Airphoto Inventory of Pulpwood in Water Storage

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ABSTRACT: *Inventory of pulpwood contained in water storage areas near paper mills constitutes a problem to mills dependent on water transportation or water storage. A study was conducted to determine the degree of accuracy with which pulpwood sticks can be counted in airphotos and to develop sampling techniques to determine the cord volume of large pulpwood water storage areas by use of airphotos.*

Pulpwood sticks in five small test booms were counted by two photo interpreters. The density of pulpwood sticks in the booms and the clarity of the photos were such that considerable accuracy was achieved. Stick counts ranged from 10 to 70 in the 250 sample plots located in the water storage areas. A Kelsh plotter was used to delineate water storage areas and acreage was determined by planimetry. By use of standard statistical procedures, the plot counts were expanded to determine the cord volume in each water storage area, with the error of estimate at 19:1 odds.

Clarity of the photography is the most important factor contributing to the accuracy of pulpwood stick counts. Stick density is also a factor in the accuracy of counts, and it may be necessary to establish factors to apply to sample counts which tend to be low. Results of this pioneer study indicate the feasibility of the airphoto interpretation and sampling procedures described.

INTRODUCTION

DURING the past two decades widespread application of airphotos to forest mapping and timber inventory has been clearly depicted by Spurr[5] in a history of forest photogrammetry. In a forest photogrammetry bibliography of over six hundred titles, Spurr[6] lists only one title that indicates a primary concern with a forest product inventory. Warburton[7] and Young[8] have described the use of airphotos to determine the volume of pulpwood in large storage piles. This method is being employed currently by numerous commercial concerns. In 1919 Kahre[9] employed vertical airphotos to count logs contained in log booms. The literature reviewed by the authors does not disclose any studies on the use of airphotos to determine the volume of pulpwood in booms and storage areas on lakes or rivers.

A boom is a mobile relatively small, raft-like mass of pulpwood sticks confined by chained logs which is capable of being towed from one place to another. A storage area is a mass of pulpwood sticks confined by boom logs which are secured to the shore or piers, (Figure 1). Booms are generally less than 20 acres in extent while storage areas may cover 50 or more acres of water. Inventory of pulpwood, in bolts four feet in length, in water storage is a problem common to all paper mills dependent on water transportation or water storage of pulpwood. Sinkage and other losses, incurred in the process of floating pulpwood bolts from the cutting area to the mill, complicate the inventory problem.

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Note: The authors wish to acknowledge the cooperation of the Great Northern Paper Company which prepared the test booms and supplied the information on the water storage areas; and the James W. Sewall Company, Old Town, Maine, which did the photography, processing and photogrammetric work.

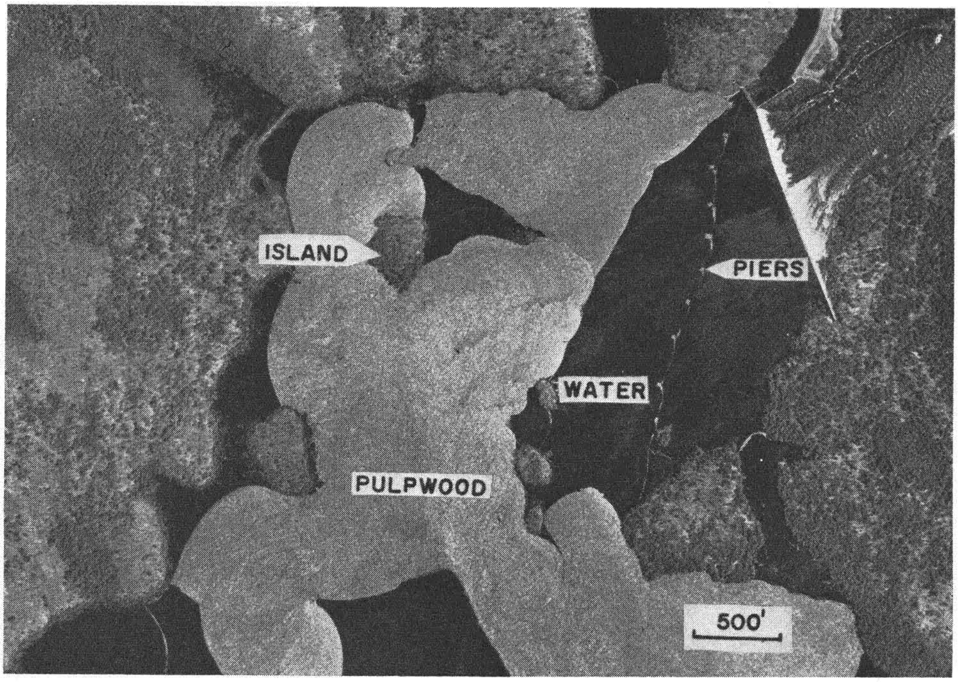

FIG. 1. A vertical airphoto of a pulpwood water storage area located in Northern Maine. Acreage of the irregular shaped mass of pulpwood was determined by photogrammetric methods using photos having a scale of 1:14,000. *Courtesy of Great Northern Paper Co., Photo by James W. Sewall Co.*

The purpose of this paper is to present the results of a study, using airphoto interpretation techniques, to determine the feasibility of counting individual bolts of pulpwood in booms and water storage areas, and to develop sampling methods which will provide a satisfactory estimate of the pulpwood volume in large water storage areas.

METHODS

PHOTOGRAPHY

An 8.25-inch focal length camera, panchromatic film and a minus blue filter were used to obtain all vertical airphotos. Airphotos at a scale of 1:14,000 were obtained to determine acreage of the water storage areas. One flight line at a scale of 1:2,400 was made across each water storage area, with no attempt to obtain complete coverage. This large-scale photography was enlarged approximately three diameters for the purpose of making counts of sample plots in the storage areas and in the small test booms (Figure 2). The low and high altitude photos were made within a few minutes of each other to minimize the possibility of a change in pulpwood stick density and total area due to wind and water action.

ACCURACY OF INDIVIDUAL STICK COUNTS

To ascertain the accuracy of pulpwood stick counts using photo interpretation methods, five small test booms containing a known number of pulpwood bolts were anchored in the vicinity of the water storage areas. Two photo interpreters without prior knowledge of the stick counts in the test booms counted the sticks by monocular use of an Old Delft scanning stereoscope, employing the 4.5 power lens. The results are shown in Table I. To avoid missing bolts or double counting, each stick was marked with a pricker as described by Lyngstad[2] and Pacey[3] for counting sawlogs in booms. One observer elected to keep track of the sticks by recording counts in batches of 25 to 100, and the other preferred to use a tally register simultaneously with one hand while pricking the sticks with the other.

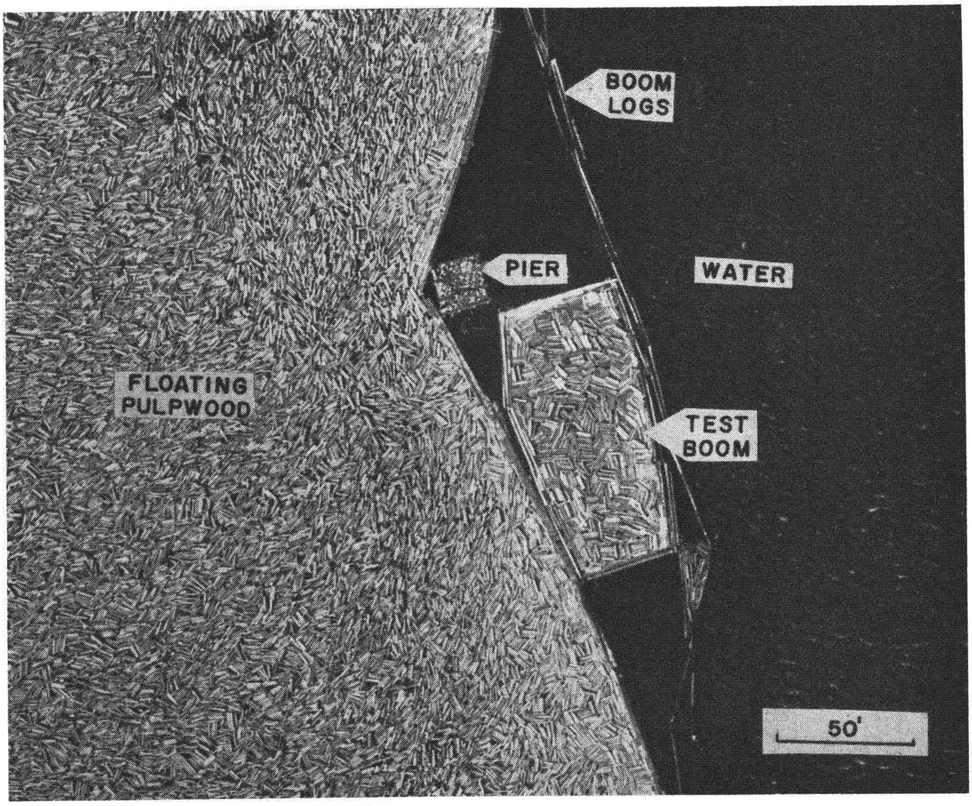

FIG. 2. A detailed view of a portion of a water storage area. For counting individual 4-foot pulpwood sticks, 3× enlargements of photos having an original scale of 1:2400 were used. Trial counts were made of test booms containing a known number of sticks. *Courtesy of Great Northern Paper Co., Photo by James M. Sewall Co.*

ESTIMATING PULPWOOD VOLUME OF A WATER STORAGE AREA

Because the number of pulpwood sticks in a relatively small storage area holding 2,000 cords is in excess of 150,000, it is not practical to attempt to count each stick. Thus it becomes necessary to develop a sampling scheme that will be applicable to the total water storage area.

The acreage of each water storage area was determined by conventional photogrammetric techniques using the 1:14,000

TABLE I

COMPARISON OF STICK COUNTS MADE BY PHOTO INTERPRETATION METHODS WITH KNOWN STICK COUNTS IN TEST BOOMS

Test Boom	*Known Count*	*Photo Interpreter 1*		*Photo Interpreter 2*	
		Stick Count	*Per Cent of Known Count*	*Stick Count*	*Per Cent of Known Count*
A	894	908	101.6	811	90.8
B	839	841	100.2	817	97.3
C	860	856	99.5	862	100.2
D	769	734	95.4	671	87.3
E	865	870	100.6	804	92.9

photography in a Kelsh plotter. Small islands and open water spots occurring within the storage area were delineated and subtracted from the computed acreage. Sample plots located at random falling in or touching these "non-wood" sites were automatically voided.

The authors experimented with a number of sample plots of different shapes and sizes. It was found that stick count variation between photo interpreters was at a minimum using a circular plot 0.184 inches in diameter. Sticks located on the plot perimeter were counted if one-half or more of the stick appeared to be inside the plot. It was the opinion of the interpreters that it was less difficult to decide whether a stick should be counted when using a circular plot than with a square or rectangular figure.

Sample plots were punched at random in a piece of slightly frosted acetate measuring 2 by 3 inches. The number of plots per templet varied from 10 to 25 depending on the total acreage of the boom. The acetate was placed on the enlargements in a random fashion to obtain plots in all portions of the boom. If the plots fell on blurry portions of a photo where the sticks were not readily discernible, the plots were discarded. Failure to take blurred plots indubitably introduced bias and affected the final volume estimate.

Fifty to 150 sample plots per storage area, depending on the total acreage, were considered sufficient to yield an estimate with a statistical error that would not exceed 4 per cent at 19:1 odds. By using standard techniques described by Schumacher and Chapman[4] sampling can be kept at a minimum so that the results will not exceed any stipulated per cent of error at any desired odds. The results of sample plot counts employed to estimate the pulpwood volume of storage areas are given in Table II.

Table II

Comparison of Airphoto and Conventional Estimates of the Cord Volume in Water Storage Areas

Area Designation	*Age of Wood*	*Airphoto Estimate*	*Conventional Estimate*	*Per Cent Difference*
X	old	64,446	78,912	19.3
Y	new	1,991	1,975	0.8
Z	old	48,139	55,191	12.8

The Kelsh plotter was used to determine the scale of each enlargement from established ground control. Minor variations in scale between enlargements were averaged to obtain a scale common to the entire storage area. The average scale of the enlargements was used in converting the sample plot stick counts to storage area volume. The number of sticks per plot, with its error of estimate, was then expanded by the appropriate scale factor to arrive at an estimated number of sticks per acre. By applying a factor representing the average number of sticks per cord, the estimated number of cords per acre was then calculated. Finally, the cord content per acre was multiplied by the acreage of the storage area to determine the pulpwood volume in cords for the entire storage area.

Discussion

Clarity or sharpness of airphotos is a major factor affecting the accuracy of pulpwood stick counts (Table III). Image motion, optics and mechanics of aerial cameras, dark-room techniques and other factors

Table III

Comparison of Counts on Blurred and Relatively Clear Pictures by the Same Photo Interpreter

Test Boom	*Known Count*	*Blurry Picture Stick Count*	*Per Cent of Known Count*	*Clear Picture Count*	*Per Cent of Known Count*
C	856	724	84.6	862	100.2
D	865	562	65.0	870	100.6
E	870	505	58.0	804	92.9

contributing to clarity have been discussed in numerous technical papers. In addition, sharpness of individual stick image is greatly affected by the density of sticks within the storage area. Density within a water storage area varies from scattered sticks surrounded by open water to a jumbled mass several bolts in depth with virtually no water exposed. Storage areas located in swift flowing rivers are very dense with sticks piled high, cocked at angles and even standing on end. Bolts are often piled up in a band on the windward edge of storage areas located in large exposed lakes. When sticks are piled up they appear fuzzy, or not readily discernible in an airphoto, and it is impossible to make a valid count. When sticks are two layers deep, portions of the lower layer are practically always discernible and reasonably accurate counts can be made. When the sticks are only two layers deep, apparent fuzziness characterizing tightly jammed wood is slight. In instances where the sticks are more than two layers deep, it is necessary for the observer to "count" and to "interpret," that is, estimate the number of bolts that "should" be found in the lower, or partially visible stratum. In addition to stick density, image clarity of individual sticks is affected by the buoyancy of the wood. Pulpwood which has been in the water for a considerable period of time becomes waterlogged and only a small portion of the stick is above water. "New" wood rides high in the water and is more readily discernible than "old" wood which may be partially submerged. Therefore more accurate counts can be made in storage areas containing "new" wood, (Table II).

To insure that the best quality photography for counting purposes is obtained, close liaison between the paper company and the flying concern regarding local weather conditions should be maintained. Ideally the photos should be taken when the water is calm and the pulpwood sticks are spread out in a single layer. The presence of a small amount of ice makes counting difficult, and a 2 or 3 inch layer of snow mantling the sticks would render such photography practically useless for counting purposes.

In the airphotos of the water storage areas examined by the authors most portions of the boom were occupied by one layer of sticks where it was possible to count individual sticks. Frequently a group of 3 to 6 sticks aligned side by side would appear as a single unit in which the individual sticks would not be discernible. In such cases it is necessary to interpret the total number of sticks within each clump. In this particular study, pulpwood sticks varied from 3 to 24 inches in diameter, averaging approximately 8 inches. When the interpreter encounters such a group, he must estimate its width in terms of sticks of average diameter. Because of the wide range in stick diameters, the possible error in estimating the number of individual sticks in a unit is high. It should be noted in Table I that both observers obtained counts actually higher than the known number. This error can be attributed, in part, to the possibility that the bolts in the test booms involved were larger than the 8-inch average diameter. With a large number of counts, however, it is likely that errors in estimating the number of sticks in clumps would be compensated.

In this study a sample plot 0.184 inches in diameter was used. This represents a circle approximately 15 feet in diameter in which the stick count varied from 10 to 70. A major possible source of error in the entire sampling procedure is the decision to count or not to count bolts located along the plot perimeter. Sticks on the perimeter were counted if it appeared that half or more of the stick was within the plot. In the small sample plots used, at least a third of the sticks in each plot were perimeter cases. It should be noted that the templet in which the holes were punched was a piece of slightly frosty transparent acetate. This permitted the interpreter to see the portion of the bolt outside the perimeter as well as within the plot, thus allowing more accurate decisions to be made.

Earlier reference was made to the monocular use of a stereoscope in preference to the customary binocular use of this instrument. After considerable experimentation it was deemed advisable, in this instance, to examine the airphotos monocularly because it was difficult to obtain and hold a satisfactory stereoscopic model at any distance from the exterior of the storage area, because of the "sameness" of the pattern created by the jumbled mass of sticks on a relatively flat surface.

The sampling technique employed was

not one that conformed to the concept of randomness in the strict sense of the word. Blurry portions of enlargements were not sampled because it was not possible to see the individual sticks or to interpret the number in clumps. In some instances, blurriness was attributed to densely jammed sticks. Since plots falling in such portions of the storage area could not be counted, the estimate would tend to be low because the stick density in the blurred spots was probably higher than in the portion of the area in which the sticks could be counted.

The importance of clarity of photography affecting accuracy of stick counts was demonstrated with the test booms. The results shown in Table III indicate that the total count is drastically reduced when the photo is not clear. The test booms provide definite information on the accuracy of pulpwood stick counts when (1) the photos are reasonably clear, (2) the stick density is not high, and (3) water provides contrast between the sticks. The differences in estimates of the two interpreters are attributed to the difference in their skill in interpreting the number of sticks in groups and those sticks that were partially or entirely under water. The test booms do not provide any information on the accuracy with which the counts were made in the sample plots of the water storage areas, because the enlargements of the latter were not as clear as the test boom enlargements, due to greater stick density and other factors.

In future studies it would be desirable to have pulpwood storage areas with known stick count so that factors could be determined to apply to sample counts which are usually low due to the sampling methods. It appears likely that continuous strip photography might prove highly satisfactory for counting purposes. However, considerable variation in scale along the strip caused by tilt and slight changes in altitude poses a significant problem in the use of continuous strip photography. In addition, cost of such photography might prove excessive. Cameras equipped with image motion compensation attachments may produce photography with such sharpness that more accurate counts can be made.[1]

By employing conventional statistical procedures, stick counts of a number of sample plots were expanded to apply to the entire water storage area containing pulpwood. In the portion of Maine where this study was conducted, sticks per cord vary from 60 to 95. Actual stick counts made of some 15,000 cords of pulpwood averaged 73 sticks per cord. This factor was applied to the sample plot counts to calculate the cord volume of the water storage areas.

In Table II the cord volume estimate of the water storage areas based on airphoto interpretation and sampling procedures is compared with an estimate obtained by the conventional method. The conventional approach of estimating the number of peeled cords of pulpwood in a water storage area begins with the woods scale (in rough cords) of the wood dumped into streams leading to the particular storage area. Studies conducted in past years have indicated that a certain percentage of wood is lost due to sinkage. In addition to sinkage losses the pulpwood sticks are partially debarked during the river drive operation, resulting in an additional loss in rough cord volume known as shrinkage. A combined sinkage and shrinkage factor is applied to the original woods scale to arrive at an estimate of the cord volume in the water storage area. The accuracy of the conventional method is dependent on the validity of the sinkage and shrinkage factors. These are considered to be of questionable value. In future studies it is anticipated that the errors in stick counts in the sample plots and in the sampling procedure can be reduced to such a degree that the airphoto interpretation method will yield more accurate results than the conventional method which has not proven to be entirely satisfactory.

Conclusions

Airphoto interpretation techniques and sampling procedures employed to determine cord volume of pulpwood in water storage areas appears to be practical and economically feasible. With further research, refinements will indubitably result in more accurate inventory estimates.

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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.*