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Cover Mapping a State from Aerial Photographs[1]

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ABSTRACT: *Vegetative cover maps are very desirable in managing our game resources and would be invaluable in determining a wildlife management policy for a state. When good aerial photographs of Massachusetts were taken in 1951 and 1952, it was recognized that these offered a good opportunity to map the forests, open land, and wet lands of the entire state. In the fall of 1953 such a project was initiated by the Massachusetts Cooperative Wildlife Research Unit. A vegetation classification system was evolved which permitted the separation of vegetation on the aerial photographs consistently and accurately under all conditions. Photographs were interpreted and annotated in India ink; the interpreted information was transferred to U.S.G.S. maps at a scale of 2" = 1 mile; these maps were reproduced in quantity in black and white; the originals were colored; areas were determined and tabulated by cover types for towns, U.S.G.S. sheets, counties, and the state.*

To a map showing both planimetric and topographic detail has been added the vegetation which clothes the land in Massachusetts. These maps coupled with area statistics of the cover types places in the hands of the wildlife biologist a very important tool in game management. Both the maps and the statistics should be of considerable use to foresters, agricultural economists, soil conservationists, town and regional planners, and others interested in large land areas in Massachusetts. Over 80 per cent of the state has been completed and black and white map reproductions are available in quantity.

INTRODUCTION

AMONG the inventories needed for the management of our game resources one of the more important is vegetative cover. It is a nearly impossible task to formulate an adequate wildlife management policy for a state without a knowledge of the area of forest, wet land, and

[1] *A contribution of the Massachusetts Cooperative Wildlife Research Unit supported by the University of Massachusetts, the Massachusetts Division of Fisheries and Game, the U. S. Fish and Wildlife Service, and the Wildlife Management Institute. The Massachusetts Department of Natural Resources is also supporting this project.*

agricultural land. In addition, a knowledge of the interspersion and juxtaposition of vegetative types, and the over-all pattern of land use is necessary for good policy planning. The mapping project described in this paper is an effort to satisfy the needs of the wildlife biologists in the way of broad cover maps and accurate area statistics of vegetative covers in Massachusetts. In working out a vegetation classification system a strong effort was made to meet the needs of the wildlife biologist and forester, and to anticipate the needs of the agriculturist and others.

In the past, wildlife research men have usually made intensive vegetative cover surveys on limited study areas employing ground methods. Such methods have advantages and are necessary when intensive data are required, but such methods are too costly for extensive areas. Broad statistics listing the percentage of forest land compared to agricultural land in Massachusetts have long been available. Inventory of the forest resource is available in many areas, but usually no attempt has been made to locate the resources on a map. The practicing wildlife biologist or forester needs to know not only how much there is, but where it is located—he needs maps. To obtain vegetation maps by ground techniques would be prohibitively expensive. Aerial photographs offer many advantages over ground methods for the analysis of vegetative cover over extensive areas, and cover mapping from aerial photographs is a technique that has been highly developed by foresters; it can also be used effectively by others who have similar needs.

To attain our objective, good vegetative maps for Massachusetts, there was a need only to apply already established techniques to delineate and classify vegetative types on standard 1:20,000 panchromatic photographs. The techniques employed were not new, but cover mapping an entire state for the purpose of applying the information to long-term game management policies on a state-wide basis is a new approach that has required some modification of techniques used in forest inventories. The purpose of the work was to locate and measure the existing and potential wildlife habitat in Massachusetts using aerial photographs taken in 1951–1952 when the deciduous species were in leaf.

The Classification System

The greatest barrier to overcome in solving the problem was the development of a vegetation classification system. No other factor has as much influence on the quality of the work and the value of the finished product, as the classification system. The system must recognize the limitations of the photographs and the very human limitations of the men who interpret them while striving for maximum utility of the finished product. A good approach to the solution of this problem is to set up a classification system based on photographic characteristics which meets ideal requirements for the finished product. The next step is to test the classification system extensively and to change it where necessary so that interpreters working with existing photographs can consistently and accurately make the separations required by the classification. A four-month period spent in extensive field reconnaissance, office photo analysis, and field check was necessary to determine the utility and limitations of the existing photographs for vegetational separation. A careful survey of the literature was made to determine what success others had had in this field, so that our sights would be set neither too high nor too low.

The following classification system represents what could be classified on 1:20,000 Soil Conservation Photographs in Massachusetts. The system contains four broad categories—forest land, open land partly reclaimed by forest, open land, and wet land. The minimum typing unit in the system is ten acres.

FOREST LAND

Species classes

S—softwoods constitute at least 80% of the stand.

H—hardwoods constitute at least 80% of the stand.

HS—a mixture of hardwoods and softwoods with hardwoods predominating.

SH—a mixture of softwoods and hardwoods with softwoods predominating.

Height classes

1. 1′—20′
2. 21′—40′
3. 41′—60′

4. 61′—80′
5. 81′—100′
6. Uneven heights (three or more height classes represented)

Density classes

A. good stocking, 80–100% crown closure
B. fair stocking, 51–80% crown closure
C. poor stocking, 30–50% crown closure

This code method of classifying or typing forest stands lists species, height, and then density as in the following examples:

H2A is a hardwood stand 21 to 40 feet in height with good stocking.

HS5A is a mixture of hardwoods and softwoods with hardwoods predominating. This stand is 81 to 100 feet tall with good stocking.

S3B is a softwood stand 41 to 60 feet in height with fair stocking.

$\frac{H3C}{H1B}$ is a hardwood stand 41 to 60 feet in height with poor stocking in the overstory with hardwood 1 to 20 feet in height, with fair stocking in the understory. Such types usually occur after logging or blowdown.

Seventy-two one-storied forest stands are recognized in this classification. About two-hundred different forest stands are possible counting both one-storied and two-storied situations. Many of these stands can appear over swamp situations to give still more variation to the forest classification system. Swamps under forest stands are verified on USGS maps.

OPEN LAND PARTLY RECLAIMED BY FOREST

A two-storied classification is used on abandoned fields invaded by forest species. The forest land symbols are placed in the numerator while the abandoned field symbol (*AF*) is the denominator.

For example:

$\frac{S1C}{AF}$ = softwoods, less than 20 feet tall with poor stocking in an abandoned field or pasture.

About twenty-four vegetational units of this type may be separated with the classification system. These types are of special interest to wildlife biologists, foresters, and others.

OPEN LAND

The open land classification contains the following 8 types:

1. *AL* is agricultural land intensively farmed. This type consists of nearly all open, continuous fields with no stonewalls, hedgerows, small patches of abandoned land, small forested areas, or wet land. Much of the intensive agriculture carried on in Massachusetts falls into this type.
2. *AL-I* is agricultural land interspersed with stonewalls, hedgerows, small forested areas, patches of abandoned land, or wet land.
3. *AL-M* is agricultural land with a small, fresh-water meadow present. If the meadow were ten acres or larger, it should be separated and classified as *FM* described below. The darker green reeds in a meadow gives a lower spectral reflectance than the surrounding grasses and sedges, distinctly revealing the field drainage pattern. The usefulness of such a type will be realized when the State Fish and Game Department selects potential sites for their small marsh development program for the production of ducks and muskrats.
4. *AF* is abandoned field which is reverting to forest land. The woody vegetation on these fields has a crown closure of less than 30 percent.
5. *O* is productive fruit orchard.
6. *AO* is abandoned orchard. Separation between orchards in use and abandoned orchards is simple on aerial photos. This separation has importance when evaluating orchards for wildlife habitat, the productive orchards have only minor wildlife value while abandoned orchards are considered exceptionally good wildlife habitat.
7. *CB* is cranberry bog.
8. *U* is urban or industrial area.

WET LAND

The wet land classification follows closely the types defined by the Office of River Basins of the Fish and Wildlife Service. (Martin, Alexander C., et al, 1953).[2] This classification was simplified so that wet land separation could be made consistently and accurately on the existing aerial photographs of Massachusetts.

[2] *Classification of wet lands of the United States*. U. S. Fish and Wildlife Service, Special Scientific Report: Wildlife No. 20.

The modification of the Fish and Wildlife Service classification is described below:

INLAND FRESH WATER AREAS

1. *FM* is fresh water meadow. The principal means of separating this type is by identifying a reed (Juncuss spp.) which commonly grows in the wetter parts of meadows. The type is often found in pastured agricultural land.

2. *SFM* is shallow fresh water marsh, a wetter type than *FM*. This type has little open water or woody vegetation. The predominant vegetation is usually cattails, and the soil is completely waterlogged or covered with water up to several inches in depth.

3. *DFM* is deep fresh water marsh which is wetter than *SFM*. This type has open water interspersed with splotchy patches of vegetation. The water ranges from 6 inches to 3 feet in depth, and the vegetation is a scattered floating type.

4. *SS* is shrub swamp. The type is fairly easy to identify on aerial photographs and *USGS* sheets may be used to verify the swamp condition.

5. Vegetation in wooded swamps is designated by the forest land symbols described above. After the forest has been classified on the aerial photographs, this information is transferred to *USGS* sheets which have swamp symbols showing the extent of swamps.

COASTAL SALINE AREAS

SM is salt marsh. Five coastal saline types are recognized by the Fish and Wildlife Service classification of wet land. A strong effort was made to make the five separations, but all had to be consolidated into one type (*SM*) which could be consistently and accurately separated under all conditions on the aerial photographs.

Interpretation Procedure

Photo interpretation is not a science but a highly skilled art. To perform the work efficiently one must correlate the appearance of vegetation in a three-dimensional vertical view on the aerial photographs with a ground view. Just as a dendrologist depends on leaves, twigs, buds, bark, etc., to identify tree species, the photo interpreter must depend on physical characteristics to identify the vegetation on aerial photographs. The elements of photo interpretation though complex, are rather well described in the literature. Each interpreter must carefully build his ability, and months or even years will elapse before an interpreter gains ability of a high order.

The field checks are more important than any other activity in photo interpretation. They fall into two classes, pretyping reconnaissance and post-typing field checks. A reconnaissance is made to familiarize the interpreter with local conditions. In carrying on the work thousands of vegetative types are visited on the ground, pin holed and classified on the back of the photo using the classification system described above. These areas are studied under the stereoscope in both the field and office. After some confidence is gained, typing begins, and the interpreter checks his classifications against the areas visited in the field and pin holed on the photographs. When a fairly large area has been completed, post typing field checks are undertaken to guarantee the accuracy of the work done and to make further correlations between photo detail and land characteristics. A never-ending cycle of reconnaissance, photo interpretation, and field check continues as the work progresses. A vehicle should always be available to the interpreter so that any doubt can be resolved by viewing the area in question on the ground.

Vegetation is delineated and classified on the aerial photographs in black India ink using special fountain pens which have recently become available. India ink has decided advantages over other media for annotating aerial photographs, and India ink fountain pens are superior to quill pens in applying the ink. Type boundaries and descriptive symbols are drawn directly on the photographs. Black India ink may easily be removed from the photographs using a weak solution of ammonia and water on a cotton swab. The annotated aerial photographs form a permanent record of the vegetation in Massachusetts in 1951–1952, and become the most important part of the work.

Transfer

Nearly all the USGS topographical maps of Massachusetts have been revised during the last ten years and all have a

scale of 2″=1 mile. (*RF*=1:31,680). We decided to transfer our vegetative types from the aerial photographs (*RF* 1:20,000) to USGS maps (*RF* 1:31,680). In this process we added vegetation types to a map having a wealth of planimetric and topographic information. Since all the other desired information was on these maps it was necessary to interpret vegetation only. Control and other problems of cartography were eliminated and our map-making process was made simple and economical. Vegetative types were transferred directly to USGS sheets by use of a vertical sketchmaster and multiscope. Photo detail was matched to map detail for control and the types were added directly to the USGS sheets using India ink fountain pens. In wild undeveloped country, hill tops identified under the stereoscope were sometimes matched to the hill tops shown by contours on the USGS sheet. In other cases a radial line triangulation network was made from mechanical templets to add additional control points to the USGS sheets. The finished product was a USGS sheet with type lines and type symbols on it in India ink. The scale of the USGS sheet determined the size of the minimum typing unit. Ten acres at *RF* 1:31,680 is a block $\frac{1}{4}$ inch on a side. This was considered the minimum size on which a classification symbol could be placed.

Map Reproduction

The cost of reproducing 186 maps each with 15 different colors on it was prohibitive, so it was decided to make reproductions in black and white. The offset reproduction process selected shows all the detail of the USGS sheet plus vegetative types added in the work. Maps which are clear and sharp on good paper suitable for coloring were reproduced in quantity for 5¢ to 11¢ a copy depending on the number desired. At least 100 copies of each map had to be ordered to make reproduction costs economical.

Area Statistics

After the maps with the vegetative types are reproduced, the originals are colored to aid in acreage determination and to increase their utility. Water colors, dye-based crayons, and wax-based crayons were all used as coloring media. Water color did not go on the USGS sheets evenly, dye-based crayons are not durable for heavy use over long periods, so wax-based crayons were used; these gave bright durable results. The acreage of each type is determined by dot grids (each dot equals four acres at *RF* 1:31,680) and acreage figures are tabulated by town, county, USGS sheet, and the state. It takes about one man-day to color a map and another man-day to count dots to determine the acreage of the types. Acreage statistics will be published when the work is complete.

Project Cost

Good cost figures are not available because of the cooperative nature of the work. Space, some equipment, materials, and much free time has been contributed by the cooperating agencies listed on the first page. A good appraisal of average time spent in the various operations and the cost of these technical activities has been made and is expressed in Table 1.

Utilization of Results

The type maps and area statistics will be used to formulate long-range game management plans for Massachusetts. The maps locate the forest, open land, and wet land of the state. The interspersion and juxtaposition of open land, wet land, and forest is basic in evaluating habitats for the various game animals. Ripley, T. H. and Garvin, L. E. (1955)[3] made a study of quail census data correlating quail populations with vegetative units mapped in this project. Game harvest could also be correlated with the vegetative types by township or other land unit, and the maps offer many other possibilities for studies of population-habitat relationships.

The cover maps can be used in forest inventory by associating a ground volume sample with the cover types. The technical problems of cover mapping from aerial photographs have been solved for foresters and others. The Department of Natural Resources is planning to use the maps in inventorying the state forests and will distribute maps to district foresters for their use. The forest inventory recently made by the U. S. Forest Service shows us

[3] *Quail whistling counts as related to area and edge variation in cover types on Cape Cod, Massachusetts.* Trans. N. E. Section of Wildlife Society, Atlantic City, New Jersey.

TABLE 1

TIME AND COST FOR MAP MAKING PROCESSES

Costs include labor and travel only

Process	Average Rate Square Mile per Hour	Average Rate Square Mile per Day	Average Cost in Dollars per Square Mile
Photo preparation (Trim edges, photo centers)	30.0	240	$ .05
Photo interpretation[4]	3.0	14	1.14
Field checking (Reconnaissance & field check)	10.4	83	.26[5]
Transfer[3] (From photos to USGS sheet)	3.1	20	.54
Map coloring	6.9	55	.25
Area tabulation (Count dots, assemble statistics)	6.9	55	.25
Total			$2.49

[4] Photo interpretation, and transfer are exacting activities which tire the operator so that efficiency falls off rapidly toward the end of the day. Daily rates are therefore not eight times the hourly rate, but less than that. The hourly rates of production expressed here may be met on half time work.

[5] Seven cents of this item is travel at $.07 a mile. The rest is salary.

how much timber there is in the state; this study locates that timber stand by stand on a map.

The type maps and area statistics should be useful to agricultural economists, soil conservationists, tax assessors, town, county, and state planners, as well as hunters, loggers, naturalists, ecologists, hikers, scouts, and nature lovers of all kinds.

ELECTRONICS TO BRING SPOT NEWS PHOTOS TO LINER PASSENGERS ON HIGH SEAS

Travelers on the Italian Line's luxury liner the SS Cristoforo Colombo can view spot news photos as soon as readers of land-based newspapers. This transmission of news photographs and their reproduction for printing on the high seas is made possible through the installation of a Fairchild Scan-A-Graver, electronic engraving device, to produce halftone plates from photographs received by the ship's radio photo equipment. Electronic technicians of Fairchild Graphic Equipment, Inc. installed the first seagoing Scan-A-Graver on December 20, 1955.

The Scan-A-Graver, first introduced to newspapers about seven years ago, is now widely used by smaller daily and weekly newspapers. It contains two cylinders. On one a sheet of special plastic is placed while the photograph to be engraved is placed on the other. Light reflections from the highlight and shadow portions of the original copy is translated by a photo cell and a subsequent amplification system into electronic energy so that a vibrating motor can direct a stylus in cutting craters in the plastic plate to form the halftone dot pattern. The plates produced on the machine require no acid etching and can be mounted and ready for the press in a matter of minutes.

The Scan-A-Graver installed on the Cristoforo Colombo is the compact Cadet model, which has found great favor with a large number of smaller newspapers in the United States. It will produce a plate six by eight inches as compared to the larger Standard console, which will engrave an eight by ten inch plate.