the utility of the developments for urban and regional research. Urban researchers, administrative functionaries, and remote sensing experts, through cooperative research efforts and experiments, may greatly extend the domain of application of remote data acquisition methodology.

It should be apparent from the previous discussion that data sources and system elements must be integrated into an information system in order to achieve current data about social, economic, and physical variables by small areas for planning and management. Such integration requires an explicit statement of objectives based on the data needs of the prospective user group and the nature and scope of the desired system.

A System for Urban Change Detection

Given the previous element definition, it is possible to illustrate a conceptual structure for an urban change detection system having general applicability. Figure 2 schematically portrays such a general system, the nature of its use, and the means by which updating the system invokes the detection of change.

Obviously there is the distinction between system development and utilization. The significant aspect here is that the original development should permit and even encourage flexibility and growth, thereby allowing the introduction into the system of developing technology. Tracing through

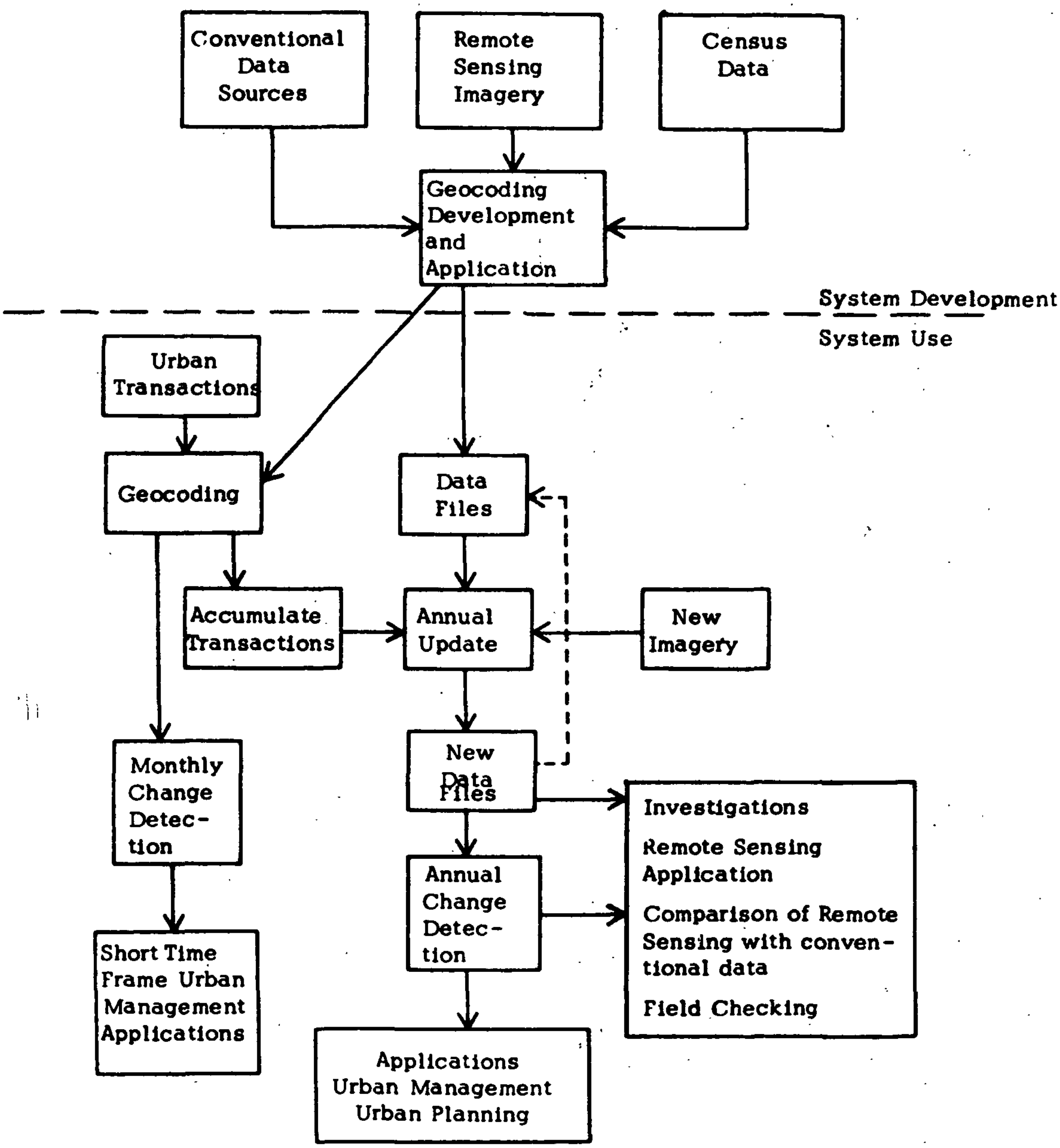


Figure 2 - Flow Diagram of Operational Urban Change Detection System

the direction of flow shown in the diagram suggests another important point, namely that urban change detection has three distinct components: 1) aggregation of urban transactions within time intervals is necessary, 2) the state of the urban system is described by reporting the level or current value of all the separate variables for a specified time, and 3) change detection is possible by comparing the state of the urban system at two different points in time. When information from imagery and aggregations of transactions for two different time periods are compared change can be monitored and described. Inventory methods or say a single space photograph provides only a "picture" or status report for a point in time. This makes it apparent that the temporal aspects of recording, aggregating, and comparing information must each be given careful thought in developing and utilizing a change detection system.

While initial contemplation may suggest an annual update urban transactions can be accumulated and reported much more frequently. Information from operational remote sensing platforms can be expected to be available on a frequent basis also. Some planning needs and especially research needs will find yearly updates insufficient for "real time" analysis and evaluation, but many other uses would find such data adequate. Almost any advances would be beneficial that improve upon the current situations where data describing the status of the urban system several years ago is used to predict the status several years hence, while neglecting the current state of relevant variables that could easily be discerned.

Two research efforts related to general urban change detection of interest are underway. One is the USAC Municipal Information System Projects being undertaken in six cities, two of which are comprehensive while the others are focusing upon a particular subsystem. Charlotte, North Carolina and Wichita Falls, Texas are developing complete municipal information systems that should provide for urban change detection.[2] However, these systems focus primarily on the needs of urban administrators and managers, thus the needs of planners and researchers may not fully be met. The U.S. Department of Transportation is funding research and development in information systems to monitor urban change for purposes of the continuing phase of urban transportation planning.[3] This work focuses on planning needs. Budget requirements for transportation planning may force choices as to geographic scale and frequency of update that might not be suitable for other users. Although it is probably not possible to design a system to be of use to all kinds of users, additional research needs to be done that provides sensitivity testing of important system elements such as areal aggregation, temporal frequency and the kinds of phenomena to be observed and collected as a function of user needs. In addition, it is important that we obtain the marginal costs of responding to particular needs. For example, how much additional cost is involved in using the city block as contrasted to the traffic zone as a unit of observation. Is the additional cost worth satisfying the additional user? Similarly, is an annual update as contrasted to a bi-annual update worth the additional cost in terms of satisfying additional users?

Encoding Spatial Data

The purpose of this section is to develop a conceptual framework for encoding spatial data for incorporation into urban change detection systems. Geographic information systems differ from other information systems in the explication of locational identifiers, and the importance of the locational identifiers in manipulating data. Spatial data are stored in machine-readable form, not as the image itself, but in some abstract form, such as intensity values for small grid units or attributes of areal units.

A frequently used approach is to relate land use data to a fixed grid. An example of a fixed grid would be one based on a lattice containing equal sized areas, such as a square mile as contrasted to variable sized areas such as counties or census tracts. The predominant land use or distribution of land use by percentage or acres are associated with the observational grid or areal unit. Aggregating or generalizing interpreted land use data to a larger area results in some information loss, but the data input, storage, and retrieval is made easier. Knowing that 50 percent of a particular square mile area is residential provides less information than replicating the image which indicates how the residential land is distributed in the area and its proximity to the other land uses in the area. Storing data in an aggregated form limits the kind of questions that can be answered but greatly simplifies the geographic information system requirements. If in fact, however, this mode of operation is sufficient in terms of user needs it is surely preferred to undertaking the tremendous systems problems of replicating areas from imagery in digital form. However, as research and planning goals become more ambitious our need to replicate images in digital form will become greater.

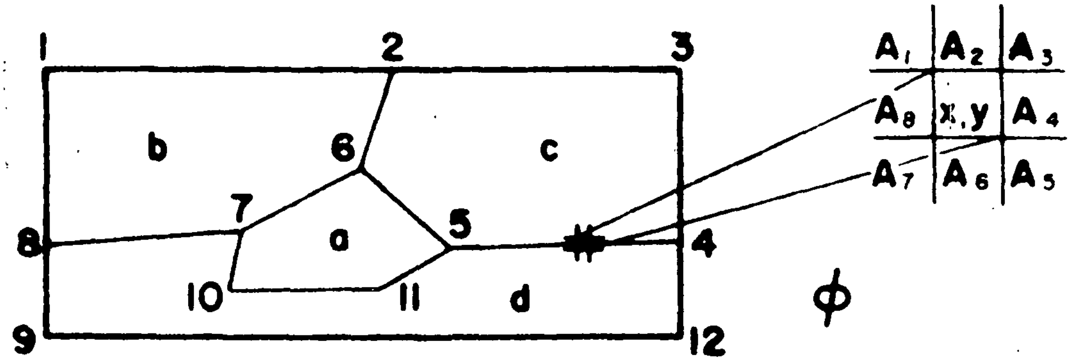
The subset of spatial data that are addressed here are those phenomena, such as land use, ownership patterns, and vegetation coverage, that can be exhaustively partitioned by type or class into regions described as polygons. For example, assume that an aerial photograph has been exhaustively partitioned into a set of polygons that identify residential, non-residential, agriculture, wooded areas, and similar land use regions. Replication of these various sized regions in digital form usually is done as a sequence of coordinate values or equivalents describing the perimeter of each area.

Technical problems in the development of a geographic information system in the generic sense can best be approached by developing a conceptual framework for encoding points, lines, and areas and then evaluating alternative ways in which this geographic data can be input, stored, retrieved, and output. Clearly, the major issue is the efficient manipulation of geographic data. Once that issue is determined, any number of data items related to a specific point, line or area can be included providing additional storage allocation is made.

All elements of the information system including input and output must be viewed in the context of handling geographic data encoded as points, lines, or areas. For example, data might be abstracted from imagery in terms of coordinates for points, and areas encoded as a sequence of points. Data might then be stored as coordinate values for points making up areas, and the data might be displayed as line segments making up the system of areas. Clearly, the input, storage, and output encodings are not independent. Translation from one stage to another must be thought out in advance.

Figure 3 illustrates alternative encoding methodology. Depending upon ultimate needs, and the storage media and file structure environment, not all possible encoding schemes need be utilized. However, more than one is usually needed to provide redundancy for editing, error detection, quality control, and completeness. Some encodings can also be generated from others, which provides the means for edit. Each of the procedures listed have a variety of advantages and disadvantages associated with them when viewed in light of the storage, comparison, retrieval, and output elements of the geographic information system.

The choice of an encoding method from the alternatives listed in Figure 3 must be made considering: 1) usefulness in terms of purpose, 2) ease of data capturing or encoding, 3) ability to be generated from other encodings for error detection, 4) ambiguities, caused by non-unique identification, 5) ease of synchronizing image data to descriptive data at input, and 6) storage media and file structure availability. When comparing these criteria with the possible encodings, some encodings are more



Possible Encodings

1. Areas encoded as polygons made up as a sequence of points
   E(a): A(6,5,11,10,7,6)*
   E(b): A(1,2,6,7,8,1)

2. Areas encoded as being contiguous to other areas (where Ø is the area outside the area system)
   E(b): A(c,a,d,Ø)
   E(a): A(c,d,b)

3. Line segments encoded in relationship to their end-points and their contiguity to areas
   E(1,2): A(b,Ø)
   E(1,8): A(Ø,b)
   E(2,3): A(c,Ø)
   E(2,6): A(b,c)
   E(6,2): A(c,b) } reverse encoding for redundancy edit

4. Points encoded as being connected to other points
   E(1): A(2,8)
   E(2): A(1,3,6)

5. Points encoded as being related to areas
   E(1): A(Ø,b)
   E(2): A(Ø,c,b)
   E(3): A(Ø,b)

Figure 3 Alternative Methods of Encoding Geographic Data (1 of 2)[4]

---

*Read as the entity is area a and attributes are a sequence of point numbers 6, 5, 11, 10, 7, and 6.

6. Small grid units encoded as whether part of line segments or not
   E(x,y): A(0 or 1) absense or presence of being on a line segment.

7. Small grid units encoded as whether they are same as contiguous grid units: $E(x,y)$: $(A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8) = (0, 0, 0, 1, 0, 0, 0, 1$

8. Point Connectivity Matrix

	1	2	3	4	5	6	7	8	9	10	11	12
1	0	1	0	0	0	0	0	1	0	0	0	0
2	1	0	1	0	0	1	0	0	0	0	0	0
3	0	1	0	1	0	0	0	0	0	0	0	0
4	0	0	1	0	1	0	0	0	0	0	0	1
5	0	0	0	1	0	1	0	0	0	0	1	0
6	0	1	0	0	1	0	1	0	0	0	0	0
7	0	0	0	0	0	1	0	1	0	1	0	0
8	1	0	0	0	0	0	1	0	1	0	0	0
9	0	0	0	0	0	0	0	1	0	0	0	1
10	0	0	0	0	0	0	1	0	0	0	1	0
11	0	0	0	0	1	0	0	0	0	1	0	0
12	0	0	0	1	0	0	0	0	1	0	0	0

9. Area Connectivity Matrix

	a	b	c	d
a	0	1	1	1
b	1	0	1	1
c	1	1	0	1
d	1	1	1	0

10. Coordinate definition of:

   a) points
   b) area bounds
   c) area centroids

Figure 3 Alternative Methods of Encoding Geographic Data (2 of 2) appropriate than others for typical uses of image data in machine-readable form. For example, areas encoded as polygons (encoding method #1) is highly useful in itself, can be used to generate other encodings, and can be encoded with ease. Conversely, areas encoded as being contiguous to other areas (#2) is less useful and may not uniquely identify an area when two separate areas are wholly contained within the same larger area. Also, method #4 is difficult to encode directly, although the encoding can be generated from method #3.

The input problem can be considered a problem of digitizing and coding a sequence of points that make up an area, or a line segment. Alternatively, the image could be scanned and encoded as small x-y cells which are or are not a part of a line segment. The data storage problem is one of selecting the appropriate encoding method to meet retrieval needs and at the same time be compatible with the file structure and medium upon which the data are stored. Pattern recognition type queries may require contiguity characteristics about small grid units be stored in a direct access mode so as to assemble homogeneous regions for comparison to a mask. Other queries might require comparison of two polygon sets, such as determining areas of vacent land use with areas of land suitable for industry. In this case the existing land use data set would be compared to the land capability data set. Thus data must be encoded to make area description and area characteristics accessible and comparable.[5]

Imagery Generation for Urban Analysis and Planning

Thus far, the nature of the change detection system elements have been discussed without addressing the nature of the data acquisition system. Given the previous discussion it is clear that the remote sensing system required could have a wide range of variability with respect to scale and resolution parameters. For example, evaluation of changes in the amount of land devoted to urban uses could utilize small scale low resolution photography while delineation of housing quality might require high resolution, large scale photography.

It would appear, that the most parsimonious data collection system for urban environments would contain multiple platforms with varying capabilities which could be called on when necessary. Such a system would require a minimum of two platforms, one a satellite and the other a high altitude aircraft with a variety of photographic sensors for small and large scale photography.

This combination of platforms would provide a cost effective system for raw data acquisition which could be called on when federal agencies would require comparative data or when local agencies require updates to existing data files. Both the aircraft and spacecraft might have multiple missions in the sense when they were not required for urban surveillance they may be acquiring data for other agencies requiring earth resources data. This is particularly true of the spacecraft.

It would appear that any attempt to develop an instrument package for a spacecraft that contained all the required data gathering mechanisms, would be inefficient and unduly costly to utilize for urban surveillance. In fact, much of the information required will necessitate high resolution and relatively large scale photography which at this point in time would indicate a continuing need for aircraft systems. This is obvious from some of the above discussion and is substantively shown by the research efforts undertaken in the Cedar Rapids, Iowa area reported in Chapter III. The primary function of imagery provided by spacecraft would be in the area of regional urban analysis and planning and perhaps to provide data for evaluating the need for updating information files of local agencies.

Discussion

Current research efforts suggest that functioning urban information systems are practical and necessary for proper management and research. This chapter has outlined the basic elements and structural aspects of a geographic urban information system. Research reported later in this volume and elsewhere, particularly in the recently completed Remote Sensors as Data Sources for Urban Research and Planning: Final Report, indicates that remote sensing can provide data concerning land use, changes in commercial structure, data for transportation planning, housing quality, residential dynamics, and most likely data concerning population density.[6] Therefore as research continues into the utility of remote sensing for the acquisition of data concerning specific urban phenomenon, an increasing proportion of the data requirements of urban change detection systems can be expected to be supplied by these methods. However, the cost parameters related to these elements in some cases are unknown. In the absence of a large scale demonstration project whose purpose is to integrate the various successful applications of remote sensing into an operational system, it is necessary to continue evaluation of remote sensing capability on a phenomenon by phenomenon basis. As indicated in this paper remote sensing technology must be considered within the context of user needs, which determines the appropriate imagery scale, size of areal unit of observation, any necessary classification schemes, and the need for appropriate data items.

Urban change detection is only partially a technical problem. It is perhaps even more an institutional and administrative one where legal, organizational, and coordination requirements are often the most significant barriers to an effective system. Admittedly, technical problems do exist, but the technical problems are often more easily solved than those stemming from a complex societal environment. In the final analysis the utility of remote sensing in this area rests on stark economic conditions and the trade-offs between costs and data delivery time requirements. In essence, this means clear explication of costs weighed against benefits.

References

1. This subject was also addressed from the point of view of comparative urban analysis in Dueker, Kenneth J. and Horton, Frank E., Remote Sensing and Geographic Urban Information Systems, Technical Report No. 3, Remote Sensing Project, Institute of Urban and Regional Research, University of Iowa, Iowa City, Iowa, January 1971.

2. Kraemer, Kenneth L. "USAC: An Evolving Intergovernmental Mechanism Urban Information Systems Development", Urban and Regional Information Systems: Past, Present, and Future, J. E. Rickert and S. L. Hale (eds.), Center for Urban Regionalism, Kent State University, 1970.

3. "Information Systems for the Urban Transportation Planning Process", RFP-20, Federal Highway Administration, U. S. Department of Transportation, January 18, 1971.

4. Dueker, Kenneth J., "A Framework for Encoding Spatial Data", Geographical Analysis, (forthcoming).

5. Ibid.

6. See, Marble, D. F. and Horton, F. E., Remote Sensors as Data Sources for Urban Research and Planning: Final Report, Remote Sensing Laboratory, Northwestern University, Evanston, Illinois, May 1971.

III. URBAN LAND USE: THE REPLICATION OF EXISTING DATA FILES

The previous chapter outlines the "state of the art" of utilizing remote sensing as a data source for urban and regional analysis. In order to justify their collection, coding, and use in an urban change detection system data items must be of some utility to urban researchers, planners, and administrators. The phenomenon being monitored and measured must be of interest to a significant user of the urban information system. Two factors may mitigate this criterion. First, the marginal cost of including extra variables may be very small in which case a degree of comprehensiveness may seem appropriate; second, there may be reason to believe that a given variable not important at the present time may shortly become so making historical data series desirable. Monitoring and planning the urban environment is a complex task involving an expensive technology and, to date, many man hours of costly survey work. Because of the increasing rate of change of urban areas and the increasing importance of knowing the status of these systems on a near real-time basis, remote sensing offers a potentially effective methodology for providing necessary inputs to the data files of change detection systems. This chapter describes a study undertaken to investigate the possibility of utilizing imagery to replicate data items which are currently considered important by urban researchers and planners.

The purpose of this investigation was to evaluate the usefulness of remote sensing imagery at scales of 1:50,000, 1:100,000 and 1:382,000 to provide information as to the amount of land devoted to particular uses at the census tract level of aggregation. The utilization of high resolution imagery at these scales could reduce both the time and cost involved in securing the desired land use information for the entire urban complex. The attractiveness of such an approach lies in the possibility of providing timely land use information on a continuing basis in a form now utilized by numerous agencies across the nation.

The Data

The study compared two basic sets of land use data pertaining to metropolitan Washington, D.C. The first data set was supplied by the metropolitan Washington Council of Governments (COG) and contains land use information by census tract (1960 tract definition). These land use data were originally collected on a parcel basis (in 1968) by the participating jurisdictions. COG subsequently utilized a variety of methods in order to assign parcels to census tracts and aggregate the land use information on a tract basis. The 1968 data for the District contained 1960 census tract identifiers which were prepared by the District government. It was, therefore, only necessary to aggregate the parcel information to the tract level. Montgomery County, on the other hand, used an address coding procedure to allocate parcels to 1960 census tracts. Parcels were allocated to subzones and these subzones were subsequently equated with 1960 census tracts.

In 1970, COG began the task of updating the 1968 parcel file using 1970 land use data and 1970 census tracts. For the 1970 land use file, the District government developed a relationship between city squares, an areal unit which has been in use in the District for several years, and 1970 census tracts. Parcels were allocated to these squares and an equivalence code, also developed by the District government, was utilized to identify city squares with 1970 census tracts.

The 1970 land use file for Montgomery County employed the same procedure as that for the 1968 file. However, since some census tracts changed boundaries between 1960 and 1970, the transportation subzones were no longer directly comparable to these tracts. Changes in land ownership also caused some identification problems.

At the time of the writing of this report, the 1970 land use file is incomplete. The address coding for Prince Georges County has not yet been completed, but data are available for 21 of the original 26 tracts.

The COG land use data for 1968 and 1970 vary in reliability with the 1968 data being somewhat more reliable than the 1970 data. The data sets are, however, comparable in that both contain land uses which are listed according to the amount of land (in acres) within a census tract devoted to each of ten major land use categories. Total tract areas are determined by summing the amount of land in each land use category for each tract. Since the initial data were obtained from parcel records, the COG files contain no information on the amount of area devoted to street rights-of-way. The land use classification scheme developed and used by COG is listed in Table 1; Table 1-A compares the 1968 and 1970 data sets.

The second basic data set was compiled for a sample of 26 tracts by conventional photo interpretation techniques. Of the 26 tracts examined in this study, 16 were within the boundaries of Washington, D.C., five were from Montgomery County, and the remaining five tracts were within the boundaries of Prince Georges County. The criteria for tract selection were as follows:

1. The area enclosed within tract boundaries had to be entirely within the flight line of the imagery used.

2. Compatibility between 1960 and 1970 tract boundaries had to be maintained.

After meeting these criteria, tracts were selected and the COG data file was examined to determine the quality of land use information listed for these tracts.

The source of this second data set consisted of color infrared imagery at scales of 1:50,000, 1:100,000 and 1:382,000. This simultaneously obtained imagery covered a north-south flight line roughly centered on the central business district of Washington, D.C. The imagery was secured by NASA in June, 1970 with a Zeiss 9" x 9" format mapping camera mounted in an RB-57-C aircraft. The high quality of the photography used in this study enabled interpreters to identify land uses according to the ten categories mentioned previously. One of the purposes of this study was to determine the accuracy of these land use identifications.

Table 1

Major Land Use Categories

Code	Category	
0	Residential	RESID
1	Industrial/Storage	IND/ST
2	Education	EDUC
3	Transportation/Communication/Utilities	T/C/U
4	Consumer Services	CON/S
5	Offices	OFF
6	Institutional	INST
7	Public Assembly	PUBAS
8	Parks & Recreation	PARKS
9	Underdeveloped & Resource Use	UND/R

The Analyses - 1968

The relevant frames of photography were placed on a light table and census tract boundaries were drawn on mylar overlays. In most cases, the identification of boundaries presented no problem since they usually coincide with the locations of streets, railroad tracks or rivers. However, in a few instances, boundaries were difficult to precisely locate due to the presence of extensive areas of tree growth. It was also somewhat difficult to place tract boundaries on the 1:382,000 imagery. The total area within each tract was then calculated with a dot planimeter. Sections within each tract devoted to a particular land use were identified, bounded, and the area calculated. The sum of these area values was then compared with the total tract area value in order to provide a check on both. If a discrepancy was

TABLE 1-A[a]

LAND USE COMPARISONS BY TRACT BY YEAR:

1968 - 1970 WASHINGTON, COG DATA

Census[b] Tract #		0[c] RESID	1 IND/ST	2 EDUC	3 T/C/U	4 CON/S	5 OFF	6 INST	7 PUBAS	8 PARKS	9 UND/R	Total Tract Area
4.0	1968	77.6	0.0	16.6	0.1	5.3	25.1	72.1	34.5	6.3	48.0	285.0
	1970	78.7	0.0	0.0	0.1	0.0	17.9	0.0	34.5	0.0	49.7	180.9
	Diff.	-1.1	0.0	16.6	0.0	5.3	7.2	72.1	0.0	6.3	-1.7	104.1
21.0	1968	159.9	0.0	8.3	0.0	10.1	0.7	0.0	1.1	0.0	42.8	223.0
	1970	156.3	0.0	8.2	0.0	9.9	0.6	0.0	1.3	0.0	10.2	186.5
	Diff.	3.6	0.0	0.1	0.0	0.2	0.1	0.0	-0.2	0.0	32.6	36.5
26.0	~~1968~~	129.4	0.0	0.0	0.0	0.0	1.9	0.0	2.7	0.0	88.3	222.0
	1970	137.6	0.0	0.0	0.0	0.0	1.9	0.0	3.5	0.0	78.7	221.7
	Diff.	-8.2	0.0	0.0	0.0	0.0	0.0	0.0	-0.8	0.0	9.6	0.3
35.0	1968	27.9	6.9	14.7	1.4	4.6	0.6	0.2	0.1	12.8	15.4	85.0
	1970	31.8	7.2	11.8	1.4	10.2	0.8	11.0	1.0	7.3	19.8	79.4
	Diff.	-3.9	-0.3	2.9	0.0	-5.6	-0.2	-10.8	-0.9	5.5	-4.4	5.6
36.0	1968	37.7	0.0	2.1	0.0	3.5	0.0	0.0	0.4	0.0	1.5	45.0
	1970	29.3	0.0	2.1	0.0	5.0	0.6	0.2	0.1	6.9	14.4	36.4
	Diff.	8.4	0.0	0.0	0.0	-1.5	-9.6	-0.2	0.3	-6.9	-12.9	8.6
42.0	1968	40.7	0.6	0.0	0.0	4.7	2.6	1.0	0.4	0.0	3.4	54.0
	1970	40.6	0.6	0.0	0.0	4.1	2.4	1.0	0.2	0.0	2.6	51.5
	Diff.	0.1	0.0	0.0	0.0	0.6	0.2	0.0	0.2	0.0	0.8	2.5

Table 1-A Continued

Census Tract[b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
49.0	1968	21.6	1.5	0.0	0.0	13.9	3.6	0.0	2.1	0.0	9.5	70.0
	1970	34.4	1.6	0.0	0.0	10.3	1.2	0.0	1.5	2.2	17.8	69.0
	Diff.	30.9	2.1	0.0	0.0	19.9	5.1	0.0	3.1	0.0	13.6	1.0
51.0	1968	6.5	0.7	1.4	1.2	6.5	14.2	0.2	1.5	4.8	10.5	48.0
	1970	6.1	0.8	1.4	1.2	6.7	16.3	0.2	1.4	4.8	8.4	47.3
	Diff.	0.4	-0.1	0.0	0.0	-0.2	-2.1	0.0	0.1	0.0	2.1	0.7
57.1	1968	18.2	0.0	8.3	0.5	1.6	16.6	2.7	1.5	0.3	18.0	68.0
	1970	17.8	0.0	6.2	0.8	1.0	26.9	2.7	1.5	0.3	25.3	82.5
	Diff.	0.4	0.0	2.1	-0.3	0.6	-10.3	0.0	0.0	0.0	-7.3	-14.5
60.0	1968	44.6	5.4	2.0	1.7	8.3	103.8	0.6	3.3	0.0	77.9	249.0
	1970	43.0	4.6	2.0	1.7	8.7	73.1	0.6	3.2	0.0	53.3	190.2
	Diff.	1.6	0.8	0.0	0.0	-0.4	30.7	0.0	0.1	0.0	24.6	58.8
63.0	1968	47.5	0.0	0.0	0.0	0.0	0.0	86.8	1.9	0.0	13.1	149.0
	1970	47.5	0.0	0.0	0.0	0.0	0.0	86.8	1.9	0.0	13.1	149.0
	Diff.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
69.0	1968	33.0	2.7	5.1	0.0	5.4	0.0	0.0	0.6	0.0	6.5	54.0
	1970	31.1	2.6	5.1	0.0	5.9	0.0	0.0	0.6	0.0	8.7	54.0
	Diff.	1.9	0.1	0.0	0.0	-0.5	0.0	0.0	0.0	0.0	-2.2	0.0
72.0	1968	25.2	36.1	1.0	10.1	4.0	79.3	0.0	0.3	1.1	66.7	224.0
	1970	26.3	37.4	1.0	8.7	5.0	82.6	0.0	0.3	3.2	63.0	227.5
	Diff.	-1.1	-1.3	0.0	1.4	-1.0	-3.3	0.0	0.0	-2.1	3.7	-3.5

Table 1-A Continued

Census Tract[b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
73.2	1968	70.4	0.0	28.1	0.0	12.5	0.0	43.4	0.4	0.0	133.7	289.0
	1970	97.5	0.2	28.1	0.0	5.9	0.0	423.3	1.6	3.1	108.9	668.6
	Diff.	-27.1	-0.2	0.0	0.0	6.6	0.0	-379.9	-1.2	-3.1	24.8	-379.6
77.1	1968	73.6	3.8	0.0	8.7	1.8	0.0	0.0	1.5	0.0	64.4	154.0
	1970	66.2	0.0	5.3	7.5	0.5	6.8	0.0	1.1	0.0	52.4	139.8
	Diff.	7.4	3.8	-5.3	1.2	1.3	-6.8	0.0	0.4	0.0	12.0	14.2
88.2	1968	54.1	0.5	2.1	0.3	3.6	0.0	0.0	0.0	0.0	7.6	68.0
	1970	54.5	0.3	2.1	0.7	3.4	0.0	0.0	0.0	0.0	7.8	68.8
	Diff.	-0.4	0.2	0.0	-0.4	0.2	0.0	0.0	0.0	0.0	-0.2	-0.8
18.0	1968	213.8	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	885.4	1136.0
	1970	167.4	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	57.1	225.0
	Diff.	46.4	6.0	0.0	0.0	-0.5	0.0	0.0	0.0	0.0	828.3	911.0
20.0	1968	97.5	3.6	0.0	0.0	1.2	0.0	0.0	0.0	0.0	39.0	142.0
	1970	91.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.4	106.0
	Diff.	5.9	-3.6	0.0	0.0	1.2	0.0	0.0	0.0	0.0	24.6	136.0
28.0	1968	277.4	13.5	0.0	0.0	22.7	0.0	0.0	0.0	147.8	115.1	597.0
	1970	177.9	8.1	0.0	0.0	8.3	0.0	0.0	0.0	0.0	64.5	258.8
	Diff.	99.5	5.4	0.0	0.0	14.4	0.0	0.0	0.0	147.8	50.6	338.2
31.0	1968	302.4	0.0	0.0	0.0	42.7	0.0	0.0	0.0	0.0	173.7	530.0
	1970	254.6	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	47.8	303.9
	Diff.	47.8	0.0	0.0	0.0	41.2	0.0	0.0	0.0	0.0	125.9	226.1

Table 1-A Continued

Census Tract[b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
40.0	1968	285.1	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0	58.7	357.0
	1970	277.8	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	36.2	315.6
	Diff.	7.3	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	22.5	41.4

[a] Not applicable or missing values are shown as 0.0.

[b] Tracts 15.0, 16.0, 47.0, 50.0, and 61.0 are Prince Georges County tracts. (1970 Data not available). Tracts 18.0, 20.0, 28.0, 31.0, and 40.0 are Montgomery County tracts. The remaining tracts are within the District.

[c] Refer to Table 1 for land use categories.

found, both calculations were repeated. Because the primary purpose of this study was to evaluate the usefulness of various scales of imagery, interpretation of the three sets of imagery were conducted separately and area calculations were not adjusted across the three scales. This means for example, that individual and total land use areas were determined for each of the three scales of imagery resulting in different values for land areas at the three scales. As might be expected the most difficulty was encountered when interpreting the smaller scale imagery.

The 1968 and 1970 COG and the imagery derived land use area values were translated into machine readable form and subsequent computer assisted comparisons were made for census tracts at the three scales.

<u>1968 COG - 1:50,000</u>

The results of the comparison of 1968 COG land use data with the 1:50,000 imagery data are shown in Table 2. The first row represents the land use area values derived from COG's census summary tape. The second row lists the corresponding land use area values obtained from the remote sensing imagery. These latter values were algebraically subtracted from the COG land area values and the results are displayed in the third row. The last row represents the percentage of each COG, value accounted for by each respective remote sensing value. In all cases, the land devoted to streets was assigned to the adjacent land use. (This description of Table 2 applies to similar tables in the remainder of this chapter.)

TABLE 2[a]

1:50,000

1968 LAND USE COMPARISONS

Census Tract #[b]	0[c] RESID	1 IND/ST	2 EDUC	3 T/C/U	4 CON/S	5 OFF	6 INST	7 PUBAS	8 PARKS	9 UND/R	Total Tract Area
4.0											
COG	77.6	0.0	16.6	0.1	5.3	25.1	72.1	34.5	6.3	48.0	285.0
R.S.	114.0	71.0	54.0	0.0	0.0	7.0	0.0	11.0	30.0	0.0	386.0
Diff.	-36.4	-71.0	-37.4	0.1	5.3	18.1	72.1	23.5	-23.7	48.0	-101.0
%	146.9	0.0	325.3	0.0	0.0	27.9	0.0	31.9	476.2	0.0	135.4
21.0											
COG	159.9	0.0	8.3	0.0	10.1	0.7	0.0	1.1	0.0	42.8	223.0
R.S.	281.5	0.0	17.0	0.0	18.0	0.0	0.0	0.0	12.0	0.0	328.5
Diff.	-121.6	0.0	-8.7	0.0	-7.9	0.7	0.0	1.1	-12.0	42.8	-105.5
%	176.0	0.0	204.8	0.0	178.2	0.0	0.0	0.0	0.0	0.0	147.3
26.0											
COG	129.4	0.0	0.0	0.0	0.0	1.9	0.0	2.7	0.0	88.3	222.0
R.S.	169.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	148.0	8.0	331.0
Diff.	-39.6	0.0	0.0	0.0	0.0	1.9	0.0	-0.3	-148.0	80.3	-109.0
%	130.6	0.0	0.0	0.0	0.0	0.0	0.0	111.1	0.0	9.1	149.1
35.0											
COG	27.9	6.9	14.7	1.4	4.6	0.6	0.2	0.1	12.8	15.4	85.0
R.S.	76.5	0.0	4.0	0.0	0.0	0.0	0.0	0.0	16.0	0.0	96.5
Diff.	-48.6	6.9	10.7	1.4	4.6	0.6	0.2	0.1	-3.2	15.4	-11.5
%	274.2	0.0	27.2	0.0	0.0	0.0	0.0	0.0	125.0	0.0	113.5

Table 2 Continued

Census[b] Tract #	0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
36.0											
COG	37.7	0.0	2.1	0.0	3.5	0.0	0.0	0.4	0.0	1.5	45.0
R.S.	59.5	0.0	0.0	0.0	3.0	0.0	0.0	0.0	11.0	0.0	73.5
Diff.	-21.8	0.0	2.1	0.0	0.5	0.0	0.0	0.4	-11.0	1.5	-28.5
%	157.8	0.0	0.0	0.0	85.7	0.0	0.0	0.0	0.0	0.0	163.3
42.0											
	40.7	0.6	0.0	0.0	4.7	2.6	1.0	0.4	0.0	3.4	54.0
	82.5	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	91.5
	-41.8	0.6	0.0	0.0	-4.3	2.6	1.0	0.4	0.0	3.4	-37.5
	202.7	0.0	0.0	0.0	191.5	0.0	0.0	0.0	0.0	0.0	169.4
49.0											
	21.6	1.5	0.0	0.0	13.9	3.6	0.0	2.2	0.0	9.5	70.0
	110.0	0.0	5.0	0.0	11.0	0.0	0.0	0.0	2.0	2.0	130.0
	-88.4	1.5	-5.0	0.0	2.9	3.6	0.0	2.2	-2.0	7.5	-60.0
	509.3	0.0	0.0	0.0	79.1	0.0	0.0	0.0	0.0	21.1	185.7
51.0											
	6.5	0.7	1.4	1.2	6.5	14.2	0.2	1.5	4.8	10.5	48.0
	0.0	0.0	0.0	0.0	17.0	69.0	0.0	0.0	8.0	0.0	94.0
	6.5	0.7	1.4	1.2	-10.5	-54.8	0.2	1.5	-3.2	10.5	-46.0
	0.0	0.0	0.0	0.0	261.5	485.9	0.0	0.0	166.7	0.0	195.8

Table 2 Continued

Census[b] Tract #	0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
57.1											
COG	18.2	0.0	8.3	0.5	1.6	16.6	2.7	1.5	0.3	18.0	68.0
R.S.	0.0	13.0	0.0	11.0	0.0	127.0	0.0	0.0	24.0	6.0	181.0
Diff.	18.2	-13.0	8.3	-10.5	1.6	-110.4	2.7	1.5	-23.7	12.0	-113.0
%	0.0	0.0	0.0	2200.0	0.0	765.1	0.0	0.0	8000.0	33.3	266.2
60.0											
	44.6	5.4	2.0	1.7	8.3	103.8	0.6	3.3	0.0	77.9	249.0
	64.0	0.0	15.0	21.0	31.0	43.0	0.0	0.0	47.0	35.0	245.0
	-19.4	5.4	-13.0	-19.3	-22.7	60.8	0.6	3.3	-47.0	42.9	4.0
	143.5	0.0	750.0	1235.3	373.5	41.4	0.0	0.0	0.0	44.9	98.4
63.0											
	47.5	0.0	0.0	0.0	0.0	0.0	86.8	1.9	0.0	13.1	149.0
	80.5	0.0	12.0	0.0	0.0	20.0	0.0	0.0	59.0	0.0	171.5
	-33.0	0.0	-12.0	0.0	0.0	-20.0	86.8	1.9	-59.0	13.1	-22.5
	169.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	115.1
69.0											
	33.0	2.7	5.1	0.0	5.4	0.0	0.0	0.6	0.0	6.5	54.0
	81.5	0.0	12.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	97.5
	-48.5	2.7	-6.9	0.0	1.4	0.0	0.0	0.6	0.0	6.5	-43.5
	247.0	0.0	235.3	0.0	74.1	0.0	0.0	0.0	0.0	0.0	180.6

Table 2 Continued

Census Tract # [b]	0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
72.0											
COG	25.2	36.1	1.0	10.1	4.0	79.3	0.0	0.3	1.1	66.7	224.0
R.S.	49.0	96.0	3.0	13.0	0.0	139.0	0.0	0.0	0.0	168.0	476.0
Diff.	-23.8	-59.9	-2.0	-2.9	4.0	-59.7	0.0	0.3	1.1	-101.3	-252.0
%	-194.4	265.9	300.0	128.7	0.0	175.3	0.0	0.0	0.0	251.9	212.5
73.2											
	70.4	0.0	28.1	0.0	12.5	0.0	43.4	0.4	0.0	133.7	289.0
	163.0	0.0	10.0	53.0	3.0	0.0	0.0	0.0	95.0	0.0	324.0
	-92.6	0.0	18.1	-53.0	9.5	0.0	43.4	0.4	-95.0	133.7	-35.0
	231.5	0.0	35.6	0.0	24.0	0.0	0.0	0.0	0.0	0.0	112.1
77.1											
	73.6	3.8	0.0	8.7	1.8	0.0	0.0	1.5	0.0	64.4	154.0
	175.0	0.0	2.0	59.0	7.0	0.0	0.0	3.0	35.0	178.0	459.0
	-101.4	3.8	-2.0	-50.3	-5.2	0.0	0.0	-1.5	-35.0	-113.6	-305.0
	237.8	0.0	0.0	678.2	388.9	0.0	0.0	200.0	0.0	276.4	298.1
88.2											
	54.1	0.5	2.1	0.3	3.6	0.0	0.0	0.0	0.0	7.6	68.0
	105.5	0.0	4.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	112.5
	-51.4	0.5	-1.9	0.3	0.6	0.0	0.0	0.0	0.0	7.6	-44.5
	195.0	0.0	190.5	0.0	83.3	0.0	0.0	0.0	0.0	0.0	165.4

Table 2 Continued

Census[b] Tract #	0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
15.0											
COG	181.8	0.0	18.6	0.0	2.1	0.0	2.1	0.0	0.0	12.4	217.0
R.S.	220.0	0.0	18.0	10.0	11.0	0.0	0.0	0.0	10.0	0.0	269.0
Diff.	-38.2	0.0	0.6	-10.0	-8.9	0.0	2.1	0.0	-10.0	12.4	-52.0
%	121.0	0.0	96.8	0.0	523.8	0.0	0.0	0.0	0.0	0.0	124.0
16.0											
	138.4	0.0	0.0	0.0	10.3	0.0	0.0	0.0	8.3	4.1	157.0
	113.5	0.0	0.0	0.0	56.0	0.0	0.0	0.0	6.0	0.0	175.5
	24.9	0.0	0.0	0.0	-45.7	0.0	0.0	0.0	2.3	4.1	-18.5
	82.0	0.0	0.0	0.0	543.7	0.0	0.0	0.0	72.3	0.0	111.8
18.0											
	213.8	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	885.4	1136.0
	321.0	0.0	33.0	0.0	5.0	0.0	0.0	0.0	19.0	0.0	378.0
	-107.2	6.0	-33.0	0.0	-5.0	0.0	0.0	0.0	-19.0	885.4	758.0
	150.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3
20.0											
	97.5	3.6	0.0	0.0	1.2	0.0	0.0	0.0	0.0	39.0	142.0
	177.5	0.0	37.0	0.0	7.0	0.0	0.0	0.0	10.0	0.0	231.5
	-80.0	3.6	-37.0	0.0	-5.8	0.0	0.0	0.0	-10.0	39.0	-89.5
	182.1	0.0	0.0	0.0	583.3	0.0	0.0	0.0	0.0	0.0	163.0

Table 2 Continued

Census[b] Tract #	0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
28.0											
COG	277.4	13.5	0.0	0.0	22.7	0.0	0.0	0.0	147.8	115.1	597.0
R.S.	285.5	0.0	19.0	18.0	37.0	0.0	0.0	0.0	18.0	0.0	377.5
Diff.	-8.1	13.5	-19.0	-18.0	-14.3	0.0	0.0	0.0	129.8	115.1	219.5
%	102.9	0.0	0.0	0.0	163.0	0.0	0.0	0.0	12.2	0.0	63.2
31.0											
	302.4	0.0	0.0	0.0	42.7	0.0	0.0	0.0	0.0	173.7	530.0
	337.5	0.0	29.0	10.0	12.0	0.0	0.0	0.0	100.0	0.0	488.5
	-35.1	0.0	-29.0	-10.0	30.7	0.0	0.0	0.0	-100.0	173.7	41.5
	111.6	0.0	0.0	0.0	28.1	0.0	0.0	0.0	0.0	0.0	92.2
40.0											
	285.1	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0	58.7	357.0
	517.0	0.0	23.0	0.0	6.0	2.0	0.0	0.0	66.0	0.0	544.0
	-231.9	0.0	-23.0	0.0	-3.3	-2.0	0.0	0.0	-66.0	58.7	-187.0
	181.3	0.0	0.0	0.0	222.2	0.0	0.0	0.0	0.0	0.0	152.4
47.0											
	134.4	2.1	14.4	0.0	33.1	0.0	12.3	0.0	0.0	10.3	207.0
	215.5	0.0	5.0	0.0	19.0	0.0	0.0	2.0	0.0	0.0	241.5
	-81.1	2.1	9.4	0.0	14.1	0.0	12.3	-2.0	0.0	10.3	-34.5
	160.3	0.0	34.7	0.0	57.4	0.0	0.0	0.0	0.0	0.0	116.7

Table 2 Continued

Census Tract # [b]	0 [c]	1	2	3	4	5	6	7	8	9	Total Tract Area
50.0											
COG	117.7	6.2	31.4	0.0	24.8	0.0	16.5	0.0	55.8	86.8	347.0
R.S.	262.0	0.0	31.0	20.0	42.0	0.0	0.0	4.0	67.0	21.0	447.0
Diff.	-144.3	6.2	0.4	-20.0	-17.2	0.0	16.5	-4.0	-11.2	65.8	-100.0
%	222.6	0.0	98.7	0.0	169.4	0.0	0.0	0.0	120.1	24.2	128.8
61.0											
	140.5	0.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	12.4	157.0
	241.5	0.0	2.0	0.0	3.0	0.0	15.0	0.0	0.0	0.0	261.5
	-101.0	0.0	2.1	0.0	-3.0	0.0	-15.0	0.0	0.0	12.4	-104.5
	171.9	0.0	48.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	166.6

[a] Not applicable or missing values are shown as 0.0.

[b] Tracts 15.0, 16.0, 47.0, 50.0, and 61.0 are Prince Georges County tracts. Tracts 18.0, 20.0, 28.0, 31.0, and 40.0 are Montgomery County tracts. The remaining tracts are within the District.

[c] Refer to Table 1 for land use categories.

The most consistent difference may be noted from an inspection of the last column of Table 2. For the District and Prince Georges County tracts the imagery derived total tract area exceeds the corresponding areas reported by COG. The differences range from a low of 11.5 acres to a high of 305.0 acres. Three of the five Montgomery County tracts, however, have lower imagery derived total land area values than those reported by COG. The respective tract boundaries were checked and the total area values were recomputed. The imagery derived values were verified correct and it appears that three discrepancies are largely due to errors in the COG data file. For tract 18.0, almost all of the difference can be accounted for by the 885.4 acres listed for underdeveloped and resource use. In this case, the utility of remote sensing imagery as a check on conventional data files is abundantly clear.

Residential

In three out of 26 cases estimates derived from the imagery for land area devoted to residential use are lower than those reported by COG. These differences range from a low of 6.5 acres to a high of 24.9 acres. For the remaining 23 tracts, the imagery estimates exceeded the corresponding COG values with a range of 8.1 acres for tract 28.0 to 231.9 acres for tract 40.0. In general, the magnitude of the differences in residential land use is somewhat less for the District tracts since these tracts probably experienced less residential development from 1968-70 than the non-District tracts.

Industrial/Storage

For this land use category, imagery land area values exceeded COG values for only three tracts all of which are within the District. The imagery land area value for tract 72.0 is 96 acres while the COG value is listed as 36.1 acres. This is the only case in which both data sets reported a non-zero value for this category. Ten additional tracts have no land area devoted to this use as determined by both data sets. In the remaining cases, it appears that the use of remote sensing imagery at a scale of 1:50,000 is insensitive to the presence of small land areas devoted to Industrial/Storage use.

Educational

Examination of the Educational land use category reveals 14 tracts with imagery values larger than those reported by COG. These differences range from a low of 1.9 acres to a high of 37.4 acres. Six of the remaining 12 tracts have non-zero land area values reported by both data sets with the largest discrepancy being 18.1 acres. Due to the variety of structural forms included in this category, proper identification of Educational land uses is at best difficult.

Transportation/Communication/Utilities

Land area devoted to this category generally either tends to be overestimated or is not identified for small amounts of land. Imagery derived estimates exceeded COG values for nine tracts while COG land area values exceeded imagery values for four tracts. The remaining 13 tracts had no land devoted to this use. On a relative basis the differences noted in Table 2 for this category are large especially for tracts 73.2 and 77.1. Excluding land devoted to streets, street rights-of-way, and railroad yards the remaining land devoted to this category is probably quite small at the tract level.

Consumer Services

The results of the comparison of the two data sets for this category are somewhat surprising. In 13 cases, imagery values are larger than the corresponding COG values but the differences in nine of these 13 cases are not unacceptable since some of the discrepancy in each case can be attributed to land area devoted to streets.

Offices

Only five tracts had larger imagery than COG values for land uses in this category. Three of these five tracts exhibit differences which are larger than 50 acres. A portion of these differences may be attributed to land area in street use, but a larger portion probably results from inaccurate identification.

Institutional

Examination of this category reveals only one tract in which imagery estimates exceeded those reported by COG. In 11 cases, interpretation of the imagery was insensitive to the existence of land devoted to this use.

Public Assembly

Only one tract had a significant proportion of land devoted to this use. COG reported a value of 34.5 acres for tract 4.0 whereas the imagery derived value was 11.0 acres resulting in a difference of 23.5 acres. The identification of uses in this category was extremely difficult and there was a tendency to underestimate the amount of land occupied by this use.

Parks and Recreation -- Underdeveloped and Resource Use

Uses in the land use category "Parks and Recreation" are frequently difficult to distinguish from land devoted to "Underdeveloped and Resource Use". In the former case, 18 tracts had imagery values exceeding COG values while, in the latter case, only one tract had a larger imagery land area value. There seems to be a tendency for COG values to over represent land areas in the underdeveloped and resource use category. In a similar manner, imagery values overestimate the amount of land devoted to the Parks and Recreation category. As mentioned previously, there is little doubt that the 885.4 acres listed for Underdeveloped and Resource Use in tract 18.0 is an error in the COG data.

Discrepancies and Adjustment

The results of this analysis indicate that the largest discrepancies consistently occur in the amount of land attributed to residential use. However, the COG data file does not contain land which is devoted to street use since it was originally developed from parcel information.

The remote sensing data, on the other hand, does include street use as part of the amount of land in residential use. Following a procedure used previously, the COG residential land use values were expressed as percentages of the COG census tract total land area values. These percentages were then multiplied by the imagery derived tract totals to obtain proportional adjustments which should partially account for areas in street use. This procedure was not applied to tract 18.0 because of the extreme total area value. The results of these adjustments are shown in Table 3. The differences between the COG and imagery derived values were improved in all but five cases. The five tracts for which no improvement was noted had either larger tract totals or larger areas devoted to residential use according to the COG data. While the adjustment procedure was appropriate for decreasing the discrepancies in residential land areas, it was not appropriate when applied to other land use categories.

Table 3

1968 Original and Weighted Land Use Comparisons

1:50,000

(Residential Category)

CT#	4.0	21.0	26.0	35.0	36.0	42.0	49.0
1. Original COG Value	77.6	159.0	129.4	27.9	37.7	40.7	21.6
2. Weighted COG Value	104.0	236.0	191.0	32.0	61.0	68.0	40.0
3. R.S. Value	114.0	281.5	169.0	76.5	59.5	82.5	110.0
4. Original Difference	-36.4	-121.6	-39.6	-48.6	-21.8	-41.8	-88.4
5. Weighted Difference	-26.4	-45.5	22.0	-44.5	1.5	-14.5	-70.0

CT#	51.0	57.1	60.0	63.0	69.0	72.0	73.2
1. Original COG Value	6.5	18.2	44.6	47.5	33.0	25.2	70.4
2. Weighted COG Value	12.0	48.8	45.7	54.7	59.0	52.3	77.7
3. R.S. Value	0.0	0.0	64.0	80.5	81.5	49.0	163.0
4. Original Difference	6.5	18.2	-19.4	-33.0	-48.5	-23.8	-92.6
5. Weighted Difference	12.0	48.8	-18.3	-25.8	-22.5	3.3	-85.3

CT#	77.1	88.2	15.0	16.0	20.0	28.0	31.0
1. Original COG Value	73.6	54.1	181.8	138.4	97.5	277.4	302.4
2. Weighted COG Value	230.0	89.6	225.0	154.0	159.4	173.6	278.0
3. R.S. Value	175.0	105.5	220.0	113.5	177.5	285.5	337.5
4. Original Difference	-101.4	-51.4	-38.2	24.9	-80.0	-8.1	-35.1
5. Weighted Difference	55.0	-15.9	5.0	40.5	-18.1	-111.9	-59.5

CT#	40.0	47.0	50.0	61.0
1. Original COG Value	285.1	134.4	117.7	140.5
2. Weighted COG Value	435.2	157.0	152.0	232.0
3. R.S. Value	517.0	215.5	262.0	241.5
4. Original Difference	-231.9	-81.1	-144.3	-101.0
5. Weighted Difference	-81.8	-58.5	-110.0	-9.5

1968 COG - 1:100,000

Table 4 reveals the differences obtained by comparing the 1968 COG land use values with the 1:100,000 imagery. It can be seen that 23 of the 26 tracts have larger imagery derived total land use values. The magnitude of difference between the COG and imagery total values ranges from a low of 9.5 acres for tract 35.0 to a high of 317.0 acres for tract 77.1. This range does not include tract 18.0 which appears to exhibit considerable error for the underdeveloped and resource use category.

Residential

Large plots of residential land, especially suburban land, are relatively easy to identify. However, small areas interspersed with non-residential development are sometimes difficult to identify. In four of the 26 cases, estimates derived from the imagery are smaller than those reported by COG. The differences range from a low of 6.5 acres for tract 51.0 to a high of 77.6 acres for tract 4.0. Imagery derived values exceeding COG values ranged from 22.8 acres for tract 36.0 to 160.9 acres for tract 40.0. Although the above mentioned ranges are greater for the 1:50,000 imagery than for the 1:100,000 imagery the total error in the latter case is approximately 221.7 acres greater. Larger errors occurred for several tracts at a scale of 1:50,000 than at the 1:100,000 scale.

TABLE 4[a]

1:100,000

1968 LAND USE COMPARISONS

Census Tract #[b]		0[c] RESID	1 IND/ST	2 EDUC	3 T/C/U	4 CON/S	5 OFF	6 INST	7 PUBAS	8 PARKS	9 UND/R	Total Tract Area
4.0	COG	77.6	0.0	16.6	0.1	5.3	25.1	72.1	34.5	6.3	48.0	285.0
	R.S.	0.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	127.0	0.0	394.0
	Diff.	77.6	-13.0	16.6	0.1	5.3	25.1	72.1	34.5	-120.7	48.0	-109.0
	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2015.9	0.0	138.2
21.0	COG	159.9	0.0	8.3	0.0	10.1	0.7	0.0	1.1	0.0	42.8	223.0
	R.S.	306.0	0.0	15.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0	334.0
	Diff.	-146.1	0.0	-6.7	0.0	10.1	0.7	0.0	1.1	-13.0	42.8	-111.0
	%	191.4	0.0	180.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	149.8
26.0	COG	129.4	0.0	0.0	0.0	0.0	1.9	0.0	2.7	0.0	88.3	222.0
	R.S.	192.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	162.0	0.0	354.0
	Diff.	-62.6	0.0	0.0	0.0	0.0	1.9	0.0	2.7	-162.0	88.3	-132.0
	%	148.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	159.5
35.0	COG	27.9	6.9	14.7	1.4	4.6	0.6	0.2	0.1	12.8	15.4	85.0
	R.S.	70.5	0.0	15.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	94.5
	Diff.	-42.6	6.9	-0.3	1.4	-4.4	0.6	0.2	0.1	12.8	15.4	-9.5
	%	252.7	0.0	102.0	0.0	195.7	0.0	0.0	0.0	0.0	0.0	111.2

Table 4 Continued

Census[b] Tract #		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
36.0	COG	37.7	0.0	2.1	0.0	3.5	0.0	0.0	0.4	0.0	1.5	45.0
	R.S.	60.5	0.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.5
	Diff.	-22.8	0.0	-9.9	0.0	3.5	0.0	0.0	0.4	0.0	1.5	-27.5
	%	160.5	0.0	571.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	161.1
42.0		40.7	0.6	0.0	0.0	4.7	2.6	1.0	0.4	0.0	3.4	54.0
		91.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	93.0
		-50.3	0.6	0.0	0.0	4.7	0.6	1.0	0.4	0.0	3.4	-39.0
		223.6	0.0	0.0	0.0	0.0	76.9	0.0	0.0	0.0	0.0	172.2
49.0		21.6	1.5	0.0	0.0	13.9	3.6	0.0	2.2	0.0	9.5	70.0
		129.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	141.0
		-107.4	1.5	-6.0	0.0	13.9	3.6	0.0	2.2	-6.0	9.5	-71.0
		597.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	201.4
51.0		6.5	0.7	1.4	1.2	6.5	14.2	0.2	1.5	4.8	10.5	48.0
		0.0	0.0	0.0	0.0	11.0	78.0	0.0	0.0	10.0	0.0	99.0
		6.5	0.7	1.4	1.2	-4.5	-63.8	0.2	1.5	-5.2	10.5	-51.0
		0.0	0.0	0.0	0.0	169.2	549.3	0.0	0.0	208.3	0.0	206.3
57.1		18.2	0.0	8.3	0.5	1.6	16.6	2.7	1.5	0.3	18.0	68.0
		0.0	12.0	0.0	0.0	0.0	136.0	0.0	0.0	30.0	5.0	183.0
		18.2	-12.0	8.3	0.5	1.6	-119.4	2.7	1.5	-29.7	13.0	-115.0
		0.0	0.0	0.0	0.0	0.0	819.3	0.0	0.0	10000.0	27.8	269.1

Table 4 Continued

Census Tract # [b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
60.0	COG	44.6	5.4	2.0	1.7	8.3	103.8	0.6	3.3	0.0	77.9	249.0
	R.S.	77.0	0.0	13.0	30.0	10.0	54.0	0.0	0.0	62.0	15.0	261.0
	Diff.	-32.4	5.4	-11.0	-28.3	-1.7	49.8	0.6	3.3	-62.0	62.9	-12.0
	%	172.6	0.0	650.0	1764.7	120.5	52.0	0.0	0.0	0.0	19.3	104.8
63.0		47.5	0.0	0.0	0.0	0.0	0.0	86.8	1.9	0.0	13.1	149.0
		111.5	4.0	10.0	0.0	0.0	0.0	0.0	0.0	45.0	0.0	170.5
		-64.0	-4.0	-10.0	0.0	0.0	0.0	86.8	1.9	-45.0	13.1	-21.5
		234.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.4
69.0		33.0	2.7	5.1	0.0	5.4	0.0	0.0	0.6	0.0	6.5	54.0
		71.5	0.0	8.0	0.0	10.0	0.0	0.0	0.0	0.0	4.0	93.5
		-38.5	2.7	-2.9	0.0	-4.6	0.0	0.0	0.6	0.0	2.5	-39.5
		216.7	0.0	156.9	0.0	185.2	0.0	0.0	0.0	0.0	61.5	173.1
72.0		25.2	36.1	1.0	10.1	4.0	79.3	0.0	0.3	1.1	66.7	224.0
		70.0	64.0	6.0	0.0	0.0	208.0	0.0	0.0	0.0	178.5	526.5
		-44.8	-27.9	-5.0	10.1	4.0	-128.7	0.0	0.3	1.1	-111.8	-302.5
		277.8	177.3	600.0	0.0	0.0	262.3	0.0	0.0	0.0	267.6	235.0
73.2		70.4	0.0	28.1	0.0	12.5	0.0	43.4	0.4	0.0	133.7	289.0
		191.5	0.0	5.0	47.0	0.0	0.0	0.0	0.0	84.0	0.0	327.5
		-121.1	0.0	23.1	-47.0	12.5	0.0	43.4	0.4	-84.0	133.7	-38.5
		272.0	0.0	17.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	113.3

Table 4 Continued

Census Tract # [b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
77.1	COG	73.6	3.8	0.0	8.7	1.8	0.0	0.0	1.5	0.0	64.4	154.0
	R.S.	178.0	0.0	3.0	78.0	6.0	0.0	0.0	0.0	31.0	175.0	471.0
	Diff.	-104.4	3.8	-3.0	-69.3	-4.2	0.0	0.0	1.5	-31.0	-110.6	-317.0
	%	241.8	0.0	0.0	896.6	333.3	0.0	0.0	0.0	0.0	271.7	305.8
88.2		54.1	0.5	2.1	0.3	3.6	0.0	0.0	0.0	0.0	7.6	68.0
		125.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.5
		-71.4	0.5	2.1	0.3	3.6	0.0	0.0	0.0	0.0	7.6	-57.5
		232.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	184.6
15.0		181.8	0.0	18.6	0.0	2.1	0.0	2.1	0.0	0.0	12.4	217.0
		234.5	0.0	0.0	10.0	5.0	0.0	0.0	0.0	21.0	0.0	270.0
		-52.7	0.0	18.6	-10.0	-2.9	0.0	2.1	0.0	-21.0	12.4	-53.0
		129.0	0.0	0.0	0.0	238.1	0.0	0.0	0.0	0.0	0.0	124.4
16.0		138.4	0.0	0.0	0.0	10.3	0.0	0.0	0.0	8.3	4.1	157.0
		116.5	41.0	0.0	0.0	17.0	0.0	0.0	0.0	12.0	0.0	186.5
		21.9	-41.0	0.0	0.0	-6.7	0.0	0.0	0.0	-3.7	4.1	-29.5
		84.2	0.0	0.0	0.0	165.0	0.0	0.0	0.0	144.6	0.0	118.8
18.0		213.8	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	885.4	1136.0
		337.0	0.0	17.0	0.0	0.0	0.0	0.0	0.0	22.0	0.0	376.0
		-123.2	6.0	-17.0	0.0	0.0	0.0	0.0	0.0	-22.0	885.4	760.0
		157.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.1

Table 4 Continued

Census Tract # [b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
20.0	COG	97.5	3.6	0.0	0.0	1.2	0.0	0.0	0.0	0.0	39.0	142.0
	R.S.	189.0	18.0	11.0	0.0	10.0	0.0	0.0	0.0	9.0	0.0	237.0
	Diff.	-91.5	-14.4	-11.0	0.0	-8.8	0.0	0.0	0.0	-9.0	39.0	-95.0
	%	193.8	500.0	0.0	0.0	833.3	0.0	0.0	0.0	0.0	0.0	166.0
28.0		277.4	13.5	0.0	0.0	22.7	0.0	0.0	0.0	147.8	115.1	597.0
		317.5	0.0	15.0	4.0	38.0	0.0	0.0	0.0	21.0	0.0	395.5
		-40.1	13.5	-15.0	-4.0	-15.3	0.0	0.0	0.0	126.8	115.1	201.5
		114.5	0.0	0.0	0.0	167.4	0.0	0.0	0.0	14.2	0.0	66.2
31.0		302.4	0.0	0.0	0.0	42.7	0.0	0.0	0.0	0.0	173.7	530.0
		366.0	0.0	8.0	0.0	14.0	0.0	0.0	4.0	103.0	0.0	495.0
		-63.6	0.0	-8.0	0.0	28.7	0.0	0.0	-4.0	-103.0	173.7	35.0
		121.0	0.0	0.0	0.0	32.8	0.0	0.0	0.0	0.0	0.0	93.4
40.0		285.1	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0	58.7	357.0
		446.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	93.0	0.0	559.0
		-160.9	0.0	-20.0	0.0	2.7	0.0	0.0	0.0	-93.0	58.7	-202.0
		156.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	156.6
47.0		134.4	2.1	14.4	0.0	33.1	0.0	12.3	0.0	0.0	10.3	207.0
		216.0	0.0	5.0	0.0	16.0	0.0	0.0	0.0	0.0	0.0	237.0
		-81.6	2.1	9.4	0.0	17.1	0.0	12.3	0.0	0.0	10.3	-30.0
		160.7	0.0	34.7	0.0	48.3	0.0	0.0	0.0	0.0	0.0	114.5

Table 4 Continued

Census Tract # [b]		0 [c]	1	2	3	4	5	6	7	8	9	Total Tract Area
50.0	COG	117.7	6.2	31.4	0.0	24.8	0.0	16.5	0.0	55.8	86.8	347.0
	R.S.	210.0	0.0	64.0	32.0	38.0	0.0	0.0	0.0	101.0	19.0	464.0
	Diff.	-92.3	6.2	-32.6	-32.0	-13.2	0.0	16.5	0.0	-45.2	67.8	-117.0
	%	178.4	0.0	203.8	0.0	153.2	0.0	0.0	0.0	181.0	21.9	133.7
61.0		140.5	0.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	12.4	157.0
		258.5	0.0	4.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0	274.5
		-118.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-12.0	12.4	-117.5
		184.0	0.0	97.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	174.8

a Not applicable or missing values are shown as 0.0.

b Tracts 15.0, 16.0, 47.0, 50.0, and 61.0 are Prince Georges County tracts. Tracts 18.0, 20.0, 28.0, 31.0, and 40.0 are Montgomery County tracts. The remaining tracts are within the District.

c Refer to Table 1 for land use categories.

Industrial/Storage

COG land use acreage values were exceeded in six of the 26 tracts by imagery derived values. Twenty tracts have no land area devoted to this use as determined by the imagery analysis, while 12 tracts have no recorded land for this category in the COG file.

Educational

For this category, 15 of the 26 tracts have imagery values larger than the corresponding COG values. In ten cases both data sets repeated some land devoted to this use with a range of 0.1 acre to 32.6 acres. Three tracts have zero entries for both data sets. Total error for this category is 58.3 acres less for the 1:100,000 imagery than for the 1:50,000.

Transportation/Communication/Utilities

As noted previously, this category does not include street rights-of-way, It does include uses such as bus terminals and railroad stations however, Both data sets reported no land in this use category for 14 tracts. Only six tracts have larger imagery derived values than those reported by COG. The difference in total discrepancy between the 1:50,000 and 1:100,000 imagery values is only 7.1 acres. The larger scale imagery has the smaller total error.

Consumer Services

The results of the comparison for this category reveal that imagery land use values exceed those of the COG data for ten tracts. Only four of the remaining 16 tracts have no land devoted to this use in either data set. Identification of consumer services is more difficult in central city tracts. This is supported by the fact that in nine of the 16 District tracts the imagery analysis was insensitive to the presence of land devoted to this category.

Offices

For this category both data sources reported no land devoted to office use in 16 tracts. In the remaining 10 tracts, only three had larger imagery than COG derived area values.

Institutional

The results for this category are identical with the 1:50,000 comparison with the exception of tract 61.0 which had 15.0 acres assigned to institutional use for the larger scale analysis. This singular difference probably constitutes an identification error since the COG data reveal no land in this category.

Public Assembly

Examination of this category reveals some similarities to the corresponding 1:50,000 analysis. However, the larger scale analysis proved to be somewhat more sensitive to the existence of land devoted to this use. The tendency for land in this category to be underestimated is magnified at the 1:100,000 scale.

Parks and Recreation -- Underdeveloped and Resource Use

The Parks and Recreation category had 18 tracts with imagery values exceeding COG values. Five of the eight remaining tracts had zero entries for both data sets. Land uses in the Underdeveloped and Resource Use category seem to be overstated by the COG data file, and in terms of land assigned within tract boundaries this is indeed the case. Since the COG data are based primarily on ownership, it is possible for land to be allocated to an adjacent tract even though a major portion of it is not actually within the boundaries of this adjacent tract.

Discrepancies and Adjustment

In this analysis, as in the 1:50,000 analysis, the most consistent discrepancies occur in the residential category. To compensate for the absence of land area devoted to streets and street rights-of-way the weightings previously employed were also calculated for the present analysis. Table 5 shows the results of the weighting procedure for the 1:100,000 imagery. As before, tract 18.0 was omitted from these weighted land use comparisons. The differences between the COG and imagery derived residential land use values were decreased in all but six cases. The tracts characterized by decreased differences are the same for both the 1:50,000 and 1:100,000 weighting analysis with the exception of tract 4.0.

Table 5

1968 Original and Weighted Land Use Comparisons

1:100,000

(Residential Category)

CT#	4.0	21.0	26.0	35.0	36.0	42.0	49.0
1. Original COG Value	77.6	159.9	129.4	27.9	37.7	40.7	21.6
2. Weighted COG Value	107.2	240.5	205.3	31.2	60.9	69.7	43.7
3. R.S. Value	0.0	306.0	192.0	70.5	60.5	91.0	129.0
4. Original Difference	77.6	-146.1	-62.6	-42.6	-22.8	-50.3	-107.4
5. Weighted Difference	107.2	-65.5	-13.3	-39.3	0.4	-21.3	-85.3

CT#	51.0	57.1	60.0	63.0	69.0	72.0	73.2
1. Original COG Value	6.5	18.2	44.6	47.5	33.0	25.2	70.4
2. Weighted COG Value	13.4	49.0	46.7	54.4	57.1	58.9	79.9
3. R.S. Value	0.0	0.0	77.0	111.5	71.5	70.0	191.5
4. Original Difference	6.5	18.2	-32.4	-64.0	-38.5	-44.8	-121.1
5. Weighted Difference	13.4	49.0	-30.3	-57.1	-14.4	-11.1	-111.6

CT#	77.1	88.2	15.0	16.0	20.0	28.0	31.0
1. Original COG Value	73.6	54.1	181.8	138.4	97.5	277.4	302.4
2. Weighted COG Value	225.1	99.9	226.3	164.5	162.8	183.9	282.6
3. R.S. Value	178.0	125.5	234.5	116.5	189.0	317.5	366.0
4. Original Difference	-104.4	-71.4	-52.7	21.9	-91.5	-40.1	-63.6
5. Weighted Difference	47.1	-25.6	-8.2	48.0	-26.2	-133.6	-83.4

CT#	40.0	47.0	50.0	61.0
1. Original COG Value	285.1	134.4	117.7	140.5
2. Weighted COG Value	446.6	153.8	157.3	245.7
3. R.S. Value	446.0	216.0	210.0	258.5
4. Original Difference	-160.9	-81.6	-92.3	-118.0
5. Weighted Difference	0.6	-62.2	-52.7	-12.8

1968 COG - 1:382,000

The analysis of the smallest scale imagery proceeded in essentially the same manner as for the two previous scales. The results are encouraging although some difficulties were encountered. Table 6 displays the specific results by tract. An examination of the last column of this table reveals that in five out of twenty-six instances imagery derived total land use values are lower than those reported by COG. The specific differences in total tract areas range from a low of 2.5 acres to a high of 360.5 acres which compares favorably with the 1:50,000 analysis.

With this imagery there was some difficulty in locating tract boundaries and in identifying land use not covering large tracts of land. Areal calculations proved to be more difficult also. The small scale of the imagery contributed to this problem.

Offsetting the above mentioned difficulties was the interpreter's increasing familiarity with the Washington metropolitan area and the land use patterns of the tracts. It is impossible to know the contribution this factor made to the analysis, but it seems reasonable to assume that if such work were done on a continuing basis such familiarity could be used advantageously.

TABLE 6[a]

1:382,000

1968 LAND USE COMPARISONS

Census Tract #[b]		0[c] RESID	1 IND/ST	2 EDUC	3 T/C/U	4 CON/S	5 OFF	6 INST	7 PUBAS	8 PARKS	9 UND/R	Total Tract Area
4.0	COG	77.6	0.0	16.6	0.1	5.3	25.1	72.1	34.5	6.3	48.0	285.0
	R.S.	125.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	282.0	0.0	407.0
	Diff.	-47.4	0.0	16.6	0.1	5.3	25.1	72.1	34.5	-275.7	48.0	-122.0
	%	161.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4476.2	0.0	142.8
21.0	COG	159.9	0.0	8.3	0.0	10.1	0.7	0.0	1.1	0.0	42.8	223.0
	R.S.	365.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	16.0	0.0	386.0
	Diff.	-205.1	0.0	3.3	0.0	10.1	0.7	0.0	1.1	-16.0	42.8	-163.0
	%	228.3	0.0	60.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	173.1
26.0	COG	129.4	0.0	0.0	0.0	0.0	1.9	0.0	2.7	0.0	88.3	222.0
	R.S.	171.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	171.0	0.0	342.0
	Diff.	-41.6	0.0	0.0	0.0	0.0	1.9	0.0	2.7	-171.0	88.3	-120.0
	%	132.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	154.1
35.0	COG	27.9	6.9	14.7	1.4	4.6	0.6	0.2	0.1	12.8	15.4	85.0
	R.S.	66.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.0
	Diff.	-38.1	6.9	4.7	1.4	4.6	0.6	0.2	0.1	12.8	15.4	9.0
	%	236.6	0.0	68.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	89.4

Table 6 Continued

Census Tract #[b]	0^c	1	2	3	4	5	6	7	8	9	Total Tract Area
36.0											
COG	37.7	0.0	2.1	0.0	3.5	0.0	0.0	0.4	0.0	1.5	45.0
R.S.	106.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	116.0
Diff.	-68.3	0.0	-7.9	0.0	3.5	0.0	0.0	0.4	0.0	1.5	-71.0
%	281.2	0.0	476.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	257.8
42.0	40.7	0.6	0.0	0.0	4.7	2.6	1.0	0.4	0.0	3.4	54.0
	98.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.0
	-57.3	0.6	0.0	0.0	4.7	2.6	1.0	0.4	0.0	3.4	-44.0
	240.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	181.5
49.0	21.6	1.5	0.0	0.0	13.9	3.6	0.0	2.2	0.0	9.5	70.0
	134.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	7.0	145.0
	-112.4	1.5	0.0	0.0	13.9	3.6	0.0	2.2	-4.0	2.5	-75.0
	620.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.7	207.1
51.0	6.5	0.7	1.4	1.2	6.5	14.2	0.2	1.5	4.8	10.5	48.0
	0.0	0.0	0.0	0.0	0.0	103.0	0.0	0.0	8.0	0.0	111.0
	6.5	0.7	1.4	1.2	6.5	-88.8	0.2	1.5	-3.2	10.5	-63.0
	0.0	0.0	0.0	0.0	0.0	725.4	0.0	0.0	166.7	0.0	231.3

Table 6 Continued

Census Tract # [b]	0 [c]	1	2	3	4	5	6	7	8	9	Total Tract Area
57.1											
COG	18.2	0.0	8.3	0.5	1.6	16.6	2.7	1.5	0.3	18.0	68.0
R.S.	0.0	18.0	0.0	0.0	0.0	151.0	0.0	0.0	34.0	0.0	203.0
Diff.	18.2	-18.0	8.3	0.5	1.6	-134.4	2.7	1.5	-33.7	18.0	-135.0
%	0.0	0.0	0.0	0.0	0.0	909.6	0.0	0.0	11333.3	0.0	298.5
60.0	44.6	5.4	2.0	1.7	8.3	103.8	0.6	3.3	0.0	77.9	249.0
	12.0	0.0	8.0	27.0	0.0	150.0	0.0	0.0	27.0	11.0	242.0
	32.6	5.4	-6.0	-25.3	8.3	-46.2	0.6	3.3	-27.0	66.9	7.0
	26.9	0.0	400.0	1588.2	0.0	144.5	0.0	0.0	0.0	14.1	97.2
63.0	47.5	0.0	0.0	0.0	0.0	0.0	86.8	1.9	0.0	13.1	149.0
	65.5	0.0	0.0	0.0	0.0	0.0	0.0	10.0	83.0	0.0	146.5
	-18.0	0.0	0.0	0.0	0.0	0.0	86.8	-8.1	-83.0	13.1	2.5
	137.9	0.0	0.0	0.0	0.0	0.0	0.0	526.3	0.0	0.0	98.3
69.0	33.0	2.7	5.1	0.0	5.4	0.0	0.0	0.6	0.0	6.5	54.0
	76.0	0.0	4.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	83.0
	-43.0	2.7	1.1	0.0	2.4	0.0	0.0	0.6	0.0	6.5	-29.0
	230.3	0.0	78.4	0.0	55.6	0.0	0.0	0.0	0.0	0.0	153.7

Table 6 Continued

Census Tract # [b]	0 [c]	1	2	3	4	5	6	7	8	9	Total Tract Area
72.0											
COG	25.2	36.1	1.0	10.1	4.0	79.3	0.0	0.3	1.1	66.7	224.0
R.S.	90.0	300.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	194.0	584.5
Diff.	-64.8	-264.4	1.0	10.1	4.0	79.3	0.0	0.3	1.1	-127.3	-360.5
%	357.1	832.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	290.9	269.9
73.2	70.4	0.0	28.1	0.0	12.5	0.0	43.4	0.4	0.0	133.7	289.0
	145.0	26.0	0.0	55.0	0.0	0.0	0.0	0.0	74.0	0.0	300.0
	-74.6	-26.0	28.1	-55.0	12.5	0.0	43.4	0.4	-74.0	133.7	-11.0
	206.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	103.8
77.1	73.6	3.8	0.0	8.7	1.8	0.0	0.0	1.5	0.0	64.4	154.0
	204.0	0.0	0.0	84.0	0.0	0.0	0.0	0.0	29.0	109.0	426.0
	-130.4	3.8	0.0	-75.3	1.8	0.0	0.0	1.5	-29.0	-44.6	-272.0
	277.2	0.0	0.0	965.5	0.0	0.0	0.0	0.0	0.0	169.3	276.6
88.2	54.1	0.5	2.1	0.3	3.6	0.0	0.0	0.0	0.0	7.6	68.0
	127.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	127.0
	-72.9	0.5	2.1	0.3	3.6	0.0	0.0	0.0	0.0	7.6	-59.0
	234.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	186.8

Table 6 Continued

Census Tract #[b]	0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
15.0											
COG	181.8	0.0	18.6	0.0	2.1	0.0	2.1	0.0	0.0	12.4	217.0
R.S.	267.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	267.0
Diff.	-85.2	0.0	18.6	0.0	2.1	0.0	2.1	0.0	0.0	12.4	-50.0
%	146.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	123.0
16.0											
	138.4	0.0	0.0	0.0	10.3	0.0	0.0	0.0	8.3	4.1	157.0
	161.0	41.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	202.0
	-22.6	-41.0	0.0	0.0	10.3	0.0	0.0	0.0	8.3	4.1	-45.0
	116.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	128.7
18.0											
	213.8	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	885.4	1136.0
	332.0	0.0	26.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	372.0
	-118.2	6.0	-26.0	0.0	0.0	0.0	0.0	0.0	-14.0	885.4	764.0
	155.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.7
20.0											
	97.5	3.6	0.0	0.0	1.2	0.0	0.0	0.0	0.0	39.0	142.0
	241.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	246.0
	-143.5	3.6	-5.0	0.0	1.2	0.0	0.0	0.0	0.0	39.0	-104.0
	247.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	173.2

Table 6 Continued

Census[b] Tract #	0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
28.0											
COG	277.4	13.5	0.0	0.0	22.7	0.0	0.0	0.0	147.8	115.1	597.0
R.S.	386.0	0.0	13.0	0.0	33.0	0.0	0.0	0.0	4.0	0.0	436.0
Diff.	-108.6	13.5	-13.0	0.0	-10.3	0.0	0.0	0.0	143.8	115.1	161.0
%	139.1	0.0	0.0	0.0	145.4	0.0	0.0	0.0	2.7	0.0	73.0
31.0	302.4	0.0	0.0	0.0	42.7	0.0	0.0	0.0	0.0	173.7	530.0
	439.0	0.0	8.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	538.0
	-136.6	0.0	-8.0	0.0	31.7	0.0	0.0	0.0	0.0	173.7	-8.0
	145.2	0.0	0.0	0.0	25.8	0.0	0.0	0.0	0.0	0.0	101.5
40.0	285.1	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0	58.7	357.0
	484.0	0.0	27.0	0.0	0.0	0.0	0.0	0.0	95.0	0.0	607.0
	-198.9	0.0	-27.0	0.0	2.7	0.0	0.0	0.0	-95.0	58.7	-250.0
	169.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	170.0
47.0	134.4	2.1	14.4	0.0	33.1	0.0	12.3	0.0	0.0	10.3	207.0
	269.0	0.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	281.0
	-134.6	2.1	2.4	0.0	33.1	0.0	12.3	0.0	0.0	10.3	-74.0
	200.1	0.0	83.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	135.7

Table 6 Continued

Census Tract # [b]	0 [c]	1	2	3	4	5	6	7	8	9	Total Tract Area
50.0											
COG	117.7	6.2	31.4	0.0	24.8	0.0	16.5	0.0	55.8	86.8	347.0
R.S.	312.0	12.0	24.0	0.0	15.0	0.0	0.0	0.0	44.0	22.0	429.0
Diff.	-194.3	-5.8	7.4	0.0	9.8	0.0	16.5	0.0	11.8	64.8	-82.0
%	265.1	193.5	76.4	0.0	60.5	0.0	0.0	0.0	78.9	25.3	123.6
61.0	140.5	0.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	12.4	157.0
	287.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.0	0.0	304.0
	-146.5	0.0	4.1	0.0	0.0	0.0	0.0	0.0	-17.0	12.4	-147.0
	204.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0 0	0.0	193.6

a Not applicable or missing values are shown as 0.0.

b Tracts 15.0, 16.0, 47.0, 50.0, and 61.0 are Prince Georges County tracts. Tracts 18.0, 20.0, 28.0, 31.0, and 40.0 are Montgomery County tracts. The remaining tracts are within the District.

c Refer to Table 1 for land use categories.

Residential

The estimates for the residential land use category when compared to the 1:50,000 analysis generally appear to be greater. The total error for this category is 463.7 acres greater than the corresponding error for the 1:50,000 imagery. When comparing these results with the 1:100,000 results, the difference in total error is 333.5 acres. These results indicate that the present analysis is somewhat more deviant from the COG data than was the case for the two larger scales.

Industrial/Storage

For this category, only tracts 4.0, 72.0 and 16.0 exhibit substantial differences when compared to the 1:50,000 analysis. A land area value of 71.0 acres was computed for this imagery while no area was found to be devoted to this use for either the COG data or the 1:50,000 imagery and only 13.0 acres were computed for the 1:100,000 case.

The discrepancies associated with tract 72.0 are larger at this scale than those of the 1:50,000 analysis. In the former case land area devoted to this category exceeds the reported COG value by 264.4 acres whereas in the latter case, the difference is only 59.9 acres. The COG land area value for this category in tract 16.0 is 0 as is the value derived from the 1:50,000 imagery. However, both of the smaller scale analyses reveal a value of 41.0 acres (Tables 4 and 6).

Most of the differences noted for this category appear to be the result of the varying importance of identification problems associated with changing scale. This is especially true for land uses which are somewhat difficult to identify at any scale due to their relatively small spatial extent or to the lack of visual indicators related to their presence.

Education

The locations of areas devoted to educational uses has a greater spatial dispersion than the previous category and therefore the majority of tracts have some area in education use. Most of the discrepancies between this and the 1:50,000 analysis are not great. However, when one adds the discrepancies between the COG values and the imagery derived values for each of the analyses and finds the difference the two analyses are seen to differ by 91.0 acres.

Transportation/Communication/Utilities

With respect to this land use category, examination of Tables 2, 4, and 6 reveals that overall the 1:100,000 and 1:382,000 analyses deviate less from the COG data than the 1:50,000 analysis. Furthermore, the smallest scale imagery data exhibits less error than the 1:100,000 analysis. Nevertheless, tracts 60.0, 73.2, and 77.1 have errors in excess of 25 acres when compared to the COG data.

Consumer Services

Tracts 31.0 and 47.0 have relatively large errors for this category. Land area values for both tracts are larger than the COG area values by

31.7 and 33.1 acres respectively. Upon comparing the total differences of the three scales of imagery with the COG data it is found that this analysis has the smallest absolute error and the 1:100,000 data exhibits a smaller error than the 1:50,000 data.

Offices

For this category, tracts 4.0, 51.0, 57.1, 60.0, and 72.0 exhibit relatively large deviations when compared to the COG data. These errors are exclusively confined to central city tracts. Tracts 4.0 and 72.0 represent underestimates of 25.1 and 79.3 acres respectively, whereas the land area in tracts 51.0, 57.1, and 60.0 is overestimated by 88.8, 134.4, and 46.2 acres respectively. The smallest total absolute error is associated with the 1:50,000 analysis, while the two smaller scale analyses are virtually identical in terms of absolute deviation from the COG data.

Institutional

Errors of 72.1, 86.8, and 43.4 acres are found for tracts 4.0, 63.0, and 73.2 respectively. Once again, the large errors are confined to central city tracts. Comparing the present analysis with the 1:50,000 and 1:100,000 analyses reveals little difference among the total absolute land area values when compared to the COG data. The error associated with the 1:50,000 data exceeds the two smaller scale absolute errors by approximately 15.0 acres.

Public Assembly

The total deviation of the imagery derived values from the COG values is small for this category at all three scales. The 1:50,000 analysis, however, is somewhat more sensitive to the presence of land in this category. Total absolute errors increase as scale decreases -- a result that is in agreement with expectations.

Parks and Recreation

The discrepancies between imagery derived land area values in this category and the corresponding COG values are relatively large and are not confined to central city tracts. Seven tracts exhibit differences between the COG data and imagery derived data that exceed 33 acres. The largest difference is 275.7 acres for tract 4.0. For this category, it is important to remember that the COG data are based on land ownership whereas the imagery data are based on actual use. Problems of identification and discrimination between this category and land devoted to underdeveloped and resource use may account for the large discrepancies noted above.

Underdeveloped and Resource Use

This category exhibits relatively large discrepancies between COG and imagery derived values. As noted previously, the difference of 885.4 acres for tract 18.0 is probably an error in the COG data set. At least thirteen tracts exhibit "significantly" large differences. Since the COG data are based primarily on tax assessor records, one might expect considerable under reporting for this category.

Discrepancies and Adjustment

The previously employed weighting procedure for the residential category was also computed for this analysis to adjust for land devoted to streets and street rights-of-way and the results are shown in Table 7. Discrepancies for this land use category were reduced in 19 of the 25 tracts. Substantial improvement was accomplished for tracts 21.0, 77.1, 40.0, and 61.0. The original difference (unweighted difference between COG value and imagery value) for tract 21.0 is -205.1 and the weighted difference is -88.2. For tract 77.1 the original and weighted differences are -130.4 and -0.4 respectively. An original difference of -198.9 and a weighted difference of 0.9 is found for tract 40.0, and for tract 61.0 the two values are -146.5 and -14.9. Application of the weighting procedure had virtually no affect on tracts 35.0, 60.0, 63.0, and 73.2. Considering the scale at which the residential land use information was obtained, these results are promising.

Table 7

1968 Original and Weighted Land Use Comparisons

1:382,000

(Residential Category)

CT#	4.0	21.0	26.0	35.0	36.0	42.0	49.0
1. Original COG Value	77.6	159.9	129.4	27.9	37.7	40.7	21.6
2. Weighted COG Value	110.7	276.8	199.4	24.9	97.2	73.9	44.8
3. R.S. Value	125.0	365.0	171.0	66.0	106.0	98.0	134.0
4. Original Difference	-47.0	-205.1	-41.6	-38.1	-68.3	-57.3	-112.4
5. Weighted Difference	-14.3	-88.2	28.4	-41.1	-8.8	-24.1	-89.2

CT#	51.0	57.1	60.0	63.0	69.0	72.0	73.2
1. Original COG Value	6.5	18.2	44.6	47.5	33.0	25.2	70.4
2. Weighted COG Value	14.9	54.4	43.3	46.7	50.7	65.5	73.2
3. R.S. Value	0.0	0.0	12.0	65.5	76.0	90.0	145.0
4. Original Difference	6.5	18.2	32.6	-18.0	-43.0	-64.8	-74.6
5. Weighted Difference	14.9	54.4	31.3	-18.8	-25.3	-24.5	-71.6

CT#	77.1	88.2	15.0	16.0	20.0	28.0	31.0
1. Original COG Value	73.6	54.1	181.8	138.4	97.5	277.4	302.4
2. Weighted COG Value	203.6	101.1	223.7	178.2	169.0	202.7	307.2
3. R.S. Value	204.0	127.0	267.0	161.0	241.0	386.0	439.0
4. Original Difference	-130.4	-72.9	-85.2	-22.6	-143.5	-108.6	-136.6
5. Weighted Difference	-0.4	-25.9	-43.3	17.2	-72.0	-183.3	-131.8

CT#	40.0	47.0	50.0	61.0
1. Original COG Value	285.1	134.4	117.7	140.5
2. Weighted COG Value	484.9	182.4	145.4	272.1
3. R.S. Value	484.0	269.0	312.0	287.0
4. Original Difference	-198.9	-134.6	-194.3	-146.5
5. Weighted Difference	0.9	-86.6	-166.6	-14.9

The 1970 Analyses

The analyses discussed in this section evaluate differences in the imagery derived data and the 1970 COG data files. As such, there should be less discrepancy between the two data sets. However, since funds were not made available for ground checks, the nature of the discrepancies can only be hypothesized.

1970 COG - 1:50,000

Comparisons between the 1970 COG land use data and the imagery data are made for only 21 of the original 26 census tracts since land use information for Prince Georges County tracts is not yet available. It should be noted that despite the relatively short time interval between the 1968 and 1970 COG data sets, substantial changes in land use seems to have taken place. However, it is not known to what extent these changes reflect actual land use modifications since some of the changes may reflect errors in either of the two COG data sets.

Residential

Examination of Table 8 reveals that the imagery land area values exceeded the COG values in 19 of the 21 tracts considered. Tracts 51.0 and 57.1, according to the imagery analyses, do not contain land devoted to residential use whereas the COG data report 6.1 and 17.8 acres respectively. The major differences between the 1968 and 1970 land use comparisons for this category (Table 1-A) exist in tracts 18.0, 28.0, and 31.0. For these tracts the two sets of COG data reveal differences of 46.4, 99.5,

TABLE 8[a]

1:50,000

1970 LAND USE COMPARISONS

Census[b] Tract #		0[c] RESID	1 IND/ST	2 EDUC	3 T/C/U	4 CON/S	5 OFF	6 INST	7 PUBAS	8 PARKS	9 UND/R	Total Tract Area
4.0	COG	78.7	0.0	0.0	0.1	0.0	17.9	0.0	34.5	0.0	49.7	180.9
	R.S.	114.0	71.0	54.0	0.0	0.0	7.0	0.0	11.0	30.0	0.0	386.0
	Diff.	-35.3	-71.0	-54.0	0.1	0.0	10.9	0.0	23.5	-30.0	49.7	-205.1
	%	144.9	0.0	0.0	0.0	0.0	39.1	0.0	31.9	0.0	0.0	213.4
21.0	COG	156.3	0.0	8.2	0.0	9.9	0.6	0.0	1.3	0.0	10.2	186.5
	R.S.	281.5	0.0	17.0	0.0	18.0	0.0	0.0	0.0	12.0	0.0	328.5
	Diff.	-125.2	0.0	-8.8	0.0	-8.1	0.6	0.0	1.3	-12.0	10.2	-142.0
	%	180.1	0.0	207.3	0.0	181.8	0.0	0.0	0.0	0.0	0.0	176.1
26.0	COG	137.6	0.0	0.0	0.0	0.0	1.9	0.0	3.5	0.0	78.7	221.7
	R.S.	169.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	148.0	8.0	331.0
	Diff.	-31.4	0.0	0.0	0.0	0.0	1.9	0.0	0.5	-148.0	70.7	-109.3
	%	122.8	0.0	0.0	0.0	0.0	0.0	0.0	85.7	0.0	10.2	149.3
35.0	COG	31.8	7.2	11.8	1.4	10.2	0.8	11.0	1.0	7.3	19.8	79.4
	R.S.	76.5	0.0	4.0	0.0	0.0	0.0	0.0	0.0	16.0	0.0	96.5
	Diff.	-44.7	7.2	7.8	1.4	10.2	0.8	11.0	1.0	-8.7	19.8	-17.1
	%	240.6	0.0	33.9	0.0	0.0	0.0	0.0	0.0	219.2	0.0	121.5

TABLE 8 Continued

Census[b] Tract #		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
36.0	COG	29.3	0.0	2.1	0.0	5.0	0.6	0.2	0.1	6.9	14.4	36.4
	R.S.	59.5	0.0	0.0	0.0	3.0	0.0	0.0	0.0	11.0	0.0	73.5
	Diff.	-30.2	0.0	2.1	0.0	2.0	0.6	0.2	0.1	-4.1	14.4	-37.1
	%	203.1	0.0	0.0	0.0	60.0	0.0	0.0	0.0	159.4	0.0	201.9
42.0		40.6	0.6	0.0	0.0	4.1	2.4	1.0	0.2	0.0	2.6	51.5
		82.5	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	91.5
		-41.9	0.6	0.0	0.0	-4.9	2.4	1.0	0.2	0.0	2.6	-40.0
		203.2	0.0	0.0	0.0	219.5	0.0	0.0	0.0	0.0	0.0	177.7
49.0		34.4	1.6	0.0	0.0	10.3	1.2	0.0	1.5	2.2	17.8	69.0
		110.0	0.0	5.0	0.0	11.0	0.0	0.0	0.0	2.0	2.0	130.0
		-75.6	1.6	-5.0	0.0	-0.7	1.2	0.0	1.5	0.2	15.8	-61.0
		319.8	0.0	0.0	0.0	106.8	0.0	0.0	0.0	90.9	11.2	188.4
51.0		6.1	0.8	1.4	1.2	6.7	16.3	0.2	1.4	4.8	8.4	47.3
		0.0	0.0	0.0	0.0	17.0	69.0	0.0	0.0	8.0	0.0	94.0
		6.1	0.8	1.4	1.2	-10.3	-52.7	0.2	1.4	-3.2	8.4	-46.7
		0.0	0.0	0.0	0.0	253.7	423.3	0.0	0.0	166.7	0.0	198.7

TABLE 8 Continued

Census[b] Tract #		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
57.1	COG	17.8	0.0	6.2	0.8	1.0	26.9	2.7	1.5	0.3	25.3	82.5
	R.S.	0.0	13.0	0.0	11.0	0.0	127.0	0.0	0.0	24.0	6.0	181.0
	Diff.	17.8	-13.0	6.2	-10.2	1.0	-100.1	2.7	1.5	-23.7	19.3	-98.5
	%	0.0	0.0	0.0	1375.0	0.0	472.1	0.0	0.0	8000.0	23.7	219.4
60.0		43.0	4.6	2.0	1.7	8.7	73.1	0.6	3.2	0.0	53.3	190.2
		64.0	0.0	15.0	21.0	31.0	43.0	0.0	0.0	47.0	35.0	245.0
		-21.0	4.6	-13.0	-19.3	-22.3	30.1	0.6	3.2	-47.0	18.3	-54.8
		148.8	0.0	750.0	1235.3	356.3	58.8	0.0	0.0	0.0	65.7	128.8
63.0		47.5	0.0	0.0	0.0	0.0	0.0	86.8	1.9	0.0	13.1	149.0
		80.5	0.0	12.0	0.0	0.0	20.0	0.0	0.0	59.0	0.0	171.5
		-33.0	0.0	-12.0	0.0	0.0	-20.0	86.8	1.9	-59.0	13.1	-22.5
		169.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	115.1
69.0		31.1	2.6	5.1	0.0	5.9	0.0	0.0	0.6	0.0	8.7	54.0
		81.5	0.0	12.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	97.5
		-50.4	2.6	-6.9	0.0	1.9	0.0	0.0	0.6	0.0	8.7	-43.5
		262.1	0.0	235.3	0.0	67.8	0.0	0.0	0.0	0.0	0.0	180.6

TABLE 8 Continued

Census[b] Tract #		0^c	1	2	3	4	5	6	7	8	9	Total Tract Area
72.0	COG	26.3	37.4	1.0	8.7	5.0	82.6	0.0	0.3	3.2	63.0	227.5
	R.S.	49.0	96.0	3.0	13.0	0.0	139.0	0.0	0.0	0.0	168.0	476.0
	Diff.	-22.7	-58.6	-2.0	-4.3	5.0	-56.4	0.0	0.3	3.2	-105.0	-248.5
	%	186.3	256.7	300.0	149.4	0.0	168.3	0.0	0.0	0.0	266.7	209.2
73.2		97.5	0.2	28.1	0.0	5.9	0.0	423.3	1.6	3.1	108.9	668.6
		163.0	0.0	10.0	53.0	3.0	0.0	0.0	0.0	95.0	0.0	324.0
		-65.5	0.2	18.1	-53.0	2.9	0.0	423.3	1.6	-91.9	108.9	344.6
		167.2	0.0	35.6	0.0	50.8	0.0	0.0	0.0	3064.5	0.0	48.5
77.1		66.2	0.0	5.3	7.5	0.5	6.8	0.0	1.1	0.0	52.4	139.8
		175.0	0.0	2.0	59.0	7.0	0.0	0.0	3.0	35.0	178.0	459.0
		-108.8	0.0	3.3	-51.5	-6.5	6.8	0.0	-1.9	-35.0	-125.6	-319.2
		264.4	0.0	37.7	786.7	1400.0	0.0	0.0	272.7	0.0	339.7	328.3
88.2		54.5	0.3	2.1	0.7	3.4	0.0	0.0	0.0	0.0	7.8	68.8
		105.5	0.0	4.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	112.5
		-51.0	0.3	-1.9	0.7	0.4	0.0	0.0	0.0	0.0	7.8	-43.7
		193.6	0.0	190.5	0.0	88.2	0.0	0.0	0.0	0.0	0.0	163.5

TABLE 8 Continued

Census[b] Tract #	0^c	1	2	3	4	5	6	7	8	9	Total Tract Area
18.0 COG	167.4	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	57.1	225.0
R.S.	321.0	0.0	33.0	0.0	5.0	0.0	0.0	0.0	19.0	0.0	378.0
Diff.	-153.6	0.0	-33.0	0.0	-4.5	0.0	0.0	0.0	-19.0	57.1	-153.0
%	191.8	0.0	0.0	0.0	1000.0	0.0	0.0	0.0	0.0	0.0	168.0
20.0	91.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.4	106.0
	177.5	0.0	37.0	0.0	7.0	0.0	0.0	0.0	10.0	0.0	231.5
	-85.9	0.0	-37.0	0.0	-7.0	0.0	0.0	0.0	-10.0	14.4	-125.5
	193.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	218.4
28.0	177.9	8.1	0.0	0.0	8.3	0.0	0.0	0.0	0.0	64.5	258.8
	285.5	0.0	19.0	18.0	37.0	0.0	0.0	0.0	18.0	0.0	377.5
	-107.6	8.1	-19.0	-18.0	-28.7	0.0	0.0	0.0	-18.0	64.5	-118.7
	160.5	0.0	0.0	0.0	445.8	0.0	0.0	0.0	0.0	0.0	145.9
31.0	254.6	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	47.8	303.9
	337.5	0.0	29.0	10.0	12.0	0.0	0.0	0.0	100.0	0.0	488.5
	-82.9	0.0	-29.0	-10.0	-10.5	0.0	0.0	0.0	-100.0	47.8	-184.6
	132.6	0.0	0.0	0.0	800.0	0.0	0.0	0.0	0.0	0.0	160.7

TABLE 8 Continued

Census Tract #[b]	0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
40.0 COG	277.8	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	36.2	315.6
R.S.	517.0	0.0	23.0	0.0	6.0	2.0	0.0	0.0	66.0	0.0	544.0
Diff.	-239.2	0.0	-23.0	0.0	-4.4	-2.0	0.0	0.0	-66.0	36.2	-228.4
%	186.1	0.0	0.0	0.0	375.0	0.0	0.0	0.0	0.0	0.0	172.4

[a] Not applicable or missing values are shown as 0.0.

[b] Tracts 15.0, 16.0, 47.0, 50.0, and 61.0 are Prince Georges County tracts. Tracts 18.0, 20.0, 28.0, 31.0, and 40.0 are Montgomery County tracts. The remaining tracts are within the District.

[c] Refer to Table 1 for land use categories.

and 47.8 acres with the 1968 values exceeding the 1970 values in all three cases. Since these are not central city tracts one would expect residential area stability or expansion rather than contraction. Apparently these Montgomery County tract values are inflated for two reasons: (a) for Montgomery County (approximately 142 tracts) a considerable amount of land area (109 square miles) has not been allocated to tracts, (b) land devoted to institutional uses is contained primarily within the residential land use category.

Industrial/Storage

The 1968 and 1970 COG data values for this category are virtually identical. Only minor changes exist for nine tracts and in no case do these differences exceed 3.8 acres. Major discrepancies between the 1970 COG and imagery data are found in tracts 4.0, and 72.0. Since the COG values for this category probably reflect the actual land devoted to this use, the imagery values for these two tracts must be interpreted as excessive.

Education

With respect to educational uses the analysis reveals that imagery values exceed COG values in 13 of the 21 tracts. These differences range from a low of 1.9 acres to a high of 54.0 acres. Only two tracts have zero land area values reported for both imagery and COG data. And while only minor variation exists between the two COG data sets the imagery values show greater deviation. In particular there is a problem of reporting educational land use where none is indicated by the COG data.

Transportation/Communication/Utilities

As mentioned previously, this category does not include area devoted to streets but would include bus terminals, railroad yards, etc. One would expect, therefore, only small amounts of land devoted to this use in most tracts. Indeed this is the case for the 21 tracts examined. The possible exceptions are tracts 73.2 and 77.1 showing 53.0 acres and 59.0 acres respectively. These imagery values are not in agreement with the values reported by COG. In the former case (tract 73.2) the COG data shows a value of 0.0 and in the latter case (tract 77.1) a value of 7.5 acres. Ten tracts have no land area devoted to this use for both data sets.

Consumer Services

Imagery derived values for this category exceed COG values in 11 out of 21 cases. These overestimates range from a low of 0.7 acres to a high of 28.7 acres. Of the remaining tracts, seven had higher values reported by the COG data ranging from 0.4 acres to 10.2 acres. The extreme differences such as the 28.7 acres for tract 28.0 and the 10.2 acres for tract 35.0 are proportionally more important than their actual magnitude suggests. Most consumer services, with the exception of large planned shopping facilities, are not extensive but intensive users of land. There is little doubt that problems of interpretation and data compatibility are responsible for the major differences noted above.

Offices

Three tracts exhibit especially large discrepancies for this land use category. The imagery derived land use value for tract 51.0 exceeds the corresponding COG value by 52.7 acres. Apparently, the interpretation of the imagery for this tract resulted in the inclusion of other land uses within this category as evidenced by the occurrence of zero values (see Table 8) for most of the remaining categories. Tract 57.1 has an imagery value which exceeds the COG value by 100.1 acres, a considerable difference relative to the total tract area. Finally, the imagery value for tract 72.0 is 56.4 acres larger than the COG value.

Institutional

In all 21 tracts COG land area values either equal or exceed the imagery values. Zero values are reported by both data sets for 13 tracts. The largest discrepancy is 423.0 acres for tract 73.2. However, there is strong reason to believe that this difference is primarily the result of an inconsistency in the 1970 COG data file. The 1968 COG data file reports a value of 43.4 acres whereas the 1970 data file lists a value of 423.3 acres (Table 1-A). It is believed that this latter value is a gross overestimation of the amount of land devoted to institutional uses. On the basis of the comparisons made, however, it is evident that the imagery analysis is insensitive to land devoted to this use.

Public Assembly

The present analysis is almost identical with the 1968 analysis. Tract 4.0 has the largest amount of land devoted to this use in both cases. A COG value of 34.5 acres and an imagery value of 11.0 acres results in a difference of 23.5 acres. Discrepancies for the remaining tracts are, for the most part, small, the largest being 3.2 acres.

Parks and Recreation - Underdeveloped and Resource Use

The ability to distinguish between land devoted to "Parks and Recreation" and "Underdeveloped and Resource Use" was disappointing. In the former case, imagery values exceeded COG values in 16 tracts while in the latter, only two tracts had larger imagery land area values. The two COG data sets are similar for the Parks and Recreation category, but there are two major differences in the Underdeveloped and Resource Use category. It was previously argued that the 885.4 acres devoted to this use category for tract 18.0 is an overly large estimate. This is supported by the 1970 COG data which reports a value of 57.1 acres. However, analysis of the imagery failed to identify any land devoted to this use. It is possible, due to tree cover, that some of the land allocated to the residential category actually belongs to the category under consideration. Tract 31.0 has a difference of 125.9 acres between the two COG data sets. The 1968 file lists a value of 173.7 acres and the 1970 file reports a value of 47.8 acres.

Discrepancies and Adjustment

Following the form adopted for previous sections, the residential land area values were proportionally weighted on the basis of total tract area and comparisons were made. Table 9 shows the results of this weighting procedure. The original differences were reduced for 16 tracts and "substantial" improvements were obtained for tracts 21.0, 36.0, 42.0, 72.0, 77.1, 88.2, 18.0, 20.0, 28.0, and 40.0. The difference for tract 73.2, on the other hand, increased from 65.5 acres to 115.7 acres. Much of this increase can be attributed to the inflated total tract area value of 668.6 acres resulting from the 423.3 acres reported for the institutional category.

Table 9

1970 Original and Weighted Land Use Comparisons

1:50,000

(Residential Category)

CT#	4.0	21.0	26.0	35.0	36.0	42.0	49.0
1. Original COG Value	78.7	156.3	137.6	31.8	29.3	40.6	34.4
2. Weighted COG Value	167.9	275.3	205.5	38.7	59.2	72.1	64.8
3. R.S. Value	114.0	281.5	169.0	76.5	59.5	82.5	110.0
4. Original Difference	-35.3	-125.2	-31.4	-44.7	-30.2	-41.9	-75.6
5. Weighted Difference	53.9	-6.2	36.5	-37.8	-0.3	-10.4	-45.2

CT#	51.0	57.1	60.0	63.0	69.0	72.0	73.2
1. Original COG Value	6.1	17.8	43.0	47.5	31.1	26.3	97.5
2. Weighted COG Value	12.1	39.1	55.4	54.7	56.2	55.2	47.3
3. R.S. Value	0.0	0.0	64.0	80.5	81.2	49.0	163.0
4. Original Difference	6.1	17.8	-21.0	-33.0	-50.4	-22.7	-65.5
5. Weighted Difference	12.1	39.1	-8.6	-25.8	-25.0	6.2	-115.7

CT#	77.1	88.2	18.0	20.0	28.0	31.0	40.0
1. Original COG Value	66.2	54.5	167.4	91.6	177.9	254.6	277.8
2. Weighted COG Value	217.6	89.1	281.2	200.0	259.3	409.4	478.7
3. R.S. Value	175.0	105.5	321.0	177.5	285.5	337.5	517.0
4. Original Difference	-108.8	-51.0	-153.6	-85.9	-107.6	-82.9	-239.2
5. Weighted Difference	42.6	-16.4	-39.8	22.5	-26.2	71.9	-38.3

<u>1970 COG - 1:100,000</u>

Land use comparisons between the 1970 COG data and the 1:100,000 imagery are similar to the comparisons between the 1968 COG data and this scale of imagery. The only major differences are those which have already been pointed out in the corresponding comparisons for 1968. However, for the convenience of the reader, these discrepancies will be reiterated here.

Residential

For this category, 18 tracts have larger imagery values than COG values. These differences range from a low of 31.2 acres to a high of 169.9 acres. (Table 10) Tracts 4.0, 51.0, and 57.1 have a zero entry for land devoted to this use while the COG data report 78.7, 6.1 and 17.8 acres respectively. Due to adjustments of the COG data files from 1968 to 1970 tracts 73.2, 18.0, and 31.0 exhibit considerable differences when compared to the 1968 COG - 1:100,000 analysis.

Industrial/Storage

The total deviation across tracts for this category is smaller than the corresponding deviation for the 1968 analysis. Because of changes in the COG files between 1968 and 1970, the imagery values correspond more closely in the latter case as expected.

Education

The total absolute value deviation for this category between the imagery and COG data sets is 160.9 acres. The largest discrepancy is

TABLE 10[a]

1:100,000

1970 LAND USE COMPARISONS

Census Tract # [b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
4.0	COG	78.7	0.0	0.0	0.1	0.0	17.9	0.0	34.5	0.0	49.7	180.9
	R.S.	0.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	127.0	0.0	394.0
	Diff.	78.7	-13.0	0.0	0.1	0.0	17.9	0.0	34.5	-127.0	49.7	-213.1
	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	217.8
21.0	COG	156.3	0.0	8.2	0.0	9.9	0.6	0.0	1.3	0.0	10.2	186.5
	R.S.	306.0	0.0	15.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0	334.0
	Diff.	-149.7	0.0	-6.8	0.0	9.9	0.6	0.0	1.3	-13.0	10.2	-147.5
	%	195.8	0.0	182.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	179.1
26.0	COG	137.6	0.0	0.0	0.0	0.0	1.9	0.0	3.5	0.0	78.7	221.7
	R.S.	192.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	162.0	0.0	354.0
	Diff.	-54.4	0.0	0.0	0.0	0.0	1.9	0.0	3.5	-162.0	78.7	-132.3
	%	139.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	159.7
35.0	COG	31.8	7.2	11.8	1.4	10.2	0.8	11.0	1.0	7.3	19.8	79.4
	R.S.	70.5	0.0	15.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	94.5
	Diff.	-38.7	7.2	-3.2	1.4	1.2	0.8	11.0	1.0	7.3	19.8	-15.1
	%	221.7	0.0	127.1	0.0	88.2	0.0	0.0	0.0	0.0	0.0	119.0

Table 10 Continued

Census Tract #[b]		0^c	1	2	3	4	5	6	7	8	9	Total Tract Area
36.0	COG	29.3	0.0	2.1	0.0	5.0	0.6	0.2	0.1	6.9	14.4	36.4
	R.S.	60.5	0.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.5
	Diff.	-31.2	0.0	-9.9	0.0	5.0	0.6	0.2	0.1	6.9	14.4	-36.1
	%	206.5	0.0	571.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	199.2
42.0		40.6	0.6	0.0	0.0	4.1	2.4	1.0	0.2	0.0	2.6	51.5
		91.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	93.0
		-50.4	0.6	0.0	0.0	4.1	0.4	1.0	0.2	0.0	2.6	-41.5
		224.1	0.0	0.0	0.0	0.0	83.3	0.0	0.0	0.0	0.0	180.6
49.0		34.4	1.6	0.0	0.0	10.3	1.2	0.0	1.5	2.2	17.8	69.0
		129.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	141.0
		-94.6	1.6	-6.0	0.0	10.3	1.2	0.0	1.5	-3.8	17.8	-72.0
		375.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	272.7	0.0	204.3
51.0		6.1	0.8	1.4	1.2	6.7	16.3	0.2	1.4	4.8	8.4	47.3
		0.0	0.0	0.0	0.0	11.0	78.0	0.0	0.0	10.0	0.0	99.0
		6.1	0.8	1.4	1.2	-4.3	-61.7	0.2	1.4	-5.2	8.4	-51.7
		0.0	0.0	0.0	0.0	164.2	478.5	0.0	0.0	208.3	0.0	209.3
57.1		17.8	0.0	6.2	0.8	1.0	26.9	2.7	1.5	0.3	25.3	82.5
		0.0	12.0	0.0	0.0	0.0	136.0	0.0	0.0	30.0	5.0	183.0
		17.8	-12.0	6.2	0.8	1.0	-109.1	2.7	1.5	-29.7	20.3	-100.5
		0.0	0.0	0.0	0.0	0.0	505.6	0.0	0.0	10000.0	19.8	221.8

Table 10 Continued

Census Tract # [b]	0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
60.0 COG	43.0	4.6	2.0	1.7	8.7	73.1	0.6	3.2	0.0	53.3	190.2
R.S.	77.0	0.0	13.0	30.0	10.0	54.0	0.0	0.0	62.0	15.0	261.0
Diff.	-34.0	4.6	-11.0	-28.3	-1.3	19.1	0.6	3.2	-62.0	38.3	-70.8
%	179.1	0.0	650.0	1764.7	114.9	73.9	0.0	0.0	0.0	28.1	137.2
63.0	47.5	0.0	0.0	0.0	0.0	0.0	86.8	1.9	0.0	13.1	149.0
	111.5	4.0	10.0	0.0	0.0	0.0	0.0	0.0	45.0	0.0	170.5
	-64.0	-4.0	-10.0	0.0	0.0	0.0	86.8	1.9	-45.0	13.1	-21.5
	234.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.4
69.0	31.1	2.6	5.1	0.0	5.9	0.0	0.0	0.6	0.0	8.7	54.0
	71.5	0.0	8.0	0.0	10.0	0.0	0.0	0.0	0.0	4.0	93.5
	-40.4	2.6	-2.9	0.0	-4.1	0.0	0.0	0.6	0.0	4.7	-39.5
	229.9	0.0	156.9	0.0	169.5	0.0	0.0	0.0	0.0	46.0	173.1
72.0	26.3	37.4	1.0	8.7	5.0	82.6	0.0	0.3	3.2	63.0	227.5
	70.0	64.0	6.0	0.0	0.0	208.0	0.0	0.0	0.0	178.5	526.5
	-43.7	-26.6	-5.0	8.7	5.0	-125.4	0.0	0.3	3.2	-115.5	-299.0
	266.2	171.1	600.0	0.0	0.0	251.8	0.0	0.0	0.0	283.3	231.4
73.2	97.5	0.2	28.1	0.0	5.9	0.0	423.3	1.6	3.1	108.9	668.6
	191.5	0.0	5.0	47.0	0.0	0.0	0.0	0.0	84.0	0.0	327.5
	-94.0	0.2	23.1	-47.0	5.9	0.0	423.3	1.6	-80.9	108.9	341.1
	196.4	0.0	17.8	0.0	0.0	0.0	0.0	0.0	2709.7	0.0	49.0

Table 10 Continued

Census[b] Tract #		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
77.1	COG	66.2	0.0	5.3	7.5	0.5	6.8	0.0	1.1	0.0	52.4	139.8
	R.S.	178.0	0.0	3.0	78.0	6.0	0.0	0.0	0.0	31.0	175.0	471.0
	Diff.	-111.8	0.0	2.3	-70.5	-5.5	6.8	0.0	1.1	-31.0	-122.6	-331.2
	%	268.9	0.0	56.6	1040.0	1200.0	0.0	0.0	0.0	0.0	334.0	336.9
88.2		54.5	0.3	2.1	0.7	3.4	0.0	0.0	0.0	0.0	7.8	68.8
		125.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.5
		-71.0	0.3	2.1	0.7	3.4	0.0	0.0	0.0	0.0	7.8	-56.7
		230.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	182.4
18.0		167.4	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	57.1	225.0
		337.0	0.0	17.0	0.0	0.0	0.0	0.0	0.0	22.0	0.0	376.0
		-169.6	0.0	-17.0	0.0	0.5	0.0	0.0	0.0	-22.0	57.1	-151.0
		201.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	167.1
20.0		91.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.4	106.0
		189.0	18.0	11.0	0.0	10.0	0.0	0.0	0.0	9.0	0.0	237.0
		-97.4	-18.0	-11.0	0.0	-10.0	0.0	0.0	0.0	-9.0	14.4	-131.0
		206.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	223.6
28.0		177.9	8.1	0.0	0.0	8.3	0.0	0.0	0.0	0.0	64.5	258.8
		317.5	0.0	15.0	4.0	38.0	0.0	0.0	0.0	21.0	0.0	395.5
		-139.6	8.1	-15.0	-4.0	-29.7	0.0	0.0	0.0	-21.0	64.5	-136.7
		178.5	0.0	0.0	0.0	457.8	0.0	0.0	0.0	0.0	0.0	152.8

Table 10 Continued

Census Tract # [b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
31.0	COG	254.6	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	47.8	303.9
	R.S.	366.0	0.0	8.0	0.0	14.0	0.0	0.0	4.0	103.0	0.0	495.0
	Diff.	-111.4	0.0	-8.0	0.0	-12.5	0.0	0.0	-4.0	-103.0	47.8	-191.1
	%	143.8	0.0	0.0	0.0	933.3	0.0	0.0	0.0	0.0	0.0	162.9
40.0		277.8	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	36.2	315.6
		446.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	93.0	0.0	559.0
		-168.2	0.0	-20.0	0.0	1.6	0.0	0.0	0.0	-93.0	36.2	-243.4
		160.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	177.1

[a] Not applicable or missing values are shown as 0.0.

[b] Tracts 15.0, 16.0, 47.0, 50.0, and 61.0 are Prince Georges County tracts. Tracts 18.0, 20.0, 28.0, 31.0, and 40.0 are Montgomery County tracts. The remaining tracts are within the District.

[c] Refer to Table 1 for land use categories.

23.1 acres for tract 73.2 and the lowest is 1.4 acres for tract 51.0. Only three tracts report zero values for both imagery and parcel data. The major difference between the COG data sets is for tract 4.0 which showed a value of 16.6 acres in 1968 and zero acres in 1970.

Transportation/Communication/Utilities

The imagery derived values for this category exceed the corresponding COG values in four tracts and three of these are greater than 28 acres. The maximum discrepancy is 70.5 acres for tract 77.1. These results closely resemble the 1968 analysis since only minor changes are found between the COG data sets.

Consumer Services

There is one relatively large difference noted for this category. Tract 28.0 has a 1970 acreage of 8.3 and an imagery value of 38.0 resulting in a difference of 29.7 acres. However, approximately half of this difference is attributable to a discrepancy of 14.4 acres in the reported COG values for this data item between 1968 and 1970 (Table 1-A).

Offices

Several large discrepancies associated with this category are worthy of mention here. For tract 51.0 the imagery value is 61.7 acres larger than the COG value. The difference for tract 57.1 is a substantial 109.1 acres and a difference of 125.4 acres is found for tract 72.0. However, tract 72.0 contains the Washington Navy Yard. This use was allocated to the present category and includes all land area within the boundary surrounding the military complex.

Institutional and Public Assembly

At this scale the imagery interpretation proved inadequate for these two land use categories. Only one tract was reported as having land use devoted to either of these uses, and this was at variance with the COG file. Yet several tracts exhibit large acreages both in 1968 and 1970 based on the parcel data. Apparent discrepancies in the COG data make accurate interpretation of the results more difficult than might otherwise be the case. Nevertheless, Institutional and Public Assembly acreage interpretability would seem to require better definition and a more systematic investigation.

Parks and Recreation - Underdeveloped and Resource Use

Compared to the 1968 analysis, the major differences noted at this scale are for tracts 18.0 and 25.0. In the former the 885.4 acres from the 1968 data has been modified to 57.1 acres for Underdeveloped and Resource Use and in the latter, the Parks and Recreation value changed from 147.8 acres to zero acres. The COG value for the Underdeveloped and Resource Use category was 115.1 acres in 1968 and 64.5 acres in 1970. These differences partially account for the reversal of the total tract area comparisons for tract 28.0. In 1968 the COG value exceeded the imagery value by 201.5 acres (Table 4) whereas in 1970 the imagery value was 136.7 acres larger than the corresponding COG value.

Discrepancies and Adjustment

Returning to a reconsideration of the residential category, adjustments applied to the COG residential values (see Table 11) results in improvement for 16 of the 21 tracts examined. The differences for the remaining tracts increased and this is primarily due to the proportional difference for several categories within each of these tracts and the failure of the imagery interpretation analysis to identify any land within the residential category.

Table 11

1970 Original and Weighted Land Use Comparisons

1:100,000

(Residential Category)

CT#	4.0	21.0	26.0	35.0	36.0	42.0	49.0
1. Original COG Value	78.7	156.3	137.6	31.8	29.3	40.6	34.4
2. Weighted COG Value	171.4	279.9	219.8	37.9	58.4	73.3	70.4
3. R.S. Value	0.0	306.0	192.0	70.5	60.5	91.0	129.0
4. Original Difference	78.7	-149.7	-54.4	-38.7	-31.2	-50.4	-94.6
5. Weighted Difference	171.4	-26.1	27.8	-32.6	-2.1	-17.7	-58.6
CT#	51.0	57.1	60.0	63.0	69.0	72.0	73.2
1. Original COG Value	6.1	17.8	43.0	47.5	31.1	26.3	97.5
2. Weighted COG Value	12.8	39.5	58.9	54.4	53.8	61.1	47.8
3. R.S. Value	0.0	0.0	77.0	111.5	71.5	70.0	191.5
4. Original Difference	6.1	17.8	-34.0	-64.0	-40.4	-43.7	-94.0
5. Weighted Difference	12.8	39.5	-18.1	-57.1	-17.7	-8.9	-143.7
CT#	77.1	88.2	18.0	20.0	28.0	31.0	40.0
1. Original COG Value	66.2	54.5	167.4	91.6	177.9	254.6	277.8
2. Weighted COG Value	223.3	99.4	279.7	204.8	271.7	414.8	491.9
3. R.S. Value	178.0	125.5	337.0	189.0	317.5	366.0	446.0
4. Original Difference	-71.0	-71.0	-169.6	-97.4	-139.6	-111.4	-168.2
5. Weighted Difference	45.3	-26.0	-57.3	15.8	-45.8	48.8	45.9

1970 COG - 1:382,000

Table 12 shows higher imagery values in 18 of the 21 tracts. These values range from 29.0 acres to 357.0 acres. The magnitude of the latter value is due to the 300.5 acres allocated to the Industrial/Storage category according to the imagery analysis.

Residential

One consistent finding for this category is that in almost all tracts and at the three scales, imagery estimates exceed the COG estimates because of the differing methods of including land area devoted to streets. As mentioned previously, residential land in Montgomery County tracts 18.0, 28.0, and 31.0 decreased substantially during the two year data collection interval.

Industrial/Storage

Only three tracts have non-zero land area values recorded for the imagery data. Tract 72.0 has a value of 300.5 acres and tract 73.2 a value of 25.8 acres. Both differ substantially from the corresponding COG values.

Education

The imagery data for this category compares more favorably with the 1970 COG data than the 1968 COG data because of the changes in land allocated to this use during the two year period. The 1:100,000 scale analysis results deviate from the present analysis by 16.8 acres in terms of total absolute differences.

TABLE 12[a]

1:382,000

1970 LAND USE COMPARISONS

Census Tract #[b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
4.0	COG	78.7	0.0	0.0	0.1	0.0	17.9	0.0	34.5	0.0	49.7	180.9
	R.S.	125.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	282.0	0.0	407.0
	Diff.	-46.3	0.0	0.0	0.1	0.0	17.9	0.0	34.5	-282.0	49.7	-226.1
	%	158.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	225.0
21.0	COG	156.3	0.0	8.2	0.0	9.9	0.6	0.0	1.3	0.0	10.2	186.5
	R.S.	365.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	16.0	0.0	386.0
	Diff.	-208.7	0.0	3.2	0.0	9.9	0.6	0.0	1.3	-16.0	10.2	-199.5
	%	233.5	0.0	61.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	207.0
26.0	COG	137.6	0.0	0.0	0.0	0.0	1.9	0.0	3.5	0.0	78.7	221.7
	R.S.	171.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	171.0	0.0	342.0
	Diff.	-33.4	0.0	0.0	0.0	0.0	1.9	0.0	3.5	-171.0	78.7	-120.2
	%	124.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	154.3
35.0	COG	31.8	7.2	11.8	1.4	10.2	0.8	11.0	1.0	7.3	19.8	79.4
	R.S.	66.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.0
	Diff.	-34.2	7.2	1.8	1.4	10.2	0.8	11.0	1.0	7.3	19.8	3.4
	%	207.5	0.0	84.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	95.7

TABLE 12 Continued

Census Tract[b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
36.0	COG	29.3	0.0	2.1	0.0	5.0	0.6	0.2	0.1	6.9	14.4	36.4
	R.S.	106.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	116.0
	Diff.	-76.7	0.0	-7.9	0.0	5.0	0.6	0.2	0.1	6.9	14.4	-79.6
	%	361.8	0.0	476.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	318.7
42.0		40.6	0.6	0.0	0.0	4.1	2.4	1.0	0.2	0.0	2.6	51.5
		98.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.0
		-57.4	0.6	0.0	0.0	4.1	2.4	1.0	0.2	0.0	2.6	-46.5
		241.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	190.3
49.0		34.4	1.6	0.0	0.0	10.3	1.2	0.0	1.5	2.2	17.8	69.0
		134.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	7.0	145.0
		-99.6	1.6	0.0	0.0	10.3	1.2	0.0	1.5	-1.8	10.8	-76.0
		389.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	181.8	39.3	210.1
51.0		6.1	0.8	1.4	1.2	6.7	16.3	0.2	1.4	4.8	8.4	47.3
		0.0	0.0	0.0	0.0	0.0	103.0	0.0	0.0	8.0	0.0	111.0
		6.1	0.8	1.4	1.2	6.7	-87.7	0.2	1.4	-3.2	8.4	-63.7
		0.0	0.0	0.0	0.0	0.0	631.9	0.0	0.0	166.7	0.0	234.7

TABLE 12 Continued

Census Tract[b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
57.1	COG	17.8	0.0	6.2	0.8	1.0	26.9	2.7	1.5	0.3	25.3	82.5
	R.S.	0.0	18.0	0.0	0.0	0.0	151.0	0.0	0.0	34.0	0.0	203.0
	Diff.	17.8	-18.0	6.2	0.8	1.0	-124.1	2.7	1.5	-33.7	25.3	-120.5
	%	0.0	0.0	0.0	0.0	0.0	561.3	0.0	0.0	11333.3	0.0	246.1
60.0		43.0	4.6	2.0	1.7	8.7	73.1	0.6	3.2	0.0	53.3	190.2
		12.0	0.0	8.0	27.0	0.0	150.0	0.0	0.0	27.0	11.0	242.0
		31.0	4.6	-6.0	-25.3	8.7	-76.9	0.6	3.2	-27.0	42.3	-51.8
		27.9	0.0	400.0	1588.2	0.0	205.2	0.0	0.0	0.0	20.6	127.2
63.0		47.5	0.0	0.0	0.0	0.0	0.0	86.8	1.9	0.0	13.1	149.0
		65.5	0.0	0.0	0.0	0.0	0.0	0.0	10.0	83.0	0.0	146.5
		-18.0	0.0	0.0	0.0	0.0	0.0	86.8	-8.1	-83.0	13.1	2.5
		137.9	0.0	0.0	0.0	0.0	0.0	0.0	526.3	0.0	0.0	98.3
69.0		31.1	2.6	5.1	0.0	5.9	0.0	0.0	0.6	0.0	8.7	54.0
		76.0	0.0	4.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	83.0
		-44.9	2.6	1.1	0.0	2.9	0.0	0.0	0.6	0.0	8.7	-29.0
		244.4	0.0	78.4	0.0	50.8	0.0	0.0	0.0	0.0	0.0	153.7

TABLE 12 Continued

Census Tract #[b]		0^c	1	2	3	4	5	6	7	8	9	Total Tract Area
72.0	COG	26.3	37.4	1.0	8.7	5.0	82.6	0.0	0.3	3.2	63.0	227.5
	R.S.	90.0	300.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	194.0	584.5
	Diff.	-63.7	-263.1	1.0	8.7	5.0	82.6	0.0	0.3	3.2	-131.0	-357.0
	%	342.2	803.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	307.9	256.9
73.2		97.5	0.2	28.1	0.0	5.9	0.0	423.3	1.6	3.1	108.9	668.6
		145.0	26.0	0.0	55.0	0.0	0.0	0.0	0.0	74.0	0.0	300.0
		-47.5	-25.8	28.1	-55.0	5.9	0.0	423.3	1.6	-70.9	108.9	368.6
		148.7	13000.0	0.0	0.0	0.0	0.0	0.0	0.0	2387.1	0.0	44.9
77.1		66.2	0.0	5.3	7.5	0.5	6.8	0.0	1.1	0.0	52.4	139.8
		204.0	0.0	0.0	84.0	0.0	0.0	0.0	0.0	29.0	109.0	426.0
		-137.8	0.0	5.3	-76.5	0.5	6.8	0.0	1.1	-29.0	-56.6	-286.2
		308.2	0.0	0.0	1120.0	0.0	0.0	0.0	0.0	0.0	208.0	304.7
88.2		54.5	0.3	2.1	0.7	3.4	0.0	0.0	0.0	0.0	7.8	68.8
		127.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	127.0
		-72.5	0.3	2.1	0.7	3.4	0.0	0.0	0.0	0.0	7.8	-58.2
		233.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	184.6

TABLE 12 Continued

Census Tract #[b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
18.0	COG	167.4	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	57.1	225.0
	R.S.	332.0	0.0	26.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	372.0
	Diff.	-164.6	0.0	-26.0	0.0	0.5	0.0	0.0	0.0	-14.0	57.1	-147.0
	%	198.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	165.3
20.0		91.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.4	106.0
		241.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	246.0
		-149.4	0.0	-5.0	0.0	0.0	0.0	0.0	0.0	0.0	14.4	-140.0
		263.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	232.1
28.0		177.9	8.1	0.0	0.0	8.3	0.0	0.0	0.0	0.0	64.5	258.8
		386.0	0.0	13.0	0.0	33.0	0.0	0.0	0.0	4.0	0.0	436.0
		-208.1	8.1	-13.0	0.0	-24.7	0.0	0.0	0.0	-4.0	64.5	-177.2
		217.0	0.0	0.0	0.0	397.6	0.0	0.0	0.0	0.0	0.0	168.5
31.0		254.6	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	47.8	303.9
		439.0	0.0	8.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	538.0
		-184.4	0.0	-8.0	0.0	-9.5	0.0	0.0	0.0	0.0	47.8	-234.1
		172.4	0.0	0.0	0.0	733.3	0.0	0.0	0.0	0.0	0.0	177.0

TABLE 12 Continued

Census Tract[b]		0[c]	1	2	3	4	5	6	7	8	9	Total Tract Area
40.0	COG	277.8	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	36.2	315.6
	R.S.	484.0	0.0	27.0	0.0	0.0	0.0	0.0	0.0	95.0	0.0	607.0
	Diff.	-206.2	0.0	-27.0	0.0	1.6	0.0	0.0	0.0	-95.0	36.2	-291.4
	%	174.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	192.3

[a] Not applicable or missing values are shown as 0.0.

[b] Tracts 15.0, 16.0, 47.0, 50.0, and 61.0 are Prince Georges County tracts. Tracts 18.0, 20.0, 28.0, 31.0, and 40.0 are Montgomery County tracts. The remaining tracts are within the District.

[c] Refer to Table 1 for land use categories.

Transportation/Communication/Utilities

The imagery data report non-zero land area values for only three tracts. In each case, the imagery values exceed those listed by COG. Overall, there is essentially no difference between the interpretation of this imagery and that at the 1:100,000 scale.

Consumer Services

Interpretation of the imagery failed to identify any land devoted to this use in 14 tracts even though the COG data reported the occurrence of some land in consumer service use. Comparing this analysis with the 1970 COG - 1:50,000 analysis uncovers an interesting and surprising result. The smaller scale imagery deviates from the COG data by a total of 73.9 acres whereas the larger scale imagery values differ by 132.3 acres. However, it must be remembered that these total differences are based on a comparison with the 1970 COG data.

Offices

Imagery derived values exceed COG values for three of the 21 tracts examined. Comparison of the present analysis with the results of the 1:50,000 analysis reveals less total deviation from the COG data for the larger scale imagery.

Institutional

The imagery derived values for all three scales are virtually identical. Two tracts, 63.0 and 73.2, have extremely large land areas devoted to this category according to the COG values shown in Table 12.

In both cases, the corresponding imagery values are zero.

Public Assembly

The only large discrepancy which exists for this land use category is a COG value of 34.5 acres in tract 4.0. The difference obtained from the 1:50,000 analysis (Table 8) is 23.5 acres since, in this case, an imagery value of 11.0 acres was reported. In general, the analyses at all three scales were acceptable.

Parks and Recreation - Underdeveloped and Resource Use

Both of these categories have been the source of serious identification problems since it is exceedingly difficult to distinguish between the two land uses on the basis of visual information. The 282.0 acre value obtained for tract 4.0 is probably located in the proper category. Other substantial differences are basically the result of either unallocated land in the COG data file or misinterpretations in the imagery analysis.

Discrepancies and Adjustment

The weights applied to the COG values in the residential category for comparison with the 1:382,000 imagery analysis result in improvement in 13 of the 21 tracts (Table 13). Essentially the same tracts for which no improvement was made in the 1:50,000 and 1:100,000 analyses also show no improvement here; these tracts are 4.0, 51.0, 57.1, and 73.2. The remaining four tracts showing little improvement at the present scale are 26.0, 35.0, 60.0, and 63.0. Changes across several land use categories have resulted in modifications of the total tract areas, and subsequently biased the magnitude of the weights.

Table 13

1970 Original and Weighted Land Use Comparisons

1:382,000

(Residential Category)

CT#	4.0	21.0	26.0	35.0	36.0	42.0	49.0
1. Original COG Value	78.7	156.3	137.6	31.8	29.3	40.6	34.4
2. Weighted COG Value	177.1	323.5	212.4	30.5	93.4	77.2	72.4
3. R.S. Value	125.0	365.0	171.0	66.0	106.0	98.0	134.0
4. Original Difference	-46.3	-208.7	-33.4	-34.2	-76.7	-57.4	-99.6
5. Weighted Difference	52.1	-41.5	41.4	-35.5	-12.6	-20.8	-61.6

CT#	51.0	57.1	60.0	63.0	69.0	72.0	73.2
1. Original COG Value	6.1	17.8	43.0	47.5	31.1	26.3	97.5
2. Weighted COG Value	14.3	43.8	54.7	46.7	47.8	67.8	43.8
3. R.S. Value	0.0	0.0	12.0	65.5	76.0	90.0	145.0
4. Original Difference	6.1	17.8	31.0	-18.0	-44.9	-63.7	-47.5
5. Weighted Difference	14.3	43.8	42.7	-18.8	-28.2	-22.2	-101.2

CT#	77.1	88.2	18.0	20.0	28.0	31.0	40.0
1. Original COG Value	66.2	54.5	167.4	91.6	177.9	254.6	277.8
2. Weighted COG Value	201.9	100.6	276.8	212.5	299.5	450.8	534.2
3. R.S. Value	204.0	127.0	332.0	241.0	386.0	439.0	484.0
4. Original Difference	-137.8	-72.5	-164.6	-149.4	-208.1	-184.4	-206.2
5. Weighted Difference	-2.1	-26.4	-55.2	-28.5	-86.5	-11.8	50.2

Evaluation and Summary

The research discussed in this chapter suggests a high potential for utilizing small scale imagery for obtaining land use information. The results presented here, however, are not conclusive because a thorough and systematic analysis could not be completed.

Had it been feasible to establish and correct the discrepancies in the existing COG data files before the analyses were underway more definite results might have obtained. This would be especially true if the field workers needed for such "ground truth" could have been used as interpreters. Familiarity with a study area can be expected when an operational system is established and such a useful bias seems to have developed in this research.

A major problem also results because of definitional differences between parcel data and that derived by imagery interpretation. The approach taken with the adjustment in residential values exemplifies this problem. The parcel definition of residential space excludes streets, and similar non-inhabitable uses which must normally be components of residential areas. The adjustment utilized in this analysis is a first approximation to correcting this definitional problem. Refinements are obviously possible.

Despite the problems mentioned the research is encouraging. In certain cases and using appropriate imagery it would seem possible to obtain land use information in essentially the format now being used by some agencies. The Washington COG categories would appear to have rather broad applicability and this research shows that imagery can be utilized to obtain reasonable estimates of acreage in each use. Furthermore, a continuing program of remote sensing inputs would probably be much more reliable than the exploratory work completed here.

While the 1:100,000 scale imagery apparently is capable of providing an adequate data base ease and reliability of interpretation improve with larger scales. The trade-off between areal coverage and interpretability lies somewhere between scales of 1:50,000 and 1:100,000 in regard to the purpose of replicating land use at the census tract level. A more detailed classification schema or greatly increased reliability would require a corresponding adjustment in the scale of the imagery. Ultimate utilization of the data set will determine the criteria upon which such parameters must be judged.

The provision of land use inputs for macro-models of urban development would seem to be feasible. The next chapter discusses research undertaken to determine the possibility of developing population and housing counts, and subsequently densities, from the imagery (1:50,000) utilized for the present analyses. Such inputs are common in urban models.

A serious void in present knowledge would appear to be the lack of accurate cost information regarding acquisition of metropolitan wide data sets in comparison with other collection methodologies. Additionally little is known regarding improving the compatibility between user needs and imagery data. That is, can a model input be redefined in order that it might be directly derived from the photography? Would models so redefined be more or less useful? Only through systematic research can such questions be properly answered. If other situations are analogous, for instance, agricultural applications, then optimism is appropriate in the present case.

IV. ESTIMATING POPULATION AND DWELLING UNITS FROM IMAGERY

Urban areas are dynamic systems where changes in the location of demands for public or quasi-public services occur more rapidly than our means for monitoring such changes. Census data provide a bench mark every ten years as to population and housing characteristics. Land use or origin-destination surveys supply an occasional cross-sectional look at the status of other phenomena in the city. Yet, these data sources are insufficient for many planning and management needs. In Chapter I the need for current information by small area units was discussed. Rates and locations of change in population and housing counts are not known with accuracy, especially in neighborhoods that are experiencing high annual migration rates or in new neighborhoods that have come about since the previous census.

Ideally, administrative records of the city and utility company records could be combined in ways to determine change and to maintain current accounts of important socio-economic variables by small areas that are useful in planning and management such as census tracts, traffic zones, school districts, etc. However, this simple conceptual scheme has been implemented in only a few metropolitan areas. The problems of data compatibility, cost of assembly and processing, and establishing a computerized system are difficult to overcome.

Population and housing counts are important variables for many planning functions and when available for small areal units density characteristics can be derived. If such variables can be reliably derived from imagery flexibility and timeliness of data might be improved. Used in conjunction with other methodology remote sensing inputs may provide for a more efficient and effective planning function.

Approach

This investigation attempted to estimate population variables by small areas using variables acquired from photographic imagery. Relationships were developed between housing units and population via multiple regression analysis as applied to imagery derived variables. The general model is formulated as:

$$Y = C + b_1X_1 + b_2X_2 + \ldots + b_nX_n$$

where:

Y = housing unit counts or population (1970 Tract Statistics)

$X_1, \ldots, X_n$ = imagery derived variables such as the number of single family structures, number of multiple family structures, and distance to the CBD, etc.

C and b's are estimates from the regression.

Table 1 displays a list of the initial variables used in the analysis.

The model described above was evaluated through the application of step-wise multiple linear regression with units of observation being 1970 census tracts located within the boundaries of a north-south flight line through the Washington, D.C. metropolitan area. The dependent variables

(Y) were derived from 1970 Census data. All independent variables were to be obtained from infrared imagery. The imagery was obtained with an RC8 mapping camera at a scale of 1:50,000, flown by NASA's RB57 aircraft.

Discussion of Variables

Three dependent and eleven independent variables are listed in Table 1. The former are taken from the United States Census (1970) definitions while the latter were defined to be imagery derivable. Descriptions of these variables follow the table.

Table 1

LIST OF VARIABLES*

Dependent

Y_1	:	1970 Housing Unit Count
Y_2	:	1970 Population Count
Y_3	:	One Unit Structure Count

Independent

X_1	:	Multiple Unit Structures
X_2	:	Single Family Structures
X_3	:	15+ Housing Unit Structures
X_4	:	6-14 Housing Unit Structures
X_5	:	2-5 Housing Unit Structures
X_6	:	Distance to the CBD
X_7	:	Total Area
X_8	:	Residential Area
X_9	:	Elementary or Secondary School
X_{10}	:	Urban/Suburban
X_{11}	:	Age of Housing

*See text for discussion.

"Dependent" Census Variables

1970 Housing Unit Count (Y_1): The 1970 Census includes both occupied and vacant housing units for this variable. However, no information is provided concerning the number of structures within which these units are found. In 1960, this variable was determined by enumerator observation, but in 1970, the respondent supplied information concerning the number of housing units in each structure.

1970 Population Count (Y_2): This variable represents the total population of each census tract as reported by the 1970 Census and was provided by the Metropolitan Washington Council of Governments from Census tapes.

One Unit Structure (Y_3): This Census derived variable includes all structures containing one housing unit. However, this variable is not directly comparable to the single family imagery derived variable since it includes structures containing mixed uses. For example, a structure predominantly devoted to commercial use, but containing one housing unit is included in this category by the Census.

"Independent" Imagery Variables

To the extent that housing unit categories of the census correspond to the categories derived from an examination of the imagery, one obtains a check on the accuracy of the imagery interpretation. While the information provided by the Census Bureau is straightforward, the use of imagery necessitates a careful evaluation of a variety of housing unit categories. The development of the categories is not arbitrary but governed by the interpreter's ability to distinguish between structures which contain a variable number of housing units. Because of the scale of imagery used (1:50,000) some identifiers, such as roof division lines and housing unit entranceways, were difficult to employ.

The interpretation consisted of placing mylar over the imagery and identifying the boundaries of 51 selected tracts, the basic areal unit of analysis. Tract boundaries were drawn on the overlays and the total tract land area was computed with a dot planimeter. Within the boundaries of each tract, the land devoted to residential use was identified and the residential land area computed. An effort was made to include isolated structures found in predominantly non-residential areas. However, in areas characterized by dense settlement and mixed land uses, residential structures were somewhat difficult to identify. In some predominantly residential areas, extensive tree cover hampered the identification and accurate counting of structures. The utility of imagery in deriving structure counts would, therefore, be greatly increased if the imagery were obtained in a season with minimal foliage.

With the residential areas of each tract having been identified, a block-by-block structure count was made using four categories based on size of structure as explained below. The accuracy of structure counts varied from tract to tract. Those tracts with high density, diversified development and/or extensive tree cover presented a serious problem resulting in substantial under-reporting of structures in all categories. However, counts of assumed single-family structures were affected more by tree cover than by high-density development. Multiple-unit structures located in areas of intensive land use were extremely difficult to identify. The scale and viewing angle of the imagery did not permit adequate discrimination between multiple-unit residential structures and structures devoted to other uses. Multiple-unit planned residential structures in suburban tracts were, however, easily identified. Many of the suburban structures in this category are characterized by their physical layout and parking facility arrangement.

The Census definition for "structural characteristics" provided some difficulty in relating census data to the imagery derived counts of structures. For example, a one unit structure may contain business units and may be attached as would be the case with row houses. Thus, it sometimes proves difficult to distinguish row houses from garden apartments and residential walk-up apartment buildings from exclusive non-residential structures. In addition self-enumeration census forms tend to cloud the distinction between single family structures and multiple family structures.

The variables that were to be derived from the imagery were selected after some initial experimentation with a larger set. Items which proved extremely difficult to identify or those that were shown to be inappropriate for the projected model were dropped from consideration. If the projected utility of a variable in terms of the regression model was low it did not warrant the effort of measurement and recording. Utilizing these criteria the eleven independent variables displayed in the lower part of Table 1 were defined. Their explanation follows.

Multiple Unit Structures (X_1): This is a composite variable representing the number of multiple unit structures. That is, those residential buildings interpreted as having more than a single unit.

Single Family Structures (X_2): For this variable, the housing unit and structure are synonymous terms. However, unlike the Census, this does not include structures devoted to mixed uses having only one housing unit. It does include detached one-unit structures and row houses with each housing unit representing a separate structure. The individual housing units associated with row house development can be determined by counting the roof division lines as well as observing the size of structure and roof type.

15+ Housing Unit Structures (X_3): This category includes structures that vary greatly in size but usually not in number. Identification problems were expecially prominent in central city tracts. For example, it was difficult to distinguish between a structure devoted to office use and a residential structure. Some of the more salient identifiers common in photo interpretation techniques could not be utilized because of the scale of the imagery. Suburban structures in this category, especially those providing adjacent off-street parking, posed less serious identification problems. In such areas, large residential structures are prominent even at a scale of 1:50,000.

6-14 Housing Unit Structures (X_4): As the size of residential structure increased, it became more difficult to distinguish between these structures and structures devoted to other uses. This problem appeared to begin with the attempt to identify structures in this category. One indication of the number of housing units in planned structures of this type was obtained by observing the number of adjacent parking spaces available. Other indicators such as the size of the structure and the character of the adjacent environment provided additional information necessary to identify structures of this size.

2-5 Housing Unit Structures (X_5): Duplexes and similar units located in predominantly residential areas were easily interpreted. This category represents those types of units. The imagery was not of sufficient scale to determine the extent to which this class contains only duplexes although the size of the structures and similar indicators suggest a high percentage. A field survey would have more precisely revealed the nature of this category but such work was not possible within the study design.

Distance to the CBD (X_6): If imagery were available as a regional mosaic interpoint distances could easily be recorded. Because a mosaic was not available distances were measured on a census tract map of the metropolitan area. The value recorded was the measured distance between the approximate centroid of each sample tract to the center of the Washington business district. Distance to the nearest tenth of a mile was derived from the measured values. This was the only variable not taken from the infrared imagery but, as stated, it would be feasible to do so thereby justifying its inclusion in the analysis.

Total Area (X_7): This variable was obtained by first outlining the tract boundaries on mylar overlays and computing the tract area in acres with a dot planimeter. In most cases, tract boundaries were easily located since they tend to correspond to streets or other linear boundaries such as railroad tracks. The computations for each tract were made at least three times and, if no large discrepancies existed among these values, the average of the three values was used. If, on the other hand, large discrepancies were found, the computations were repeated and checked by another investigator.

Residential Area (X_8): Total residential area consists of all land within each respective tract primarily devoted to residential use plus adjacent land devoted to street use. This is to say that areas of residential use include within their boundaries that land area devoted to streets and street rights-of-way. In the case of isolated residential uses such as an apartment building, only the land area used for the structure and its adjacent parking facilities (if existent) was included in the calculations. Upon identifying areas devoted to residential use, their boundaries were delineated on the mylar overlays and land areas were computed with a dot planimeter.

Elementary or Secondary School (X_9): This is a binary variable indicating the presence or absence of an elementary or secondary school within each sample tract. Tracts with a school within their boundaries were assigned a value of 0 whereas tracts with no school were assigned a value of 1. In terms of the variability in population among tracts, the rationale for the inclusion of this variable is based on the contention that the presence of a school should be associated with a larger tract population.

Urban/Suburban (X_{10}): This item was included to differentiate central city tracts from those of a suburban nature. Because it proved to be a key concept in the subsequent analysis more will be said of it later.

Age of Housing (X_{11}): This trichotomous variable was intended as a measure of the relative age of census tracts in the sample. This variable did not prove to be very useful for several reasons. First, its use in essentially a regression design could only be justified if separate analyses were carried through for each of the three area types or some other appropriate methodology were employed. As interpretation proceeded it became increasingly clear that the assignment of tracts to age classes was inappropriate. Tracts appear to be too extensive areally for such assignment. Experience suggested the variable would have little explanatory power and it was dropped from the analysis.

Analysis

A sample of 51 tracts was delineated for the analysis stage. A list of these 51 tracts by jurisdiction is shown in Table 2. The selection of tracts was governed in part by the areal coverage provided by the imagery and the selection of tracts in the previously discussed study dealing with an evaluation of the utility of remote sensing imagery in providing urban land use information.

As mentioned previously, the analysis employs step-wise multiple regression analysis. A number of designs were run to determine the importance of variables in accounting for variation in the dependent variables. Some of these variables were deleted because of collinearity effects or doubtful explanatory power.

Because the census tracts are not of uniform size the variables utilized in the analysis were transformed to densities. Both "gross" and "net-residential" population densities were derived using total tract area and residential tract area respectively. Because the total and residential areas are relatively accurate the limiting parameters are the numerators in such calculations, that is, the number of housing units, etc. To carry through on the analysis the reverse transformation would be necessary to convert density estimates back into absolute counts. Neither the original or reproduced data are provided here.

Very early in the analysis the "age of neighborhood" variable was deleted. The only other variable completely deleted from the analysis was the school item. There was a moderate degree of association between 2-5 unit dwellings and this latter item but only very little association between schools and the population variables.

The Suburban/Urban dichotomy seemed to possess explanatory power. Interpretation of results became clearer when the analyses were made with the sample tracts divided into two sub-groups according to this criterion. The division of the 51 tracts is shown in Table 2 where it can be seen that the visual information was sufficient to separate the District of Columbia tracts from the surrounding areas. This result should not be surprising in view of the nature of the Washington region and the definition of tract boundaries in the central area.

Table 2

URBAN/SUBURBAN DICHOTOMIZATION OF SAMPLE TRACTS

Urban

District Tracts

4.0	8.0	21.0	26.0	35.0	36.0	42.0	49.0
51.0	60.0	63.0	69.0	72.0	73.2	77.1	88.2
71.0	34.0	45.0	41.0	29.0	93.0	90.0	

Suburban

Montgomery County

10.02	18.0	20.0	21.0	28.0	31.0	34.0	40.0
44.0	45.0	47.0	53.0	56.0			

Prince Georges County

15.0	16.0	36.05	47.0	50.0	51.0	58.01	58.02
60.0	61.0						

Arlington County

15.0	18.0	19.0

Fairfax County

2.0

A relationship of interest to the analysis of the imagery is that between the number of single family structures (imagery derived) and the number of structures containing one dwelling unit (census derived). This relationship will be only approximate even disregarding normal sampling errors because of the practice of including predominantly non-residential structures containing a single living unit. Because this practice takes on more significance within the central city than in the suburban tracts a higher correlation is expected in the latter compared with the former. The following regression equations support this hypothesis:

Central City:

$$\underset{}{Y = 194.8 + \underset{(0.17)}{1.19}\,X} \qquad (R^2 = 0.71);$$

Suburban:

$$Y = 181.8 + \underset{(0.06)}{0.94}\,X \qquad (R^2 = .90);$$

where Y represents the 1970 Census variable "number of structures containing one housing unit" and X represents the number of single family units as counted on the photograph.

As might be expected the regression coefficient is near unity but the constant term is large suggesting a general under-counting of one unit structures. Two points should be made concerning these generally favorable results. First the sample sizes are small and only one city has been utilized. Second, nothing can be said about the stability of these results over time. The results shown above do provide an indication of the usefulness of the data derived from the imagery for in the suburban case it was 90% effective in reproducing its quasi-equivalent census statistic. Further analysis seems justified.

The variables utilized in Tables 3 and 4 are derived from those presented earlier. Each of the variables, except for the distance measure, are expressed as densities in the following order:

Y : population density
X_1 : distance to the CBD
X_2 : single family units
X_3 : 2-5 units
X_4 : 5-14 units
X_5 : 15+ units
X_6 : composite multiple units

In both Table 3 and Table 4 the Central City results are shown above the diagonal with correlations below the diagonal being derived from suburban tract data. Table 3 depicts correlations derived from gross density variables (total tract area as denominator) while Table 4 shows results from net density variables (residential tract area as denominator); this change is indicated by the use of primes (') and in the table title.

Table 3

GROSS DENSITIES: CORRELATION MATRIX
CENTRAL CITY[a] AND SUBURBAN[b] TRACTS

	Y	X_1	X_2	X_3	X_4	X_5	X_6
Y	city \ suburb	-.290	0.712	0.157	0.827	0.242	0.617
X_1	-.477	-	0.047	-.201	-.217	-.443	-.323
X_2	0.292	-.184	-	0.067	0.499	0.058	0.342
X_3	0.752	-.202	0.079	-	0.073	0.124	0.779
X_4	0.657	-.469	0.098	.608	-	0.366	0.669
X_5	0.011	-.281	-.164	-.065	0.037	-	0.428
X_6	0.779	-.401	0.088	0.870	0.919	0.024	-

[a] N = 23; above diagonal [b] N = 28; below diagonal

Table 4

NET DENSITIES: CORRELATION MATRIX
CENTRAL CITY[a] AND SUBURBAN[b] TRACTS

	Y	X_1	X_2'	X_3'	X_4'	X_5'	X_6'
Y	city / suburb	-.489	0.270	0.410	0.499	0.405	0.623
X_1	-.348	-	0.172	-.138	-.237	-.448	-.276
X_2'	0.026	0.042	-	0.279	-.144	-.076	0.205
X_3'	0.790	-.205	0.042	-	-.120	0.055	0.915
X_4'	0.730	-.374	-.028	0.536	-	0.230	0.266
X_5'	-.083	-.248	-.515	-.126	0.126	-	0.274
X_6'	0.850	-.357	-.018	0.808	0.930	0.056	-

[a]N = 23; above diagonal [b]N = 28; below diagonal

The top row and left-most column of each table are of primary interest as they show the correlations between the dependent variable, population density, to the imagery derived variables. The composite variable (X_6) is seen to have a relatively high correlation with the dependent variable in all four cases. The utilization of the "composite" as a predictor might therefore be warranted because it generally should be less in error than the individual variables. However, the composite variable actually has differing meanings. For instance in Table 4 the 3rd, 4th, and 5th variables, those from which the composite is derived, all have moderate correlations with population density for city tracts, while the suburban analysis shows only the first two of these variables as significant contributors.

Several interesting features of these correlation tables should be pointed out. Note the effect of the "net" and "gross" density criterion on the correlation between population density and single family units density. For the central city sample the correlation shifts from 0.712 to 0.270 when net densities are substituted for gross density variables. A similar shift is shown when suburban tracts are utilized rather than central city tracts while maintaining the gross density variables. The effect is in the same direction for net densities and central as compared to suburban tracts (0.292 to 0.026).

The correlation is negligible between the dependent variable and the "15+ units" item for both net and gross densities for the suburban tracts. The importance of this variable is greatest for city tracts and net density calculations.

Utilizing the variables presented above stepwise multiple linear regression equations were estimated for the four cases discussed. The results are expressed by the following equations:

<u>Central City Tracts</u>

Gross density:

$$Y = 16.5 + \underset{(17.3)}{87.5}\, X_4 + \underset{(1.6)}{6.2}\, X_2 - \underset{(2.4)}{4.6}\, X_1 \qquad (R^2 = .91)$$

Net density:

$$Y = 43.3 + \underset{(19.9)}{67.7}\, X_4 + \underset{(7.5)}{16.7}\, X_3 - \underset{(4.6)}{11.9}\, X_1 + \underset{(2.4)}{5.1}\, X_2 \qquad (R^2 = .81)$$

Suburban Tracts

Gross density:

$$Y = 14.5 + \underset{(9.2)}{55.1}\, X_3 - \underset{(0.3)}{0.9}\, X_1 + \underset{(0.8)}{1.3}\, X_2 \qquad (R^2 = .84)$$

Net density:

$$Y = 13.9 + 41.7\, X_3 + 20.8\, X_4 \qquad (R^2 = .87)$$

The four equations listed above are suggestive of the relations that can be developed which will provide population density (and population) estimates from imagery derived variables. The relatively high multiple correlations obtained indicate the probable utility of imagery of the scale utilized in this analysis if the relationships can be shown to be stable across samples and through time.

One problem known to effect the utility of such equations is the changing ratio of people to dwelling units. In some central cities, Des Moines, Iowa for example, the number of dwelling units has increased while the population declined. The direction and extent of such changing "parameters" would require investigation if projections of demographic data were to be reliably derived from photographic imagery.

The distance variable might also be of interest because of its entry in three of the four equations above even though the dichotomization to city - suburban tracts should negate much of the variance of this variable. In a multi-nuclear urban area this variable might exhibit much less strength, but more importantly decentralization may effect the stability of the density/ distance relation over time.

One other interesting point should be noted. The analysis presented here assumed equal validity for both "gross" and "net" population densities. But the dependent variable as derived from the census reports reflects total tract area while the single and multiple dwelling unit counts when expressed as "net densities" reflects an imagery observed residential area. The present analysis is definitionally more correct for the gross density formulation than for the net density form. As was indicated in chapter one, however, net densities may be of greater sociological and psychological significance.

With central-city tracts the gross density form of the equation yields a high multiple correlation while the net density form is the least "explanatory" of the four suggested equations. This latter result is not surprising because the imagery derivation of residential area in central city tracts is prone to higher errors than in suburban tracts. In suburban tracts where residential areas, primarily single family units, are more easily delineated the net density form yields a higher correlation than the gross density form.

Interpretation of the equations presented above should be attempted with a note of caution. Factors significantly influencing population density have been omitted because of the nature of the independent variables. The regression coefficients would differ if, say, the family-age-structure of the tracts were considered or the income structure. This is so because in a regression the whole complex changes if independent variables are added or deleted. The interpretation one might wish to make in the current case is limited because the predictive value of variables is not unique, being dependent upon the other variables being used (or not being used) in the regression.[1]

Summary Evaluation

In general the results of the attempt to replicate census and "census-like" variables from items derived from the 1:50,000 Washington infrared imagery suggest that the problem is tractable. Systematic research on a broad front would be necessary to determine practical error limits and to match users with a level of reliability sufficient for their requirements. Two aspects might be considered for future work of this nature. Central city imagery might better be larger scale and higher resolution and being smaller in areal extent the increment in the number of frames would be slight compared to that for comprehensive coverage of a metropolitan region. For the more extensive non-core areas interest might focus on cues for interpretation, especially for discriminating between small apartments and small commercial structures. It would also be helpful to provide an extended classification of apartment sizes because of the effect of these structures on population densities.

Reference

1. For a discussion of these issues see George W. Snedecor and William G. Cochran, Statistical Methods, 5th Ed., The Iowa State University Press, 1956, especially Chapter 14 "Multiple Regression and Covariance".

V. URBAN LAND USE: CEDAR RAPIDS

CENSUS CITY ANALYSIS

In conjunction with a national "census cities" investigation of urban land use mapping utilizing remote sensing inputs the Cedar Rapids, Iowa SMSA was photographed on June 7, 1970.[1] The purpose of the overall research was to provide a national assessment of urban change and the utility of remote sensing inputs to monitoring change. The effort to be reported on here was undertaken to produce a land use map of the Cedar Rapids area using this imagery and to determine the utility of the result as input to the on-going programs of the Linn County Regional Planning Commission (Cedar Rapids). Input from the staff of the Commission served as input for this chapter.

Cedar Rapids was chosen as the study area for several reasons. It is an intermediate size city, SMSA population 163,000 (1970), with characteristics and attributes similar to many other cities in its size class. In addition, research for the continuing phase of urban transportation planning in the area has provided comparable conventional data as well as local planners extremely familiar with their subject - land use in Cedar Rapids. Excellent working relations existed with the Planning Commission staff before this project was initiated, and data exchange was underway. Finally, because of the close proximity of the city and the research headquarters frequent interaction with the planning agency's staff and ease of field work were facilitated. Time and cost limitations were such as to place considerable importance on the total design of the project.

The Imagery

The Cedar Rapids imagery is from NASA Mission 128 C, Test Site 234, June 7, 1970. Color infrared photography exists at three scales: 1:50,000, 1:100,000 and 1:382,000. The following information provides pertinent information regarding the imagery available for the analysis.

Table 1 : Imagery

Zeiss/5L
Focal length: 12"
Film: SO-117
Filter: D
Roll: 3
Scale: 1:50,000

RC-8/4L
Focal length: 6"
Film: SO-117 CIR
Filter: 12
Roll: 1
Scale: 1:100,000

Hasselblad 1-6
40 mm lens
Film: SO-117, SO-276, SO-278, 2402, 2424, 2402
Filter: 15 & 30B, 2E, 3, 25, 89B, 58
Rolls: 4-9
Scale: 1:382,000

The Hasselblad camera utilized a 70 mm. film while the other two cameras both use a 9 by 9 inch format.

Study Methodology

Within the framework of the larger "census cities" project a land use classification schema was suggested. The classification utilized for the present study is a compromise between the suggested classification and the operational interpretation process. Evolution of the classification resulted in the schema summarized in Table 2. While the classification parallels that originally suggested and subsequently refined by the USGS Geographic Applications Program staff it is not identical to it.

The imagery which was to be the primary data source for the analysis was pre-defined to be the 1:100,000 scale photographs. An areal unit of approximately 4 hectares (about 10 acres) was suggested as an appropriate recognition level. This meant that a parcel of land was not recognized as being within a specific category unless it covered 4 hectares or more. This sieve or areal screen will by definition generalize the ultimate land use map much as does a restrictive classification schema. For many purposes the results may be quite useful, however.

Through the use of the 1970 Metropolitan Map (U.S. Bureau of the Census) and a street map, the census tract boundaries for Cedar Rapids were drawn on a mylar overlay which was fitted to the photographic transparency at the 1:100,000 scale. A semi-transparent mylar overlay was used because of its proven durability, low rate of shrinkage, and its adaptability to most drawing mediums. The interpretation was completed on a Richards light table with an eight power Agfa hand lens, or on a carriage-mounted Richards light table fitted with a Bausch and Lomb stereo zoom microscope at 7-power. Imagery interpretation was performed directly on the mylar overlay with land uses being shown as a numerical code from 0 to 9.

TABLE 2: CLASSIFICATION SYSTEM FOR LAND-USE AREA ANALYSIS[a]

Livelihood			
0	Industrial	-	Industrial, storage, urban mining
1	Transportation	-	Transportation, communication, utilities, sewage & water treatment plants, reservoirs
2	Commercial	-	School larger than 4 hectares[b] (High schools, colleges), Consumer Services, offices, institutional (Hospitals, etc.), large downtown churches, public assembly (arenas, etc.).
3	Liv. w/non agri. Residence		
Residential			
4	Single family	-	Single family, elementary schools (less than 4 hectares), neighborhood churches
5	Multi-family	-	Multi-family dwelling units
Other			
6	Improved open space	-	Parks, recreation, cemeteries, golf courses, etc.
7	Unimproved open space	-	Vacant land, land under construction
8	Water		
Livelihood and Residence			
9	Agri. w/Residence	-	All ag. land.

---

[a]Adapted from GEOGAP directives.

[b]1 hectare equals 2.47 acres.

The results of the interpretation were checked in three ways. The first check was completed by referring to the 1:50,000 scale transparency. A second check was completed through the use of oblique aerial photographs of Cedar Rapids. Finally, a field check in the Cedar Rapids area was completed.

The census tract boundaries were manually located on $7\frac{1}{2}$-minute U.S.G.S. topographic mapsheets, scale 1:24,000. The land use boundaries were also plotted on this base. In addition, centroids of the predominant land use were plotted for each census tract. Finally, the 1,000-meter Universal Transverse Mercator (UTM) grid was superimposed on the topographic sheet for the 20 square kilometer study area.[2] By drafting the census tract boundaries, centroids and UTM grid on to one sheet and the coded land use boundaries on to another, two outline maps at a scale of 1:24,000 were produced.

The area of the tracts, and of each land use within a tract, was calculated by using a polar planimeter. These data were summarized in tabular form for each of the 30 tracts which constitute the "Cedar Rapids-Marion Urban Area" (see Tables 3a and 3b). Land use information was not tabulated for the surrounding peripheral tracts which are only partially within the study area. The urban area was to be delimited on the basis of the land use interpretation. Thus, a critical category was "livelihood with non-agricultural residence." Since this category occurs both in the urban and non-urban categories of the GEOGAP classifications, and since

TABLE 3a: LAND USES* AS PERCENTAGE OF TOTAL AREA OF CENSUS TRACTS
CEDAR RAPIDS, 1970

Tract #	0	1	2	3**	4	5	6	7	8	9	Total
1	0.32	----	0.32		0.32	----	----	8.44	0.16	90.44	100.00
2	1.68	----	----		3.21	0.20	----	1.83	0.20	92.88	100.00
3	----	----	2.56		21.16	----	3.20	3.20	----	69.88	100.00
4	----	----	4.55		73.86	----	5.68	6.82	----	9.09	100.00
5	----	----	3.68		15.59	----	----	42.66	0.91	37.16	100.00
6	----	----	2.07		15.85	----	----	75.18	----	6.89	100.00
7	----	----	24.23		43.95	----	16.66	15.16	----	----	100.00
8	----	----	10.00		58.01	5.00	25.99	1.00	----	----	100.00
9	----	----	1.29		11.39	0.43	----	73.76	3.66	9.47	100.00
10	2.00	----	2.21		15.59	----	0.40	18.60	0.60	60.60	100.00
11	----	----	----		28.25	----	10.64	59.72	1.39	----	100.00
12	----	----	4.54		84.10	----	----	11.36	----	----	100.00
13	16.54	4.83	4.83		31.72	1.38	2.08	15.16	23.46	----	100.00
14	5.57	----	1.86		90.71	----	1.86	----	----	----	100.00
15	1.38	----	5.52		29.66	----	16.55	46.89	----	----	100.00
16	----	----	0.46		56.22	----	----	27.19	----	16.13	100.00
17	----	----	1.41		85.93	----	1.41	11.25	----	----	100.00
18	5.00	----	2.50		90.00	----	2.50	----	----	----	100.00
19	----	----	16.67		83.33	----	----	----	----	----	100.00
20	----	----	89.47		10.53	----	----	----	----	----	100.00
21	88.89	----	----		----	----	----	----	11.11	----	100.00
22	4.78	----	21.44		61.87	----	----	----	11.91	----	100.00
23	----	----	8.95		80.62	----	10.43	----	----	----	100.00
24	20.82	----	11.49		33.33	----	1.05	8.33	----	24.98	100.00
25	16.95	----	----		72.88	----	10.17	----	----	----	100.00
26	3.94	10.52	2.63		36.85	5.26	10.53	27.63	2.63	----	100.00
27	30.64	----	3.23		41.93	----	11.29	----	12.91	----	100.00
28	----	----	----		12.42	----	1.28	60.20	1.28	24.82	100.00
29	8.72	----	0.92		27.50	2.76	9.63	9.18	0.92	40.37	100.00
30	1.63	----	0.90		3.15	----	0.73	12.14	0.62	80.83	100.00

TABLE 3b : LAND USES* BY CENSUS TRACTS (in km^2)
CEDAR RAPIDS, 1970

Tract #	0	1	2	3**	4	5	6	7	8	9	Total Tract Area
1	0.148	-----	0.148		0.148	-----	-----	3.925	0.074	42.074	46.518
2	1.296	-----	-----		2.481	0.148	-----	1.407	0.185	71.814	77.333
3	-----	-----	0.148		1.222	-----	0.185	0.185	-----	4.037	5.777
4	-----	-----	0.148		2.407	-----	0.185	0.222	-----	0.296	3.259
5	-----	-----	0.296		1.259	-----	-----	3.444	0.074	3.000	8.074
6	-----	-----	0.111		0.851	-----	-----	4.037	-----	0.370	5.370
7	-----	-----	0.592		1.074	-----	0.407	0.370	-----	-----	2.444
8	-----	-----	0.370		2.148	0.185	0.962	0.037	-----	-----	3.703
9	-----	-----	0.222		1.962	0.074	-----	12.703	0.629	1.629	17.222
10	0.370	-----	0.407		2.888	-----	0.074	3.444	0.111	11.222	18.518
11	-----	-----	-----		2.259	-----	0.851	4.777	0.111	-----	8.000
12	-----	-----	0.074		1.370	-----	-----	0.185	-----	-----	1.629
13	0.888	0.259	0.259		1.703	0.074	0.111	0.814	1.259	-----	5.370
14	0.111	-----	0.037		1.814	-----	0.037	-----	-----	-----	2.000
15	0.074	-----	0.296		1.592	-----	0.888	2.518	-----	-----	5.370
16	-----	-----	0.037		4.518	-----	-----	2.185	-----	1.296	8.037
17	-----	-----	0.037		2.259	-----	0.037	0.296	-----	-----	2.629
18	0.074	-----	0.037		1.333	-----	0.037	-----	-----	-----	1.481
19	-----	-----	0.111		0.555	-----	-----	-----	-----	-----	0.666
20	-----	-----	0.629		0.074	-----	-----	-----	-----	-----	0.703
21	0.296	-----	-----		-----	-----	-----	-----	0.037	-----	0.333
22	0.074	-----	0.333		0.962	-----	-----	-----	0.185	-----	1.555
23	-----	-----	0.222		2.000	-----	0.259	-----	-----	-----	2.481
24	0.074	-----	0.407		1.185	-----	0.037	0.296	-----	0.888	3.555
25	0.370	-----	-----		1.592	-----	0.222	-----	-----	-----	2.185
26	0.111	0.296	0.074		1.037	0.148	0.296	0.777	0.074	-----	2.814
27	0.703	-----	0.074		0.962	-----	0.259	-----	0.296	-----	2.294
28	-----	-----	-----		1.444	-----	0.148	7.000	0.148	2.888	11.629
29	0.703	-----	0.074		2.222	0.222	0.777	0.740	0.074	3.259	8.074
30	1.074	-----	0.592		2.074	-----	0.481	8.000	0.407	53.259	65.888

* For description of numerical codes see classification, Table 2

** Not applicable for tracts used.

the interpreters were handicapped by the lack of specific information for this category, the urban area was operationally defined as the thirty "urban" census tracts. These tracts cover a majority of the study area, except for a strip on the western side of the area and a section in the southeast. In both cases, the dominant land uses are agricultural with residence (9) or unimproved open space (7).

As a result of this operational decision, category (3) only occurs beyond the urban area as indicated previously and thus does not appear in the tables. It should be noted that these tracts cover an area which is more extensive than the 1970 Urbanized Area of Cedar Rapids, as defined by the Bureau of the Census. For completeness, it should also be noted that the areal extent of the study area and the area of air photo coverage do not exactly coincide. The photo does not cover the eastern most part of the designated study area.

Interpretation Problems

While residential uses were easily distinguishable at a scale of 1:100,000, especially in suburban areas, confusion sometimes arose between multi-family housing and some types of commercial uses, such as offices in the central city area. Transportation uses, which include communication and utilities, were generally easy to interpret.

Heavy industry provided few problems, but light industry often appeared similar to commercial uses. An example is the area occupied by the large Lindale Plaza Shopping Center (about $1\frac{1}{2}$ km^2) in census tract 7.

The photo interpretation initially classified this as industrial. It is located in proximity to the Collins manufacturing plant, a new, modern one-story facility surrounded by ample parking space for its several thousand employees. Institutional uses, such as small schools and hospitals, proved difficult to identify.

Accuracy of Study Results

In addition to the two imagery checks, a field check was undertaken. Six census tracts were chosen at random from among the thirty "urban" census tracts, these were 05, 07, 09, 11, 14, 23.

The interpreter and a member of the planning agency systematically travelled the selected tracts and recorded the observed land uses on field maps at a scale of one inch to 300 feet. In addition, those areas that had caused particular difficulties in the photographic interpretation were checked.

The comparison between the air photo interpretation and the field check was encouraging. Except for a few cases, in which the field checks confirmed the difficulties of separating "unimproved open space" from "improved open space," no major discrepancies were found. Moreover, the total area affected was very small relative to the total area devoted to these two land uses. The only other discrepancies between interpretation and field check was the already mentioned case of the Lindale Plaza Shopping Center. Aside from these two problems, the field checks proved that a high degree of accuracy in photographic interpretation at a scale of

1:100,000 could be achieved using the given classification.

A source of possible error was the manual transfer of the land use boundaries from the unrectified photo, scale 1:100,000, to the topographic sheet, scale 1:24,000.[3] It was often difficult to locate exactly the boundaries between different land uses on the topographic map.

Local Planning Agency Evaluation

Studies of the existing land use within an urbanized region provide a basis for a wide range of planning activities. Generally, such studies are valuable in providing a record of current land use available for both immediate and future reference and analysis. This information has application for two major areas of the Linn County Regional Planning Commission's continuing planning program - comprehensive planning at the metropolitan regional scale, and small area planning for particular subareas within the urban region.

Comprehensive Studies

The requirement for acceptable land use data is generally less specific for the planning study at the larger scale. Typical comprehensive studies for Linn County which could utilize land use information at a fairly generalized level include: 1) the analysis of existing patterns and interrelationships of land uses, 2) the development of historical urban and regional growth models, and 3) the provision of information for transportation travel demand model development. However, the one digit level classification of land use would seem to have rather limited utility even for these kinds of planning studies. Perhaps this generalized level would be most appropriate for historical analysis of regional development as illustrated by maps of existing land activities recorded at 5-10 year increments. In general, the larger the study area (e.g. multi-county or state) the greater the potential utility would appear to be for land use data at this level of generality.

Subregional Studies

Planning studies which focus on small areas within Linn County generally demand a higher level of specificity of land use information than can be provided by the one digit classification employed in the current remote sensing project. Zoning decisions, renewal area programming, neighborhood planning, and road corridor and alignment studies are a few of the types of planning for which more detailed land use identification is necessary. Generally, land use information is needed at the parcel level for such studies. The data acquired from small scale imagery does not appear to have any value for subregional planning studies.

Evaluation of Remote Sensing Data

In evaluating the potential utility of the land use data produced from the photo interpretation, several criteria were utilized: 1) the appropriateness of the classification scheme employed, 2) the scale of data assembly, and reliability, and 3) the form of output information.

Classification Scheme

A review of the resultant maps from imagery interpretation indicates that the suggested classification could be improved upon. One reason for this was that for the Cedar Rapids study area differentiation of urban land does not require the category "livelihood with non-agricultural residence." Secondly, the "commercial" category appeared to be too broad and encompassing, resulting in seemingly inappropriate and confusing patterns.

Scale of Data Assembly and Reliability

The areal limitation on use detection would appear to have introduced several distortions into the study. As a result mapping of categories fails to illustrate patterns of mixed uses and strip commercial developments along major streets. For land use planning purposes these characteristics of the urban environment are of real interest. In general, this detection parameter would appear to generate a misleading pattern of nucleated nonresidential uses when mapped.

The effect of the limitation on the accuracy of the quantification of land area by generalized use is not clear. It seems logical that it results in an underestimation of the actual number of acres devoted to "commercial" uses and an exaggeration of single family residential uses. Multi-family and improved open space uses are significantly underestimated. However, at a regional scale some of these distortions may be offsetting.

Information Output

Tabulated land use data aggregated at the census tract level is of little use in an urban area no larger than the Linn County Metropolitan Area. The collection, assembly, and analysis of data as part of the Linn County Planning Commission's continuing planning program is conducted at a lower level of areal aggregation, the traffic zone. Imagery interpreted results were restructured according to these smaller zones, 100 in number. This quantification of areas by use was better suited to the on-going activities of the Planning Commission than was the same information aggregated by census tracts. The results appear in Table 4. However, at this smaller unit of description the potential distortions indicated previously to an even greater extent diminish the reliability of the land use data for any particular areal unit of aggregation.

Alternatives to Meet Local Planning Agency Needs

An alternative one digit land use classification (Table 5) has been proposed by the Linn County Regional Planning Commission. The Commission feels that this classification would better meet their specific needs than the current schema. These categories were developed from a modified three-digit Standard Land Use Code currently being used in a land use inventory of the Linn County Transportation Study area. (The modified code has seventeen generalized categories.)

The ability to utilize the proposed classification in a remote sensing context is also assessed in the table. In addition to the degree of difficulty

TABLE 4

LAND USES** BY O-D ZONES CEDAR RAPIDS, 1970

O-D	Land Use Categories (in km^2)										Total O-D
Zone #	0	1	2	3	4	5	6	7	8	9	Zone Area
1	-----	-----	0.074	-----	-----	-----	-----	-----	-----	-----	0.074
2	-----	-----	0.111	-----	-----	-----	-----	-----	0.074	-----	0.185
3	-----	-----	0.111	-----	0.296	-----	-----	-----	-----	-----	0.407
4	-----	-----	0.074	-----	0.519	-----	-----	0.111	-----	-----	0.704
5	-----	-----	-----	-----	0.852	-----	-----	0.074	-----	-----	0.926
6	-----	-----	0.148	-----	0.741	-----	-----	-----	-----	-----	0.889
7	-----	-----	-----	-----	0.741	-----	-----	0.259	-----	-----	1.000
8	-----	-----	-----	-----	0.444	-----	0.852	3.593	0.111	-----	5.000
9	-----	-----	-----	-----	1.074	-----	-----	0.926	-----	-----	2.000
10	-----	-----	0.074	-----	1.260	-----	0.259	-----	-----	-----	1.593
11	-----	-----	0.037	-----	0.630	-----	-----	0.333	-----	0.704	1.704
12	-----	-----	-----	-----	0.407	-----	-----	1.259	0.148	2.259	4.074
13	0.296	-----	-----	-----	-----	-----	-----	0.852	-----	6.666	7.815
14	0.111	-----	0.222	-----	1.556	-----	0.074	-----	-----	2.963	4.926
15	-----	-----	-----	-----	0.148	-----	-----	-----	-----	4.333	4.481
16	-----	-----	0.148	-----	0.407	-----	-----	-----	-----	1.852	2.407
17	0.185	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.185
18	-----	-----	-----	-----	0.259	-----	-----	0.148	-----	4.852	5.259
19	0.148	-----	-----	0.037	0.666	-----	-----	0.741	-----	13.148	14.741
20	-----	-----	-----	-----	-----	-----	-----	0.296	-----	4.963	5.259
21	0.555	-----	0.407	-----	1.186	-----	0.037	0.296	-----	0.888	3.370
22	-----	-----	0.037	-----	0.518	-----	-----	-----	-----	-----	0.555
23	0.222	-----	-----	-----	0.926	-----	-----	-----	-----	-----	1.148
24	0.666	-----	-----	-----	-----	-----	-----	0.333	-----	2.407	3.406
25	-----	-----	-----	-----	-----	-----	0.111	0.888	-----	3.704	4.815
26	-----	-----	0.222	-----	0.741	-----	-----	-----	-----	3.333	4.296
27	0.593	-----	0.259	-----	-----	-----	0.444	0.741	-----	1.259	3.216
28	0.111	-----	0.074	-----	1.666	0.259	-----	0.519	-----	-----	2.629
29	0.148	-----	-----	-----	0.666	-----	0.222	-----	-----	-----	1.037
30	0.037	-----	0.148	-----	0.259	-----	-----	-----	-----	-----	0.444

O-D Zone #	Land Use Categories (in km^2) 0	1	2	3	4	5	6	7	8	9	Total O-D Zone Area
31	0.111	-----	0.074	-----	0.852	-----	0.111	-----	0.037	-----	1.185
32	-----	0.333	-----	-----	0.222	0.111	0.222	0.741	-----	-----	1.629
33	-----	-----	-----	-----	0.407	-----	0.777	-----	0.074	0.777	2.037
34	0.296	-----	-----	-----	-----	-----	-----	0.333	-----	2.481	3.111
35	-----	-----	0.148	-----	-----	-----	-----	-----	-----	8.518	8.666
36	-----	-----	-----	-----	0.259	-----	-----	1.000	0.148	3.481	4.888
37	-----	-----	0.259	-----	-----	-----	-----	-----	-----	-----	0.259
38	0.185	-----	-----	-----	-----	-----	0.037	-----	-----	-----	0.222
39	0.037	0.037	0.074	-----	-----	0.037	-----	-----	-----	-----	0.185
40	-----	-----	0.185	-----	0.037	-----	-----	-----	-----	-----	0.222
41	-----	-----	0.185	-----	-----	-----	-----	-----	-----	-----	0.185
42	-----	-----	-----	-----	0.185	-----	-----	-----	-----	-----	0.185
43	0.259	-----	0.185	-----	0.296	-----	-----	-----	0.222	-----	0.962
44	-----	-----	-----	-----	0.629	-----	0.259	-----	-----	-----	0.888
45	-----	-----	0.037	-----	0.519	-----	0.037	-----	-----	-----	0.592
46	-----	-----	0.148	-----	0.074	-----	-----	-----	-----	-----	0.222
47	-----	0.111	0.111	-----	-----	-----	-----	-----	-----	-----	0.222
48	0.666	0.185	-----	-----	0.519	-----	-----	0.704	1.037	-----	3.111
49	-----	-----	0.148	-----	-----	-----	-----	-----	-----	-----	0.148
50	-----	-----	0.074	-----	0.222	-----	-----	-----	-----	-----	0.296
51	-----	-----	-----	-----	0.407	-----	-----	-----	-----	-----	0.407
52	-----	-----	-----	-----	0.814	-----	-----	-----	-----	-----	0.814
53	0.037	-----	-----	-----	1.444	-----	0.074	3.556	0.370	1.815	7.296
54	-----	-----	-----	-----	-----	-----	-----	3.704	0.074	0.888	4.666
55	-----	-----	0.074	-----	4.408	-----	-----	0.518	-----	-----	5.000
56	-----	-----	-----	-----	0.518	-----	-----	0.296	-----	-----	0.814
57	-----	-----	0.037	-----	0.333	-----	-----	-----	-----	-----	0.370
58	0.111	-----	-----	-----	0.815	-----	-----	-----	-----	-----	0.926
59	0.222	-----	0.296	-----	0.519	0.111	0.111	-----	-----	-----	1.259
60	-----	-----	-----	-----	0.370	-----	-----	2.630	0.185	-----	3.185
61	-----	-----	-----	-----	0.445	-----	-----	9.666	0.445	4.555	15.111
62	*	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
63	-----	-----	0.148	-----	1.260	0.074	-----	0.852	-----	0.888	3.222
64	-----	-----	0.259	-----	1.926	0.185	0.407	-----	-----	-----	2.777
65	-----	-----	-----	-----	0.370	0.037	0.481	-----	-----	-----	0.888

O-D Zone #	Land Use Categories (in km^2) 0	1	2	3	4	5	6	7	8	9	Total O-D Zone Area
66	-----	-----	-----	-----	0.703	-----	-----	-----	-----	-----	0.703
67	0.111	-----	0.037	-----	1.111	-----	0.037	-----	-----	-----	1.296
68	-----	-----	0.037	-----	0.481	-----	0.037	-----	-----	-----	0.555
69	0.074	-----	0.333	-----	1,000	-----	0.815	0.148	-----	-----	2.370
70	-----	-----	-----	-----	0.259	-----	0.074	2.148	-----	-----	2.481
71	-----	-----	-----	-----	0.333	-----	-----	2.593	-----	1.370	4.296
72	*	-----	-----	-----	-----	-----	-----	-----	-----	-----	*
73	*	-----	-----	-----	-----	-----	-----	-----	-----	-----	*
74	-----	-----	-----	-----	0.074	-----	-----	0.259	0.074	2.222	2.630
75	-----	-----	-----	-----	0.074	-----	-----	1.333	-----	-----	1.407
76	-----	-----	-----	-----	0.148	-----	-----	1.518	-----	-----	1.666
77	-----	-----	0.148	-----	-----	-----	-----	-----	-----	-----	0.148
78	-----	-----	0.222	-----	-----	-----	-----	-----	-----	-----	0.222
79	-----	-----	0.148	-----	-----	-----	-----	-----	-----	-----	0.148
80	-----	-----	0.148	-----	-----	-----	-----	-----	-----	-----	0.148
81	-----	-----	0.111	------	1.149	-----	0.333	0.370	-----	-----	1.963
82	0.704	-----	-----	-----	-----	-----	-----	-----	-----	0.407	1.111
83	0.518	-----	-----	-----	-----	-----	-----	-----	-----	1.000	1.518
84	-----	-----	-----	-----	1.111	-----	-----	-----	-----	2.630	3.741
85	-----	-----	-----	-----	0.333	-----	-----	-----	-----	2.704	3.037
86	*	-----	-----	-----	-----	-----	-----	-----	-----	-----	*
87	-----	-----	-----	-----	0.666	-----	-----	-----	-----	2.555	3.222
88	*	-----	-----	-----	-----	-----	-----	-----	-----	-----	*
89	-----	-----	-----	-----	0.074	-----	-----	-----	-----	1.000	1.074
90	-----	-----	-----	-----	0.407	-----	-----	-----	-----	1.556	1,963
91	-----	-----	0.074	-----	0.630	-----	0.148	0.185	-----	0.704	1.741
92	-----	-----	0.074	-----	0.667	-----	0.333	0.963	-----	-----	2.037
93	-----	-----	0.222	-----	1.111	-----	-----	0.037	-----	0.778	2.148
94	-----	-----	-----	-----	0.222	-----	-----	-----	-----	0.037	0.259
95	-----	-----	-----	-----	1.259	-----	-----	-----	-----	-----	1.259
96	-----	0.034	-----	-----	0.741	-----	-----	-----	-----	0.371	1.146
97	*	-----	-----	-----	-----	-----	-----	-----	-----	-----	*
98	*	-----	-----	-----	-----	-----	-----	-----	-----	-----	*
99	-----	-----	0.074	-----	0.407	-----	0.185	0.185	-----	0.518	1.370
100	0.111	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.111

* Only partially within study area
** For description of numerical codes, see classification, Table 2

TABLE 5

PROPOSED LAND USE CLASSIFICATION,

LINN COUNTY REGIONAL PLANNING COMMISSION

Category	Partial List of Activities Included in Category	Ease of Identification
Residential		
0 - Low Density	Single family home, duplexes, mobile homes, multifamily housing at less than 18 dwelling units per acre.	Generally good although duplexes cause difficulty
1 - High Density	Multifamily housing at more than 18 dwelling units per acre, "high-rise" (i.e. residential developments of greater than 3 storeys)	Good
Livelihood		
2 - Industrial	Inc. Manufacturing, extraction, utilities and communications.	Good
3 - Wholesale, Warehouse and Terminal	Inc. railroad and motor freight terminals	Generally good, except for wholesale areas
4 - Retail Trade	Inc. gas stations, automobile dealers, building supplies.	Can be identified only when development is large enough
5 - Commercial Services	E.g. offices, hotels, airports, auto-parking, personal services.	Generally difficult although some types of activity in this class are readily identifiable
Public		
6 - Public and Quasi-Public	Inc. schools, religious bldgs, public assembly areas, fairgrounds, organized camps.	Most activities in this class can be readily identified although there are some problems e.g. public assembly
7 - Parks and Outdoor Recreation	Inc. golf courses, parks, winter sports areas, playgrounds and athletic fields.	Some activities in this class are easily recorded, others are difficult
Other		
8 - Farm		Good
9 - Vacant, undeveloped		Good

of identification specified, there are other problems with regard to the proposed classification. It is extremely difficult to separate activities into some of the proposed classes, particularly retail and commercial. This is also true with industrial, wholesale and for warehouses. For example, it is often difficult to identify a modern light industrial plant as an industrial land use.

Graphic Materials and Evaluation

Subsequent to the imagery analysis computer graphics were prepared of the derived data and of selected census data items from the First Count Summary Tapes. The graphic output was produced using the SYMAP methodology developed at Harvard. (See the addendum to this chapter.)

The evaluation of the maps produced received a similarly low evaluation from Planning Commission staff, primarily because the areal units do not match their program needs. At the visual level distortions because of great variation in size of tracts was undesirable. Census enumeration districts would probably be more acceptable in this regard.

When working with these census data and maps, frequency distributions were found to be of considerable value, even more so than the graphic display of those values. The data-values and frequency distributions that accompanied the computer output are of greater practical interest to the planning agency than the graphics themselves, given the current limitations of the scale, classification, and reliability.

While the graphic representation of individual census data items at the tract level does not provide great utility for planning purposes there is a potential for computer mapping techniques when used in conjunction with transportation models, urban growth models, environmental and land capability studies, and housing needs studies, to mention a few. These types of models and studies require vast data bases and calculations, and make graphic representation of alternative solutions extremely difficult. When conducting a study of such a nature it would be extremely productive to have computer graphic output of the urban area showing the effects of several variable changes in an urban model being used for a specific planning purpose.

Summary Evaluation

This chapter has defined the methodology used in the Cedar Rapids study. It also contains comments related to the classification schema, production of the various graphics, imagery interpretation problems, and the accuracy of results. With respect to providing data inputs to the on-going activities of the regional planning agency the results must be considered marginal. However, the agency was asked to evaluate products resulting from generalized procedures, rather than from methodology designed to match their existing data inputs. In general, if the techniques developed in this project can be refined, especially if a more detailed land use classification scheme could be employed, a smaller areal detection unit utilized, a smaller areal unit of data aggregation, and an increase in the reliability of output data, then these techniques could have significant utility for a regional planning agency in its continuing program of monitoring urban land use change. This evaluation, coming from an operational agency, should be carefully considered prior to broad utilization of the classification and procedures currently being utilized in the Census Cities Project.

References

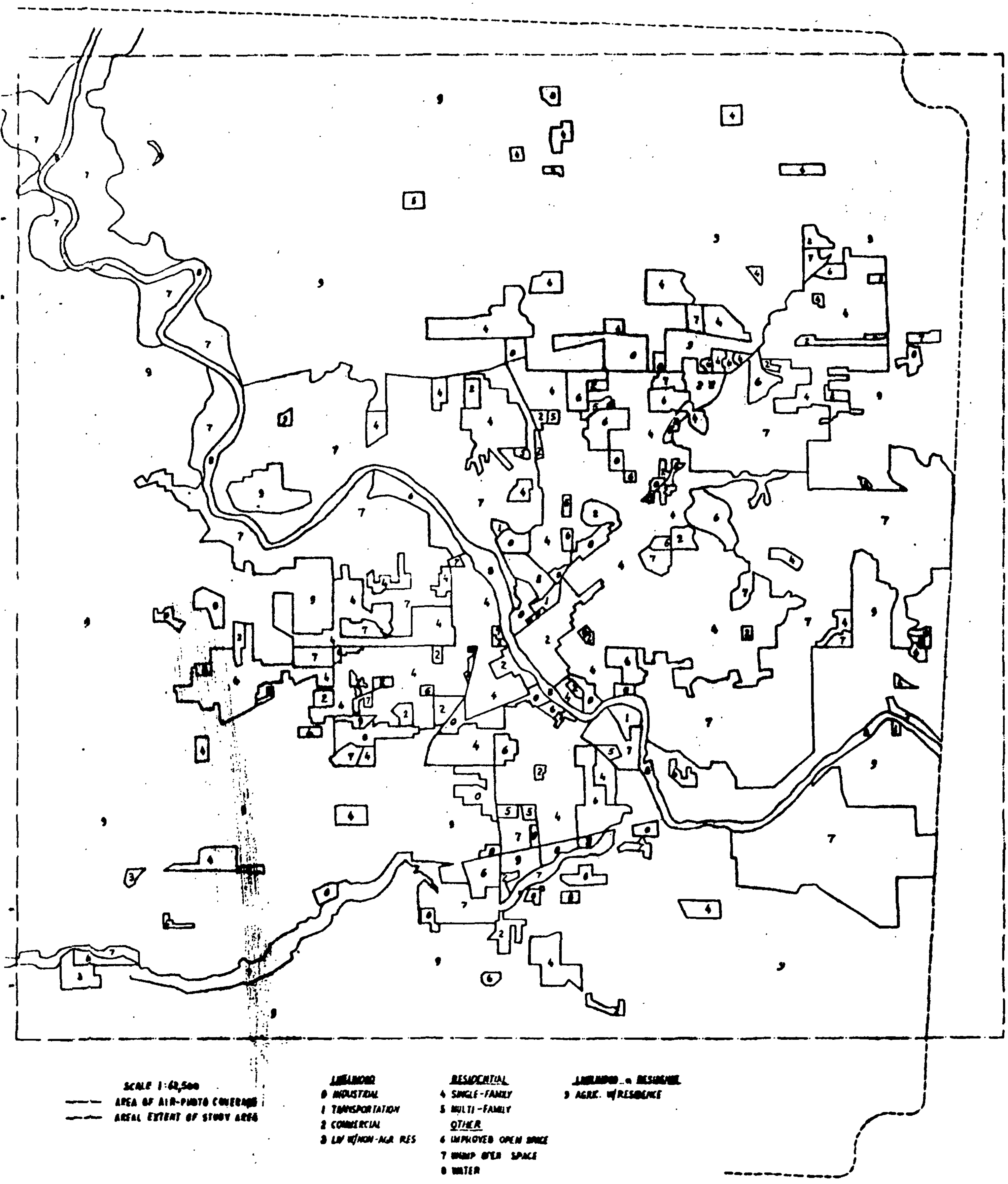
1. For a full description of the national project, see Wray, J.R., "Census Cities Project Atlas of Urban and Regional Change," paper presented at NASA, Third Annual Earth Resources Program Review, December 1970, Houston.

2. The Census Cities project specified the extent of areal coverage and the use of metric measurement.

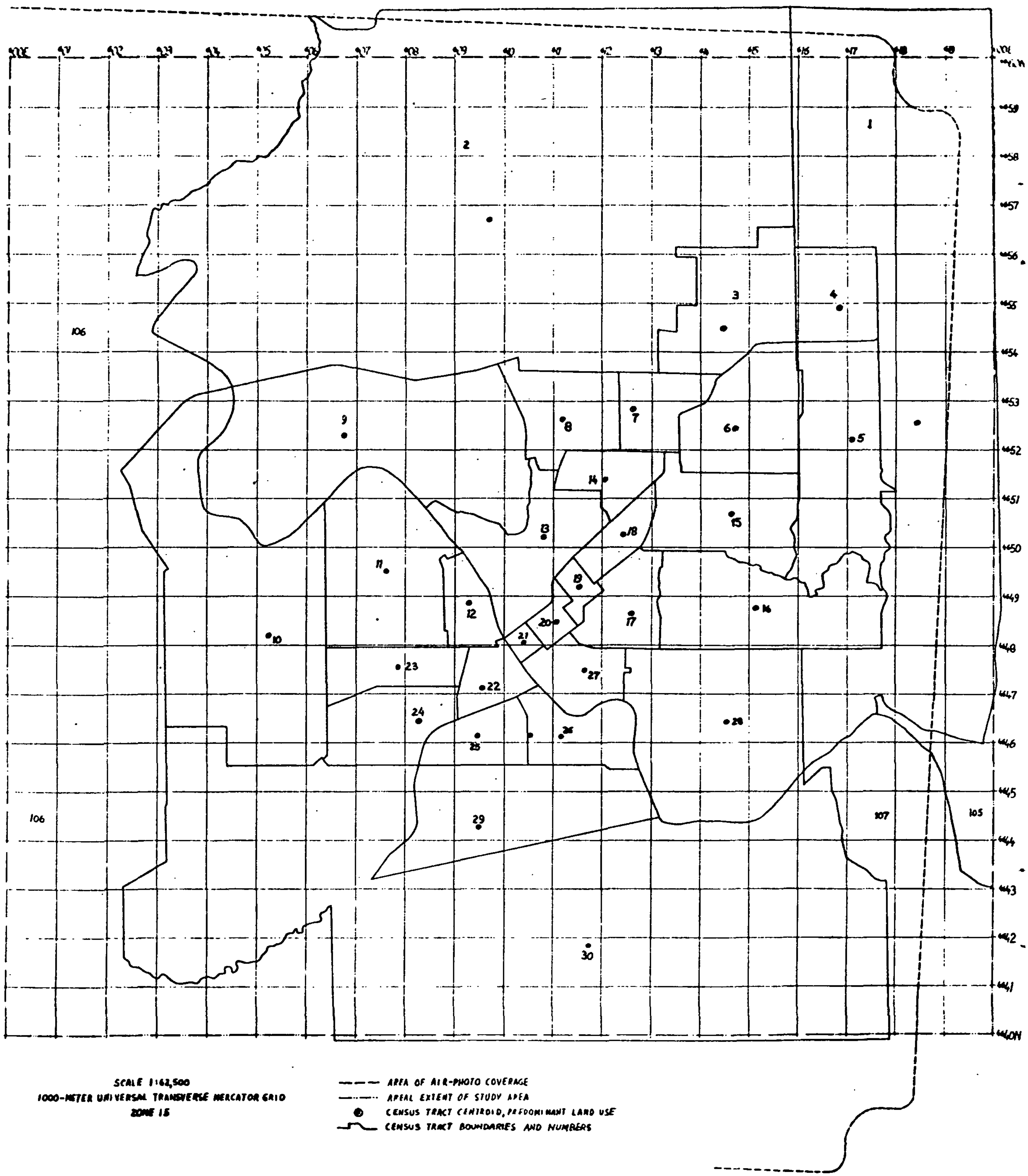
3. Rectified photomosaics of the study area were not available at the time of this work.

Addendum: Graphic Materials

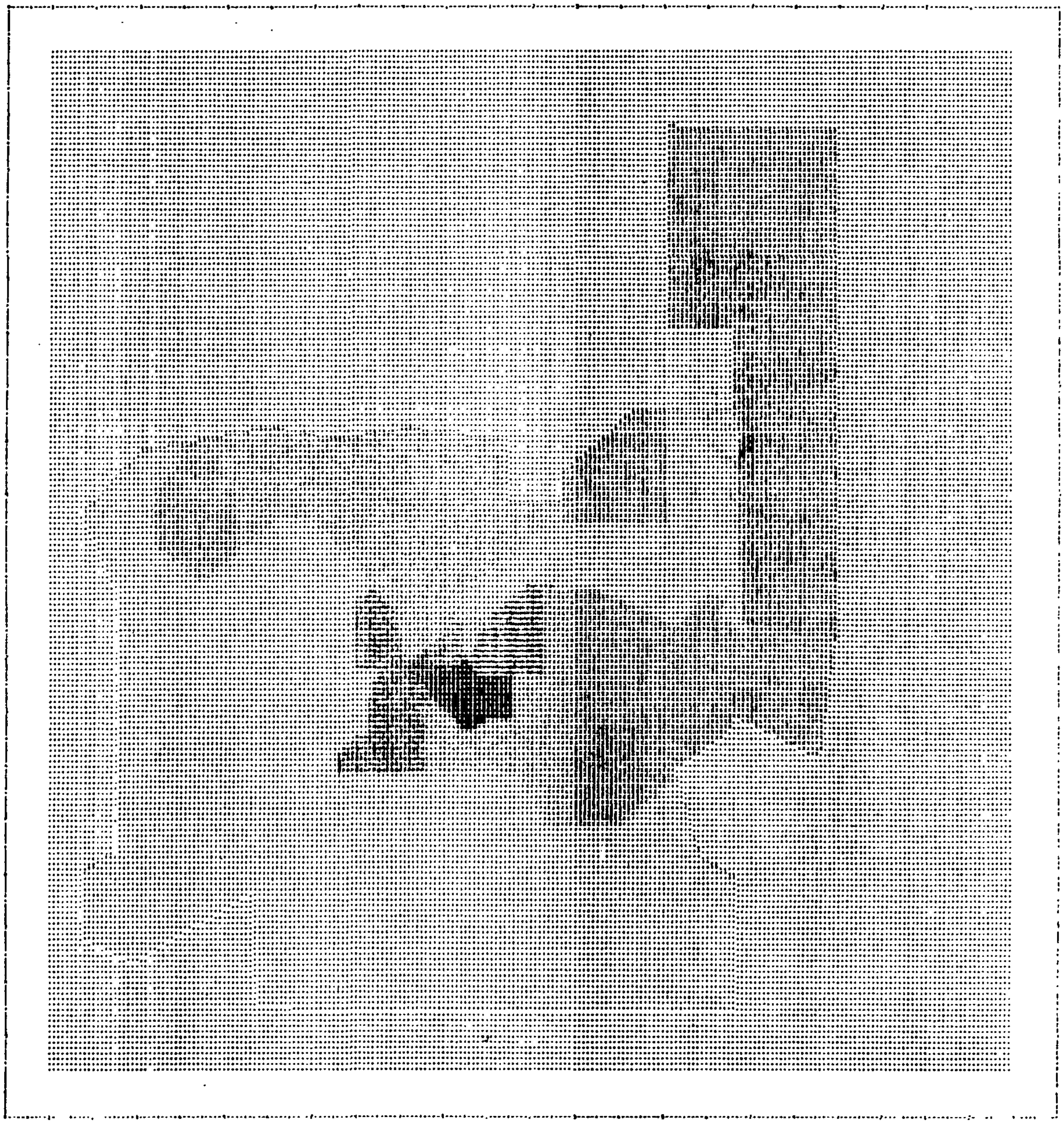
The maps in this section resulted from the Cedar Rapids analysis. Maps 1 and 2 are reproductions of mylar overlays while the remaining graphics were produced by the SYMAP routine. Map 1 is the result of photo interpretation utilizing the 9 digit classification discussed in the chapter. Map 2 is an outline of the 1970 census tracts for the area covered in the analysis Maps 3 through 12 present selected census variables or derived variables from the First Count Census Tapes. The maps were produced with a 36 inch width and photographically reproduced for this report. Copies of the original maps and accompanying statistics have been maintained at the Linn County Regional Planning Commission offices and at GEOGAP.



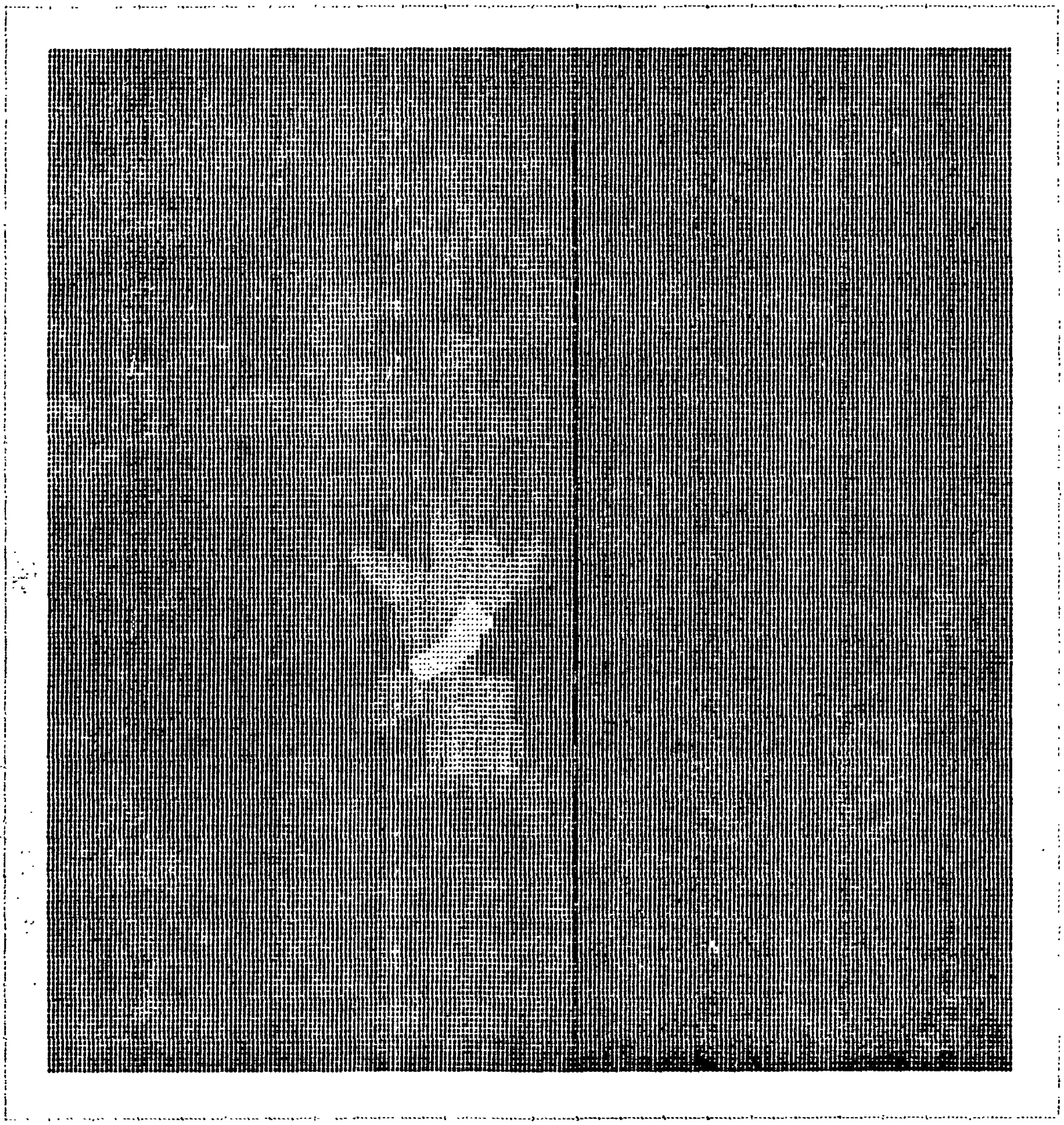
Map 1: Photo-Interpreted Land-Use, Cedar Rapids



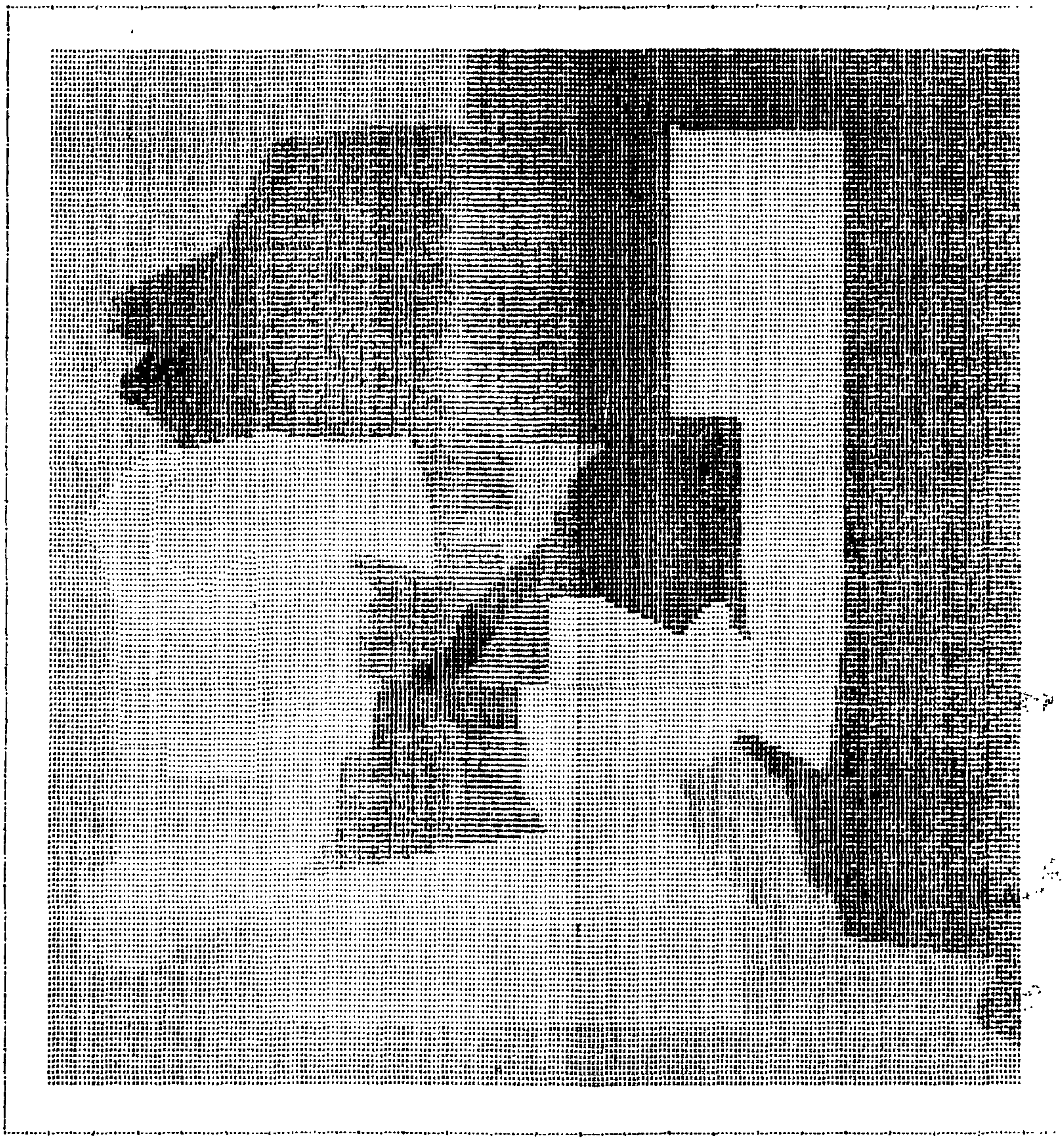
Map 2: 1970 Census Tracts, Cedar Rapids, Iowa



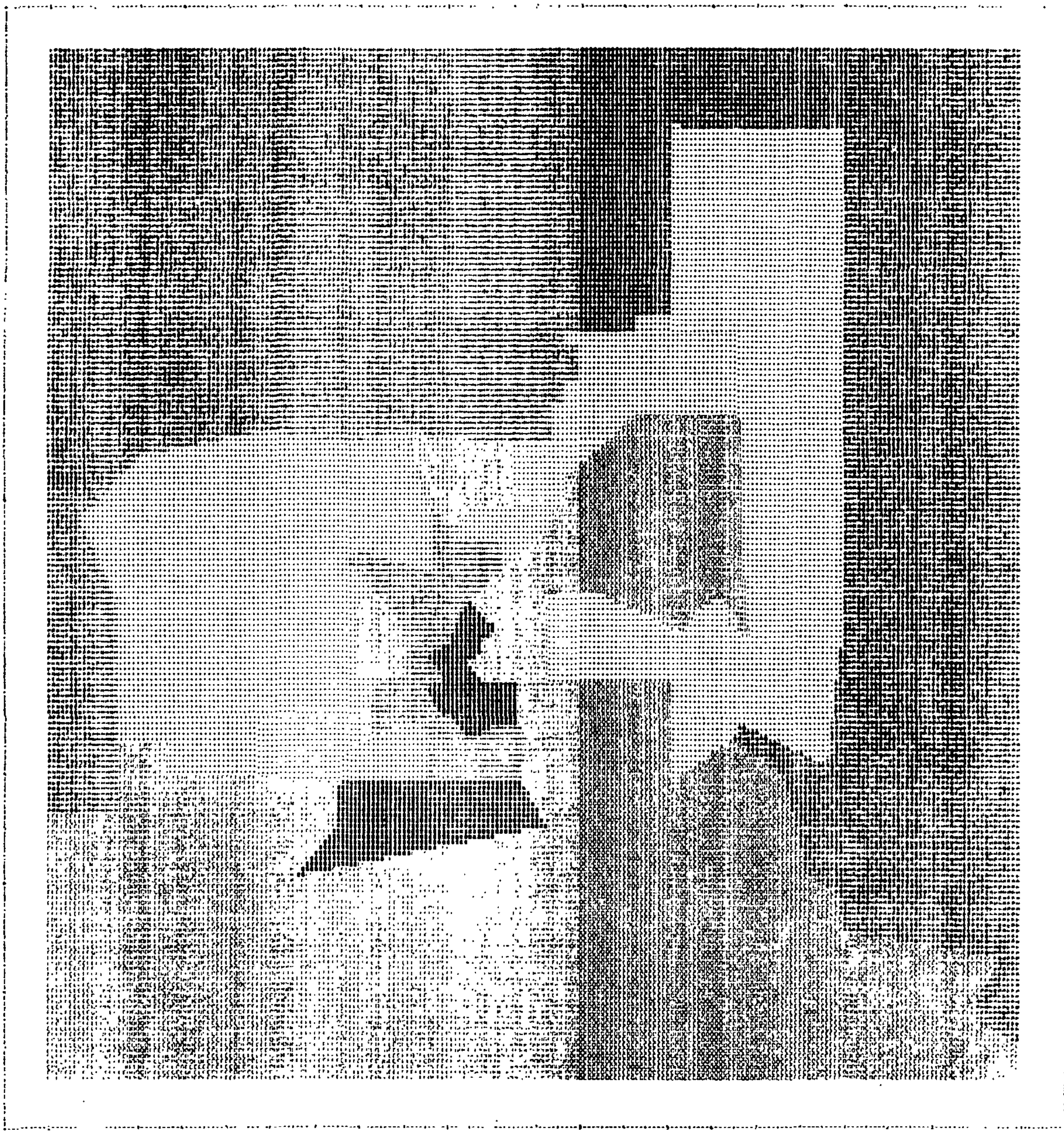
Map 3: Percent Black Population



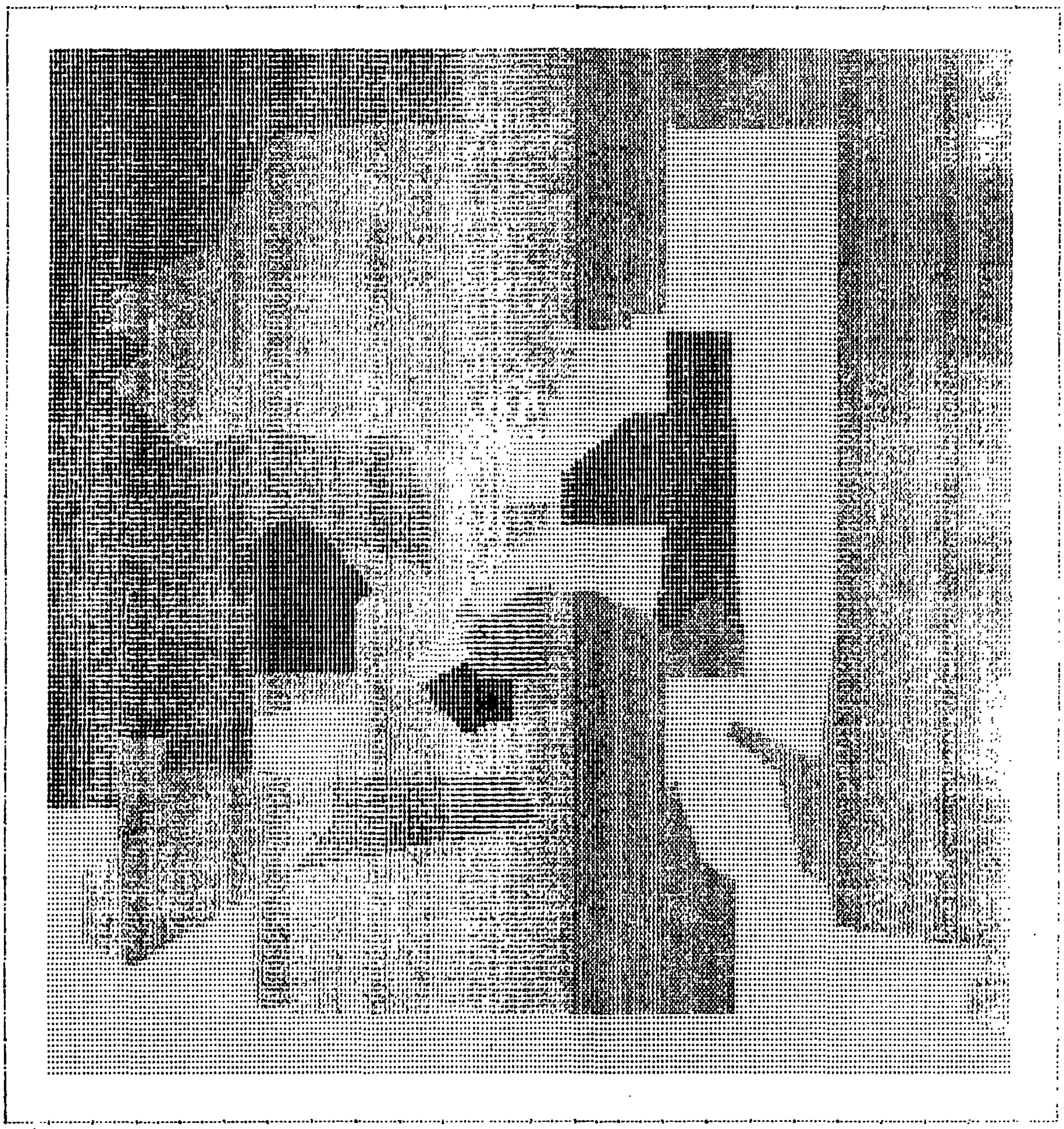
Map 4: Percent Owner Occupied



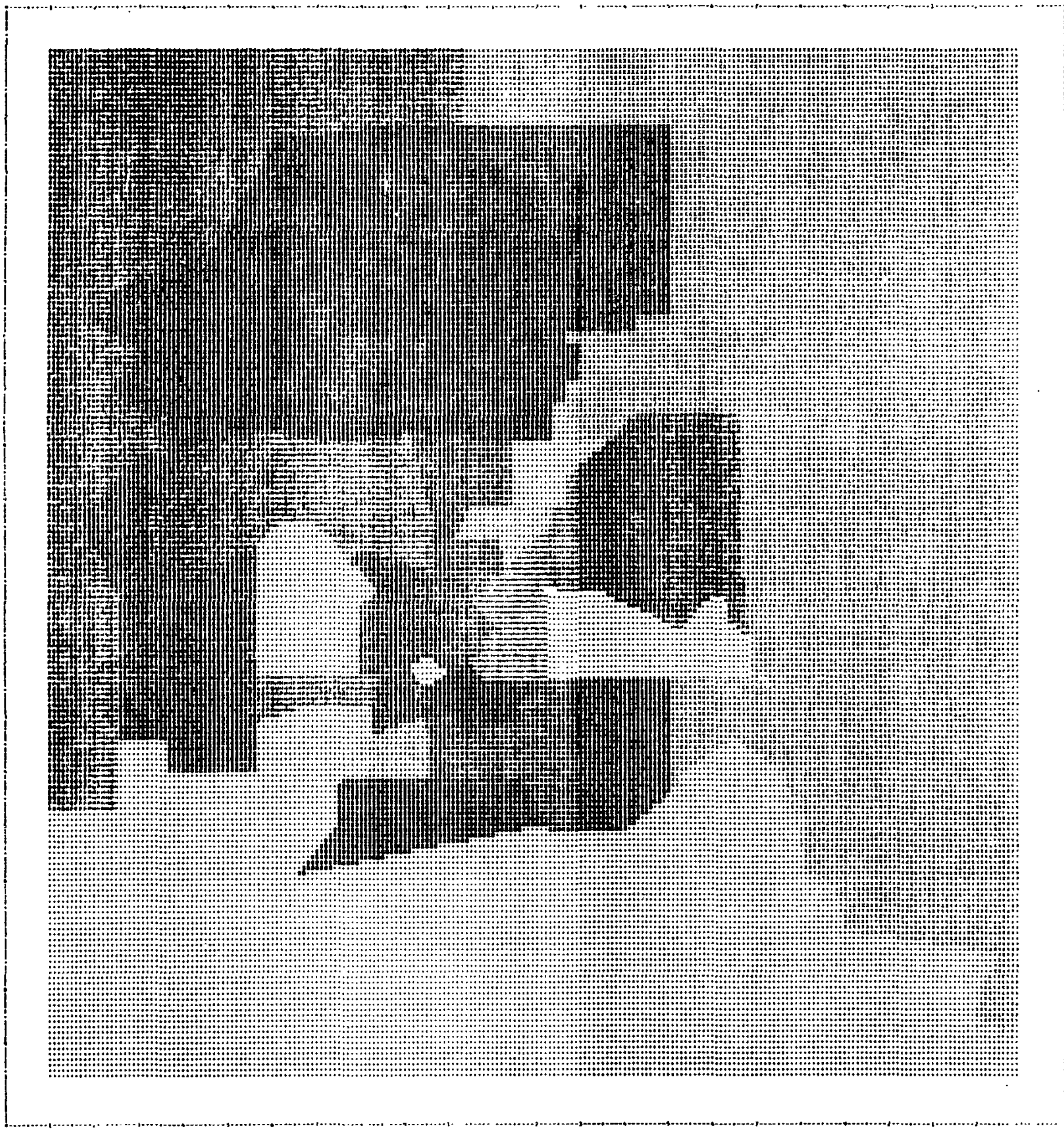
Map 5: Percent Renter Occupied



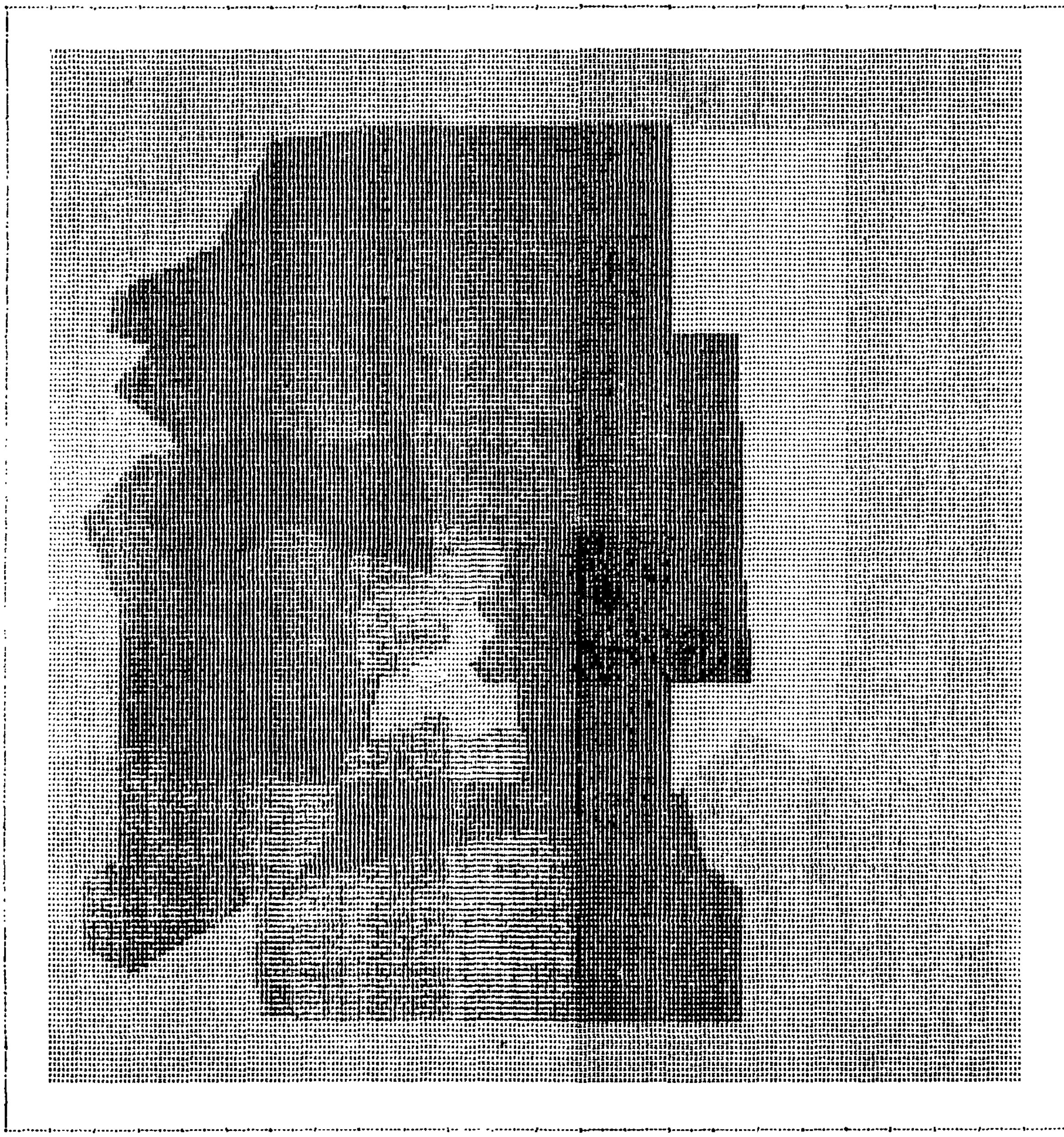
Map 6: Vacancy Ratio: All Units



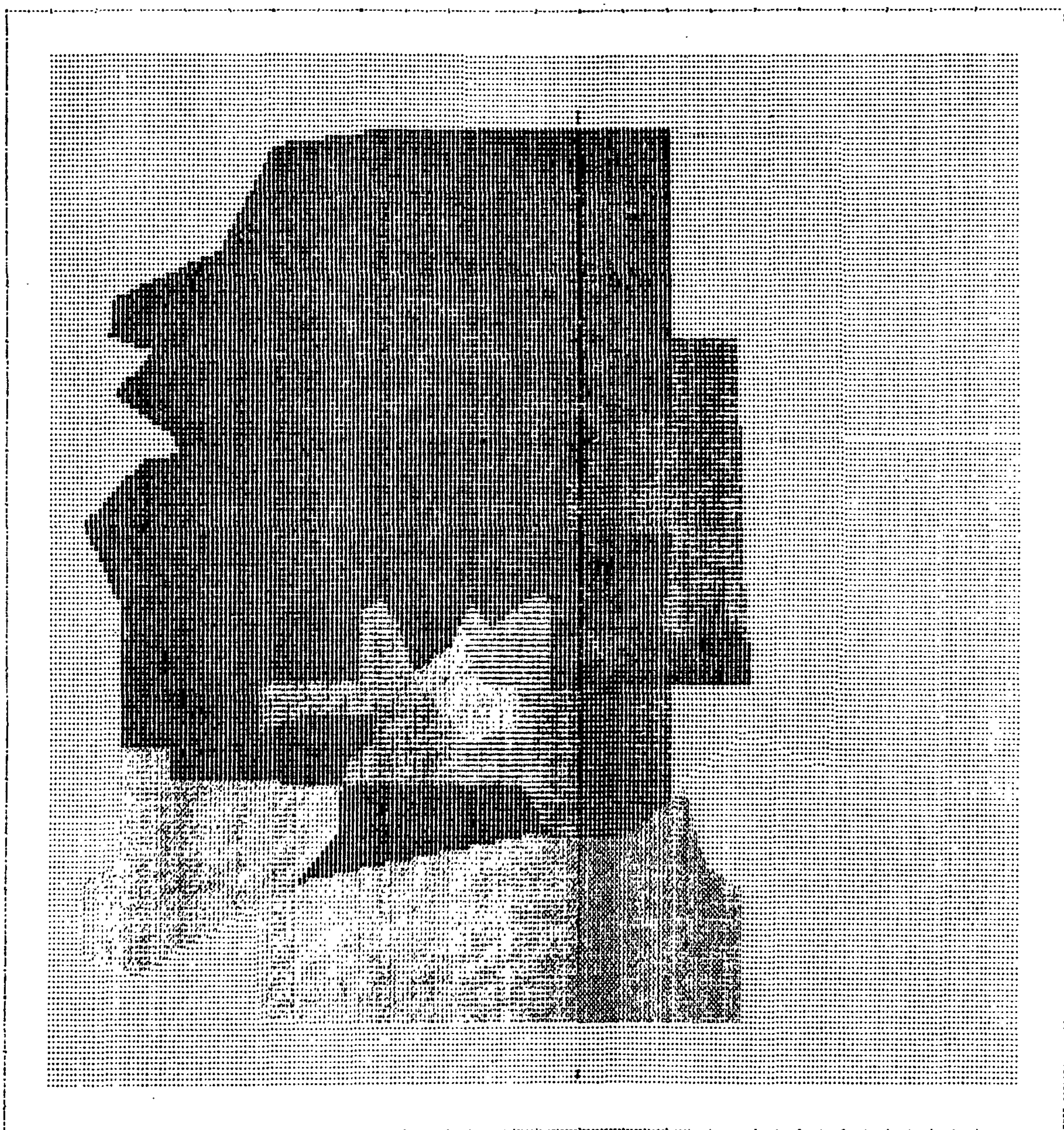
Map 7: Homeowner Vacancy Rate



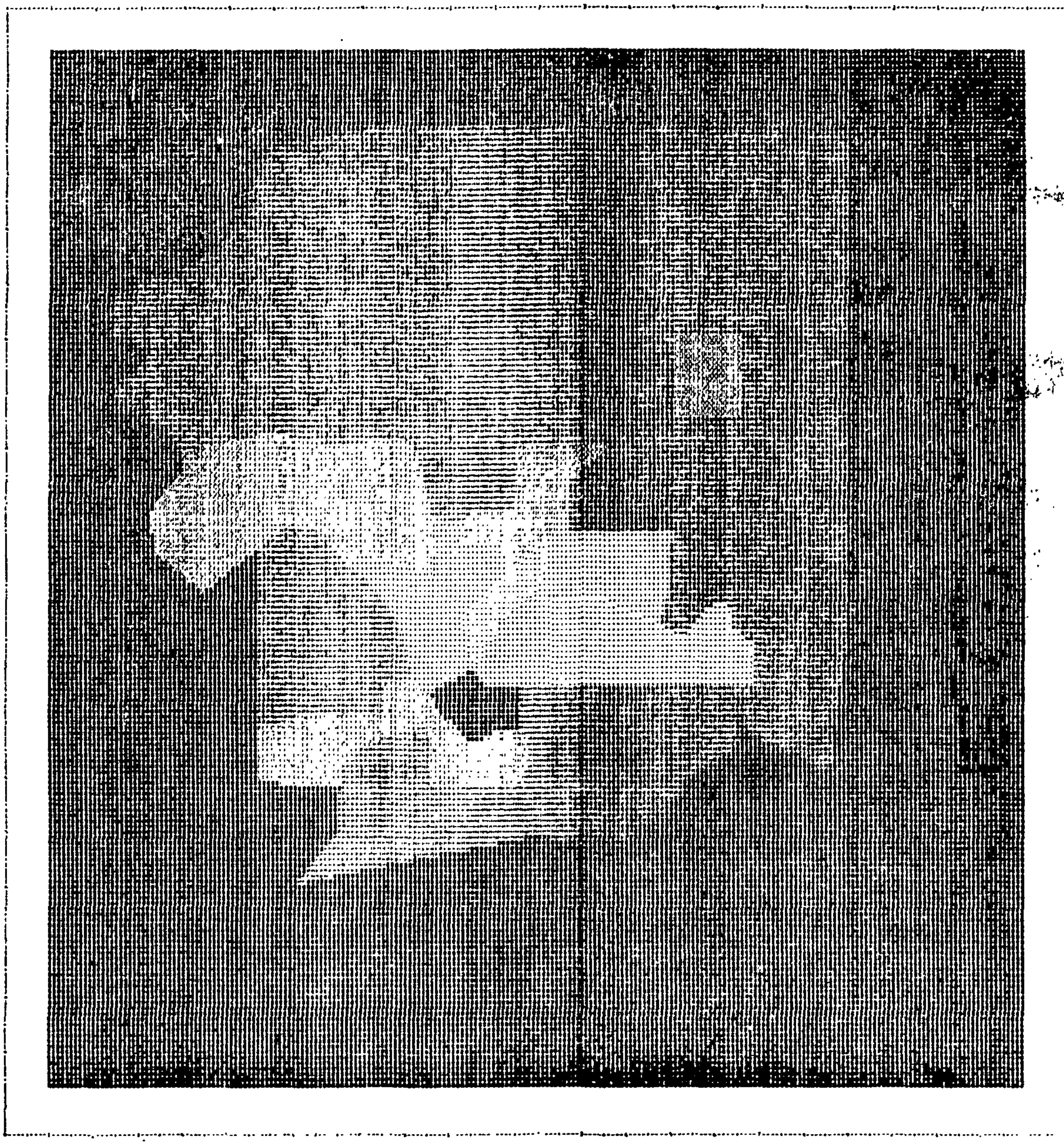
Map 8: Rental Vacancy Rate



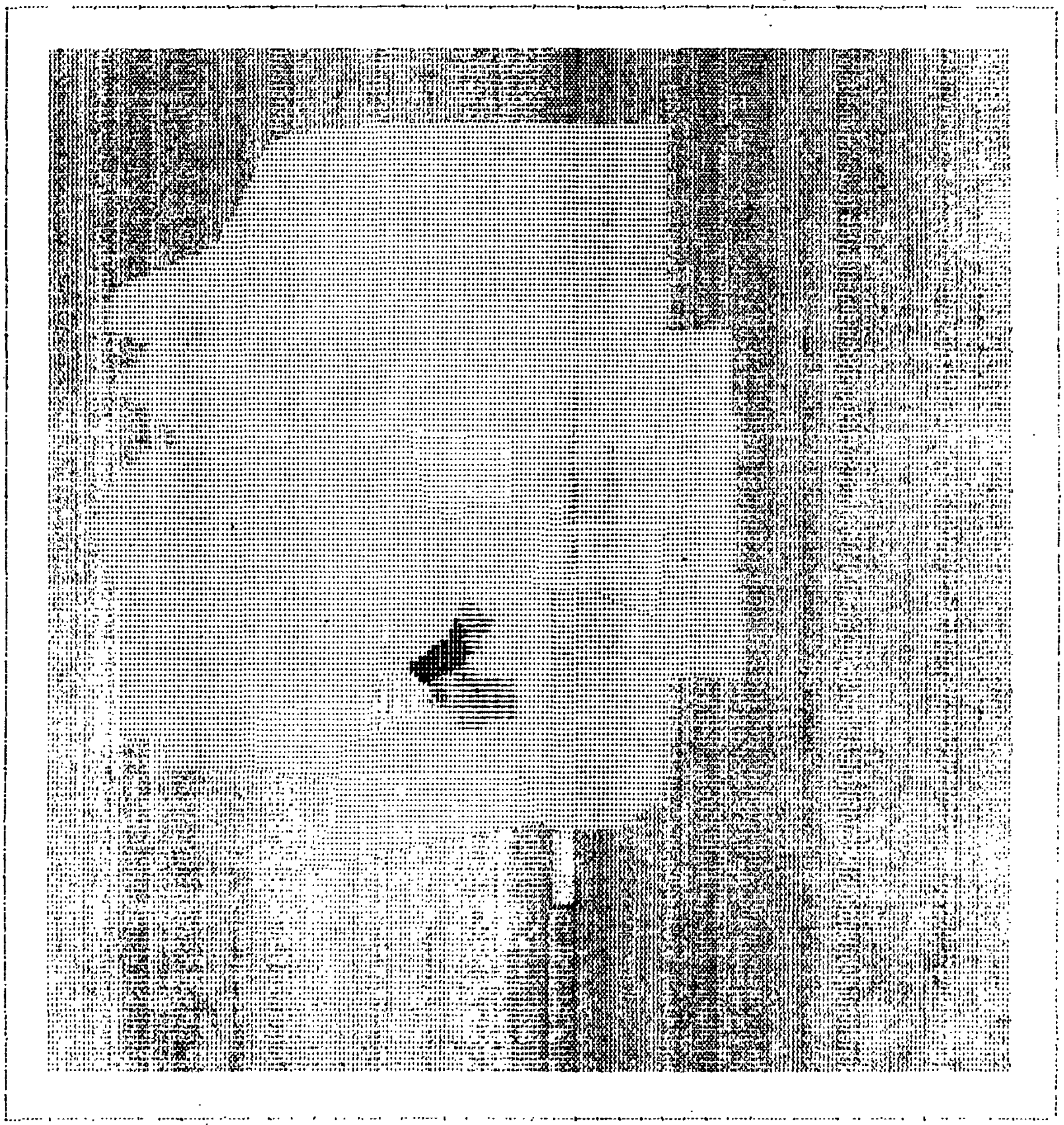
Map 9: Aggregate Value, Owner Occupied



Map 10: Aggregate Value, Monthly Rent



Map 11: Percent Overcrowding



Map 12: Percent Lacking One or More Plumbing Facilities

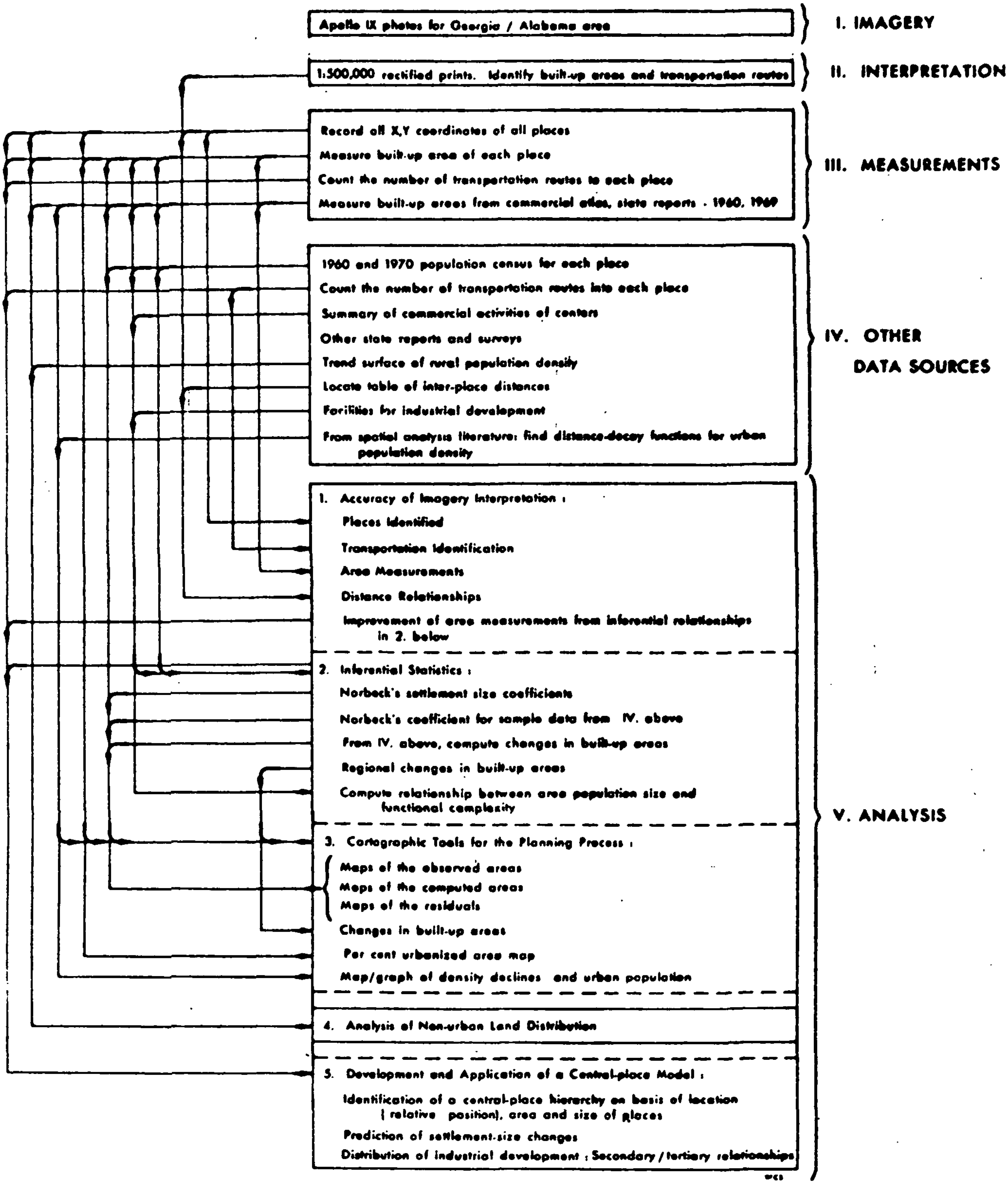
VI. IDENTIFICATION AND ANALYSIS OF A SYSTEM OF URBAN PLACES UTILIZING SPACE PHOTOGRAPHY

Previous chapters have emphasized urban land use and activity analysis within the confines of the city. In this chapter interest focuses on a regional system of cities and the remote sensing input shifts to space photography.

This chapter is divided into four parts: the first part describes the goals of the research, outlines the techniques and methodology adopted to reach these goals, and relates the task to previous literature in this area; the second part describes the interpretation procedures and the problems encountered in using Apollo IX imagery; the third part describes the results of tests to assess the quality of the information which was extracted from this low resolution imagery; the fourth part describes a model for forecasting an expected pattern of urban places in the study area from a knowledge of the approximate characteristics of the basic rural population density over the study area; in the final section this model is applied to the study area and the results are described and their significance to the research project goals are discussed. Figure 1 presents the flowchart of the research project and will be referred to throughout the report.

Figure 1

Flowchart of Research



Project Goals

One broad goal of the research was to evaluate the utility of low resolution (approximately 300 feet) space photography to problems related to the planning and functioning of large-scale urban systems. Realization of this goal requires at the outset an understanding of the quality of the information that can be extracted from such imagery. While previous research investigated the question of the accuracy with which transportation routes can be correctly identified from low resolution imagery, few systematic investigations have been made to determine the accuracy with which built-up areas can be determined (including places smaller than 1000 population).[1] However, a continuous monitoring of such information would facilitate the resolution of many regional planning problems. Despite the potential usefulness of information concerning the location and extent of urbanized areas, present sources of such information represent the results of a variety of ad hoc procedures that have been developed over the years. In other words, at the present time, no comprehensive data source exists in which land devoted to urban uses is distinguished from land devoted to other activities. Consequently, many simple, though vital questions for planning are never posed: for example one might ask, what is the quantity of presently non-urbanized land?; if a particular kind of "green-belt" policy were to be adopted, what type of land is available for urban expansion and where can it be found? Unlike the urbanized areas of Europe, where land control policies are characteristically discussed within the context of the location of available land, most parts of the United States are so close to a laissez-faire policy of land-use control that most areas have not yet begun a serious evaluation of evolving land use patterns on the urban fringe.

However, especially in the larger urban areas, the integration of autonomous local areas into viable planning regions is creating a demand for a more sensitive measurement and monitoring of land use patterns. The possibility of a uniform monitoring of the pattern of urban land uses quickly and economically, which is afforded by the availability of remote sensing imagery over wide areas of this country, may allow regional planning and forecasting to reach previously unattainable goals. Using conventional air-photos, some of the larger metropolitan areas are now developing descriptions of available industrial sites in the extended land area surrounding them.[2] Few areas have regularly updated imagery of this kind, making such procedures difficult and too expensive for the smaller towns. Space-level photography would appear to offer an ideal monitoring system for such data if the resolution were appropriate.

Current land use maps, in addition to their normal usefulness to planners, if available for a regional system of cities, would comprise an essential input to land use forecasting models. Such forecasting has normally been limited to metropolitan areas though evidence is accumulating that the spread effects of metropolitan growth extend far beyond present metropolitan area boundaries. Many towns are caught unprepared when these effects reach them. Towns that have previously felt no need for serious land-use control policies suddenly find land-use change all about them. Accurate predictive models for land-use change for a system of urban places are needed to pinpoint the problem areas. The greatest stumbling block to their development is the absence of accurate time-series data on the pattern of urbanized areas.

Accuracy of image interpretation is often considered as some overall expectation of successful recovery of a certain piece of information. However, this expectation is clearly a function of a number of variables. Thus the goal of the first phase of this project was to identify the variables which are related to the accuracy of identification of urbanized areas and, where possible, to calibrate the mathematical functions that relate accuracy of interpretation to the values of the relevant variables. A further goal was to combine these variables in a discriminant function which would be calibrated to yield the overall probability that an urbanized area would be identified as a combined function of the values of a set of relevant variables.

While the initial imagery - interpretation procedures were quite standard (see discussion below), a further goal of the research was to utilize knowledge of the spatial structure of urban systems as an aid in imagery interpretation. Too frequently, the image interpreter's knowledge of the features being identified is regarded as interpreter bias which should be eliminated wherever possible. However, if this knowledge can be systematized and introduced more formally into the interpretation procedure, a significant increase in interpretation accuracy can be expected. Traditional geographic theory concerning the size and spacing of urban centers allows prediction of many of the characteristics of such systems.[3] Some of these characteristics are best regarded as empirically derived regularities while others are deductively derived from more basic premises. The present research indicates a need for a variant on both of these standard approaches to the accumulation of knowledge. Rather than predicting expected characteristics of a total urban system, the problem calls for the development of models which start with the distribution of urban centers interpreted with a given level of accuracy and which then predict the location of other centers in the urban system from this initial information base. This report therefore develops and describes a model that could be used to provide the imagery interpreter with cues that would facilitate, and thus improve, the accuracy of image identification.

Interpretation Procedures and Signature Identification

The Apollo IX imagery used for the interpretation was an Ektachrome 70 mm slide of the Atlanta, Georgia region taken in March, 1969. Interpretation was aided by a 20-power microscope used in conjunction with a rectified black and white photograph at a scale of 1:500,000. "Urban" places were identified on the slide and their built-up areas outlined on the rectified photograph. Two measurements of area were made, and transportation routes were counted for each place (Parts I through III, Figure 1). Table 1 summarizes the interpretation procedure.

On the imagery it is relatively easy to differentiate large bodies of water, trending valleys, forest cover, interstate highways, crop and pasture land, and the larger urban developments. The signature for each is based on color, texture, shape, and pattern. Linear forms are more easily detected in forested areas where there is more contrast; whereas, in areas of less tree cover, both roads and rivers are usually indistinguishable.

Exposed soil is easily interpreted by its red hue, caused by the iron oxide present in Georgia soils. The problem is in deciding whether the red hues represent quarries, plowed land, or new construction. Linear red patterns most often are interstate highways under construction; they may also be high-powered tension line right-of-ways. Urban signatures vary according to the size of urbanized area. Normally a combination

Table 1 : Satellite 70-mm Slide Interpretation Process

Equipment: 20 Power Microscope
Light Table
2 Steel Rulers
Clear Plastic Triangle
Masonite
Plyboard

Photography: One 70-mm Color Ecktachrome
Black and White Rectified Photo of Slide

Set-up:

The microscope and light table are used to interpret the 70-mm color slide.

The rectified photo is attached to a piece of masonite with acetate covering. One steel ruler is attached to the masonite and plyboard on the right side (vertical) of the photo. Another such ruler is attached to a triangle so as to form a crude digitizer for establishing an arbitrary X, Y grid to reference places identified on the photo. Cover acetate with mylar to be removed later.

Procedure:

I. Study color and texture of photo under 20 power microscope

II. Examine physiographic nature of region in photo - search for lakes, drainage patterns, rivers, valleys, mountains

III. Trace apparent transportation network

IV. Large cities will have a color, texture, and shape differentiating them from the surrounding countryside - locate them

V. Identify the extent of "built-up" area for place

A. Cropland is light green
B. Quarries and Construction are light red
C. Houses, buildings, pavement appear as off-white splotches, with a grey sheen
D. Clouds appear as bright white, usually with shadows showing on the ground
E. Large highways (4-lane) show-up; others may, if area is forested largely; built-up area sometimes follows highways away from central density of structures

Table 1 (continued)

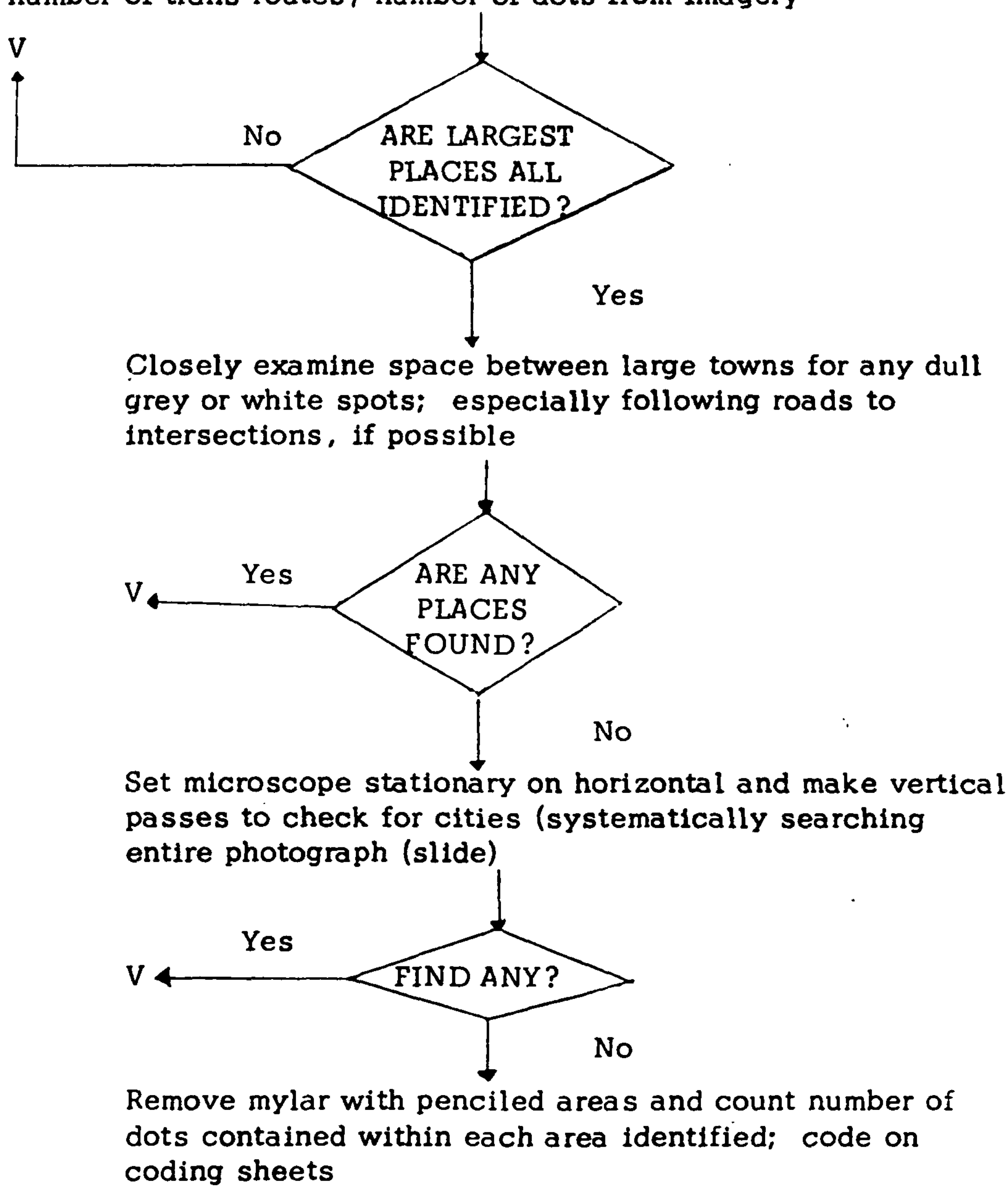
VI. Count number of dots under microscope of the area identified as anything except A, B, or D above which is contiguous and appears "built-up"

VII. Count number of distinct highways coming into or through town

VIII. Transfer to rectified photo (black and white) draw a line around the area interpreted as "built-up"

IX. Mark over city identified on acetate covering 70-mm slide

X. Record on coding sheets the X-Y coordinate location for place, number of trans routes, number of dots from imagery



of gray, dull white, and blue hues caused by the reflections of pavement, roofs, water towers, and other building-types indicate an urban place. The larger towns have a relatively distinct central city, although the periphery often merges into crop or pasture land making boundary decisions difficult. Identification of smaller places must rely on the analysis of a combination of signatures, namely: openness, transportation routes if visible, and the relationship of surrounding towns. The small towns easiest to locate are in forested areas or areas of extensively plowed fields. Pasture land, abandoned fields with scrub brush, and small wooded lots present a problem for identifying the smaller places.

Difficulties Encountered with Imagery

Clouds appear on the photograph as distinct white spots, sometimes casting visible shadows. Apparently, an excess of cover by small clouds would hamper urban place idenfication. The northwest section of the photograph contained a few clouds, which did block out portions of signatures and possibly even obscured small towns.

One other difficulty hampering explicit place interpretation is encountered in areas or urban sprawl. If one place blends into another with no visible boundary, then the built-up area is over-estimated and the number of places is under-estimated. Atlanta offers the prime example of this with the interpreted contiguous built-up area enclosing twenty-six other towns. Marietta and Smyrna merge into one large town, as do Douglasville, Mableton, and Austell. This problem occurs seriously only around the largest urban places.

Field Check

In April 1971, a field check of portions of the study area was made in order to clarify some of the questions which arose during the interpretation. Essentially there were two problems of concern -- the failure to identify towns of the same size in different parts of the photograph (under-estimation) and the apparent over-estimation of the area of some urban places.

(1) What are the characteristics of the area or of the small places which prohibit their identification?

In some forested areas places with as little as 100 population could be identified, but few towns under 2000 were identified in cropland or pasture areas. In fact, of all towns less than 2000 population that were identified, most were in forested areas of the imagery. Only 14 percent of the towns with less than 2000 population were accurately identified in an unforested area.

Examination of several small places which were not identified on the imagery suggests that several issues are involved which tend to work against accurate interpretation. South of Atlanta the area is largely unforested, yet in addition, the built-up areas of places are not compact. Legal boundaries are over-extended and pick up scattered farm houses making the population greater than would be indicated by the built-up area; in fact, the built-up areas of some places seldom consist of more than a service station and grocery store at a crossroads. Tyrone (131) has several buildings, yet not enough to show up on the imagery; Taylorsville (253) in the forested northwest does not show up at all. There was some difficulty in the Etowah River Valley of identifying small places because of a combination of cloud cover and the farm and pasture land in the area.

(2) What were the circumstances which caused identification of a town where none existed or where there was over-estimation of an existing town?

Duluth (1810) does not extend north to the Chattahoochee River, yet it was interpreted as such. Accounting for this over-estimation were large rectangular poultry houses. A similar situation occurred in Bremen (3484), whose interpreted area was equivalent to that of a town of 9000. The southern part of the town has a large petroleum product storage facility along the Plantation Pipeline, and the eastern section has a large clothing factory, accounting for the over-estimation of built-up area which consequently over-estimates the population of the town.

In the Cartersville area, a small town was identified which apparently had no real external counterpart. The field check showed it to be a large steam-powered electric generating plant surrounded by extensively plowed fields. An area west of Atlanta shows up as an area under extensive development. Field checking showed that this area is an industrial park developed along the river with a large area cleared off for construction. Subsequent photographs would no doubt indicate any changes which have taken place since March, 1969.

Computer Matching of Interpreted Data With External Information

Once the initial interpretation was complete, the interpreted towns identified by X, Y locational coordinates needed to be matched with their external equivalents. A polynomial regression program was utilized to compare the X, Y coordinates of twenty-eight known places on the imagery with their corresponding latitude and longitudes.[4] With the coefficients and constants suggested by second and fourth degree polynomials for latitude and longitude respectively, a second program assigned the remaining "unknown" places to their appropriate external equivalents. Unfortunately, a perfectly correct estimation of latitude and longitude is impossible because in the fitting procedure, an estimate which is off by several minutes will mean several earth miles. The program did indicate which towns were nearest the interpreted point, and by comparison with a map, it was easy to identify the place or places which correspond to the interpreted ones and thus to code them (Part V, (1) Figure 1).

Once the appropriate place(s) was coded for each interpreted built-up area, another computer program took the codes and created a final merged data deck including the ground-truth (Part IV, Figure 1) and interpreted information for each built-up area identified on the slide. Essential elements for this part of the study are reflected in the variables on the merged data deck, namely: the area as measured on the rectified print; the area as measured beneath the microscope directly from the slide; the population of each place or combination of places; the number of transportation routes externally derived from highway maps; and the number of transportation routes interpreted from the imagery.

Accuracy of the Interpreted Data

The relationship between the interpreted built-up area and 1970 population was investigated. In this study area, it is not possible to verify accurately the actual built-up areas of the smaller places. Commercial atlases do not provide up-to-date maps or measurements, nor do the occupants of the places themselves document this information. A sample of 125 smaller places was contacted by mail with a return response of 19%; but a question regarding an estimate of the measured area elicited answers from less than half of these responses. Therefore, verification of the interpreted built-up area measurements was virtually impossible.

Although it might be expected that the measurement made under the microscope would be more accurate than measurements from the rectified print, in fact this was not so. It is cumbersome, if not impossible, to outline the interpreted boundary of the built-up area of a place under

20-power magnification. Since many small dots are being counted for a relatively undefined area, the measurement is quite crude. For places with less than 20,000 population the correlation between total population and the measured area from the rectified print was r = .81. The correlation between population and area measured under the microscope (without Atlanta) was r = .32: the latter suggests that the area measured on the rectified photograph is a better measurement of the actual built-up area. This conclusion, however, is based on the interpretation of only one person. It would be interesting to compare the interpretations of different persons. The mathematical relationships between our measurement of built-up area and the respective populations of places will be discussed in more detail later.

In order to analyze the overall accuracy of place identification in Apollo IX imagery, the proportion of correctly identified places of the actual total number of places in each of several size classes was computed. Figure 2 indicates the resulting probability of identification curve considering places from 10 to 5000 population. The higher population classes are not shown because there are no towns in the study area in the range of 6000 to 9000 to be identified. All cities larger than 9000 were correctly identified (100%); in fact, all places over 4000 population were correctly identified.

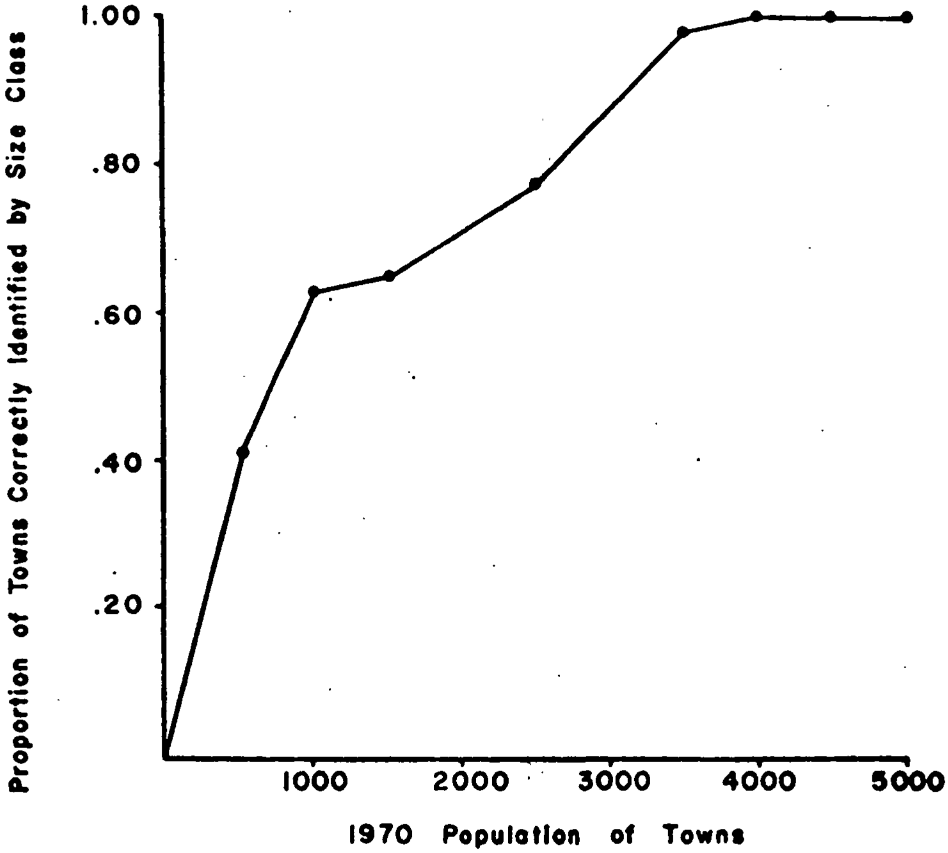


FIGURE 2. PROBABILITY OF IDENTIFYING TOWNS FROM APOLLO IX IMAGERY RELATED TO TOWN SIZE

As expected the smaller places were less accurately detected: this could be simply a function of the compactness of built-up area, or as mentioned earlier, a function of topography and vegetation cover. It should be possible to consider for each town several representative variables: *regional location, topography, population growth rate, nearness of surrounding towns*, in order to see what are the distinguishing characteristics of a town whose built-up area is accurately identifiable on low resolution imagery. It ought to be possible to calibrate a function from which the probability of correctly identifying a town in any area could be computed. The hypothesis was explored.

The accuracy with which urban places are identified from low resolution imagery may be hypothesized to be a function of both the context in which the place is found and of its internal characteristics. For example, places located in forested regions appeared to be easier to identify than those in other regions. Figure 3 shows that small towns in particular were more frequently identified when located in forested regions. For all town size categories the probability of successful identification was greater for places in forested regions. A Kolmogorov - Smirnov test indicated that this difference could not be attributed to sampling variability, if one accepts the assumption that towns in the study area comprise a cluster sample selected from a range of possible sites any one of which might have been surveyed. Figure 4 gives the

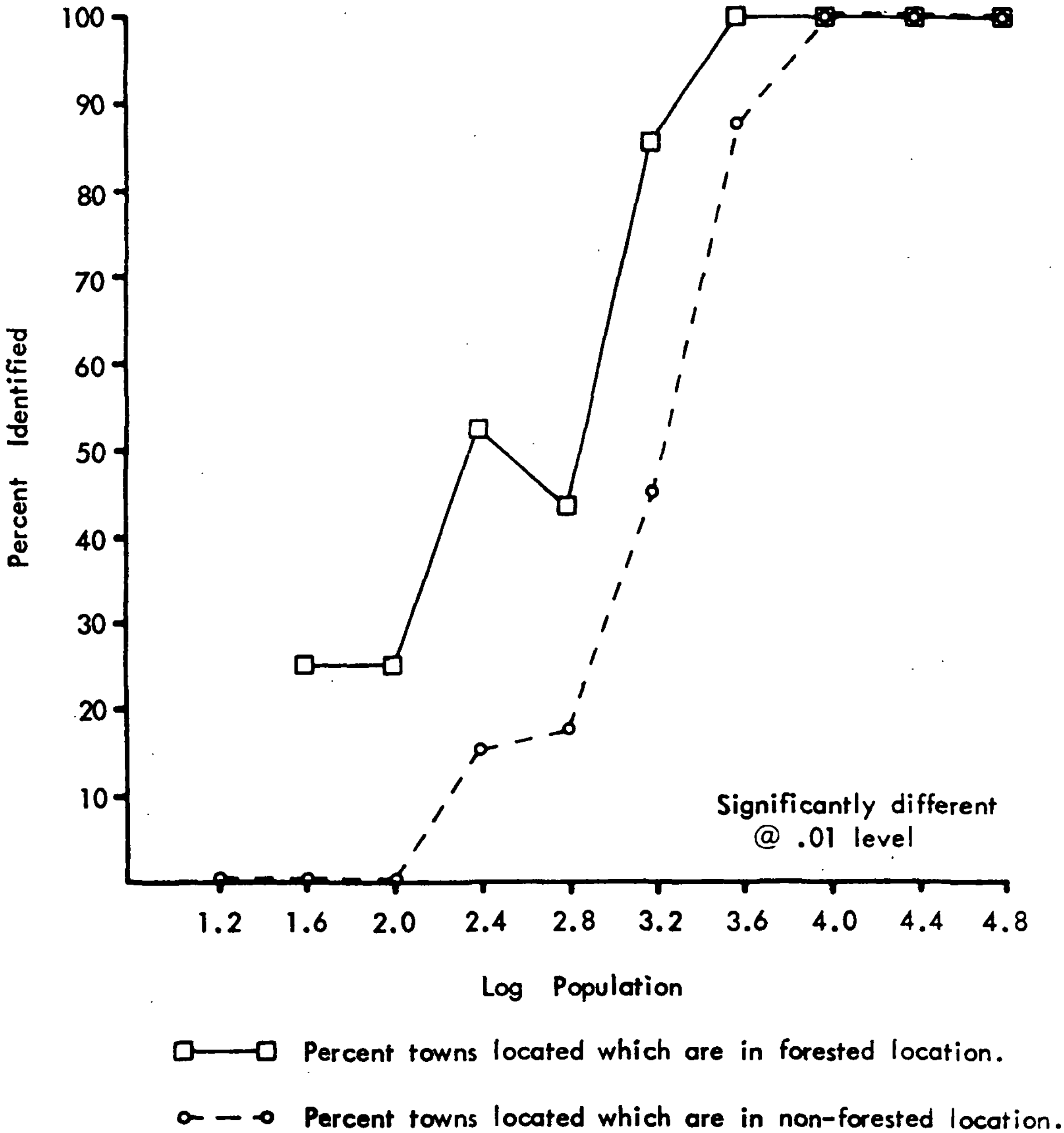


Figure 3 Forested or Non-forested Location

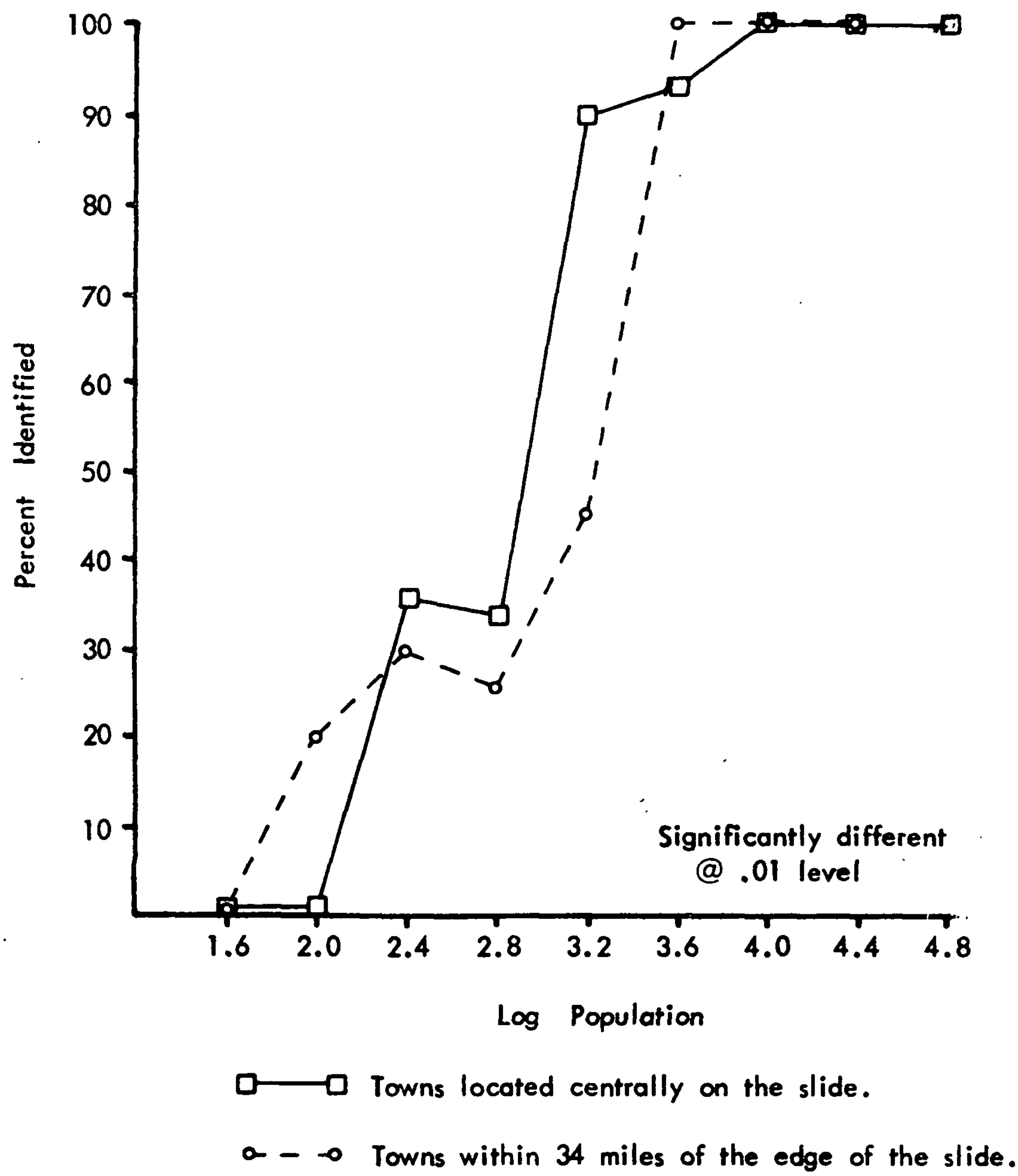


Figure 4 Relative Location of Place on 70mm Slide

results of a test to determine whether places located close to the edge of the study area might be more difficult to identify than places located in the center of the study area where the sharpness of the focus appeared to be better. Places in the center of the study area did have a higher probability of being recognized than peripherally located places. Differences were statistically significant at a conservative (.01) level. The number of observations was insufficient to actually calibrate the decay-function with respect to distance from the focal point in the center of the study area.

The degree of obstruction in imagery interpretation due to cloud cover was investigated in Figure 5. For that diagram the study area was regionalized into a "cloudless" region and one where cloud-cover, though sparse, was a factor in interpretation. The figure shows that this was a major factor in reducing the probability of identifying a place. It had been hypothesized that places which had increased in population in the previous decade would be more easily identified than stagnant or declining places. Places that are growing often are strategically located with respect to major arterial highways and other transportation modes and often have significant construction programs; the presence of any one of which was thought to facilitate identification on low-resolution imagery. However, Figure 6 indicates that no statistically significant difference exists in the probability of identifying the two types of places. Population change in the 1960-1970 intercensal period was used in that figure.

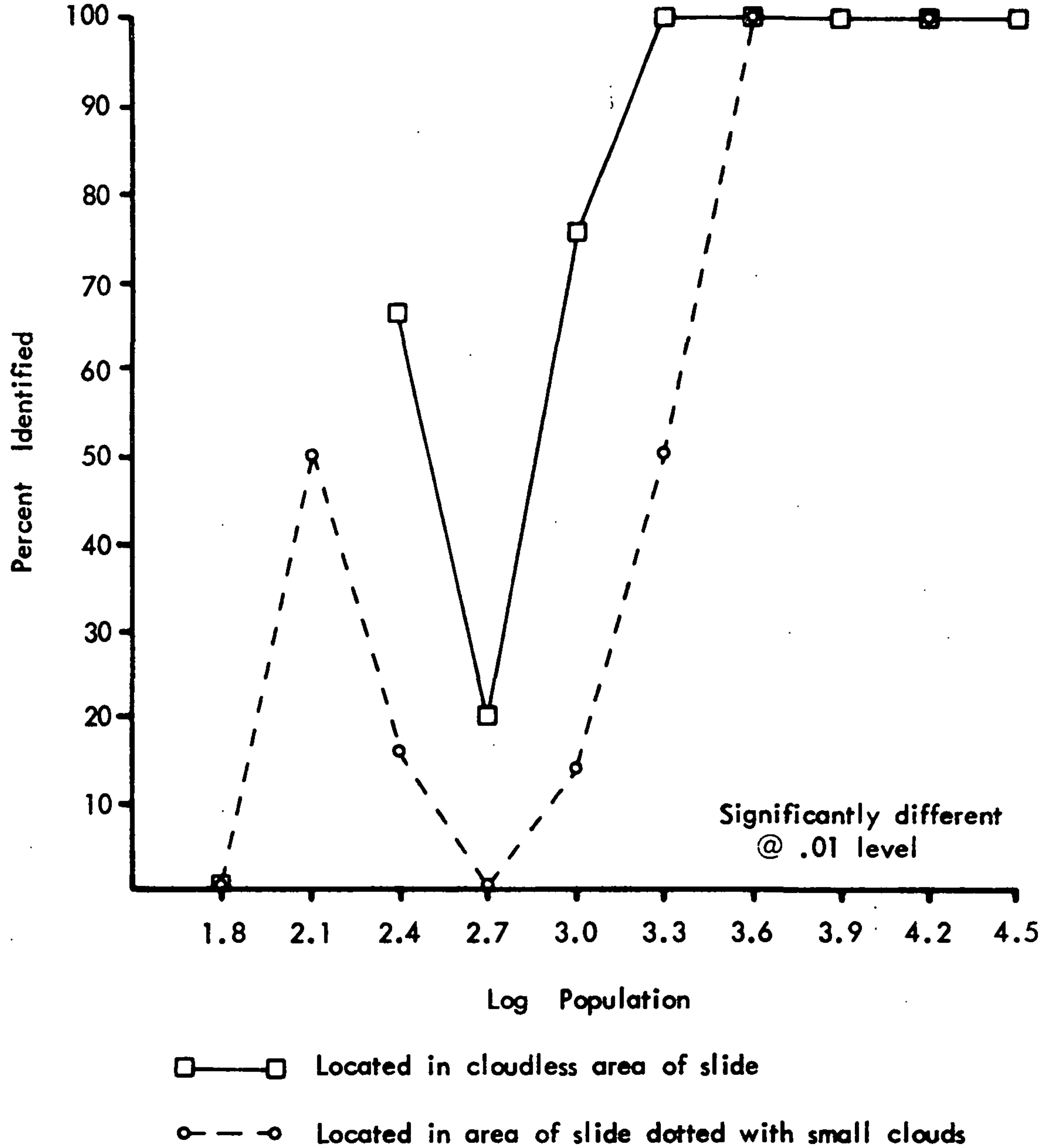


Figure 5 Location of Place with Respect to Cloud Cover on Slide

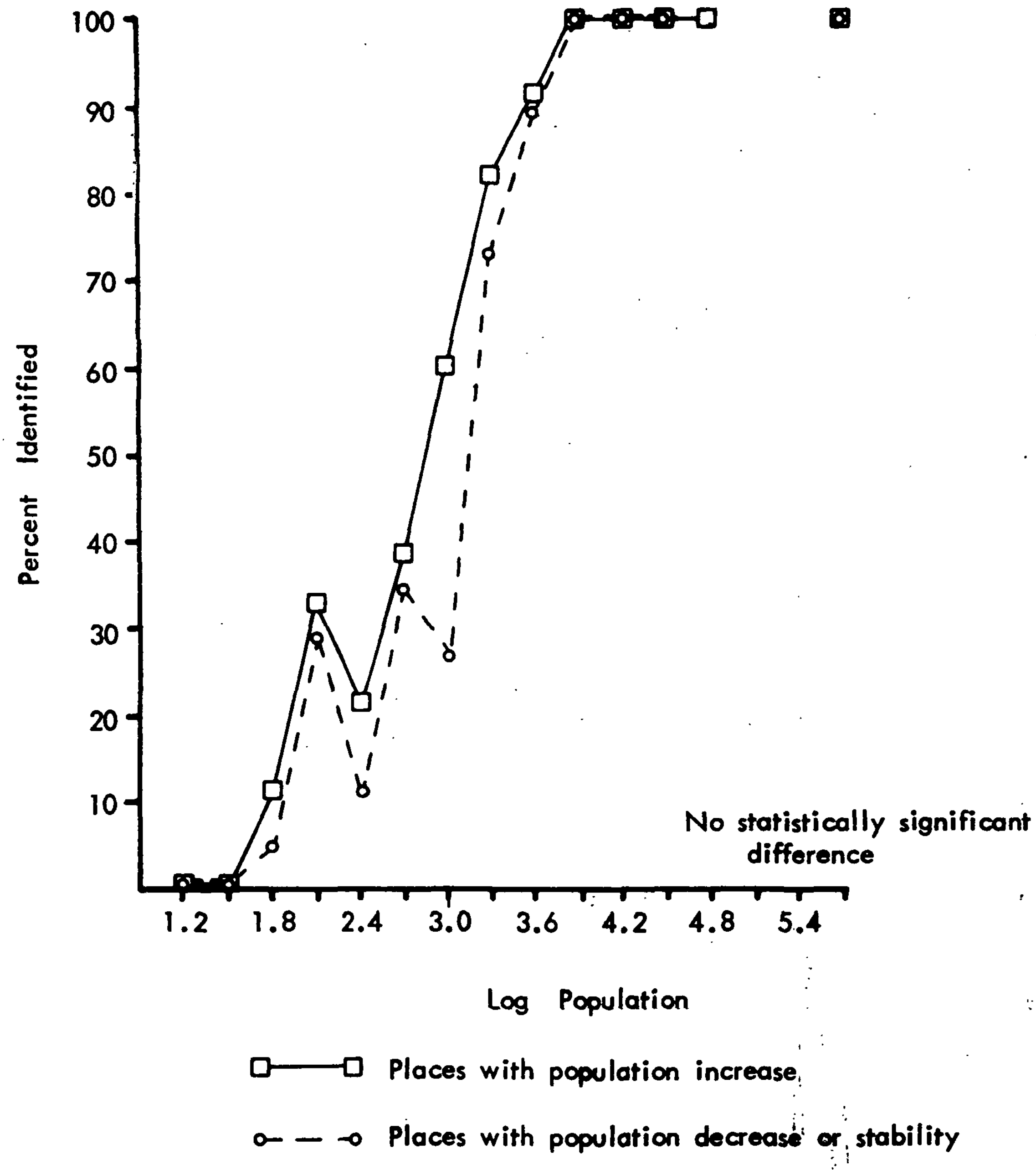


Figure 6 Places Experiencing Population Growth from 1960 - 1970

Figure 7 shows that places adjacent to larger places were, of course, more frequently identified. Figure 8 shows that the identification of transport links increased as town size increased. Figure 8a indicates considerable variability between adjacent town-size categories though the systematic increase in predictive accuracy is clarified in Figure 8b where a running average of the town-size classes is portrayed.

Mathematical Relationships Between Population and Area

The mathematical relationship between the interpreted built-up area of a place and its actual population was investigated. Holz, Huff and Mayfield provide empirical evidence which indicates a linear relationship is the appropriate one in the Tennessee area;[5] while Wellar follows Nordbeck's formulation that the relationship is an exponential one.[6]

Intuitively, one would assume an exponential relationship is appropriate because as population increases the built-up area increases at a decreasing rate. When our interpreted data were fitted to an equation of the form $P = bA^N$, where P = 1970 population; A = area in sq. miles, b and N were estimated respectively as 4102 and .977. With an exponent so very close to unity, a linear relationship is evident. Note Figure 9, which is a scatter plot of the data. This result indicating that as area increases so does population, in a direct fashion, perhaps reflects a regional variation existing in the population-area

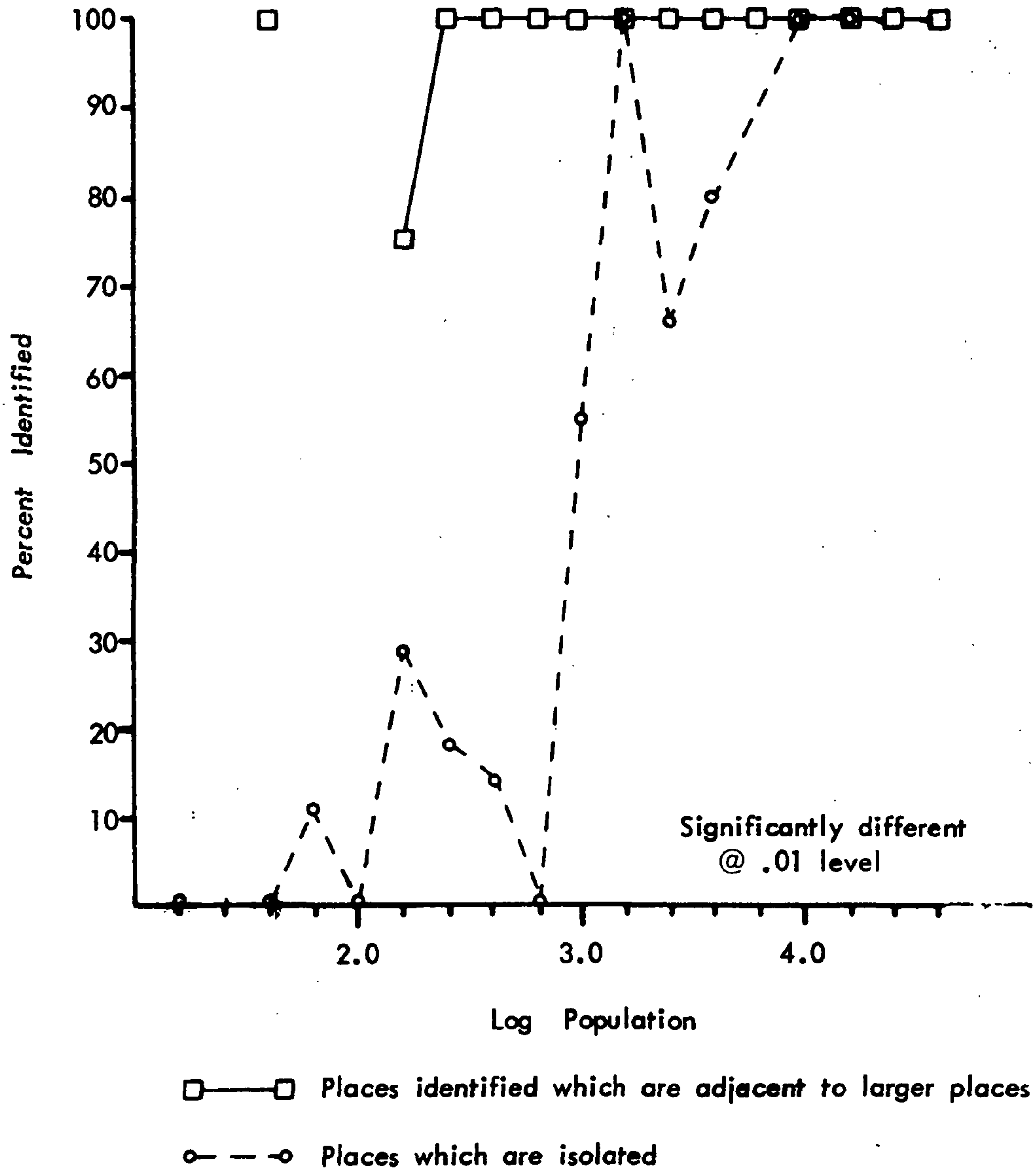


Figure 7 Location of Places Adjacent to Larger Place

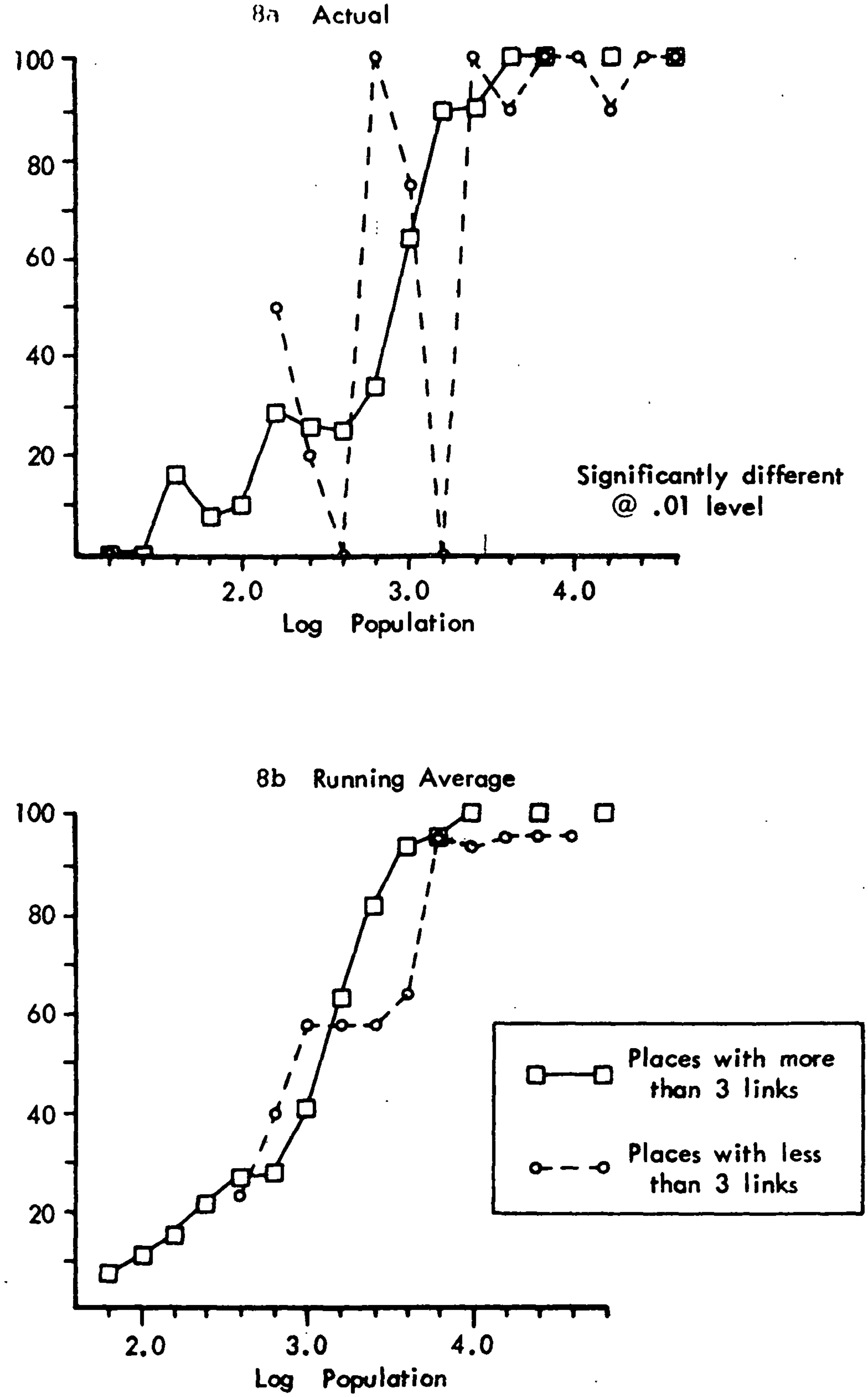


Figure 8 Transportation Links with Other Places

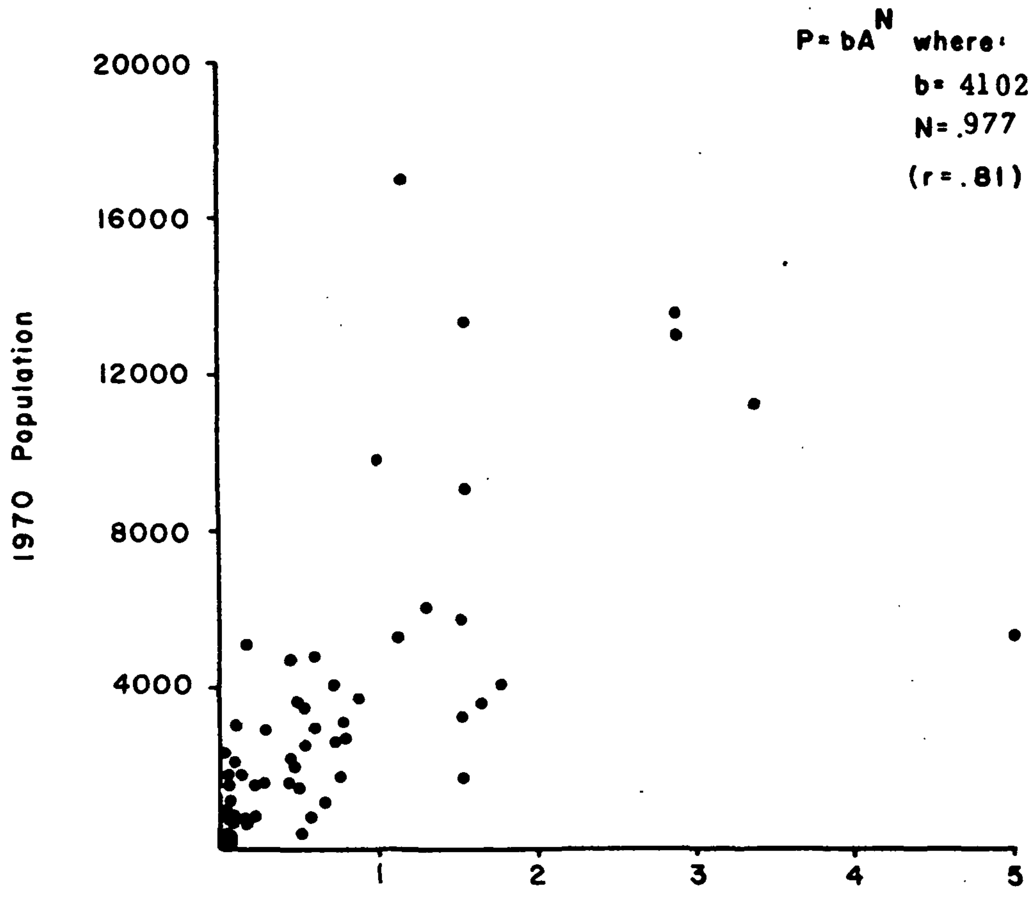


FIGURE 9. SCATTERPLOT OF POPULATION - AREA RELATIONSHIP

relationship since a linear relationship has been empirically shown to exist in a Tennessee study area as well as a Georgia study area.

The area of the towns were estimated from the known (1970) populations by least squares procedures using the functional form suggested by Nordbeck:

$$A = bP^{N}$$

with variables as previously defined. For the 64 urban places (populations less than 20,000) the parameters have the following values:

$$A = .003954P^{.67181}$$

For the 67 urban places (including the extreme observation of the Atlanta metropolitan area) the values in the equation are:

$$A = .006976P^{.75401}$$

A Model of the Urban Distribution Pattern To Facilitate Imagery Interpretation

Interpretation of low resolution imagery would be facilitated if models could be developed to generate critical characteristics of the system being interpreted. Such critical characteristics would serve as cues in interpretation. With the aid of such models it is no longer necessary for the image interpreter to presume ignorance of the phenomenon he is interpreting. For example, as discussed earlier, research has shown that all towns larger than 4000 population in the Georgia study area were correctly identified from the Apollo IX imagery. A model that took the interpreted information as correct and then predicted the approximate locational coordinates of other places might improve the probability of correctly identifying these smaller places. In this sense image interpretation and basic modelling procedures work hand in hand to improve the utility of the imagery.

The basic concept of the model developed for this purpose is that approximate locational coordinates of towns can be predicted from a knowledge of the underlying non-urban population densities. Serving this rural population with central functions is the primary purpose for the existence of small towns in rural areas. The problem is analogous to fitting a jig-saw puzzle during which the slow unravelling of the basic pattern facilitates the identification of unassigned pieces. In the case of a regional system of urban places each pattern is not unique, rather it shares a large number of salient properties with all other such systems.

Given the non-urban population density, the computerized algorithm finds the expected locational coordinates of the places.

Service Points in a Heterogeneous Area

The problem considered here has the following general form. Given a spatial trend surface function expressing density of demand as a function of locational coordinates, determine the locations of supply points and their number such that in the proximal area surrounding each supply point approximately equal amounts of demand corresponding to a given "threshold demand" will exist. By "proximal areas" is meant areas containing all points closer to the given supply point than to any other supply point .... for all supply points. "Approximately equal amounts of demand" only are specified since it is suspected that one cannot simultaneously impose a constraint that equal capacity exist at each supply point and a constraint that tributary populations be distance minimizing in their patronage of supply points unless the distribution of demand through space is uniform.[8] In response to this problem, earlier studies have either modified boundaries to meet capacity constraints,[9] or have ignored the capacity constraint in order that total distance separation between consumers and supply points could be minimized.[10] However, for many substantive applications, boundary modifications are not appropriate since patronage of the points in question is the result of free choice. Therefore, the approach used is to develop an algorithm in which substantively meaningful boundary definitions are used and then to minimize the variability in tributary area demand around a specified demand norm. In the tests of the algorithm discussed below, a distance-minimizing concept for boundary definition is used, though with some modification the algorithm could be used with alternative boundary defining concepts.

The algorithm developed here appears to differ from previous ones (with the exception of that of Tobler), in three respects.[11] Firstly, it is developed for application to continuously distributed demand density functions over space rather than with discrete data that have been aggregated, often arbitrarily, into groups prior to allocation. Secondly, it is most suited for determining the location of a large number of service points (several hundred) rather than with a few points. Alternative algorithms perform very well for small numbers of service points but because of their iterative, combinatorial approach, are ill-suited for solving allocation problems involving the simultaneous relocation of several hundred service points from many thousand sub-areas to be served.[12] Thirdly, though its accuracy appears to be high, it uses only small amounts of computer time to effect a solution for several hundred points. In both these respects it may be regarded as a complimentary algorithm to the location-allocation algorithms discussed above which rapidly become intractable where the number of points to be located and the number of sub-areas is large. The algorithm is related to that of Tobler which transforms locational coordinates so that equal areas in the space so produced have equal populations, whereas the algorithm described below estimates expected interpoint distances in the original space such that areas surrounding the points will have equal populations.[13]

General Features of the Solution Algorithm

The proposed technique for solution is an iterative one which, by making successive adjustments to an initial (uniform) configuration of points, derives the best two-dimensional configuration that satisfies a set of computed expected interpoint distances. In this respect the algorithm belongs to the general class of multidimensional scaling algorithms.[14] It may be regarded as a transformation which maps each trial point into a new trial point.

The expected distances are estimates of what the distances between neighboring points would be if the local population density prevailed throughout the area, the points were located in a triangular lattice, and the natural tributary areas around each point contained populations that were equal to threshold demand. After the configuration of points has been adjusted to reflect these distances (by the convergence process described below), revised estimates of the interpoint distances are computed. It is necessary to compute revised distance estimates as the iterations proceed since the points move across the density of demand surface during the iterations. With respect to the latter procedure, the algorithm appears to be quite different from other multidimensional scaling approaches. Since the goodness of fit measures that are used rely on the degree to which the distances in the resulting configuration of points correspond with the estimated interpoint distances, were these not representative of the local population densities where the points are located at the close of the iterations, such measures could not be used to evaluate the performance of the algorithm. Iteration proceeds until the distribution of points is most optimal with respect to the non-uniform population distribution. Criteria for ensuring that the optimal pattern is reached are discussed below.

Estimating the Number of Service Points

The first step in the algorithm is to estimate the number of points that will be needed to service the study area. It is assumed that a population density function over the space of the study area has been defined and that a given number of people (threshold) are to be serviced from each point. In this step the total population of the study area is estimated by computing population density for small units of area and thus the population of those areas and summing over the study area. Dividing this total by the threshold size gives the number of points to be distributed. This number of points is then located in a uniform pattern according to a triangular lattice in which all interpoint distances are equal (Figure 10).

Deriving the Estimated Interpoint Distances

The object of the estimated interpoint distances is to express the expected distances between neighboring points that would leave the points with a tributary area surrounding them with purchasing power approximately equal to threshold demand. These distances can be derived from some of the elementary properties of hexagonal lattices. These have been reviewed by Dacey[15] who has also stated the relationship between distances between adjacent centers and the area

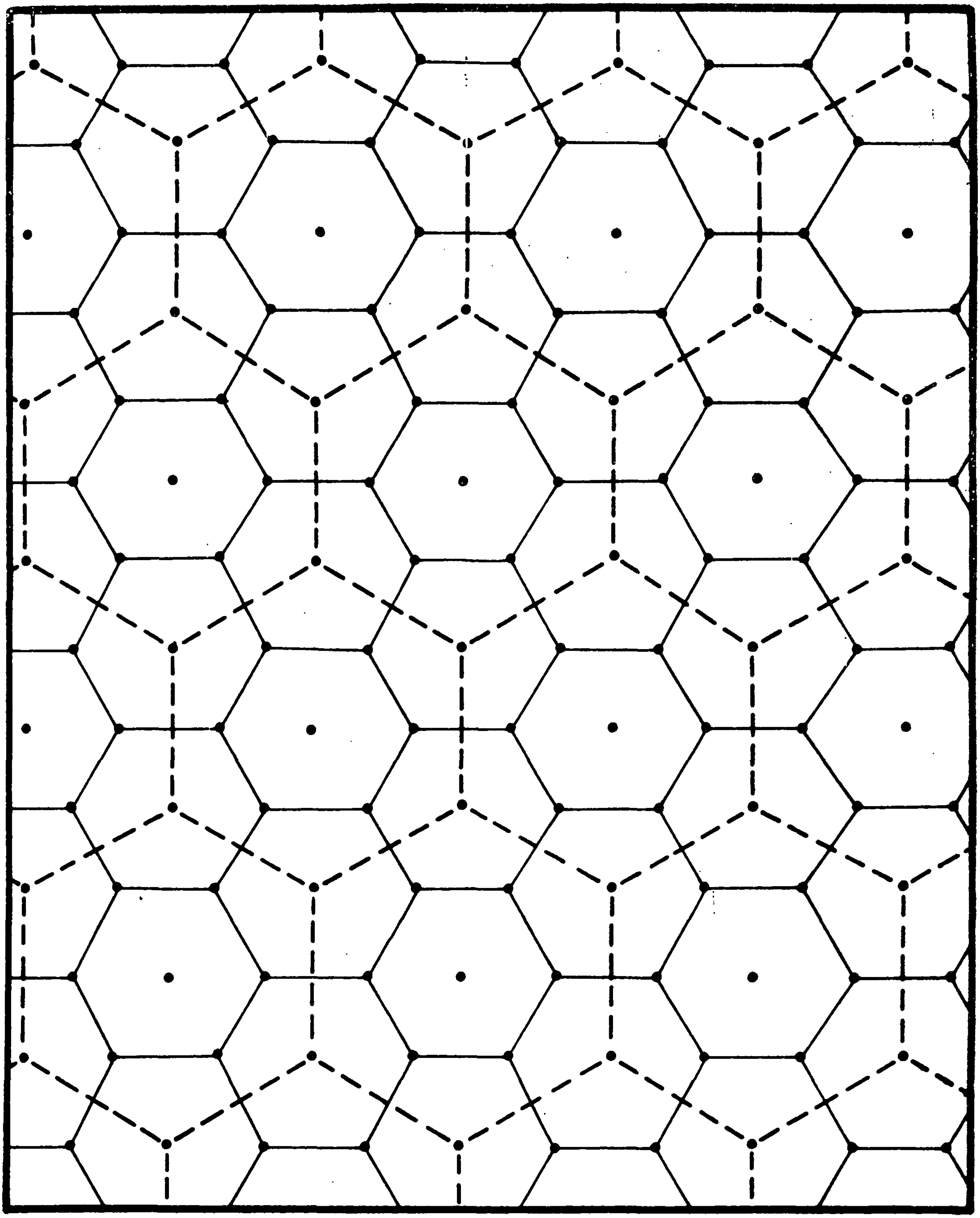


Fig. 10 The Triangular Point Lattice for First Iteration

of the Dirichlet regions in such lattices.[16] He states that:

> On the hexagonal lattice the area, H, of Dirichlet regions with distance t between centers of adjacent regions is
> $H = t^2(3/2)^{\frac{1}{2}}$.------------------------------(1)[17]

If, for any location, the population density is known, then the area of the tributary area needed to supply threshold can be computed (assuming that the population density is constant over the local area surrounding the location in question). The area required to support the mth good is:

$$H = T_m/((p_i + p_j)/2) \text{----------------------} (2)$$

where p_i and p_j are respectively the population densities for locations i and j for which an estimate of expected interpoint distance is required. Woldenberg has pointed out that formula (1) above is incorrect and should be:[18]

$$H = \sqrt{3/2}t^2 \text{------------------------------} (3)$$

and thus

$$t = \sqrt{H. {}^2/\sqrt{3}} \text{------------------------------} (4)$$

The estimated distances (d^*_{ij}) between market centers in the area for which average population density is $(P_i + P_j)/2$ is thus:

$$d^*_{ij} = \sqrt{T_m/((p_i + p_j)/2) \;.\; {}^2/\sqrt{3}} \text{--------------} (5)$$

For a plain of non-uniform population density, the lattice of the configuration of points being constructed is, of course, not hexagonal and therefore equation (5) does not apply. However, the intent is to construct a configuration of points that is as close to a hexagonal lattice as possible in the local area -- even though over the larger region distortions of the lattice may be pronounced. For this reason equation (5) gives the most suitable approximation to the required distances.

Calculating Local Population Density (p_j)

Assume that a continuous function exists for population density over area $g(x,y)$. For any set of locations in this area, tributary areas may be defined by thiesson polygons (the classical distance-minimizing postulate), by generalized distance-decay functions[19]; or by space preference functions.[20] For all tributary areas so defined, both areas and population may be estimated. Thus p_i and p_j may be computed for all places. From the computed values of interpoint distance (d^*_{ij}) the locational coordinates of the towns are derived from the method described below.

Deriving the New Configuration

The role of the d^*_{ij} is that they are target distances to which a two dimensional set of points should be fitted. Of the several methods available, the one proposed is adapted from the literature of multi-dimensional scaling.[21] In this discussion the d^*_{ij} distances are referred to as the estimated interpoint distances and the distances computed from the location coordinates of the towns are referred to as the configuration distances (d_{ij}).

At each iteration each point is moved to a new position. The amount and the direction of the move is made to depend upon the differences between the configuration interpoint distances and the estimated interpoint distances (d^*_{ij}) that take account of the variable population density surface.

Configuration distances are:

$$d_{ij} = \sum_{a=1}^{2} (x_{ia} - x_{ja})^2 \text{---------------------} (6)$$

where x_{ia} is the projection of the ith point on axis a. For example, if d_{ij} is larger than d^*_{ij} then point i is moved toward point j by an amount proportional to the size of the difference -- and <u>vice-versa</u>. Each point will have associated with it six correction vectors, one for each of the six neighbors. The mean correction vector for any point on any axis is then added to that point on that axis. When this process is completed for all points on all axes a new configuration exists.

The correction vector is defined as:

$$c_{ija} = \alpha(d_{ij} - d^*_{ij})(x_{ja} - x_{ia})/d_{ij} \text{-----------} (7)$$

where α is a constant of proportionality, and x_{ia} is the projection of point <u>i</u> on axis <u>a</u>.

The mean correction vector is thus:

$$c_{ia} = \frac{\alpha}{k} \sum_{j=1}^{k} (d_{ij} - d^*_{ij})\ (x_{ja} - x_{ia})/d_{ij} \text{-------} (8)$$

where the j subscripts refer to each of the k near neighbors of point i.

The new position of point i on axis a is given by:

$$x^1_{ia} = x_{ia} + c_{ia} \text{-----------------------------} (9)$$

The projections x^1_{ia} describe a new configuration, one that should fit more closely the estimated interpoint distances that show the configuration's adjustment to the non-uniform density surface.

Goodness of Fit Criteria

One index of goodness of fit is the extent to which the distances in the new configuration compare with the estimated distances. An index (S_d) can be constructed that will systematically decrease with each iteration if the configuration distances fit more closely the estimated distances.

$$S_d = \sqrt{\frac{\sum_{j=1}^{n} \sum_{i=1}^{k} (d_{ij} - d^*_{ij})^2}{\sum_{j=1}^{n} \sum_{i=1}^{k} d_{ij}^2}} \text{----------------------} (10)$$

where the j index refers to all n points in the study area and the i index refers to the k near neighbors of the jth point.

While S_d is a useful index for controlling the iterative process, a more appropriate final goodness-of-fit criteria is the degree to which the populations of the tributary areas differ from the specified population norm (Raw ${}_jD_p$).

$$\text{Raw } {}_jD_p = \sqrt{\frac{\sum_{i=1}^{n} ({}_jP_i - T_m)^2}{n}} \text{ ------------------------ (11)}$$

where ${}_jP_i$ is the population of the tributary area of the ith point after the jth iteration; T_m is the threshold population norm for the mth good and n is the number of tributary areas completely contained in the study area.

In so far as the tributary areas surrounding points on a final configuration developed in a heterogeneous area deviate in shape from the hexagonal figure, the estimated distances between points will be systematically under-estimated since their estimation assumed a perfect triangular lattice. When the lattice is distorted interpoint distances have to be somewhat larger than expected from theory in order for the tributary areas to realize threshold population. This systematic bias will yield the relationship (that can be empirically confirmed):

$$\frac{\sum_{i=1}^{n} {}_jP_i}{n} < T_m \text{ -- (12)}$$

In view of this bias, the variability of the population sizes of the tributary areas may be measured directly as:

$$\text{St. Dev. } {}_jD_p = \sqrt{\frac{\sum_{i=1}^{n} ({}_jP_i - {}_j\bar{P})^2}{n}} \text{ ------------------(13)}$$

Only when the final tributary areas are compact in shape will Raw ${}_jD_p \simeq$ St. Dev. ${}_jD_p$. Always Raw ${}_jD_p \geqslant$ St. Dev. ${}_jD_p$. In the classic central place solution (on a uniform plain), both Raw ${}_jD_p$ and S_d will equal zero.

Though the variability of tributary populations after the final iteration is a measure of goodness-of-fit, it is nevertheless a raw measure of fit since it is unrelated to the initial population variability for the uniform distribution of points. Traditional goodness-of-fit criteria requires a statement of the degree to which the initial variance is reduced by the employment of the model. Thus the square root of the ratio of the remaining variance to original variance may be computed and called normalized D_p.

$$\text{Normalized } {}_jD_p = 1 - \sqrt{\frac{\sum_{i=1}^{n} ({}_jP_i - T_m)^2}{\sum_{i=1}^{n} ({}_oP_i - T_m)^2}} \text{ ------------(14)}$$

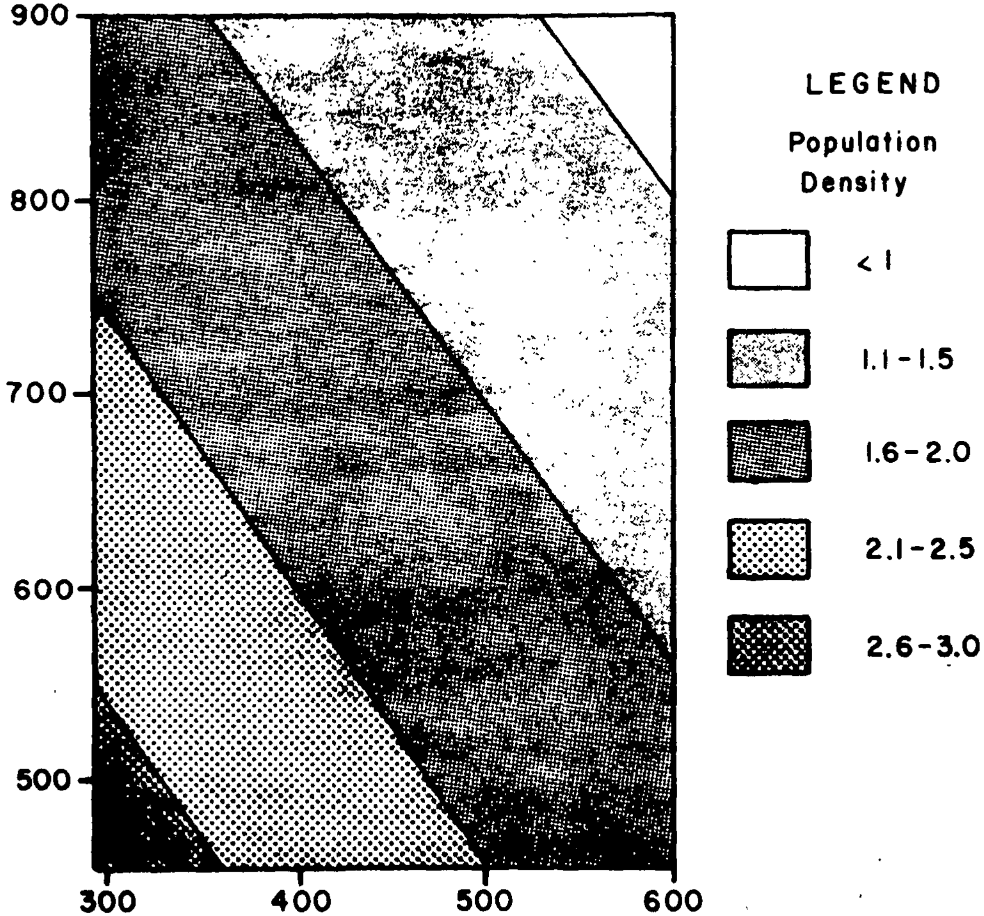
In addition to the desire to minimize the variability of the tributary populations we also wish to achieve maximum packing density of the primitive Dirichlet regions. Dacey has defined density of packing as "the ratio of the area of a circle to the area of the polygon in which the circle is inscribed ... the tessellation of regular hexagons has the maximum packing density, the density being $\pi/\sqrt{12} = .9069$ ..., Thue (1892)."[22]

Computerized Version of the Algorithm

The five steps described above were programmed for computer solution. Tests were made for four trend surface functions of increasing degrees of complexity. The results are summarized in Table 2 and in Figures 11 - 19. On all trials the change in stress value (Figure 19) shows a systematic decline indicating smooth convergence in the adjustments to the initial configuration in the direction of the final goal. The results show that the more spatially complex the trend surface functions and the greater the variability of population density in the area, the higher the stress values after a comparable number of iterations. Figure 15, for example, shows the distribution of population density peaking in two areas of the map from a high of ten persons per unit area to a low of 1.5. The high stress values shown in Figure 19 (third trial) illustrates the difficulty of solving the problem for such a complex density surface. In all cases the population sizes of the tributary areas are close to the respective threshold values though it was noted that the more distorted the tributary areas (see

TABLE 2: SUMMARY RESULTS OF TESTS OF THE MAP TRANSFORMATION ALGORITHM

Trial Number	1		2	3	4
Function Tested 1. z=Pop. density x,y: Cartesian Coords.	$z=a+b_1x+b_2y$ shed roof		$z=\frac{a}{1+\sqrt{x^2+y^2}}$ peak cone	$z=\max\left[\left(\frac{a}{1+x^2+y^2}\right), \left(\frac{a}{1+(x+b)^2+(y+c)^2}\right)\right]$ double-cone	$z=a+b_1\lvert\sin x\rvert+b_2\lvert\sin$ sin wave
2. Number of pts.	204		247	442	384
3. Number of iterations	15	65	45	47	40
4. Initial stress value	.2679	.2679	.1660	.3723	.2082
5. Final stress value	.1126	.0357	.0532	.1651	.0575
Level One Centers:					
6. Target Pop.	1800	1800	3000	2000	4500
7. Mean Area Pop.	1641	1793	2970	1818	4346
8. Raw Discord (Raw D_{jp})	220.4	65.3	186.8	435.67	322.0
9. St. Dev. Area Pop.	153.2	65.1	184.9	396.3	283.4
10. Normalized Discord	.5985	.8811	.7530	.5181	.7299
11. Mean Packing Density	.7129	.7629	.7236	.6393	.7342
Level Two Centers:					
12. Target Pop.	5400	5400	9000	6000	13500
13. Mean Area Pop.	4902	5382	8938	5453	13034
14. Raw Discord	[illegible]	133.6	538.7	1309.3	984.7
15. St. Dev. Area Pop.	472.5	132.9	535.3	1189.9	868.9
16. Normalized Discord	.5960	.9214	.7587	.5158	.7280
17. Mean Packing Density	.7077	.7568	.7211	.6404	.7312



Z= 4.5-.003X-.002Y

Fig. 11 Population Density Function for First Trial

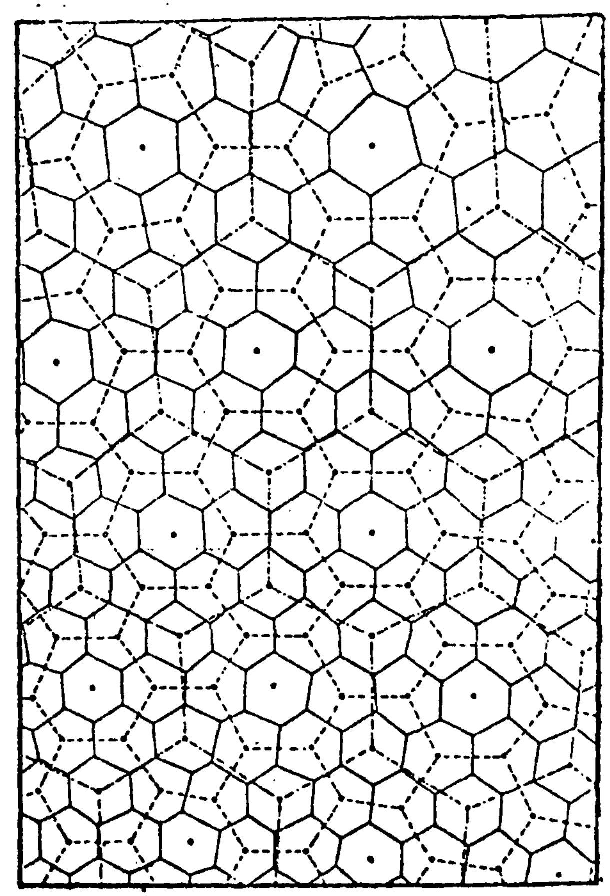
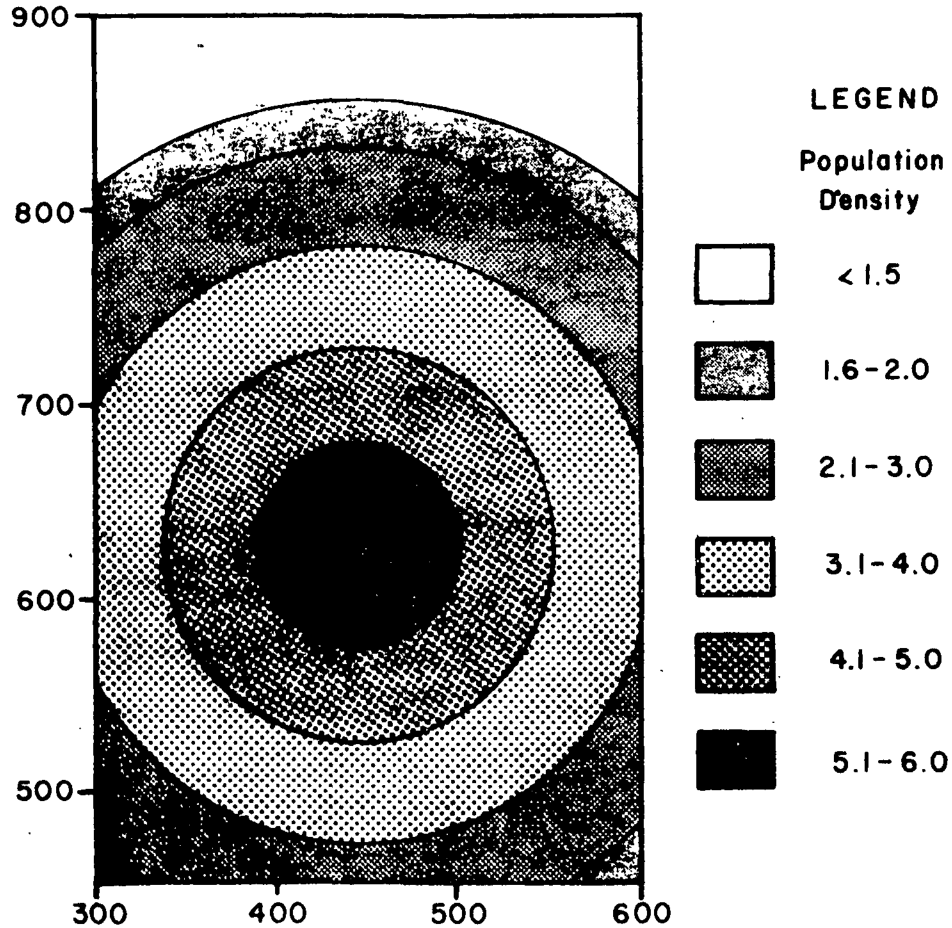


Fig. 12 Distribution of Points After 45 Iterations for First Trial



$$Z=6.0/1+\sqrt{(X-450/500)^2+(Y-625/150)^2}$$

Fig. 13 Population Density Function for Second Trial

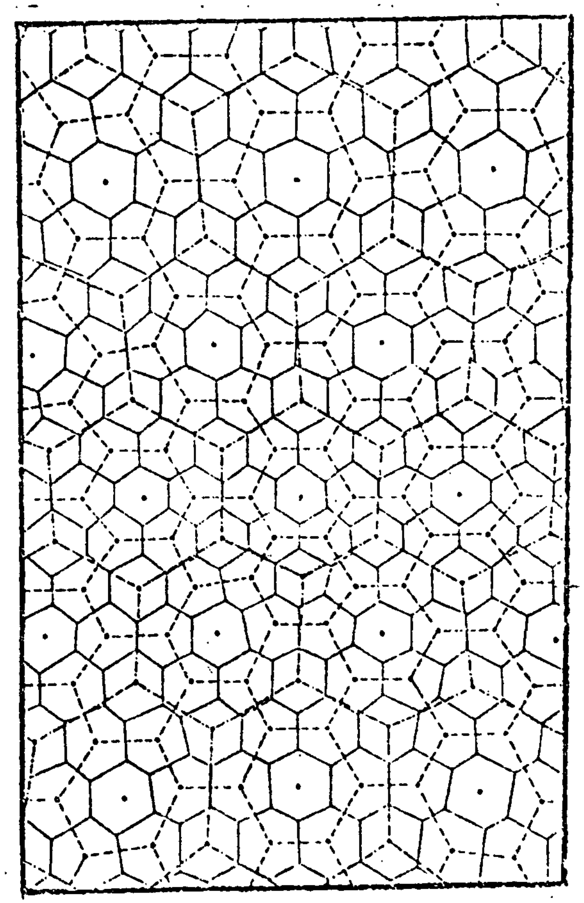
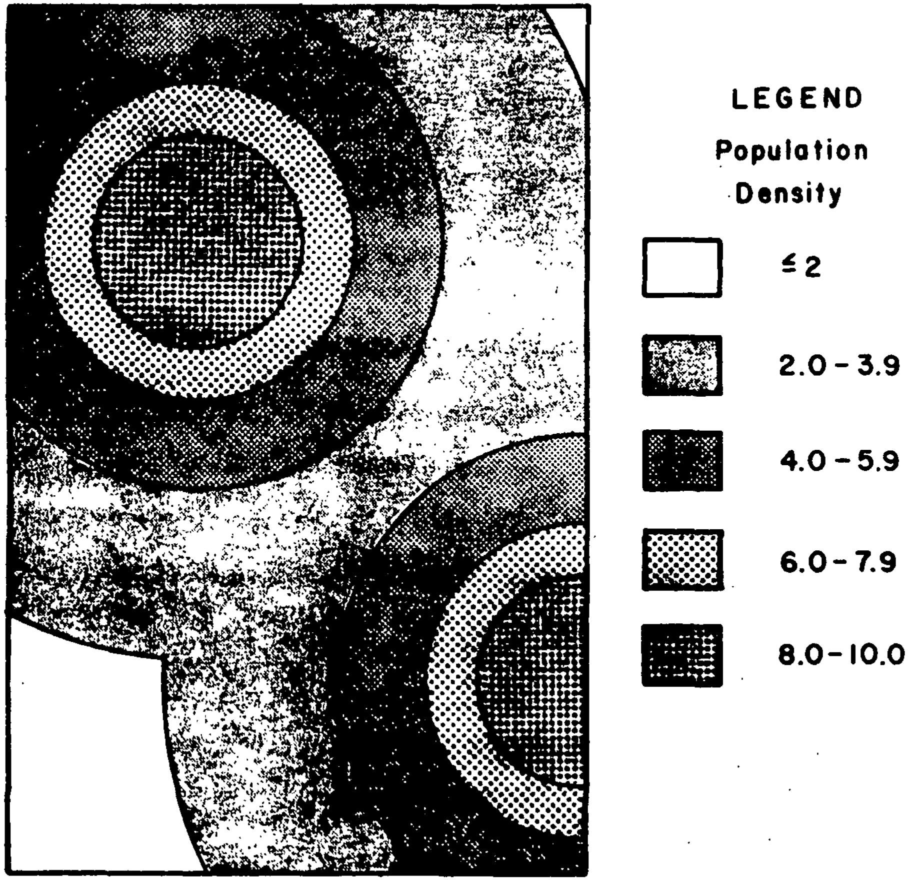


Fig. 14 Distribution of Points After 70 Iterations for Second Trial



$$Z = MAX\left[\left(10/(1+((X-400)/100)^2+((Y-780)/100)^2)\right), \left(10/(1+((X-600)/100)^2+((Y-550)/100)^2)\right)\right].$$

Fig. 15 Population Density Function for Third Trial

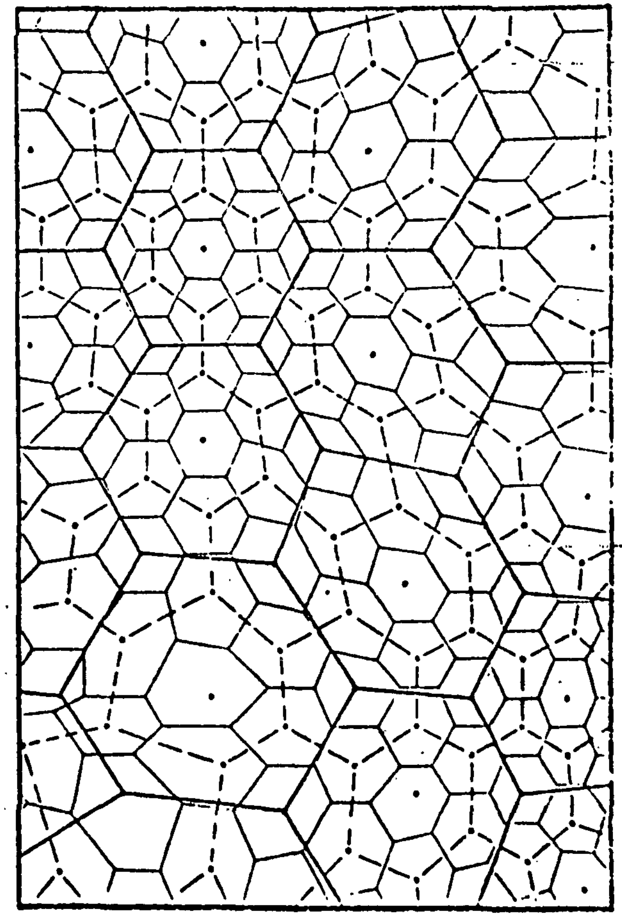
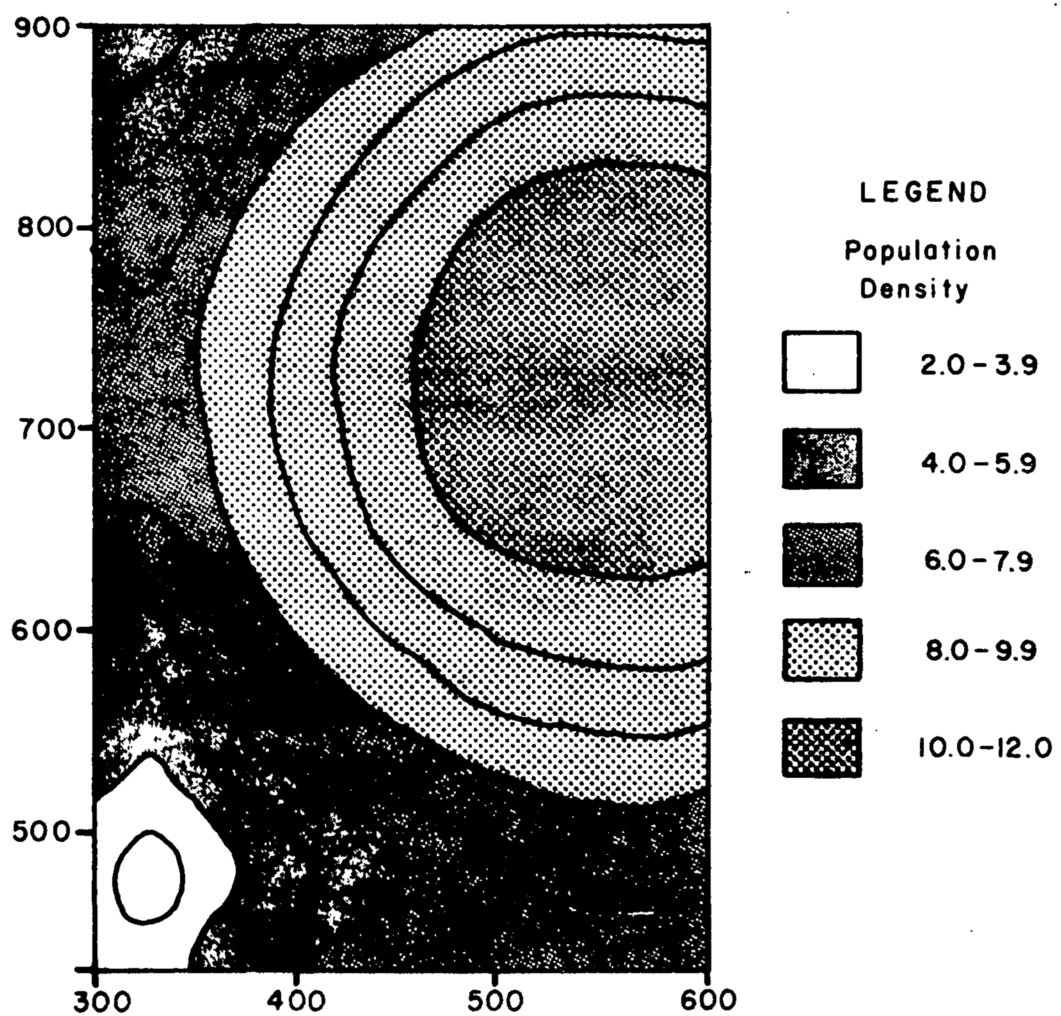


Fig. 16 Distribution of Points After 45 Iterations for Third Trial



$Z = 2 + 5.0 \left| \sin((320 - X)/150) + 5.0 \sin((500 - Y)/150) \right|$

Fig. 17 Population Density Function for Fourth Trial

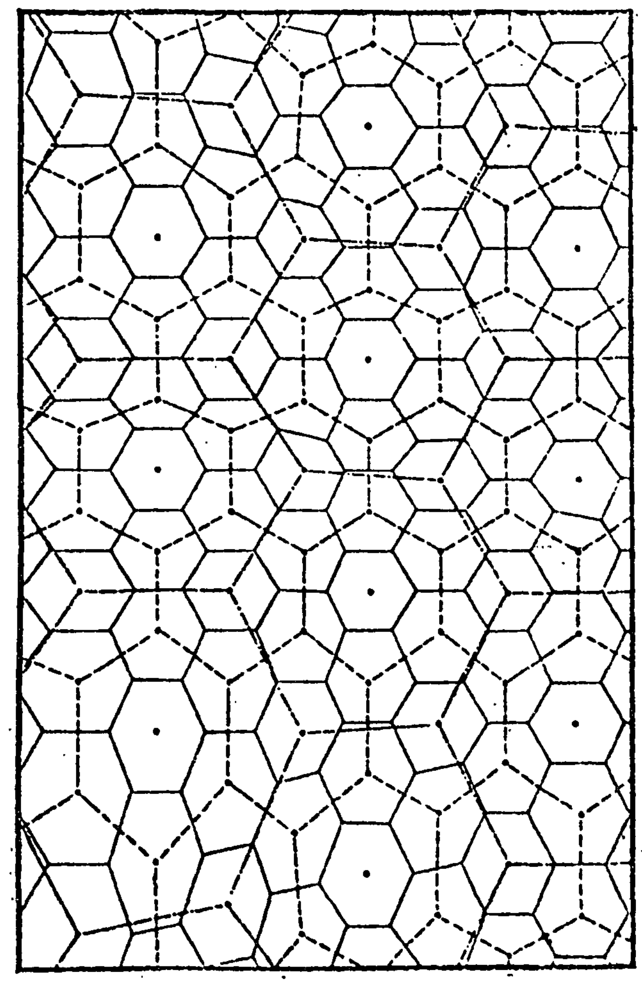


Fig. 18 Distribution of Points After 39 Iterations for Fourth Trial

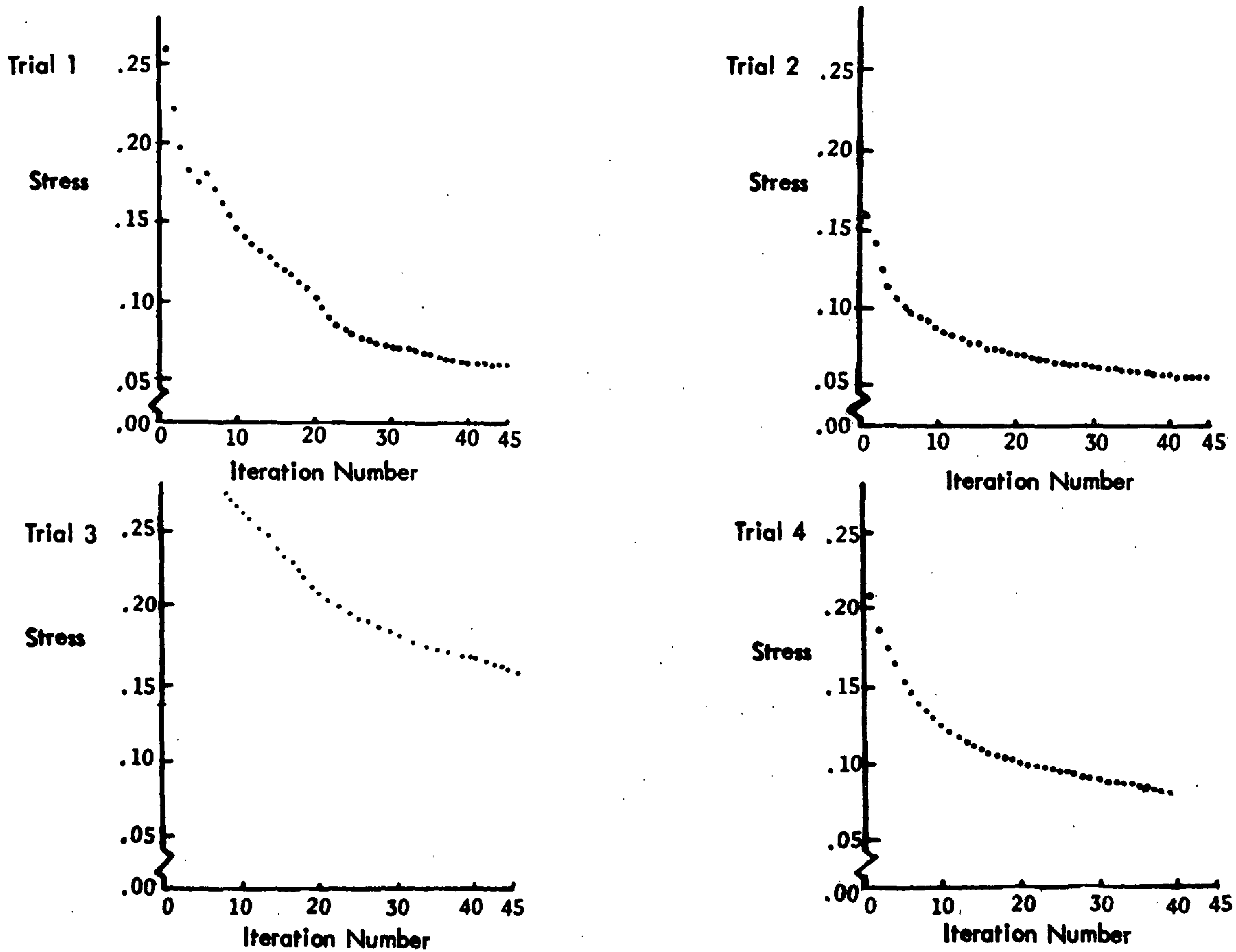


Fig. 19 Change in Stress Values During Iterations on the Four Trials

the measure of packing density) the smaller the population of the area relative to threshold size.

As is common with heuristic algorithms such as this, formal proof of convergence in all circumstances cannot be provided. Strategies for speeding the convergence process by manipulating the value of alpha (equation (7)) as the iterations proceed are being investigated.[23]

Problems Encountered with the Algorithm

Though the basic principles used in the algorithm are simple, their application in the computerized version raised several problems that were resolved by recourse to heuristics. In some circumstances it became clear that after a point had been moved, the original near-neighbor relationships had been violated. Thus, if during an iteration the left near neighbor of a point became adjusted so that it becomes a right near neighbor, the algorithm becomes unstable. The likelihood of this problem occurring appears to be related to the problem of controlling the speed of convergence and the problem of maintaining a correct relationship of the points along the edges with points within the body of the study area.

The speed of convergence is controlled by the value of the alpha parameter in the correction vector computation (equation 7). The greater the "bumpiness" of the density trend surface the smaller this parameter must be to insure correct convergence. After considerable experimentation constraints were introduced to limit the amount of movement of any point during a single iteration to insure that correct relative positions of points were maintained and yet to allow alpha to be large enough to provide fast convergence. In most circumstances this proved effective.

Efforts were made to speed up computation by solving for the location of "high-order points" in the early iterations with lower order points placed at the center of gravity of the triangles formed between the next higher level points. Although the procedure did work satisfactorily, the savings in computing time did not occur since the number of extra checks involved for finding the higher order places and their neighbors and especially for dealing with points in the portions of the polygons around the edges of the area, appeared to consume an approximately equivalent amount of computing time to that saved. This procedure has therefore recently been abandoned.

Finding the near-neighbors for points -- especially those around the edges of the study area -- proved to be difficult.[25] In each iteration of the algorithm the locations of all edge points are transformed before the locations of points in the body of the area are transformed. A problem also existed in estimating the populations of the tributary areas on the density surface. In an earlier version of the algorithm estimates were made by a process of mechanical integration of the density function over small sub-areas of the tributary region. However, this method proved to be costly in computing time and introduced errors of unknown size. The technique currently used is to compute the area of the Dirichlet region around each point by the method described by Massam and Goodchild,[25] and to multiply the area by the population density of the point at the center of the region. Clearly this is an approximation too, with error increasing as the areas of the regions increase.

Further improvements in both the efficiency and robustness of the algorithm are possible. Future work will include a study of the sensitivity of the algorithm to variations in the alpha parameter (equation 7) and an attempt to modify its value as the iterations progress. The stability of the algorithm might be improved if the matching of configuration distances with target distances proceeded through several iterations before new target distances were computed. Thus a two-phase strategy might be more profitable consisting of computation of target distances in phase 1 (equation 5) and satisfactorily matching those distances in phase 2 (equations 8 and 10). The number of iterations required to achieve satisfactory fit in phase 2 would vary from one example to another and would vary during the course of the entire iterations. By returning to phase 1 only after satisfactorily achieving the goals of phase 2 would avoid the problem in the current version of computing new target distances at each iteration for a configuration that often does not represent well the original target distances.

Monitoring the performance of the algorithm to identify unsatisfactory steps would allow for backtracking to a previous satisfactory iteration and recommencing iterations with, for example, a smaller alpha value or with more attention to previous phase 2 performances.[26]

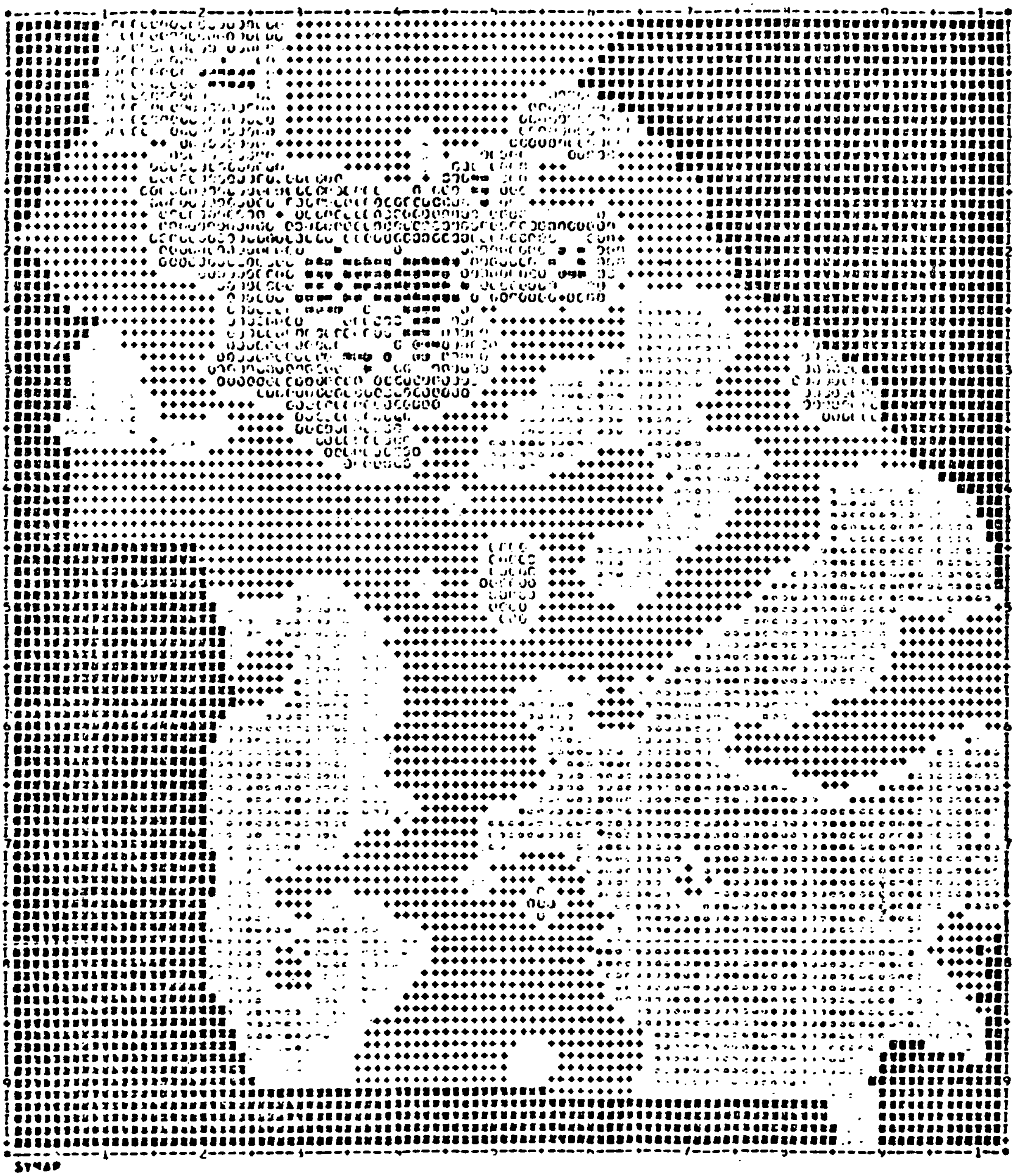
Application of the Model to Georgia

Rural population densities for the counties of Georgia were the basis for computation of a polynomial trend-surface function for the State of Georgia and for the study area centered on Atlanta. Figure 20 is an isopleth of the rural population density and Figure 21 is an isopleth map of the fourth degree trend surface function for Georgia. The parameters of this function were the critical input values for the model described previously. Figure 22 shows the location of the places that resulted from application of the model. Note the striking resemblance to Figure 23 and Figure 24 which show the actual distribution of the towns of Geogia. Formal comparisons of model results with reality are, of course, possible. However, they have not been developed at this time.

The Inverse of the Model: Predicting Rural Population Density from Urban Distribution Patterns

In some remote-sensing applications the location pattern of urban areas will be identified with a high expectation of accuracy and it is perhaps useful to note that the inverse of the model presented above could

GEORGIA AND PARTIAL ALABAMA BASED RURAL POPULATION DENSITY MAP



PERSONS PER SQUARE MILE

4 — 20

51 — 100

141 — 167

21 — 50

101 — 140

1970 DATA

FIGURE 20

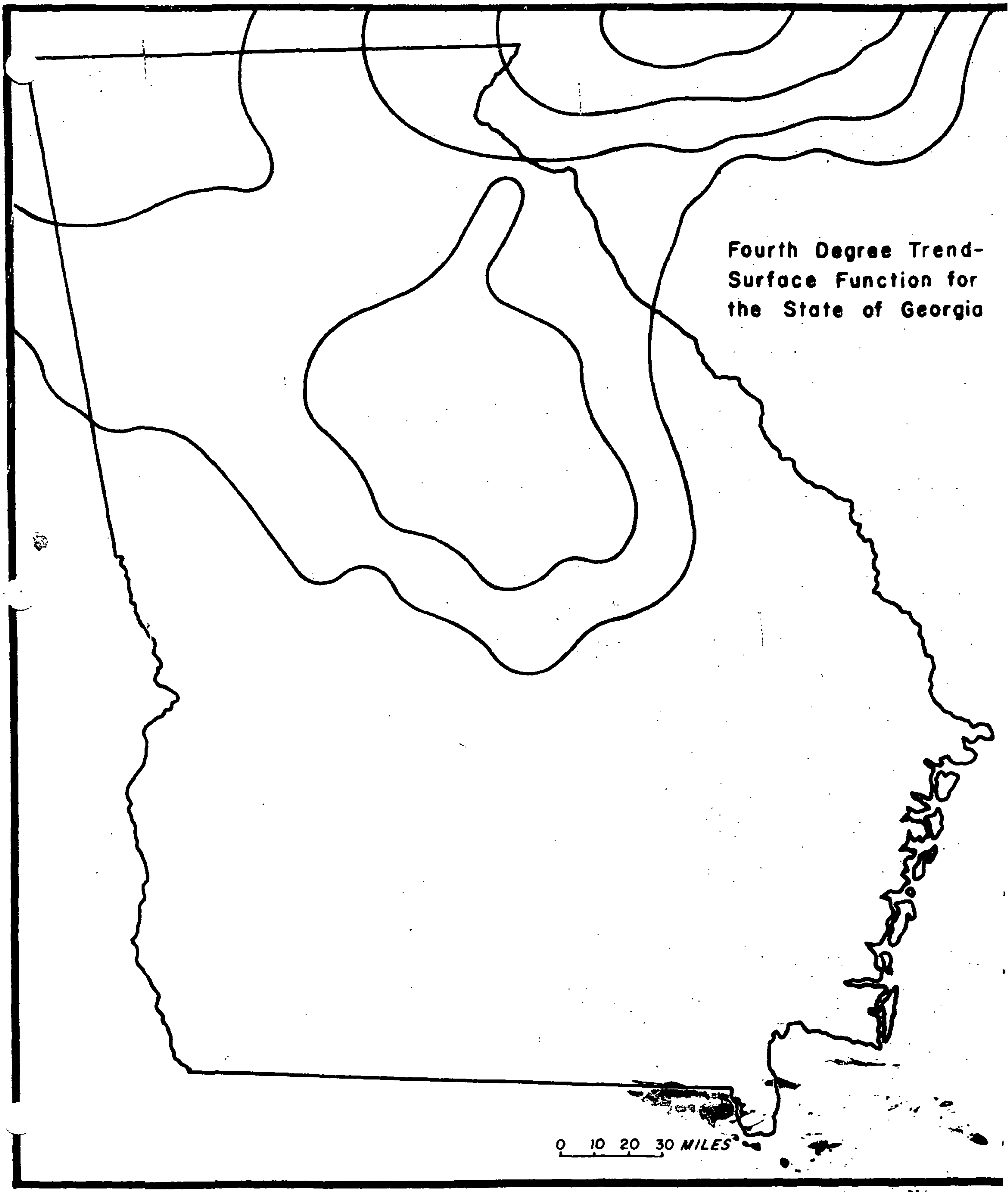

Fourth Degree Trend-
Surface Function for
the State of Georgia
0 10 20 30 MILES

Fig. 21

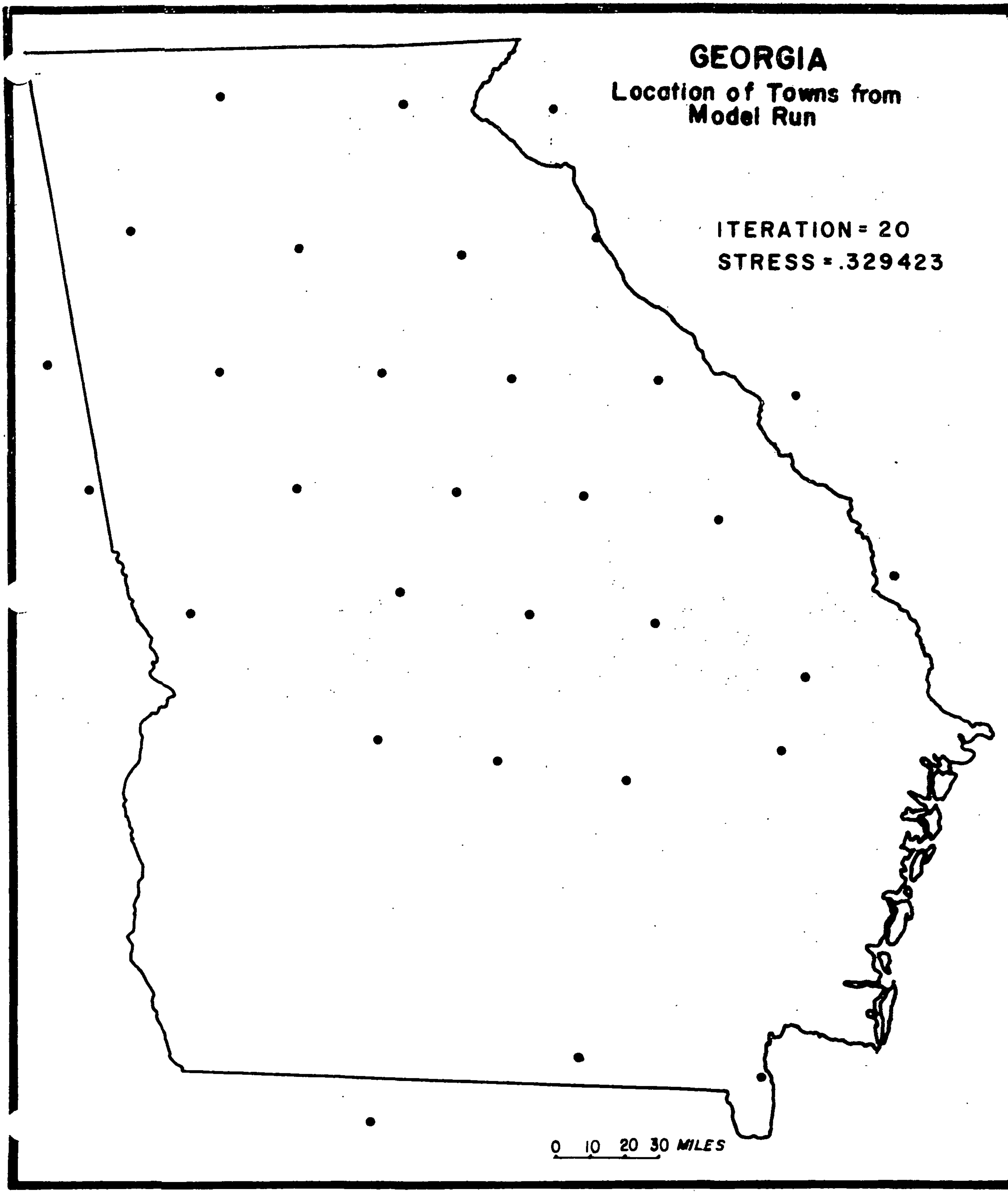
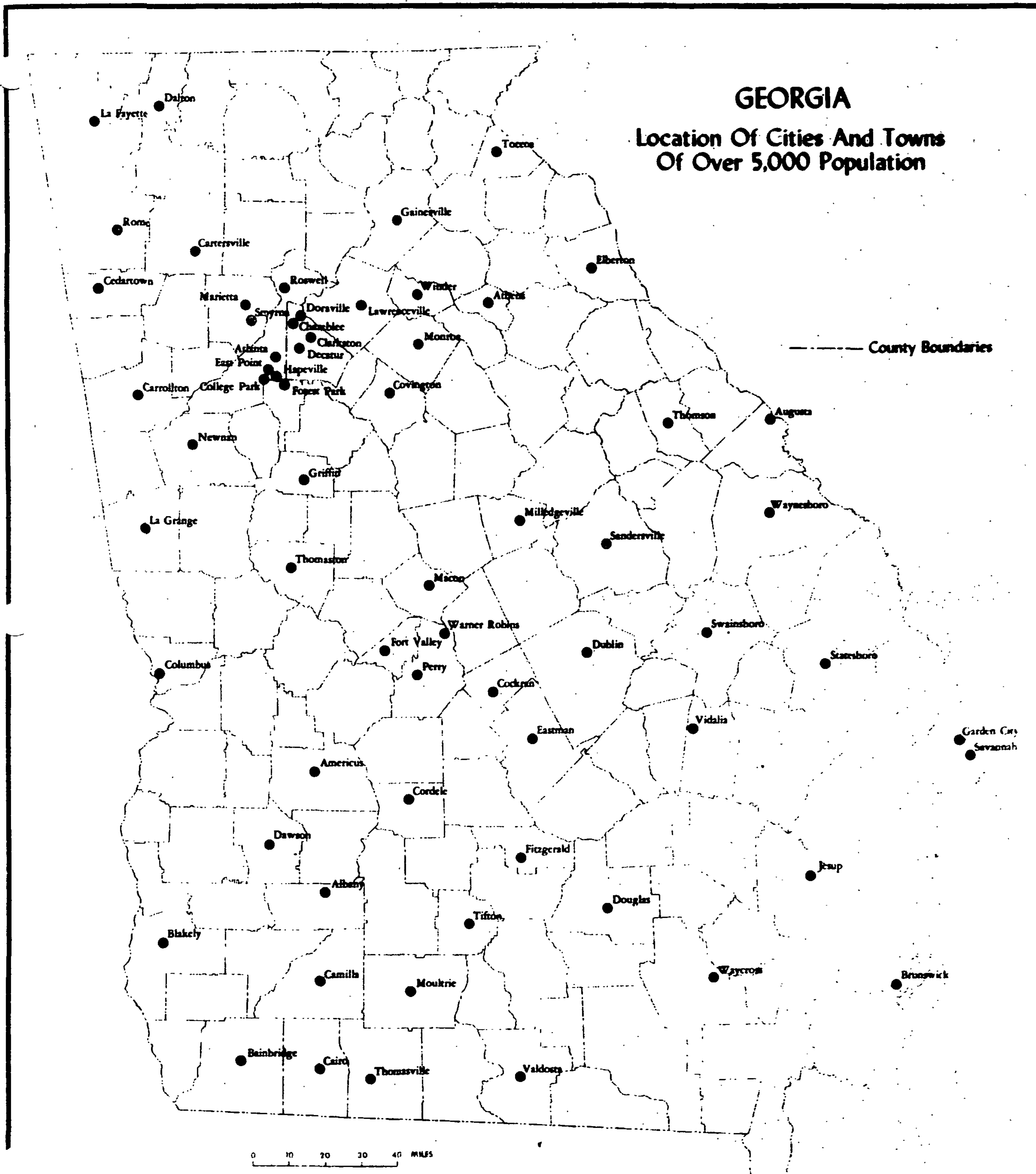

GEORGIA
Location of Towns from
Model Run
ITERATION = 20
STRESS = .329423
0 10 20 30 MILES

Fig. 22



Source: Based On 1970 U.S. Census Of Population Preliminary Reports

Fig. 23

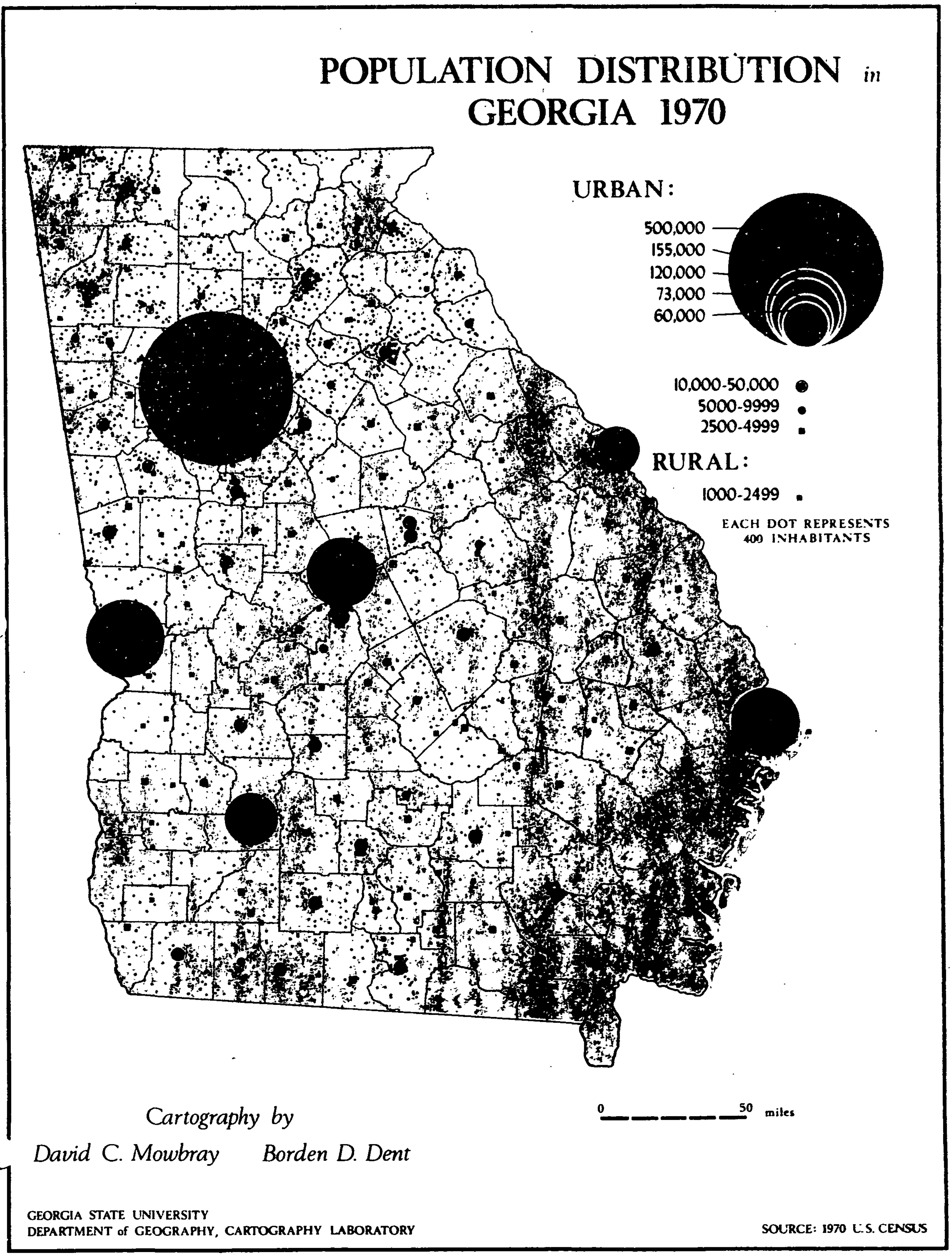

POPULATION DISTRIBUTION in GEORGIA 1970
URBAN:
500,000
155,000
120,000
73,000
60,000
10,000-50,000
5000-9999
2500-4999
RURAL:
1000-2499
EACH DOT REPRESENTS 400 INHABITANTS
0
50 miles
Cartography by
David C. Mowbray
Borden D. Dent
GEORGIA STATE UNIVERSITY
DEPARTMENT of GEOGRAPHY, CARTOGRAPHY LABORATORY
SOURCE: 1970 U.S. CENSUS

Fig. 24

be used to estimate the rural population density map of the area, where such information is not available. Equation (5) above predicts expected inter-point distances between towns ($d_{ij}*$) from the number of people to be served (T_m) and from the local rural population densities ($((p_i + p_j)/2)$. Since T_m can be estimated and $d_{ij}*$ is known, rural population densities can be computed:

$$\left[d_{ij}* = \sqrt{T_m / ((p_i + p_j)/2)} \cdot 2/\sqrt{3} \text{ ------------------ } (5) \right]$$

$$d_{ij}* = T_m / p_{ij} \cdot 4/3 \text{ ------------------------------ } (15)$$

where p_{ij} is the intervening population density between the ith and jth towns.

Population density in the region of the ith town is found as:

$$\sum_{i=1}^{k} p_{ij}/k \text{ -------------------------------------- } (16)$$

$$p_{ij} = T_m / d_{ij}*^2 \cdot 4/3 \text{ ---------------------------- } (17)$$

T_m is estimated as:

$$\sum_{i=1}^{n} P_i* \cdot \alpha /n \text{ -------------------------------- } (18)$$

where P_i* is population of the ith town estimated from remotely-sensed imagery; n towns have been identified and α is rural/urban multiplying factor (based on the socio-economic system being investigated).

Conclusions

This research has demonstrated that the probability of accurately identifying the characteristics of a system of urban places from low resolution satellite photography can be calibrated as a function of characteristics of the area being examined. The development and testing of a central-place model has shown that geographic location theory can be harnessed to facilitate the task of imagery interpretation. It is not necessary to assume total ignorance of the area being examined since formal geographic studies have proven that spatial regularities in urban phenomena are highly predictable.

References

1. Henderson, F.M. and D.S. Simonett, "Space Photography as a Tool in Delimiting Transportation Networks," Proceedings of the Association of American Geographers, Vol. 2, 1970, pp. 71-73.

2. Minor's Metro East Corporation, "A Description of Available Industrial Sites, Illinois Metro East Area," Resource Report No. 4, September, 1970.

3. Baskin, C.W., W. Christaller's Central Places in Southern Germany, (Englewood Cliffs, New Jersey: Prentice-Hall, 1966); Berry, B.J.L., and W. Garrison, "Recent Developments in Central Place Theory," Papers and Proceedings of the Regional Science Association, Vol. 4, 1958, pp. 107-120; Lösch, A., The Economics of Location, (New Haven: Yale University Press, 1954).

4. Rapp, R.H., and W.H. Sprinsky, "Gridding of Near Vertical Unrectified Space Photographs," U.S. Dept. of the Interior Geological Survey, Interagency Report NASA-122, June, 1968.

5. Holz, Robert K., David L. Huff, and Robert C. Mayfield, "Urban Spatial Structure Based on Remote Sensing Imagery," Proceedings of the Sixth International Symposium on Remote Sensing of Environment, 1969, pp. 819-830.

6. Wellar, Barry, "The Role of Space Photography in Urban and Transportation Data Series," Proceedings of the Sixth International Symposium on Remote Sensing of Environment, 1969, pp. 831-854.

7. A comparison of the model described below with earlier approaches to this problem is found in: Rushton, G., "Map Transformations of Point Patterns: Central Place Patterns in Areas of Variable Population Density," forthcoming, Proceedings, Regional Science Association, 1971.

8. Goodchild, M.F., and B. Massam, "Some Least-Cost Models of Spatial Administrative Systems in Southern Ontario," Geografiska Annaler, Vol. 52, Series B. No. 2, 1969, pp. 86-94.

9. Goodchild and Massam, op. cit.; Gould, P., and T.R. Leinbach, "An Approach to the Geographic Assignment of Hospital Services," Tijdschrift voor Economische en Sociale Geografie, Vol. 57, 1966, pp. 203-206; Yeates, M.H., "Hinterland Delimitation: A Distance Minimizing Approach," The Professional Geographer, Vol. 16, 1963, pp. 7-10.

10. Scott, A.J., "On the Optimal Partitioning of Spatially Distributed Point Sets," Studies in Regional Science, Vol. 1, 1969, pp. 57-72.

11. Tobler, W.R., "Geographic Area and Map Projections," Geographical Review, Vol. 53, 1963, pp. 59-78.

12. Goodchild and Massam, op. cit.; Gould and Leinbach, op. cit.; Morrill, R.L. and P. Kelley, "Optimum Allocation of Services: A Hospital Example," The Annals of Regional Science, Vol. 3, 1969, pp. 55-66; Törnqvist, G., P. Gould, S. Nordbeck and B. Rystedt, Locating Multiple Facilities, (Lund, Sweden: G.W.K. Gleerup, 1972).

13. Tobler, op. cit.

14. Green, P.E., and F.J. Carmone, Multidimensional Scaling and Related Techniques in Marketing Analysis, (Boston, Massachusetts: Allyn and Bacon, Inc., 1970); Torgerson, W.S., Theory and Methods of Scaling, (New York: J. Wiley and Sons, Inc., 1958).

15. Dacey, M.F., "The Geometry of Central Place Theory," Geografiska Annaler, Vol. 47, Series B, 1965, pp. 11-124.

16. "The primitive Dirichlet region is a polygon that contains a lattice point at its center and every point of the plane closer to that lattice point than to any other lattice point," ibid., p. 111.

17. Ibid., p. 113.

18. Woldenberg, M., private communication, 1 June, 1971. Woldenberg writes: "Since the altitude of the equilateral triangle in the hexagon = t/2, then

$$\sqrt{3}/2 \, . \, \text{base} = t/2; \qquad \text{base} = t/\sqrt{3};$$
$$H = 6.1/2.t/2.t/\sqrt{3}; \; H = \sqrt{3}/2.t^2"$$

19. Gambini, R., D.L. Huff and G.F. Jenks, "Geometric Properties of Market Areas," Papers, Regional Science Association, Vol. 20, 1968, pp. 85-92.

20. Rushton, G., "The Scaling of Locational Preferences," in K.R. Cox and R.G. Golledge, Behavioral Problems in Geography: A Symposium, (Evanston, Illinois: Northwestern University, Department of Geography, Studies in Geography, Number 17, 1969), pp. 197-227.

21. Young, F.W., "A Fortran IV Program for Nonmetric Multidimensional Scaling," Research Report Number 56, The L.L. Thurstone Psychometric Laboratory, University of North Carolina, Chapel Hill, 1968.

22. Dacey, *op. cit.*, p. 113.

23. A listing of the computer program (FORTRAN IV for the IBM 360/65) is available from the authors. Since many steps in the algorithm have not been described in this paper, an appendix to this chapter references the program listing and describes the sequencing of the individual steps.

24. In the appendix to this paper two pages are required to describe the procedures for finding neighbors in all circumstances.

25. Massam, B.H., and M.F. Goodchild, "Temporal Trends in the Spatial Organization of a Service Agency," *The Canadian Geographer*, Vol. 15, 1971, p. 196.

26. The present version has an option allowing punched output on the last iteration which serves as input for re-starting iterations at this point on a future run.

Appendix A

Description of Map Transformation Algorithm (November, 1971)

G. Rushton, The University of Iowa

Step 1: Line Nos.

Define a population density function as a function of locational coordinates.

Example: $z = a + b_1 \left| \sin x \right| + b_2 \left| \sin y \right|$ ------------- (1)

Step 2: Line Nos.

Input remaining data:

(i) coordinate definition of study area;
(ii) threshold population;
(iii) total population of study area if known - otherwise this will be computed within the program from the density function;
(iv) number of iterations of the algorithm;
(v) upper and lower limits for ALPHA -- a constant that controls the speed of convergence in computing the new coordinates for the points from the expected distances;
(vi) a lower limit for population density (z) in equation (1) above;
(vii) specify choice on whether areas and populations for the tributary areas at the close of iterations should be computed and whether the locational coordinates after final iteration should be punched.

Step 3: Line Nos.

If total population of the study area is not known, estimate it by covering the study area with a square lattice of grid points at a distance apart of 1/20 of the width of the study area and by calling the population density function for each sample point and assuming that this sample point is representative of the square area around it.

Step 4: Line Nos.

Compute the number of points to be distributed as the truncated integer value of total area population/threshold population.

Step 5: Line Nos.

Assume uniform population-density over the study area and thus compute the basic interpoint distance in the uniform spatial distribution of the number of points computed in Step 4 as:

Basic Distance (BID) = $\sqrt{\text{Area of study area}} \,/\, \sqrt{\text{no. of points}}$

Step 6: Line Nos.

Compute scale of maps to be produced assuming printer with 10 characters per inch and six lines per inch.

Step 7: Line Nos.

Calculate number of points per tier of points in the study area, (JNOP); find distance between tiers (for a triangular lattice of points) (BB) -- BB = $(BID/2)/(1/\sqrt{3})$; calculate number of tiers (NOTI) in the study area.

Step 8: Line Nos.

Calculate X,Y coordinates for all points in the triangular lattice.

Step 9: Line Nos.

Begin master loop for normal run or come here if this run is a continuation from the punched output of an earlier run.

Step 10: Line Nos.

Print map every specified frequency of iterations, on first three iterations and on the last iteration. Write out the locational coordinates of past iteration or of initial coordinates if this is first iteration.

Step 11: Line Nos.

Move the locations of the points on the boundary edges.

(i) find near neighbors for upper and lower edge are:

ID = (J - 1). JNOP + K
where ID is identification number of point to be moved;
J is the first or the last tier of points
JNOP is number of points per tier of points
K is an index that runs from 1 through JNOP

KK_1 = ID + 1 where KK_1 is first neighbor

KK_2 = ID - 1 where KK_2 is second neighbor

KK_3 = ID+JNOP where KK_3 is third neighbor from upper edge

KK_3 = ID-(JNOP-LL) where KK_3 is third neighbor for bottom edge and where LL is 0 if tier is odd numbered and LL is 1 where tier is even numbered

$KK_4 = KK_3 - 1$ where KK_4 is fourth neighbor

(ii) call population density function for locational coordinates of the IDth point and record it.

(iii) check whether corner points are being examined and re-compute the specific near neighbors for them.

The top left corner has only two near neighbors (KK_1 and KK_3 as defined above); the top right corner has three near neighbors (KK_2, KK_3, KK_4, as defined above). The bottom left has two neighbors if it is an odd tier (KK_1, and KK_3) and three neighbors if it is an even tier (KK_1, KK_3, KK_4). The bottom right has three neighbors if it is odd (KK_2, KK_3, KK_4) and two neighbors if it is even (KK_2, KK_4).

(iv) Line Nos.

Call the population density function and compute it for the near neighbors; compute the expected distance between the IDth point and each of its near neighbors and apply the correction formula to compute new position on both X and Y axes of the IDth point.

(v) with respect to each neighbor, increment the stress counter, i.e. add the squared distance difference between the configuration distance and the expected distance.

(vi) Line Nos.

Find identification nos. of points on western and eastern boundary edges and their near neighbors.
For right edge $ID = J.JNOP$
For left edge $ID = (J-1).JNOP + 1$
where J is an index of the tiers of points running from 2 to the number of tiers minus one and
JNOP is the number of points per tier
$KK_1 = ID-JNOP$ where KK_1 is first neighbor

$KK_2 = ID+JNOP$ where KK_2 is second neighbor

Additional neighbors depend on whether tier is odd and whether ID point is on left or right edge:
When tier even and ID point on left edge:
$KK_3 = KK_1 + 1;$

$KK_4 = ID + 1;$

$KK_5 = KK_2 + 1.$

When tier even and ID point on right edge
$KK_3 = ID - 1$

When tier odd and ID point on left edge
$KK_3 = ID + 1$

When tier odd and ID point on right edge

$KK_3 = KK_1 - 1$

$KK_4 = ID - 1$

$KK_5 = KK_2 - 1$

(vii) at this point proceed as in (iv) and (v) above.

Step 12: Line Nos.

Move the locations of all remaining points

(i) find ID index of point to be moved:
$ID = J.JNOP + K + 1$
where J is an index of tiers of points running from 1 to number of tiers less 2;
JNOP is the number of points per tier;
K is an index that runs across the tier.

(ii) find six near neighbors for IDth point
$KK_1 = (J-1).JNOP + K + LL$ where LL = 1 if tier is odd and LL = 0 when tier is even numbered.

$KK_2 = KK_1 + 1$

$KK_3 = ID + 1$

$KK_4 = (J+1).JNOP + K + LL + 1$ (where LL is defined above)

$KK_5 = KK_4 - 1$

$KK_6 = ID - 1$

(iii) call population density function for IDth point and for each of the six near neighbors. Proceed as in (iv) and (v) of Step 11.

Step 13: Line Nos.

If this is the final iteration, find distance to furthest of six near neighbors and also compute area and population of this tributary area then proceed to Step 15.

Step 14:

If this is not the final iteration, return to Step 9 and repeat procedures in Steps 9 - 12.

Step 15: Line Nos.

If requested, punch the values necessary to pick up the iterations on a future run.

Step 16: Line Nos.

Compute Goodness of Fit measures for the final configuration.

End of Map Transformation Algorithm

Input Form

Card One

Trend Surface Equation: A FORTRAN statement expressing density at a point as a function of coordinates (x,y).

Example: z=a+b sin x +b sin y

where z is population density and x and y are Cartesian Coordinates referring to geographic location.

This might be translated as:

```
FUNC (X,Y) = 2.+5. * ABS(SIN((320.-X)/150.))+5.*ABS(SIN((
             500.-Y)/150.))
```

This card follows the DIMENSION statement within the program.

Card Two

	REAL	Columns
Smallest x value	xx(1,1)	1 - 10
Largest x value	xx(1,2)	11 - 20
Smallest y value	xx(2,1)	21 - 30
Largest y value	xx(2,2)	31 - 40

Card Three

	NAME	TYPE	
Threshold population to be serviced	THPOP	REAL	1 - 10
Total population of study area (less than 10 if not known)	TPOP	REAL	11 - 20
Number of iterations	NNN	INT	21 - 30
Minimum value of alpha	ALPH1	REAL	31 - 35
Maximum value of alpha	ALPHA	REAL	36 - 40
Minimum value for population density	FFMIN	REAL	41 - 45
1 if areas and their population are to be calculated	ICAR	INT	46 - 50
1 if final locational coordinates and input values for iterations to continue are to be punched	ICAP	INT	51 - 55
Number specifies how frequently results of the iterations should be mapped	IB	INT	56 - 60
1 when output from a previous iteration is input	ICON	INT	61 - 65

Card Four

This and more cards are input when ICON = 1. They are input exactly as output in the previous run.

VII. RECAPITULATION AND DISCUSSION

The work described in the preceding chapters was undertaken to assess the applicability of air- and space-borne photography toward providing data inputs to urban and regional planning, management, and research. Because urban areas and city systems undergo continual change understanding relationships among various elements is very demanding of data.

Urban information systems are man-machine structures developed to store and supply on call data pertaining to the growth and changing elements of cities and city systems. To date much of the development of information systems has centered on urban management functions, much less on research needs, and only very minor development of regional or statewide systems has occurred. The discussion in Chapter II reflects this bias concentrating primarily on intra-urban concepts.

With the exception of chapter six which deals with space photography of the Atlanta, Georgia Region, each of the chapters deals with an aspect of urban data collection within cities. Cedar Rapids, Iowa and Washington, D.C. served as study areas for the research.

The intra-urban studies conducted confirm the usefulness of remote data collection methodology for some purposes but place it in serious question for others. Particularly for daily management decisions the remote imagery seems totally inadequate. For long term planning functions, however, the current unmet data needs could be served in part through advanced photographic interpretation and analysis of urban variable relationships. The intra-urban analysis conducted and reported on here focuses on the latter aspect. The regression formulation utilized in the study is suggestive of the possibilities for replicating census-like variables. Conversely, the "systems of cities" context of Chapter VI does have improved imagery interpretation as a direct goal of the research. A computerized mathematical algorithm provides this component.

The analysis of space-imagery of Atlanta indicates that accurate identification of the characteristics of a system of urban places from low resolution satellite photography can be shown to be a function of the characteristics of the area in which they are found. This finding and others related to the analyses completed suggest that space photography can become an important tool in acquiring information useful to regional planning. These results could be of special value in economically developing countries where secondary data sources are meager and the monitoring function extremely important.

Perhaps the greatest thrust for increased utilization of remote imagery will come when researchers recognize the potential for restructuring the nature of inputs to urban and regional models. For example in Chapter III Washington Council of Governments' data was replicated but with limited success partly because of the parcel method of recording utilized by the jurisdictions involved. Very detailed photography would be required to replicate these files with a high level of accuracy. While such accuracy may be necessary for many management functions an urban model, working with areally aggregated data, could function reasonably well with much less precision in data inputs. The possibility of more frequent updating of the data files should provide better opportunity to monitor and assess structural change.

The cost and effectiveness of data collection methodologies would appear to be a prime area of public interest. What are the alternatives to dual management and planning information systems? Can a multitude of local jurisdictions provide comparable and timely data or would the proper scale and type of remote imagery provide more uniform and useful data for metropolitan planners and researchers? Such questions have not been answered by the work presented in this monograph but the research discussed does point out the need for serious consideration of data requirements, strategy, and alternatives for urban and regional information collection.

The final issue to be addressed is one which focuses on the management strategy related to remote sensing research in an urban context. Several different federal agencies are involved in one way or another in funding urban oriented remote sensing research and coordination is lacking. As such research priorities have not been established and continuity of funding to research groups is not insured. Remote sensing research, like all research activities, requires that individual researchers and research organizations spend no small effort on familiarizing themselves with the technology and antecedent literature. Very often initial funding is sufficient to complete only the learning task. Due to the lack of funding continuity very often individuals and groups are not provided with the capability of making substantial contributions. Rather, a great deal of this effort focuses on relatively traditional research areas, the proverbial reinvention of the wheel.

Research completed in urban data acquisition indicates that we are at a point in time when large scale demonstration projects may be warranted. Careful monitoring of such a project would begin to provide critically needed data concerning the feasibility of implementing remote sensing technology in an operational context. Further demonstration projects can provide cost data about the operational utilization of remote sensing techology which is currently lacking.

Finally, it should be noted that greater emphasis should be placed on automatic data processing. While urban data acquisition is extremely complex the need for such processing will be required if large scale adoption of this technology is to come about. Automatic processing will, if technically feasible, greatly alter cost parameters associated with utilizing urban data acquired through remote sensing techniques.