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AERIAL PHOTOGRAPHIC INTERPRETATION FOR LAND USE CLASSIFICATION IN THE NEW YORK STATE LAND USE AND NATURAL RESOURCES INVENTORY

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SUMMARY

A well thought out classification and efficient project organization are essential to realize the full benefits of remote sensing in land use mapping. This paper discusses the organization and management of photo interpretation in land use classification projects.

INTRODUCTION

The Center for Aerial Photographic Studies at Cornell University has been conducting a state wide land use and natural resources inventory for the Office of Planning Coordination of the State of New York since 1966. One of the main purposes of this inventory has been the production of land use maps for the entire state at a scale of 1:24,000 by aerial photographic interpretation, utilizing a classification of 120 water and land uses. Since the background and goals of this project have been published elsewhere (SHELTON, 1968; BELCHER, 1969), this paper will be devoted to the organization and management of photo interpretation in land use classification projects covering relatively large areas of diverse complexion (which may include urban, agricultural, and forest lands).

PROJECT ORGANIZATION

In order to rapidly produce accurate maps at the lowest unit cost, the organization of the land use mapping project must be carefully thought out. For efficiency, each person's job should be as specialized as possible; this also helps reduce training costs. Since the photo interpreters are responsible for classifying each acre of land into upwards of a hundred different categories, the majority of decisions in the project are made by this group and they should be regarded as the core of the organization. A simplified flow-organization chart for a land use mapping project (Fig.1) will show a number of accessory groups whose function is to relieve the photo interpreters of as many non-photo interpretation tasks as possible (clerical, drafting, etc.).

The supplemental data group is responsible for collecting back-up information that the interpreter needs in order to classify certain land uses that can not be determined from the air photos alone and to provide the interpreter with a general outline of predominant and unusual land uses that he will find in the

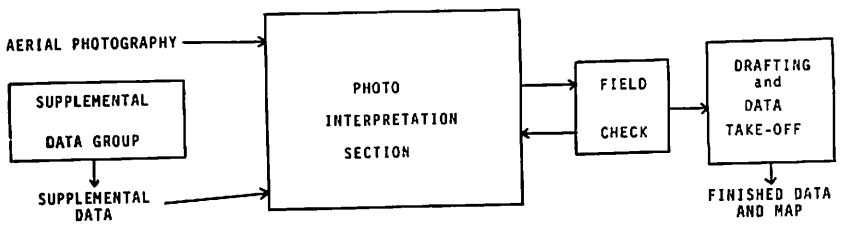

Fig.1. Simplified flow-organisation chart for land use mapping project using aerial photo interpretation.

particular quadrangle that he is assigned. The collection of supplemental data will be covered in the section on photo interpretation procedures. The drafting and data take-off groups receive the manuscript land use maps prepared by the interpreters and transfer the information to the form in which it is to be used (drafted maps, record sheets, computer tapes, and/or data tabulations).

METHODS OF PRESENTING DATA

There are two kinds of land use information obtained from supplemental data and photo interpretation: (*1*) an overlay showing the various land uses delineated by *area*; and (*2*) a *point data* map sheet showing a count of occurences and/or locations of certain items. Typical point count items would include the locations of isolated houses, power transmission lines, communication towers, ponds, pipelines, farm headquarters, etc. The maps are gridded with a suitable grid system and the land use information can then be punched onto computer cards on a cell by cell basis and stored for future use in computer graphic applications (see SHELTON, 1968; SHELTON et al., 1969).

AIR PHOTO INTERPRETATION

Land use mapping does not require true *photo interpretation* as defined by LUEDER (1959, p.6) but, for the most part, only *photo reading* and *photo analysis*. This is fortunate because, since *photo reading* involves simply recognition of an object on a photograph, the decision time for classifying that object is very small; likewise *photo analysis* requires only the more elementary evaluation of the air-photo pattern of a land use in order to classify it properly. *Photo interpretation*, on the other hand, involves a deductive and inductive evaluation of all the elements

of the air photo pattern by a highly trained and experienced air photo interpreter. Decision times for classifying objects by photo interpretation can become quite long (as much as thirty minutes) and it can easily be seen that an interpreter who effectively makes hundreds of decisions per day must reduce the average decision time to a matter of seconds. There are two ways to do this: first, is to provide easily accessible, useful supplemental data to the interpreter [1] to reduce most classification decisions to the fast, recognition type; and second, is to design the classification so that the categories can be easily separated by the interpreter.

Interpreter training

Extensive *airphoto interpretation* experience and academic training is not necessary for successful land use mapping from air photos, nor even desirable. Photo reading can become routine and then frustrating to some persons who have had extensive sophisticated training in photo interpretation. Persons with agriculture, forestry, economics, or geography backgrounds have been employed successfully as photo interpreters. Individuals with one or more formal courses in air photo interpretation have received preference. The best work is done by photo interpreters who are assigned to work on areas with which they are familiar, for example, persons with urban backgrounds should be assigned to map cities and suburbs, those with agricultural backgrounds, rural areas, etc. Difficulty has been experienced with some foreign students and personnel from other areas of the U.S. who are unfamiliar with the common types of residential, commercial and agricultural patterns found in New York State.

New photo interpreters receive a training program in which they study the classification system and the air photo characteristics of different land uses, take a conducted field trip to representative rural, urban and suburban land use associations and finally produce a practice map.

Aerial photography

The type of aerial photography used is an important factor in reducing unit costs in land use mapping. In the northeastern U.S., summer photography should be used for interpreting agricultural and forestry land uses because most agricultural activity takes place during these months and it is difficult to estimate the true height of trees in the seasons when they have dropped their leaves. Unfortunately, most aerial photography is flown for more than one purpose and usually the other reasons require spring (no foliage on trees) photography, which is the worst time from the agricultural land use aspect because most of the indications in the fields have become subdued during the past winter. Therefore, more *analysis* is required on spring photography and unit costs go up. On the other

[1] Hereafter in this paper photo interpretation should be understood to mean photo reading and photo analysis unless italicized.

hand, if emphasis is to be made on accuracy of point count items in the inventory spring photography is best because activity indicators can be seen more easily around buildings surrounded by trees.

The choice of scale of the photography is governed by three factors. First, if poor quality base maps must be used, a savings in production costs is possible in the data take-off process (when the information is transferred from the photography to a map overlay) if the photography has been flown at the same scale as the maps used. The loss in detail on a 1:24,000 photograph compared to the normal 1:20,000 scale is insignificant compared to the savings which will accrue by easier data take-off. However, when adequate base maps are available for areas with enough landmarks (roads, rivers, houses, etc.) to use as reference points, this factor is not as important as the next two. Second, a great deal of time is lost in handling and filing the larger number of photographs necessary to cover a given area at a large scale (1:6,000, for example), and third, the intensity of land uses in the region being mapped may require larger scale photography for complex urban areas.

LAND USE CLASSIFICATION SYSTEM

The proper design of the classification system is a most important factor in the successful land use mapping project. It must not only enable the interpreters to keep decision time down in utilizing it, but the classification system must also group land uses in such a manner as to be useful to planners and others who will be using the results, and satisfy the needs of the group that is financing the project. At all stages in the development of the classification the air photos must be studied to see if the proposed mapping units can be identified quickly and accurately. For example, if it is found that pasture land can frequently be identified by the presence of cow trails and a distinctive tonal texture, before including pasture land as a mapping unit a study should be made to find out what percentage of pasture lands have unique air photo characteristics that will enable them to be quickly classified correctly. If it is found that the percentage that can be correctly identified is acceptable to the future users of the land use information, only then should pasture land be placed into the classification system.

The commonly used land use classifications [1] were not designed with air-photo interpretation in mind and are much too complicated for use in an air photo survey and in fact provide more detail than is necessary for many purposes. Table I is an outline of the classification that was developed for use in the New York State Land Use and Natural Resources Inventory. It has been possible, utilizing this classification, to accurately and economically ($ 5–10 per square mile) map land uses from aerial photographs and the normally available supplemental data.

[1] For example, see URBAN RENEWAL ADMINISTRATION and BUREAU OF PUBLIC ROADS (1965).

TABLE I

NEW YORK STATE LAND USE AND NATURAL RESOURCES INVENTORY CLASSIFICATION[1]

Agriculture

Areas:
- Ao - Orchards
- Av - Vineyards
- Ah - Horticulture, floriculture
- Ay - Specialty farms
- At - High-intensity cropland
- Ac - Cropland and cropland pasture
- Ap - Permanent pasture
- Ai - Inactive agricultural lands
- Ui - Other inactive lands
- Uc - Lands under construction

Point data:
- Specialty farms (Ay): types present
  - Mink (y–1)
  - Pheasant and game (y–2)
  - Aquatic agriculture (y–5)
  - Horse farms (y–6)
- Dairy operations (d): number
- Poultry operations (e): number
- Active farmsteads (f): number

Forest land

Areas:
- Fc - Forest brushland
- Fn - Forest land
- Fp - Plantations

Water resources

Areas:
- Wn - Natural ponds and lakes (1 acre +)
- Wc - Artificial ponds and reservoirs (1 acre +)
- Ws - Streams and rivers (100′ +)
- Wh - Hudson River
- Wr - Marine lakes, rivers, and seas
- Wb - Shrub wetlands, bogs, marshes
- Ww - Wooded wetlands

Point data:
- Natural ponds and lakes (n): number
- Artificial ponds and reservoirs (c): number
- Ponds less than 1 acre in size (p): number
- Lake shoreline (l): miles
- Streams and rivers (s): miles

Nonproductive land

Areas:
- Ns - Sand (unstabilized)
- Nr - Rock (exposed)

Residential land use

Areas:
- Rh - High density (50 ft. frontage)
- Rm - Medium density (50–100 ft. frontage)
- Rl - Low density (100 ft. frontage)
- Re - Residential estates (5 acres +)
- Rs - Strip development
- Rr - Rural hamlet
- Rc - Farm labor camp
- Rk - Shoreline cottage development

Point data:
- Shoreline developed in cottages (k): miles
- High-rise apartment buildings (z): number
- Trailer parks (v): number
- Rural non-farm residences–never a farm residence (x): number
- Rural non-farm residences–once a farm residence (0): number

Commercial areas

Areas:
- Cu - Central business district
- Cc - Shopping center
- Cs - Strip development
- Cr - Resorts

Industrial areas

Areas:
- Il - Light manufacturing
- Ih - Heavy manufacturing

Extractive industry

Areas:
- Es - Stone quarries
- Eg - Sand and gravel pits
- Em - Metallic mineral extraction
- Eu - Underground mining

TABLE I (*continued*)

Point data:
Underground mining (Eu): types present
Oil and gas (u–1)
Salt (u–2)
Other (u–3)
Abandoned (u–4)

Outdoor recreation

Areas:
OR - All outdoor recreation facilities

Point data:
Outdoor recreation facilities (OR): types present
Golf courses (OR–1)
Ski areas, other winter sports (OR–2)
Beaches and pools (OR–3)
Marinas, boat launching sites (OR–4)
Campgrounds (OR–5)
Drive-in theaters, race tracks, amusement parks (OR–6)
Fairgrounds (OR–8)
Public parks (OR–9)
Shooting, archery (OR–13)
Private company facilities, community areas (OR–16)

Public and semi-public land uses

Areas:
P - All public and semi-public areas

Point data:
Public and semi-public areas (P): types present
Educational institutions (P–1)
Religious institutions (P–2)
Health institutions (P–3)
Military bases and armories (P–4)
Solid waste disposal (P–5)
Cemeteries (P–6)
Water supply treatment (P–7)
Sewage treatment plants (P–8)
Flood control structures (P–9)
Correctional institutions (P–11)
Road equipment centers (P–12)
Welfare centers, county farms (P–16)

Transportation

Areas:
Th - Highway interchanges, limited access right-of-way, etc.
Tr - Railway facilities
Ta - Airport facilities
Tb - Barge canal facilities
Tp - Marine port and dock facilities
Ts - Shipyards
Tl - Marine locks
Tt - Communication and utility facilities

Point data:
Highway category (h): highest present
None (h–0)
Unimproved, gravel, town roads (h–3)
Two-three lane highway (h–4)
Four-lane highway (h–5)
Divided highway (h–6)
Limited access highway (h–7)
Limited access interchange (h–8)
Railway facilities (Tr): types present
Abandoned right-of-way (r–1)
Active track (r–2)
Switching yards (r–3)
Stations and stuctures (r–4)
Spur (r–5)
Airport facilities (Ta): types present
Personal (a–1)
Non-commercial (a–2)
Commercial (a–3)
Airline (a–4)
Military (a–5)
Heliport (a–6)
Seaplane base (a–7)
Barge canal facilities (Tb): types present
Channel (b–1)
Lock (b–2)
Abandoned channel (b–3)
Communications and utilities (Tt): types present
TV-radio tower (t–1)
Microwave station (t–2)
Gas and oil–long-distance transmission (t–3)
Electric power–long-distance transmission (t–4)
Water–long-distance transmission (t–5)
Telephone–long-distance transmission (t–6)

[1] Summary sheet.

Symbols for the various units should be chosen by mnemonics to aid memory and with thought to avoid mistakes when the manuscript maps are drafted.

Mapping units

One of the biggest problems encountered in the larger land use surveys is in maintaining uniformity in the interpretation of land uses that are transitional between two defined classes as the project progresses from one area to the next. Each class can be defined by borrowing a method that is used by soil scientists for describing soil mapping units. This is the *central concept* system in which for each class a typical or ideal example is described and then limits are set on how far the members of each class can vary from this central concept as the units intergrade with each other. The problem then becomes one of locating the dividing line in the transitional zone between two land use classes, defining it, and preventing its migration back and forth as the mapping project progresses and insuring that all interpreters have the same idea where the dividing line should be located.

In the various transition cases between the central concepts (Fig.2) of R (residential) and Cs (commercial strip), it is not immediately clear how a closely intermingled area of residences and stores should be classified. For all units in the classification that intergrade into one another, rules have to be formulated and followed by the interpreters if a uniform product is to be produced. In the example given, the classification allowed up to 1/3 residential included in an area designated as Cs. To cut down on decision times, quantitative definitions should be avoided. In the transitions between Ai (inactive agricultural land) and Fc (forest brushland), Fc was originally defined as land with 10% or more of its area covered with brush. Later this definition was changed because land with any brush visible on the photograph was found to contain enough brush to preclude the use of farm machinery in that field.

As the photo interpretation progresses, cases will arise where the proper land use category is in doubt. For each case the decision which is made should be covered by a rule so that in all similar future cases the same decision will be made. When the photo interpretation supervisor makes a decision in a doubtful case all the interpreters must be informed. A good way to do this is to have short meetings during which recent classification rulings are reviewed and the air photos pertinent to each case are shown to the group with an opaque projector or other visual aid. Written records of the unit definitions used, case decisions, and classification changes should be kept by the photo interpretation staff for the benefit of the users of the land use data.

At each level in a classification system so-called "wastebasket classes" should be provided to avoid long decision times when miscellaneous or unknown land uses arise. A good example in the LUNR (land use and natural resources) classification is the unit OR-16, (community or private company recreational facilities) which allows the interpreter to quickly pigeonhole such items as stray

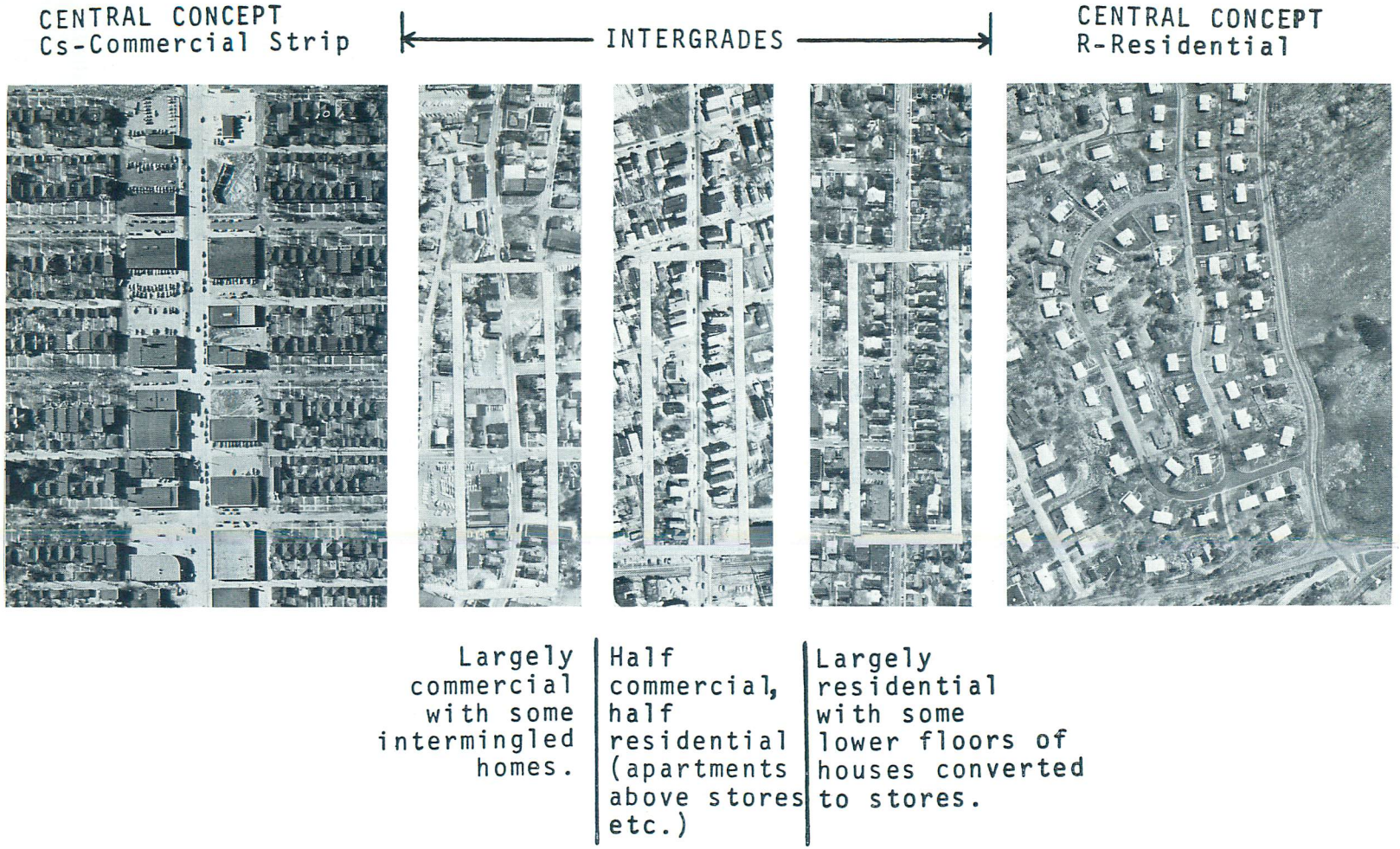

Fig.2. Land use intergrades between Cs = commercial strip and R = residential.

baseball diamonds which are seemingly unconnected to any public school or park thus avoiding the expense of trying to force the unknown item into one of the other classes. Miscellaneous items can comprise only a few percent or less of the total area of the project but unless adequate thought is given to the disposition of these items by the interpreters when the classification is being written, they will consume many times their share of the photo interpretation budget. "Wastebasket" classes should be identified as such in their written descriptions for the users.

General minimum-area/maximum complexity rules should be set forth for each classification unit. Mapping scale will generally control unit size/complexity for all land use classes however, some classes should be mapped in greater detail than others. Because of their importance in highway location and reservoir construction, cemeteries should be mapped in great detail, no matter how small or complex in area. Mapping forest brushland with such care is expensive and probably serves no purpose for most user requirements.

PHOTO INTERPRETATION PROCEDURE

The photo interpreters are first acquainted with new areas to be mapped during a brief field trip during which the major economic activities, land use trends, recent agricultural history, geography, unusual land uses, etc., of the area are discussed. Summary sheets of this information are prepared for use as supplemental information. Additional supplemental information (such as the locations of various specialty farms, industries, utilities, public buildings, etc., obtained from interviews with county agents, planners, highway superintendents, publications, maps, census reports, etc.) is located on quadrangle maps for the interpreter's use. It is important that this supplemental information be presented to the interpreter in a form which he can use most easily. If a list of campgrounds for a large area is obtained, rather than providing the list to the interpreter, the location of each campground should be transferred by the supplemental data group to the quadrangle map sheets which contain all the other back-up information. This avoids a great deal of time lost while the interpreter leafs through the list of camp grounds to see if there are any in his area and if so, finding out where they are on his map; he should have all the supplemental information summarized on one quadrangle sheet by location.

Stereoscopic examination of the photographs is essential for accurate interpretation. The common 2 power lens stereoscopes were the only instruments used for most of the interpretation work, however a 4 power stereoscope was useful for intensive study of some difficult areas.

Most improvements in photo interpreter comfort pay large dividends in quality and quantity of production because the work tends to be tedious. Interpreters delineated their area classifications and point count data on alternate prints in different colored pencils to avoid clutter. When a quadrangle is completed the

interpreters then transfer the data to overlays on topographic quadrangle maps, after their interpretations had been checked over by the photo interpretation supervisor.

Field checking

Objective field checking of the air photo interpretation must be a part of the project starting with the development of the classification and through to the production of the final maps. Failure to work field checking into the procedure early can result in expensive remapping later to correct errors that develop.

Each quadrangle has a final field check after photo interpretation is completed but before it is sent for final drafting. On the LUNR project this was done by driving representative roads for each quadrangle and checking the point count and area mapping (at roadside contact) for errors which are then entered on a score sheet. The map is then graded according to a standard score sheet, set up to allow varying weights for different errors. A Cc (shopping center) that was mapped Cs (commercial strip) is not as serious an error as confusing it with a hospital and different penalty points should be assigned for these two errors.

If the map meets the desired standard then it is sent to the drafting section, otherwise it is returned to the interpreter for correction with appropriate error analysis.

CONCLUSION

This paper has outlined the main points which should be observed in setting up land use mapping projects based primarily on air photo interpretation. The organization of the project should be carefully thought out; the photo interpretation team should be regarded as the core of the organization and each person's job should be specialized. The land use classification is one of the most important factors to be considered. The classification must be properly designed to meet the needs of those who will be using the results and to utilize the type of photography (scale, time of year, etc.) available. Field checking at various stages of the project is essential to maintain quality control of finished maps. Although these procedures were developed for a project covering a very large and diverse area, the basic principles are also applicable to the more intensive projects covering smaller areas.

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