Restoration of the 1936 statewide forest survey of Minnesota: Data description and comparisons with 2014 forest conditions.

by

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ABSTRACT

Long-term forest plot datasets have proven invaluable for understanding the changing conditions and ecology across Minnesota's 17.3 million acres of forestland. Data from past and present USDA Forest Service (USFS) Forest Inventory and Analysis (FIA) program efforts are of high quality and are informed by thousands of field plot observations for each survey. Unfortunately, only the data from 1977 to the present is available in electronic format with full detail; the earlier plot records have been lost. The aim of this study was to locate historic forest records for Minnesota, identify useful data, and develop methodologies for digitizing and restoring data to a usable format. Over 300 stand and stock tables and summary of volume tables for Minnesota were restored from the first FIA Lake States forest survey conducted between 1930 and 1938. The level of detail of the data varied, but included area of forest cover types and stand size classes, and number of trees and volumes per acre by individual species. This report is primarily intended as a reference for describing how the data was located, restored, digitized and compared with current FIA data, including overcoming limitations in the available data.

Included with this documentation is a set of comparisons of various forest conditions over an eighty-year period using the restored dataset and FIA data for Minnesota from 1977 and 2014 inventories. The results showed that overall statewide comparisons using the historic data were most complete and more dependable than comparisons made at survey unit and per-acre scales. Total forest area in Minnesota increased by 1.8 million acres during the eighty-year period, much of that due to the recovery of lands categorized as brush lands in the 1930s. The stand size class distribution in the 1930s was also dominated by an abundance of young stands, and pine forests were more common than hardwood stands across the state. Today the situation is somewhat reversed, with older forest common over large areas, less conifer acreage and much increased standing volume and hence biomass. Both merchantable volume and total cubic volume have increased three-fold since 1936. Additionally, ownership has shifted by nearly five-million acres to more public ownership today than eighty years ago. Historic volume summary tables have provided sufficient detail to develop meaningful comparisons with current FIA data, establishing linkage to the 1977 and more recent reports.

1. INTRODUCTION

The effects of environmental and human induced change on forest ecosystems is difficult to assess over short time scales. Long-term datasets subsume such short-term complexity and allow better understanding of changes in forest composition, structure and biodiversity over time (Dornelas et al. 2014; Groffman et al. 2012). For forests in Minnesota and the Great Lakes region, land use change, fire suppression and periods of heavy extraction over the past century have caused dramatic change in forest composition and structure. These changes have been explored using long-term datasets (Fei and Steiner 2007; Friedman and Reich 2005; Friedman et al. 2001; Rhemtulla 2009; Schulte et al. 2007; White and Host, 2008), but detailed statewide forest inventory data has not been available beyond the past forty years. Recovering historic forest inventory data offers a potentially powerful tool for addressing the impacts of climate change and land use change on Minnesota's 17.3 million acres of forest land.

One forest inventory data source that has contributed enormously to our understanding of our forest resources is the statewide forest inventories reported in 1936, 1953, 1962, 1977, 1990, 2003, 2008 and 2014. These data are from the USDA Forest Service (USFS) Forest Inventory and Analysis (FIA) program and represent high quality data collection methods and thousands of field plot observations for each survey. Unfortunately, only the data from 1977 to the present is available in detail; the earlier plot records have been lost. For this study we proposed to locate data from the first USFS inventory in the Lake States, conducted in the 1930s, to explore the feasibility of restoring and reconstructing such data for Minnesota. Specifically, we have focused on a level of detail useful for analysis of change from a local to ecoregion scale, and thereby reestablishing linkage to the 1977 and more recent data.

The USFS was authorized to develop the first nationwide forest survey as part of the McSweeney-McNary Forest Research Act of 1928 (Smith 2002). The purpose of the survey was to statistically quantify forest area and timber volume following a period of heavy extraction of forest resources across the nation. Eight experiment stations located throughout the U.S. were tasked with developing and implementing regionally-specific forest inventory designs. This effort also fostered a burgeoning period for what would become the national FIA program (LaBau 2007). Minnesota, Wisconsin and Michigan were included in the Lake States survey.

The Lake States survey was carried out from 1930 to 1938 under the guidance of R.M. Cunningham and Suren R. Gevorkiantz at the Lake States Forest Experiment Station in St Paul, Minnesota. Field work began in Minnesota in 1934 and continued for two years (Chase 1964; Gafvert 1938). In the years following the survey, USFS publications referred to the original survey as the '1936 Lake States survey' (Guilkey et al. 1954), referring to the year field work was completed and office work commenced. Field crews worked during harsh winter months in Minnesota to make crossing lakes and swamps more feasible (Gafvert 1938). In all, 15,600 miles of survey lines were run, 125,000 plots were sampled, and over 100 million acres were inventoried (Chase 1964).

Few publications are available describing the specific methods, preliminary calculations and final results of the 1936 USFS Lake States survey. A series of Economic Notes published from 1935-1938 provide summary reports of the final figures including total area, volume, ownership, etc., for the region and each state (USFS 1938). An unpublished Work Plan (USFS 1935)

provides detailed instructions for the field and office work portions of the survey. However, this documentation apparently has not been noted or utilized in any data restoration activities until the current study. The Land Economic Survey (MnDNR 1935), a statewide program to quantify forest resources by county, was developed around the same time using similar methodologies. However, this program was short-lived in Minnesota and data was only available for Hubbard County (Chase 1964). As such, data on Minnesota forests during this critical period of recovery following intensive logging is not readily available. Thus our understanding of how various changes (natural and anthropogenic) may have impacted successional processes in Minnesota's forests is limited.

A primary goal of this study was to make data from the 1936 forest survey available and useable for forestry research. Original records from the first Lake States survey have been stored in St Paul and at national archives throughout the U.S. Until now these forest survey records had not been revisited to determine if they provide truly usable data. The study focused on survey records from Minnesota, and asked two research questions. First, is it possible to locate and interpret eighty-year-old forest inventory records to obtain usable data? Second, are there ways to reconstruct the data so that it is compatible with current FIA data? In addressing these questions, we located many historic forest survey records, identified useful data, and developed methodologies for digitizing and restoring these recovered data to a usable format. This study serves as a reference for the restored data with explanations of methodologies, and definitions for terminology used in the original survey.

2. METHODS

Methods sections 2.1-2.3, and Appendix 1 and 2, provide detailed summaries of the methodologies, terminology and calculations used in the 1936 USFS Lake States forest survey. The purpose was to provide enough detail on the original survey and the digitized data that future applications could be developed using the restored and related database tables.

Methods sections 2.4 and Appendix 3 illustrate several applications of the data, including how we developed methods for making the 1936 data compatible with current FIA data. The database queries developed for these applications include the necessary SQL language.

2.1. Data sources

Original field tally sheets for the 1936 USFS Lake States forest survey (hereafter Survey) were not available, but searches in federal archives throughout the country are ongoing. The records utilized for the study were recovered by one of the authors (Ek) from a St. Paul storage facility (see full list of records in Appendix 1) (Ek 2014). Included was a set of six large (3'x 2'), hard-bound Survey summary books (see Figure 1). Each book contained summary data for one of the six geographic Survey units in Minnesota. Each book in turn contained two sets of tables: (1) Stand and stock tables (Figure 2) that contained average per-acre volume and tree counts, and (2) Summary of volume tables (Figure 3) that contained total volume and area in a unit by cover type, stand size class, and ownership type. In the absence of original plot-level data for Minnesota, the 296 summary tables served as the main source of data. An additional overall summary book was also included and used as a check on the data from the six unit books.

The Survey Work Plan (USFS 1935) provided detailed instructions for both the field and office work components of the Survey. The Work Plan was an unpublished, hard-bound book (approximately 2″ thick) likely compiled after the Survey was completed. The Work Plan consists of instructions, correspondence, and special notes regarding various aspects of the Survey in all three states. The Work Plan contained detailed instructions, but the book lacked chapters and page numbers making it difficult to reference. Considerable effort was made to closely read the Work Plan and organize useful information in a more user-friendly format. As part of the study, the Work Plan was digitized using Digital Library Services at the University of Minnesota Libraries.

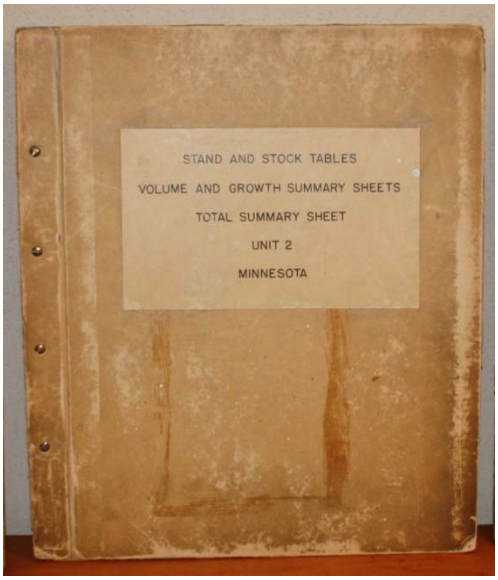

Figure 1. Summary of volume book from 1936 Lake States Survey.

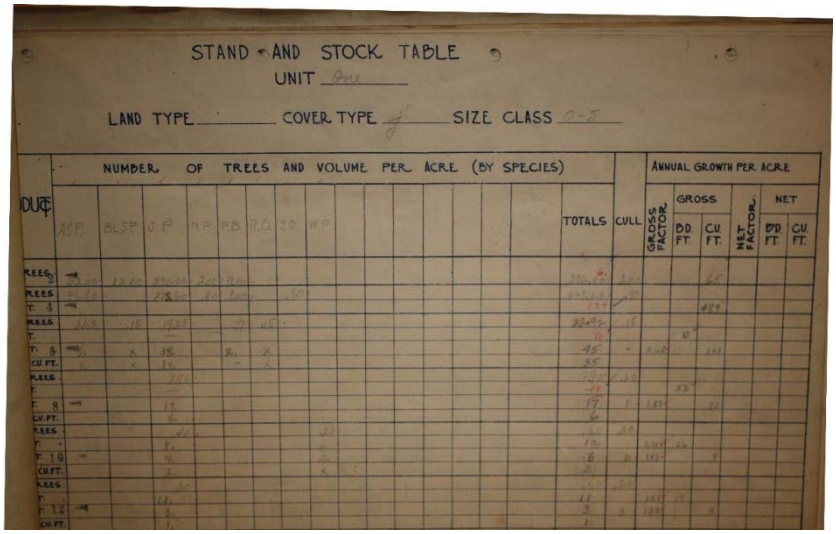

Figure 2. Example of summary and volume table from 1936 Lake States Survey.

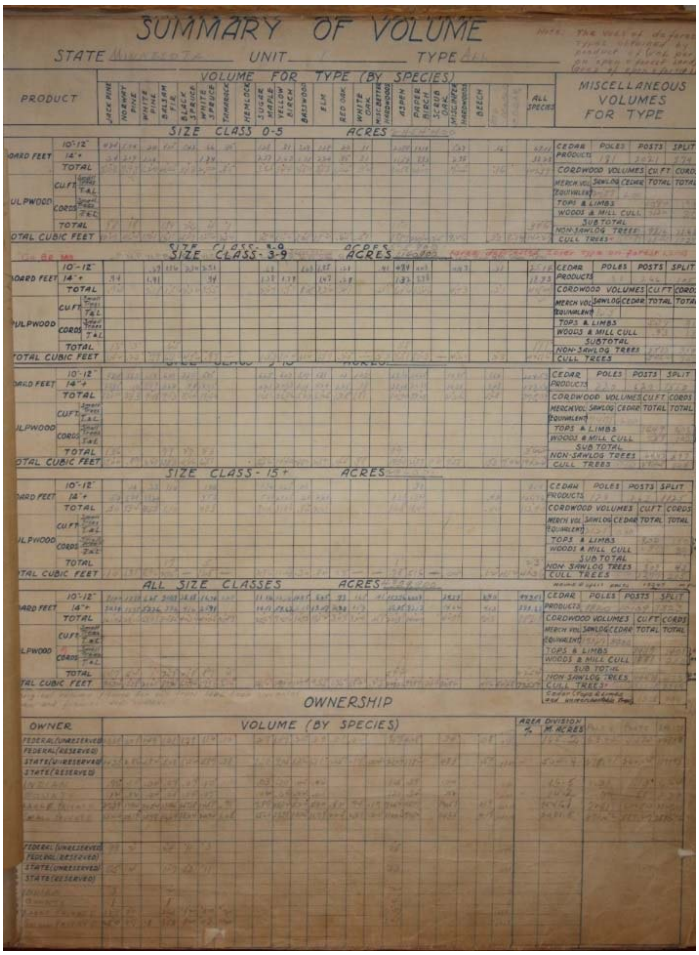

Figure 3. Example of summary and volume table from 1936 Lake States Survey.

2.2. Review of 1936 Lake States Survey methods

2.2.1. Early FIA Survey units and cover types in Minnesota

The Survey was designed to inventory all forested lands in Michigan, Wisconsin and Minnesota. Data was collected by survey units instead of by individual counties. Each state was divided into survey units of four to fifteen million acres. A sketch of the original Survey units was available (USFS 1938) and used in conjunction with county boundaries in Minnesota and ArcMap to provide an instructive map (see Figure 4). Unlike current FIA units, the 1936 survey unit boundaries did not always coincide with county lines. Portions of Aitkin, St. Louis, and Lake counties were split across two or more Survey units. There was no clear explanation as to the reason certain counties were split; it was assumed regions of St. Louis and Lake counties fell within the Superior National Forest in Unit 4.

Unit 4 (Superior) and Unit 6 (Prairie) were not surveyed as part of the Lake States Survey. A separate survey was carried out by the Superior National Forest; final summary data was reconstructed to match the Lake States Survey data. Therefore, per-acre data was not available for unit 4. Unit 6 lacked enough forestland to warrant the resources necessary to carry out a survey in the prairie region. Thus data for unit 6 was based on reconnaissance from unit 5. Although per-acre data was available for unit 6, ownership data was not.

In total, 19,701,700 acres of forestland were surveyed in Minnesota, including 17 forest cover types. Five of those cover types were classified as non-forested: Brush land (2,589,600 acres), grass land (667,700 acres), wooded pasture (565,800 acres), marsh land (300,000 acres) and shelterbelt (86,300 acres), and accounted for 4,209,400 acres across Minnesota. Non-forest cover types were not included in this study. Instead, focus was placed on the remaining 15,492,300 acres of forestland cover types.

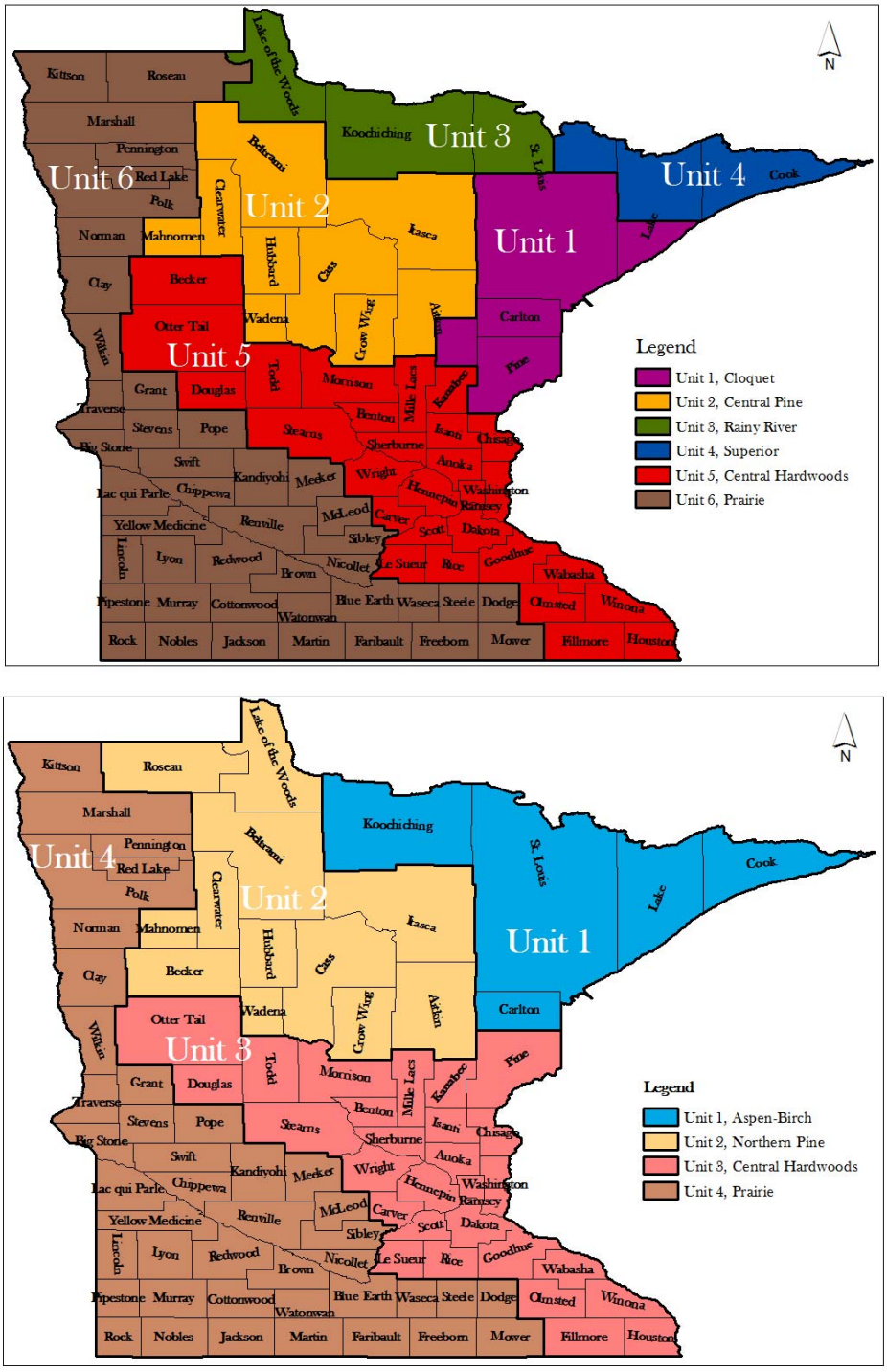

Figure 4. FIA Survey unit and county boundaries for 1936 (top) and 2014 (bottom).

2.2.2. Survey design and field work summary

Survey sample plots consisted of three circular concentric plots totaling 1/5th-acre (see Figure 5). Sample plots were placed at ten chain intervals along east-west transect lines (see Figure 6). The inventory was intended to sample all forested areas in the three states. Trees greater than one-inch diameter were tallied by species and two-inch diameter classes. Plot classifications such as cover type, stand size class, and ownership were designated. For each well-stocked plot, a sample tree of average diameter and species was measured for DBH and height. Table 1 provides a quick reference and example of each field measurement, including Appendices where more detail is provided. In all, measurements were collected for twenty species, thirteen forest cover types, four non-forest cover types, four stand size classes, and six ownership types.

Table 1. Summary of field measurements.

Field measurements		Definition	Example measurement	Appendix
individual tree	DBH	2-inch DBH classes	2" = 1.0-2.9" DBH 4" = 3.0-4.9" DBH etc.	A1.2
	species	20 species	aspen jack pine etc.	A1.3
plot	cover type	13 forest; 4 non-forest	aspen cover (forest) grassland cover (non-forest) etc.	A1.4
	stand size class	4 size classes	new growth (2-4" DBH) pole size (6-8" DBH) etc.	A1.5
	sample tree volume	1 tree per plot of average diameter and species	DBH height etc.	A1.6
	ownership	6 groups	small private large private etc.	A1.7

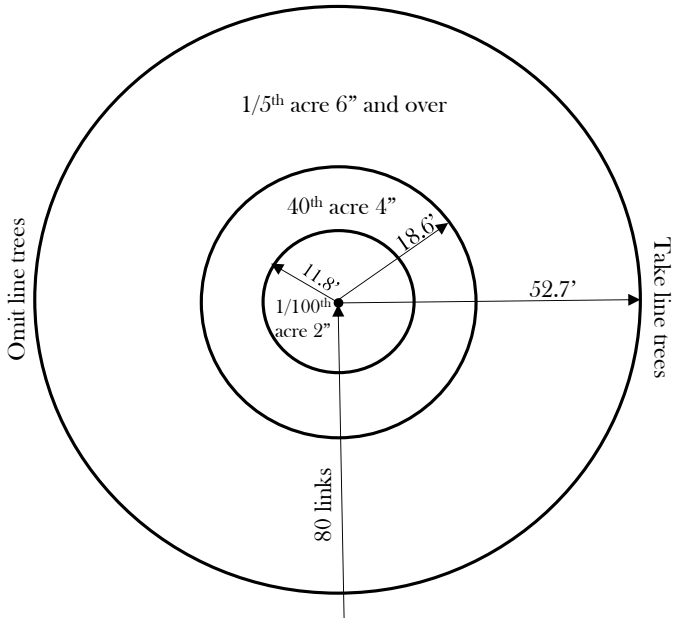

Figure 5. Sample plot design for 1936 Lake States Survey; adapted from Survey Work Plan (USFS, 1935).

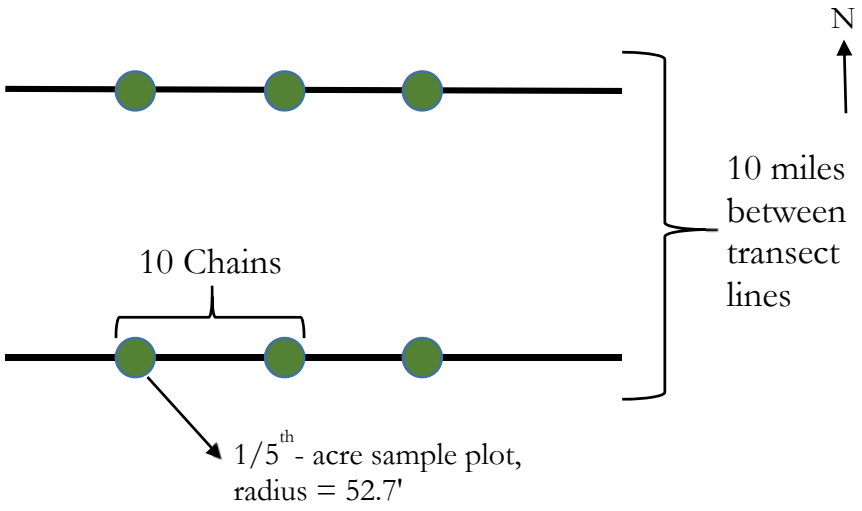

Figure 6. Lake States Survey strip survey design for 1936; adapted from Survey Work Plan and (LaBau, 2007).

2.2.3. Volume of summary books and office work summary

Stand and Stock tables—per acre estimates
A separate stand and stock table for each forest cover type and stand size class combination in a unit provided per-acre estimates for number of trees and volume for each species and diameter class[1]. Stand and stock tables were available for units 1, 2, 3, 5, 6. As mentioned previously, stand and stock tables did not exist for unit 4 because of alternative survey methods. In total, 176 stand and stock tables were available. See Appendix A1.8 for an example table.

Calculating trees per acre
Average trees per acre was a preliminary calculation whereby the total number of trees from plot tally sheets in each species, DBH, cover type and size class combination were reduced to per-acre values using an acreage reduction factor.

Calculating volume per acre
According to the Work Plan, estimating volume of each tally tree was not feasible. Instead, local volume tables were generated using sample tree measurements for board foot, pulpwood cubic foot, and total cubic foot of all sample trees. Local volume tables provided net volume for an average tree in each unit, size class, species and DBH class. See Appendix A1.7 for more details on generating volume tables.

Local volume table figures were multiplied by trees per acre (from the stand and stock tables) to generate average net volumes per acre. Board foot volume per acre was calculated using Scribner log scale for merchantable-sized trees (i.e. trees greater than 9.0" DBH). Pulpwood cubic foot volume per acre was calculated for six species (black spruce, white spruce, balsam fir, jack pine, tamarack, aspen) for pulpwood-grade trees greater than 6" DBH. Cubic foot volume per acre was calculated for all trees greater than 5.0" DBH.

Summary of Volume tables—total volume, area and ownership estimates
The second set of tables in each summary book contained volume summary tables with total volume for each species and product type, and total area in a unit for each cover type and size class. Area and volume by ownership type was also included. One-hundred-twenty summary tables were available across six survey units. See Appendix A1.8 for examples of the following calculations.

Calculating area
Forestland area was determined during Survey office work by dividing net land area of each unit between forest cover types and size classes in proportion to the distribution of sample plots for each. Data on number of plots was not available, so area represented by each plot could not be determined. Forestland areas for each cover type and size class combination were entered into the summary of volume table. Ownership area was also based on the distribution of sample plots for each ownership group in a given unit and cover type.

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[1] Summary tables contained additional data not included in this report, such as cedar volume, volume by ownership type, and annual per-acre gross volume growth estimates. These data have been digitized and are available.

Calculating total volume
Stand and stock tables and summary of volume tables were interrelated. Per-acre volume totals from the stand and stock tables were multiplied by area totals in the volume tables; the product was total volume. Unit volume totals were available for board foot of merchantable trees, cubic foot volume of all trees, and cordwood volume[2] for six pulpwood species.

2.3. Digitizing summary tables and quality control

Microsoft Excel spreadsheet templates were designed to closely mimic the original format of the 1936 tables. Data were entered manually by three personnel, and spreadsheets were then reformatted for querying in Microsoft Access. Queries were developed using SQL language. Databases were subsequently uploaded to an online resource for public use.

Quality control
See Appendix 2.1 for comparisons of digitized data with published figures found in *Economic Notes* (USFS 1938). The purpose of comparing the figures was to determine whether the digitized data was representative of the final Survey results. In most cases, the digitized data closely matched published figures (within 1%). In the case of board foot volume, published figures were based on International 1/4-inch log rule. Saw timber volume in summary books was based on Scribner log rule, underestimating published totals by 18.60%. According to a note in the *Economic Notes 10* (USFS 1938, p.52), figures were converted to International 1/4-inch volumes for publishing—about 18% higher than Scribner—because it more closely reflected output from sawmills.

2.4. Applications of 1936 Survey data

A main objective of the study was to determine whether historic data could be made compatible with recent FIA data. Given that objective, three applications using the historic data were attempted (see sections 2.4.1, 2.4.2 and 2.4.3). As a first step for statewide resolution, using totals from the summary of volume tables, compatibility between historic and current FIA conventions was accomplished by re-naming and re-categorizing attributes. At a statewide resolution, using per-acre totals from the stand and stock tables, total forest area for the state was recalculated to omit areas made up by units 4 and 6 for both historic and current surveys. At finer detail, such as at the survey unit level, historic data had to be re-summarized or re-distributed to match current conventions. This step introduced the most opportunity for error.

Where available, statewide data for 1936, 1977, and 2014 were compared. FIA data for 1977 and 2014 were queried using *EVALIDator 1.6.0.03* (Miles 2014; O'Connell et al. 2014). Appendix 3 provides a full list of tables and attributes used to generate queries. Digitized data from the 1936 Survey was queried using SQL searches in Microsoft Access.

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[2] Pulpwood volume was expressed in cubic foot for the stand and stock tables and then converted to total cubic foot volume in the summary of volume tables. In addition, pulpwood cubic foot volume was converted to cordwood in the volume summary tables. The cordwood conversion was likely 78.3 cubic feet per cord of 16’ logs in 4"+ diameter classes. The precise conversion was not mentioned in the Work Plan, but was mentioned in a USFS publication around the time of the survey for balsam fir (Zon, 1914).

2.4.1. Total statewide comparisons using multiple inventory years

Statewide comparisons by area of cover type

To compare cover type area for the three inventory years, cover types were re-organized. For 2014 and 1977 inventories, Minnesota Department of Natural Resources Cooperative Stand Assessment cover types (MnDNR 2006) were selected as the forest type attribute in *EVALIDator*. In some cases, cover types for more recent inventories had to be combined to match conventions in 1936, and *visa verse*. Table 2 provides a list of cover type combinations across the three inventory years. For instance, aspen, birch, and balsam poplar stands were designated as aspen-birch cover in 1936 (see description in Table A1.5). These three forest types were combined for 1977 and 2014.

Table 2. Forest cover types across inventory years.

2014 and 1977 Forest Types MnDNR	1936 Cover Type
Jack pine	Jack pine
Red pine	Norway pine
Eastern white pine	Eastern white pine
Balsam fir	Spruce-fir
White spruce	
Black spruce	Black spruce
Tamarack	Tamarack
Northern white-cedar	Northern White Cedar
Oak	Oak
	Scrub oak
Northern hardwoods	Northern hardwoods
Lowland hardwoods	Bottomland and swamp hardwoods
Aspen	Aspen
Birch	
Balsam poplar	
Other/non-stocked:	
Eastern red cedar	Non-productive swamp
Other softwoods	
Cottonwood/willow	
Other	
Non-forest (not included):	
	Grassland
	Brush land
	Marsh or Bog
	Wooded pasture
	Shelterbelt

Statewide comparisons by total area of stand size class

Stand size classes were re-categorized to three classes to match 2014 conventions (see Table 3). Old-growth and second-growth size classes from the 1936 Survey were combined to into one size class for large trees.

Table 3. Stand size class designation across forest inventory years.

1936			2014	
Code	**Name**	**Diameter range**	**Name**	**Diameter range**
15+	Old-growth	Trees >15.0"	Large	Trees >11"
9-15	Second-growth	Trees 9.0-14.9"		
3-9	Pole size	Trees 5.0-8.9"	Medium	Trees 5-10.9"
0-5	New growth	Trees 1-4.9"	Small	Trees 1-4.9"

Statewide comparisons of total board foot volume

Total board foot comparisons were made for merchantable-sized trees in 1936 and 2014. Although a merchantable log was defined as 16' in length in both surveys, sawlog diameters differed. For instance, in 1936, a merchantable log had a minimum DBH of 9" inches and a minimum top dib of 8" for hardwoods. FIA protocol in 2014 considered any hardwood tree greater than 11" DBH and 9" dib to be merchantable. Inconsistencies across the two years also existed for softwoods (see Table 4). Overcoming sawlog diameter discrepancies was not possible as volumes were totaled across two-inch diameter classes in the 1936 Survey.

In 1936, saw log volume estimates were based on Scribner log rule, but 2014 FIA volume data was based on the International 1/4-inch rule. Using the modal percent difference from the six units reported in *Economic Notes 10* (USFS 1938), Scribner volume data for 1936 was converted to International 1/4-inch volume estimates using a conversion factor of 18.6% for all species (see Appendix A2.3).

Table 4. Saw log definitions across forest inventory years.

	1936		2014	
Species	Minimum DBH	Minimum top DIB	Minimum DBH	Minimum top DIA
hardwood	9"	8"	11"	9"
conifer	9"	6"	9"	7"

Total cordwood volume of pulpwood

Total cordwood volume of six major pulpwood species was calculated for the 1936 Survey. The six pulpwood species were aspen, balsam fir, black spruce, jack pine, tamarack and white spruce. See Appendix A1.7 for the definition of a cord of wood in 1936. Later FIA inventories did not collect pulpwood volume estimates; therefore, comparisons were not possible for pulpwood between inventory years.

Total cubic foot volume comparisons
In 1936, total forest volume, including board foot and pulpwood, was estimated in cubic foot for all trees greater than 5" DBH. This convention was similar for more recent FIA inventories. Data for cubic foot volume for all trees greater than 5" DBH was available for the 2014 FIA inventory.

Statewide ownership comparisons
The 1936 Survey categorized ownership type into eight categories (see Appendix A1.6), but there were only four categories in the 2014 FIA data. The four ownership groups for 2014 were federal, state, county and private. The 1936 totals were re-categorized into these four groups by combining reserved and unreserved public lands, and small and large private ownership into one group. Unit 6 ownership data was not available from 1936. Since unit 6 was predominately prairie land, it was assumed the 1,416,800 acres of forestland in unit 6 were either privately or county owned. Using 0.17% (the percentage of the remainder of land in county and municipal ownership in the state), unit 4 forestland area was split into county ownership (2,478 acre) and the remainder in private ownership (1,414,322 acres).

Table 5. Ownership groups across forest inventory years.

2014 Ownership Group	1936 Ownership Group
Federal	Federal reserved
	Federal unreserved
	Indian
State	State reserved
	State unreserved
County and municipal	County and municipal
Private	Small private
	Large private

2.4.2. Per-acre statewide comparisons

Statewide totals for average trees-per-acre were compared for 1936 and 2014 inventories by size class and cover type. Due to missing per-acre tree and volume data for unit 4 and much of unit 6, the comparison required recalculating total forest area for both inventory years to exclude the area comprised by unit 4. The total forested area for unit 4 in 1936—1,951,500 acres—was subtracted from the state total. Forested area in Minnesota in 1936 went from 15,492,300 acres to 13,540,800 acres.

For the 2014 inventory, trees-per-acre was calculated using total tree counts divided by area of each size class and cover type combination, less an area and tree count representative of 1936 unit 4. From a sketch of 1936 Survey units (USFS 1938), it was estimated that about 25% of St. Louis, 66% of Lake, and 100% of Cook Counties fell within unit 4 boundaries (see Table 6). Data for 2014 was adjusted by these county percentages. For instance, tree counts and forested area in Cook County were excluded altogether, and data for St. Louis and Lake Counties were partially excluded.

Per-acre estimates were originally calculated for each size class and cover type combination at the unit scale. For statewide comparisons, it was necessary to recalculate the 1936 Survey for trees per acre using total number of trees and total area of each size class and cover type combination. This was similar to how trees-per-acre was calculated using the 2014 data above.

Table 6. County areas in Survey unit 4 for 1936.

County	% of County in 1936 unit 4	% of County data included in 2014 per-acre calculations
Cook	100	0
Lake	66	34
St. Louis	20	80

Trees-per-acre was also compared at the statewide level for white pine stands, including species and DBH. The white pine cover type was chosen based on the assumption that this cover type was assigned similarly across both inventory years, thus minimizing type definition differences. The four most common species in white pine cover in 1936 were aspen, balsam fir, paper birch, and white pine. The two-inch DBH classes were grouped into three DBH ranges (see Table 7).

Table 7. Diameter range classes for summarizing trees-per-acre by species.

Diameter class	Diameter range label
small	2-8"
medium	10-14"
large	>16"

2.4.3. Redistributing historic data across current FIA unit boundaries and quality control

In some instances, complex changes were necessary to make data compatible, most notably for the issue of unit boundaries. Data from the 1936 Survey was organized by six geographic units as opposed to four units in 2014 (see Figure 4). This required a redefinition of boundaries from six units to four. The procedure required several steps and assumptions. A first step involved the development of methods for evenly re-proportioning area of forestland in a unit by *all* the counties making up the unit. The following is an example:

The total area of Mille Lacs County is about 336,000 acres of total land (both forested and non-forested), which is equivalent to about 3% of the 11,800,000 acres of total land making up 1936 unit 5. It was assumed that 3.0% of the 2,300,000 acres of forestland in unit 5, or about 71,000 acres, existed in Mille Lacs County.

To generate the proportions of a unit represented by each county, it was then assumed that 1) all forests were evenly distributed across the unit, and 2) all forests were evenly distributed across the counties in which they were proportioned. This was a crude assumption due to the variability of forest cover and area within any given unit. However, with no additional information, proportionate distribution of the forest was the only reasonable assumption.

Counties were assigned both 1936 and 2014 FIA units. Once units were re-proportioned to individual counties, they were reorganized using the 2014 FIA unit id, and new 2014 unit totals

were calculated using 1936 data. For instance, Lake Mille Lacs County moved from unit 5 in 1936 to unit 3 in 2014.

Quality control

The 1935 Land Economic Survey (MnDNR 1935) provided a means of comparing re-proportioned county totals described above with Hubbard County to determine how the assumptions and methods compared to actual county totals. Appendix A2.2 provides a comparison of total forest area by four stand size classes between the two surveys. In all but the old-growth size class, the re-proportioned county data using USFS data underestimated the Land Economic Survey county totals between 22-25%. The old-growth totals overestimated the Land Economic Survey by 11%. The total forested area of Hubbard County in the re-proportioned data was 13% less than the Land Economic Survey. This is an indication of the error involved with the assumption of proportionate distribution of forest area across counties.

3. RESULTS

3.1. Total statewide comparisons for multiple inventory years

3.1.1. Comparison: Total forest cover type area

Figures 7a and b provide comparisons of area by forest cover types (with and without aspen, respectively) for 1936, 1977, and 2014 FIA inventories. Table 8 provides acres of forest types and total acres for each inventory year. The overall forest area for the three inventories was 15,492,300 acres in 1936, 16,537,380 aces in 1977, and 17,260,177 acres in 2014.

Aspen dominated forest area in all three inventory years, with approximately 7 million acres, roughly 40% of the total forestland area, in all three years. Black spruce was also a common forest type in all three years. Jack pine cover dwindled across the three periods, while oak, Northern hardwoods, and red pine, among others, all increased.

3.1.2. Comparison: Total stand size class area

Comparisons of stand size class for 1936 and 2014 are shown in Figure 8; area by stand size class is listed in Table 9. The most common stand size class in 1936 was small diameter stands, with 9,366,900 acres across the state, followed by 4,558,900 acres of pole-size stands and 1,566,500 acres of stands dominated by large-diameter trees. In 2014, area by three size classes were fairly evenly distributed. Small, medium and large size classes were 6,114,147 acres, 6,191,578 acres, and 4,954,453 acres, respectively.

3.1.3. Comparison: Total volume—board foot, cubic foot, pulpwood cords

The shift in size class distributions between 1936 and 2014 was also reflected in volume estimates for the two inventories. Board foot volume (Figure 9) of merchantable timber in 2014 was over three times greater than in 1936, with totals of 12.4 and 45.3 billion board feet, respectively. The volume of softwood species was slightly greater than hardwoods in 1936; in 2014, volume of hardwood species was greatest, with 27 billion board feet statewide.

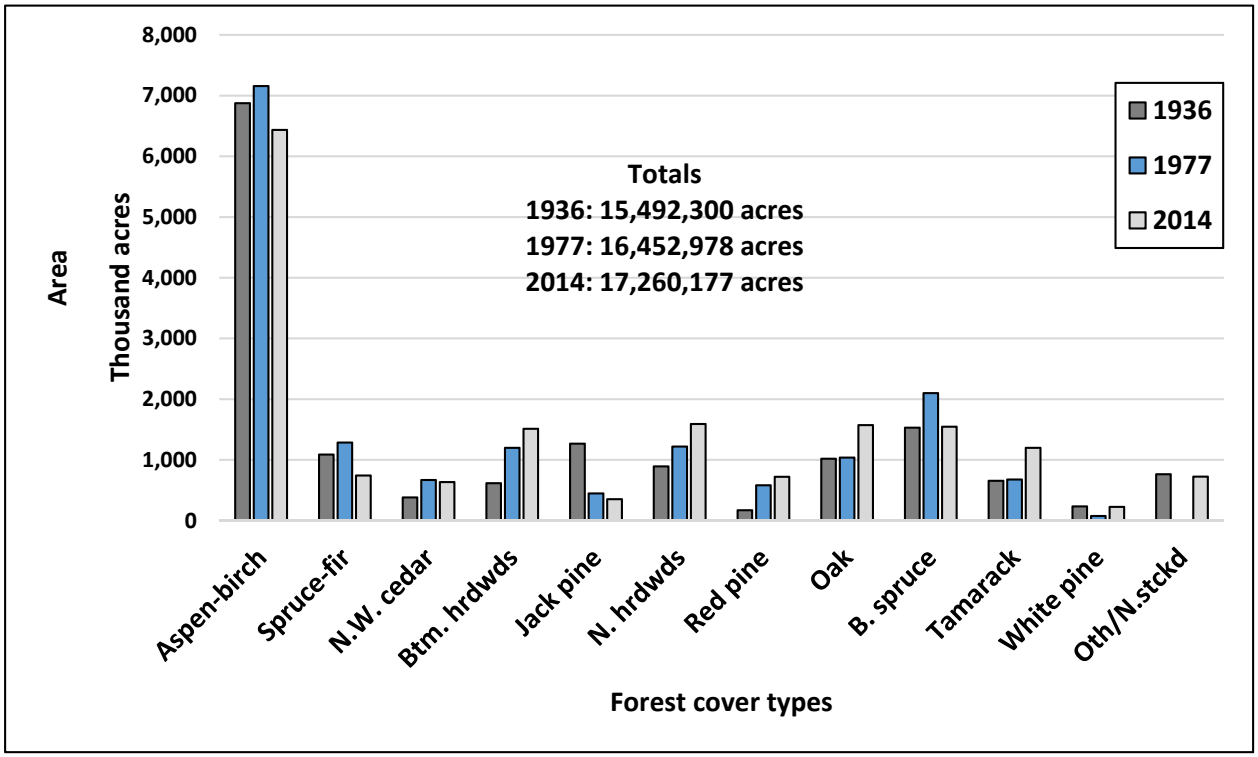

Figure 7a. Area of forestland by forest cover type.

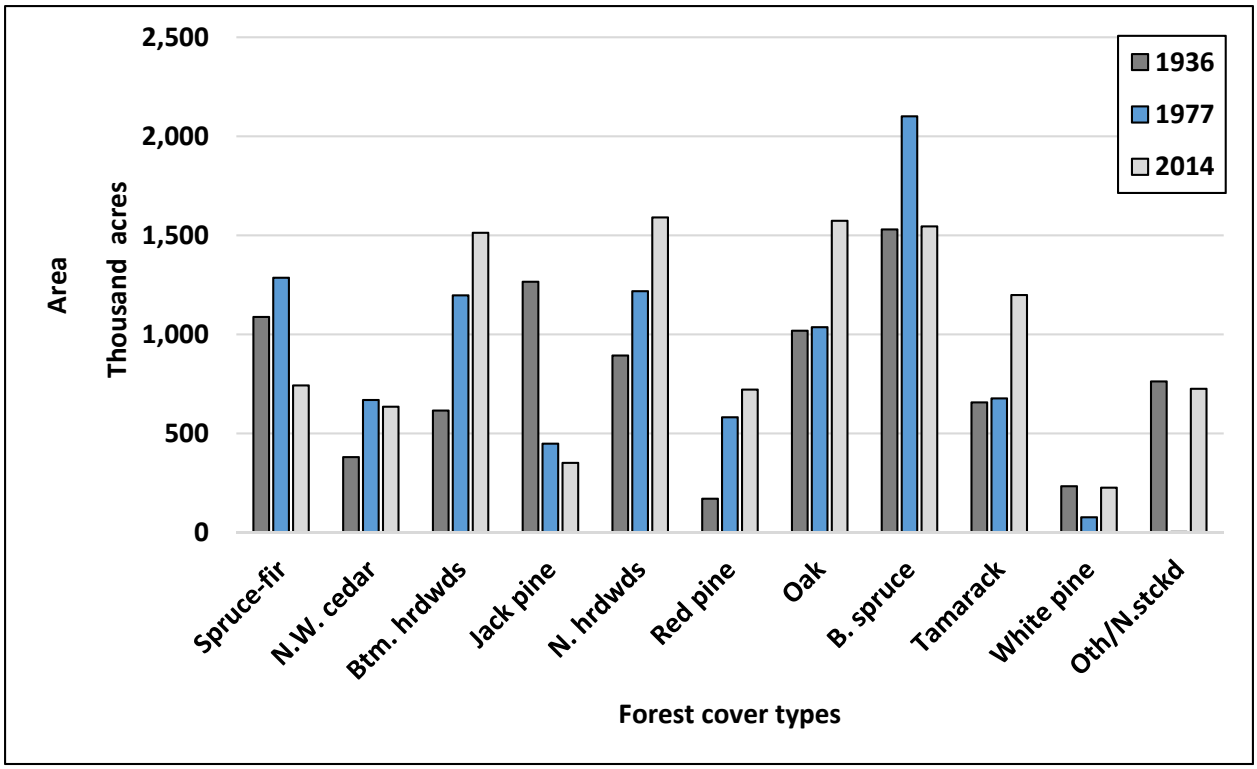

Figure 7b. Area of forestland by forest cover type, excluding aspen.

3.1.3. Comparison: Total volume—board foot, cubic foot, pulpwood cords

The shift in size class distributions between 1936 and 2014 was also reflected in volume estimates for the two inventories. Board foot volume (Figure 9) of merchantable timber in 2014 was over three times greater than volume totals in 1936, with totals equaling 12.4 and 45.3 billion board feet, respectively. Volume of softwood species was slightly greater than hardwoods in 1936; in 2014, volume of hardwood species was greatest, with 27 billion board feet statewide.

Total cubic foot volume by species was also compared between two inventory years (Figure 10); cubic foot by cover type is listed in Table 10. Cubic foot volume of aspen species was greatest in both years, but much greater in 2014 than 1936, with totals around 4.4 billion and 1.6 billion cubic feet, respectively. Similar to cover type area, the volume of oaks and other hardwoods increased greatly between the two years, along with red pine. Jack pine volume decreased, but all other species increased in volume from 1936 to 2014.

The total cordwood volume of six major species used for pulpwood (aspen, balsam fir, black spruce, jack pine, tamarack, and white spruce) is shown in Figure 11. In 1936, the Superior National Forest (unit 4) contained the most pulpwood, over 7 million cords. The other three northern units (units 1, 2, and 3) comprised the second-most pulpwood volume, with units 5 and 6 contributing but a small proportion of total pulpwood. Table 11 lists cordwood volume totals by species and unit. In 1936, jack pine and aspen species provided the highest volume of cordwood; 5.4 and 4.2 million cords, respectively. In total, there were 18.25 million cords of pulpwood in 1936.

Table 8. Area of forestland by forest type across multiple inventory years.

Forest Type	1936	1977	2014
		(acres)	
Aspen-birch	6,875,300	7,157,014	6,434,322
Spruce-fir	1,088,300	1,286,046	742,952
Northern white cedar	380,600	668,720	635,336
Bottomland hardwoods	616,100	1,197,491	1,513,483
Jack pine	1,266,000	448,675	351,962
Northern hardwoods	893,600	1,218,646	1,591,054
Red pine	170,500	581,449	721,609
Oak	1,018,400	1,036,569	1,573,699
B. spruce	1,529,800	2,100,800	1,545,309
Tamarack	656,900	677,057	1,198,742
White pine	233,700	76,711	226,313
Other/Non-stocked	763,100	3,800	725,396
Total	15,492,300	16,452,978	17,260,177

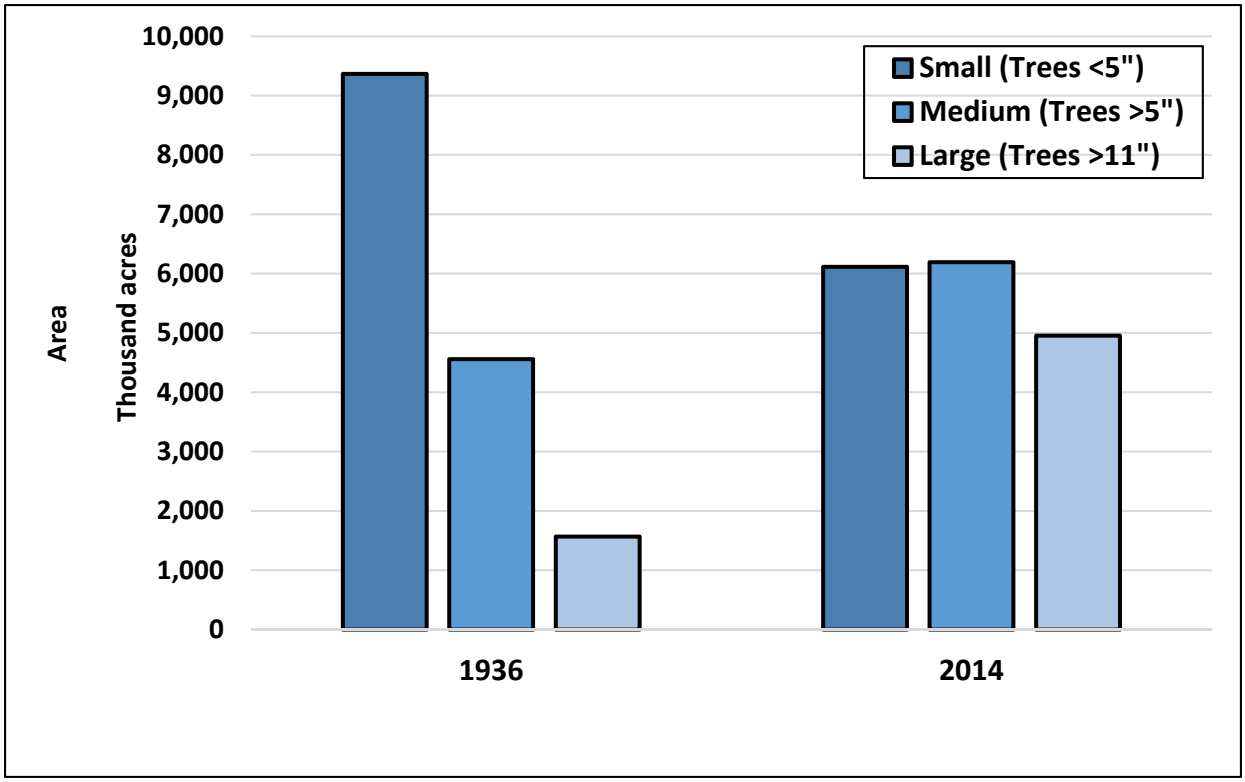

Figure 8. Area by stand size class distribution across two inventory years.

Table 9. Area of stand size class distribution across two inventory years.

Stand Size Class (DBH range)	1936	2014
	(acres)	
Small (Trees <5")	9,366,900	6,114,147
Medium (Trees >5")	4,558,900	6,191,578
Large (Trees >11")	1,566,500	4,954,453
Total	15,492,300	17,260,178

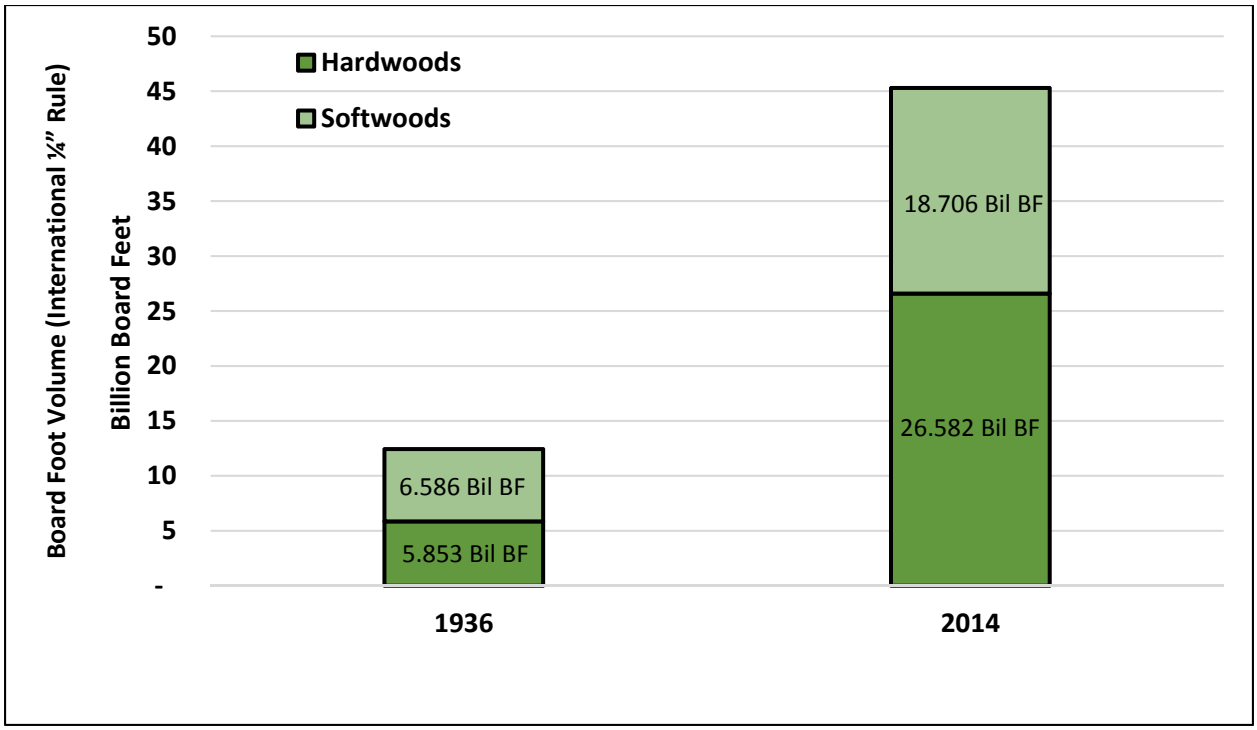

Figure 9. Merchantable volume for hardwood and softwood types, 1936 vs 2014.

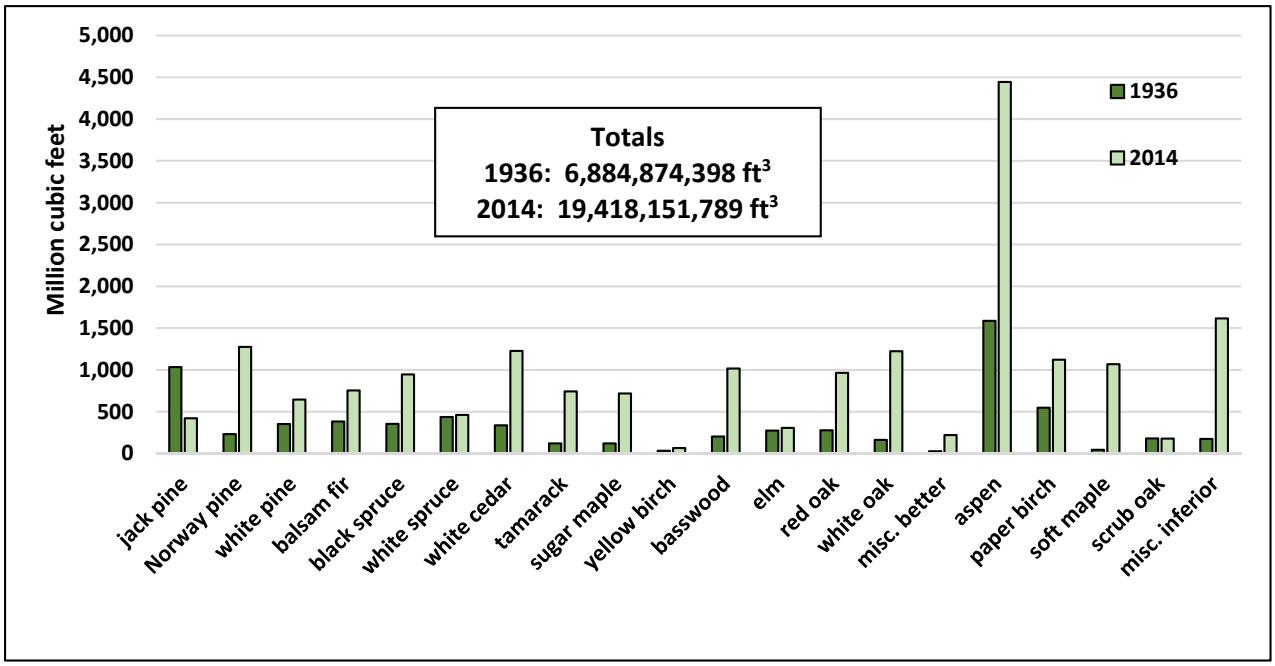

Figure 10. Total cubic foot volume by species across two inventory years.

Table 10. Volume of total cubic volume by species across two inventory years.

Species group	1936	2014
	cubic foot	
jack pine	1,034,451,369	421,167,044
Norway pine	231,301,281	1,274,498,584
white pine	352,165,791	645,694,579
balsam fir	383,523,000	754,772,678
black spruce	355,538,020	946,200,441
white spruce	436,743,135	461,018,030
white cedar	336,563,700	1,226,671,184
tamarack	121,000,636	742,619,459
sugar maple	121,263,508	719,113,502
yellow birch	33,340,700	65,770,543
basswood	202,867,278	1,016,940,837
elm	274,358,800	306,407,957

Species group	1936	2014
	cubic foot	
red oak	277,401,400	964,869,729
white oak	162,292,500	1,222,871,787
misc. better hardwoods	26,390,200	221,538,587
aspen	1,587,602,880	4,445,148,582
paper birch	547,287,200	1,122,273,281
soft maple	44,717,000	1,068,041,276
scrub oak	180,740,900	177,683,429
misc. inferior hardwoods	175,325,100	1,614,850,280
Total	6,884,874,398	19,418,151,789

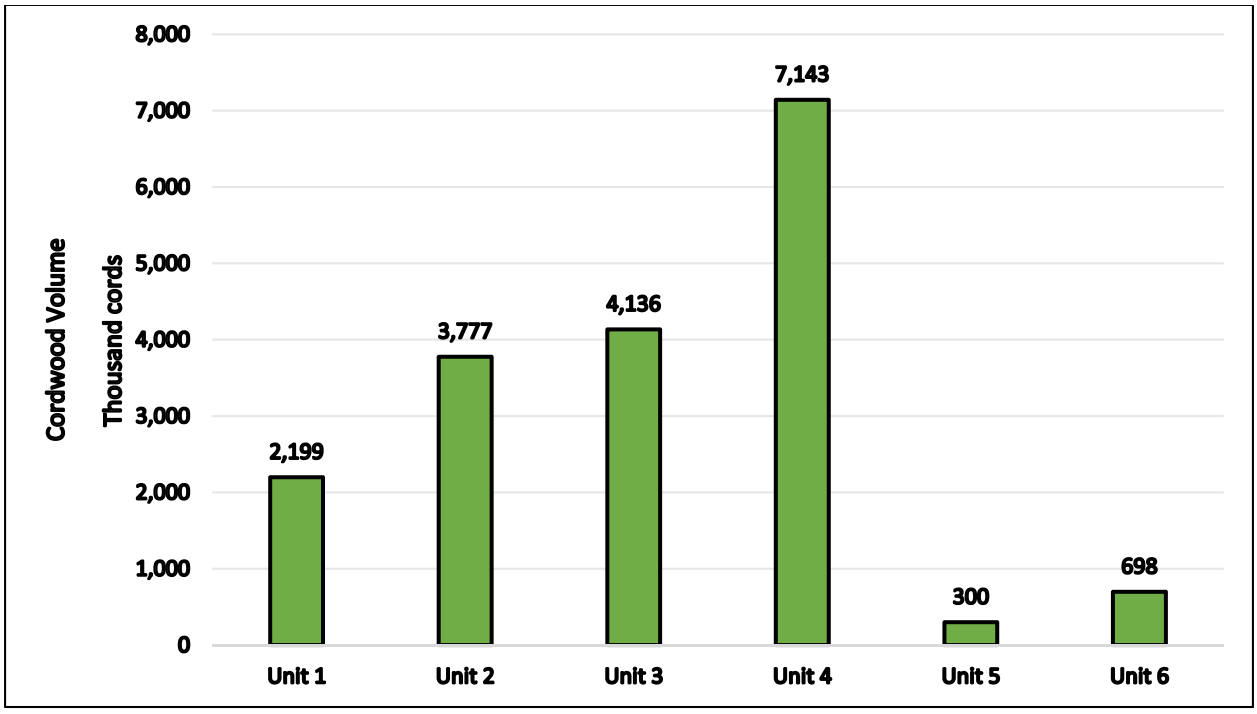

Figure 11. Cordwood volume for six pulpwood species in 1936 survey units.

Table 11. Cordwood volume for six species in 1936 survey units.

Species	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Total
Aspen	593,000	1,567,000	650,588	738,000	197,049	476,540	4,222,178
Balsam fir	751,061	574,000	694,157	484,000	22,441	25,581	2,551,240
Black spruce	216,911	292,000	1,748,401	0	14,605	142,159	2,414,075
Jack pine	546,737	1,144,000	441,607	3,259,000	2,255	11,876	5,405,476
Tamarack	3,563	95,000	436,837	9,000	61,296	34,646	640,343
White spruce	87,753	105,000	164,451	2,653,000	2,425	6,980	3,019,609
Total	2,199,025	3,777,000	4,136,042	7,143,000	300,070	697,783	18,252,920

3.1.4. Comparison: Area by ownership type

Figure 12 compares ownership groups between 1936 and 2014; Table 12 lists area by ownership group for both inventory years. Public ownership, most notably municipal and county-owned land, increased from a total of 24,100 acres in 1936 to 2.6 million acres in 2014. We note the 1930s were a period of considerable tax forfeiture of private land. Private ownership decreased from 11,184,500 acres in 1936 to 7,806,457 acres in 2014.

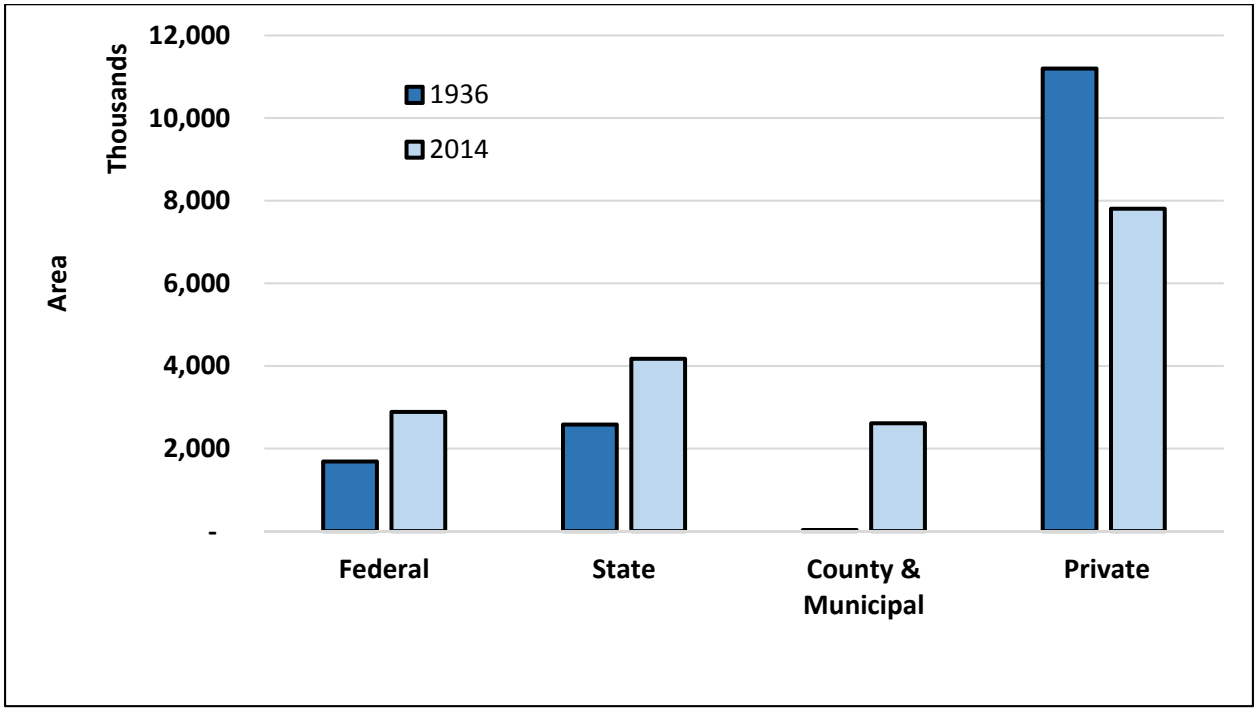

Figure 12. Forestland area by ownership group across two inventory years.

Table 12. Forestland area by ownership group across two inventory years[3].

Ownership Group	1936	2014
	(acres)	
Federal	1,684,500	2,885,441
State	2,582,400	4,174,438
County and Municipal	26,578	2,610,977
Private	11,198,822	7,806,457
Total	15,492,300	17,477,313

[3] Ownership data was not available for the prairieland region (Unit 6 in 1936). The 1,416,800 acres of forestland in unit 6 was split between county and private ownership. From unit 6 forestland area, 2,478 acres were added to the county and municipal ownership type based on the statewide percentage of land in county ownership (0.17%). The remainder of unit 6 forestland, 1,414,322 acres, were added to the private ownership group.

3.2. Per-acre statewide comparisons

Trees-per-acre estimates by forest cover type were compared across two inventory years (see Figure 13). In 1936, stands rarely exceeded 750 trees-per-acre (all species), except in the large diameter stand size class. Trees-per-acre in aspen stands in 1936 were among the lowest in the state in small and medium size classes. Overall, trees-per-acre in 1936 were higher in pine species than hardwoods, but forests were relatively poorly stocked throughout the state. In 2014, cedar was an important species across all three size classes. However, the high per acre count for cedar includes all tree species—a majority of which were small balsam fir. In addition, trees-per-acre in 2014 were highest in aspen and black spruce cover types.

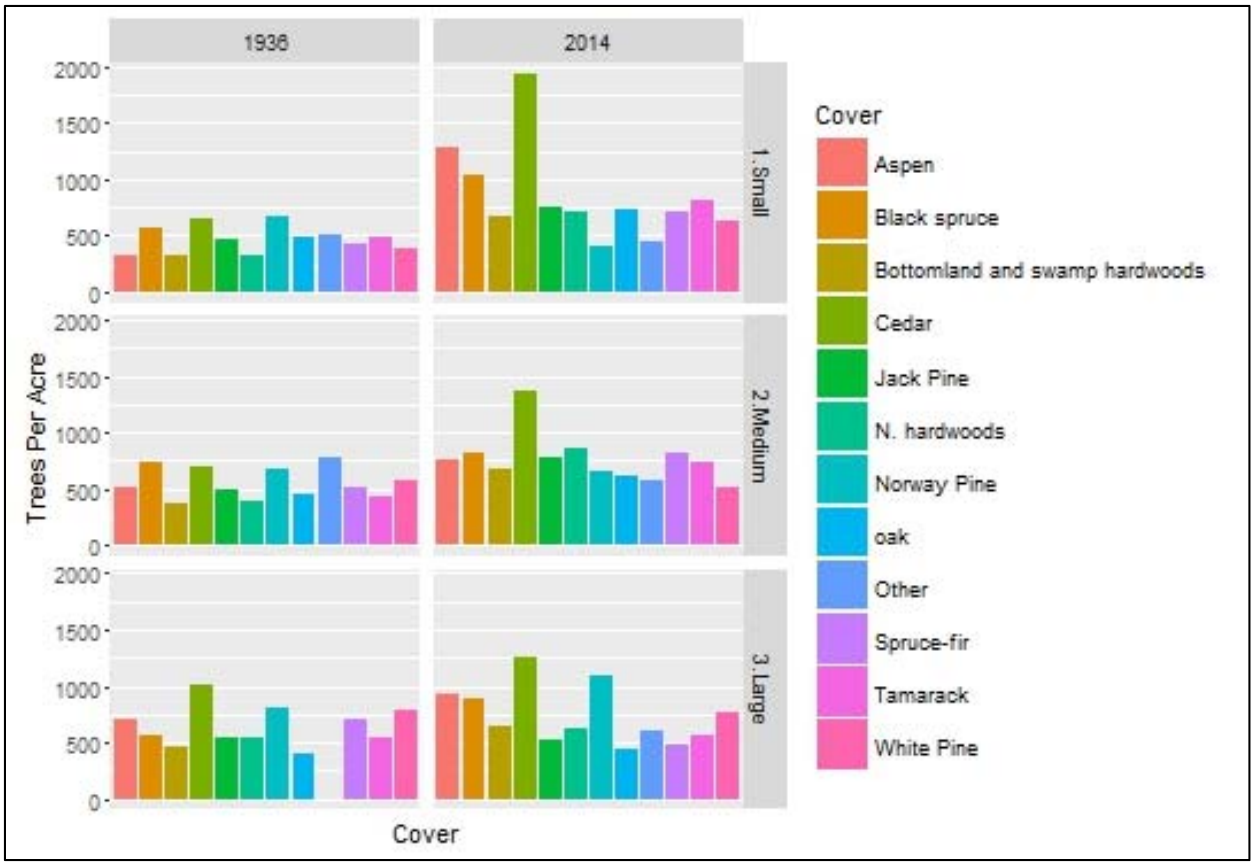

Figure 13. Trees per acre by cover type and stand size classes for 1936 vs 2014.[4]

Trees per acre estimates were also compared for four important species in white pine stands across three diameter classes and three size classes (see Figure 14). Species and diameter composition shifted across the three size classes. Very few large trees existed in small and medium size classes, with white pine, aspen and paper birch dominating species type. In the large size class, white pine made up most of the larger diameter trees, but balsam fir became most common in the small diameter range in the larger size class.

[4] Excludes 2 million acres of forested land in 1936 unit 4. Total adjusted forested area for 1936 and 2014 inventories were 13,540,800 and 15,308,677 acres, respectively

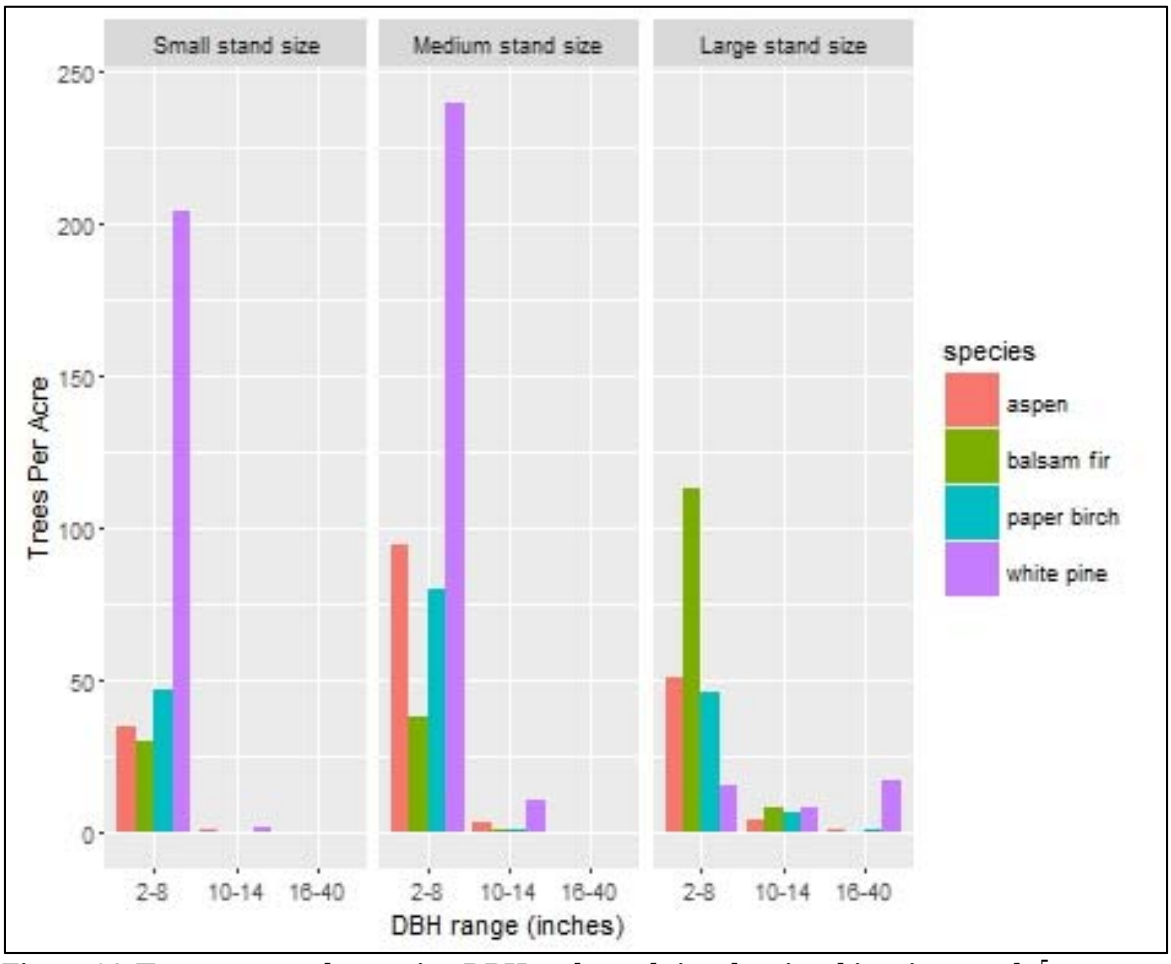

Figure 14. Trees per acre by species, DBH and stand size class in white pine stands.[5]

[5] Excludes 2 million acres of forested land in 1936 unit 4. Total adjusted forested area for 1936 and 2014 inventories were 13,540,800 and 15,308,677 acres, respectively

3.3. Unit comparisons using redistributed FIA unit boundaries

Figure 15 provides a comparison of total forest area across two inventory years with re-proportioned unit totals so that both inventory years are represented by four survey units. Total area of forestland from 1936 to 2014 increased in units 1, 2, and 3. Unit 4 forestland decreased from 1936 to 2014.

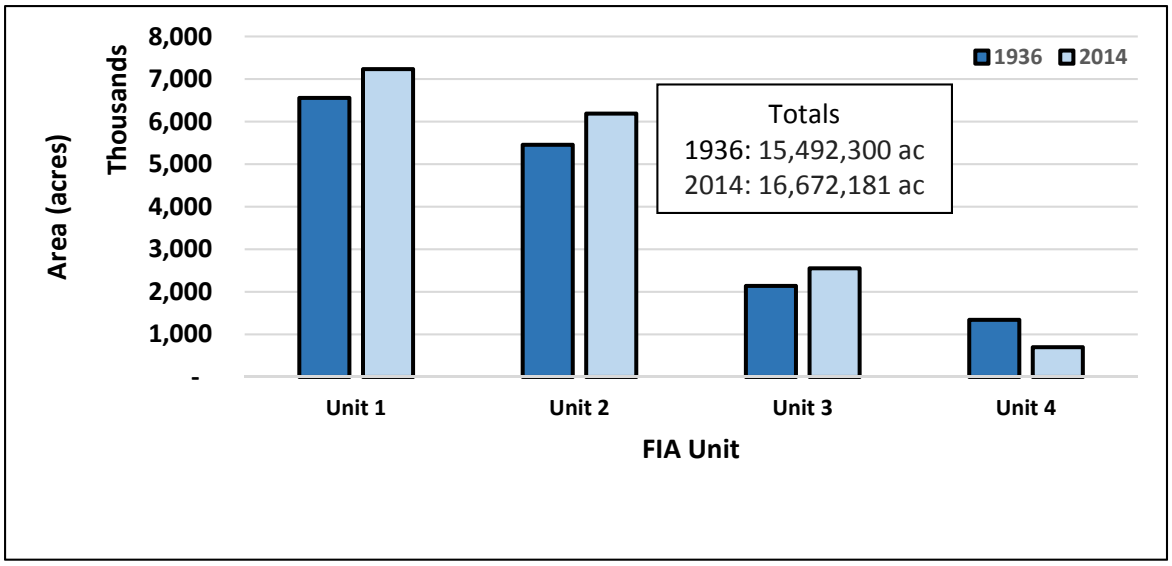

Figure 15. Forest area by adjusted unit boundaries.

4. DISCUSSION

It was possible to restore historic data from the 1936 Survey using available summary books. However, restored data was most complete and compatible with current FIA data when compared statewide. Restored data closely matched final figures published at the time of the survey for area of size class, cover, and volume in each unit (USFS 1938). This conclusion was despite likely differences in naming conventions and other survey methodologies across inventory years.

At smaller scales, limitations in the data made meaningful comparisons more difficult. Without number of plots and thus the area represented by each plot, it was not feasible to accurately deduce per acre estimates for unit 4 using per acre volume and tree counts from nearby units. Furthermore, without number of sample plots it was not possible to determine the measure of variability of the dataset within Survey units.

When county boundaries were redistributed from 1936 FIA units to 2014 FIA units and data was re-proportioned, restored data was less accurate than at the unit level due to assumptions that cover types, size classes, and species locations were evenly distributed across each respective FIA unit. When compared to final figures from a county survey at the time, restored data both underestimated and overestimated published figures by more than 10% (MnDNR 1935).

Despite its limitations, the dataset offers a meaningful resource: a large systematic sample of the entire forested regions of Minnesota following a period of high extraction and preceding an era of rapid forest growth. Not only does the dataset offer insight into the conditions of forests over eighty years ago, but it provides opportunity for observing shifts in species composition and forest dynamics.

4.1. Total statewide comparisons

Comparisons generated in the study demonstrated the types of summary comparisons that could be made using the restored data. Statewide total comparisons across two or three inventory years showed clear changes in forest conditions during an eighty-year period. Firstly, total forest area expanded by 2 million acres. It was important to note that over four-million acres of lands inventoried in the Survey consisted of then non-forested covers such as brush land and grass land that were omitted from the analysis. This seemed compatible with current FIA protocol, which also omits such non-forested cover from "forest types"

Minnesota forests in 1936 were highly cut-over, with little mature and older stands remaining. The state was dominated by large areas of newly developing forests leading to the often noted "wall of wood" coming forward over the subsequent decades. On a whole, the state resembled a largely even-aged forest, with three distinct age classes descending in acreage from large areas dominated by young stands to much smaller areas of mature and old-growth forest. Today, our forests are much older, on average, with similar acreage in the small, medium and large stand size classes.

Minnesota's forests have also shifted from a balance between hardwoods and softwoods (if not a slight dominance by softwoods), to being dominated by hardwoods. In 1936, a slight majority of cubic foot volume of wood in Minnesota's forests was softwoods. While both hardwoods and softwoods volumes have increased, hardwoods contribute substantially more cubic foot volume than softwoods in 2014. Fire suppression has also favored the less fire-dependent hardwood species like oak and other hardwoods instead of pines. Red pine, however, increased substantially in both volume and acreage likely due to its popularity as a merchantable timber species for sawlogs, pulpwood and utility poles, and a focus on red pine for reforestation efforts over the last century years. Adding to the decline in pine species is the increasingly important role that aspen has played in Minnesota's forests and forest industry over the last 4-5 decades.

In addition to changes in forest structure and composition, forest ownership has also shifted. Public ownership increased while private ownership decreased between 1936 and 2014. Land ownership held by municipalities and counties increased dramatically, which is a reflection of high land tax delinquency during the Great Depression (MACLC, 2006).

4.2. Per-acre statewide comparisons

Trees per acre comparisons across early and more recent inventories provided a means of comparing stocking of stands across forest types. Overall, the results mimic other statewide comparisons. Forests in 1936 were highly cut over and poorly stocked; pine species were more dominant than hardwoods. Trees per acre in aspen cover was much lower than expected, but is likely a testament to the low stocking at the time. According to published figures, over half of the aspen stands in Minnesota were poorly stocked in the 1936 Survey (USFS 1938).

In 2014, per acre stocking was generally much higher than in 1936. Cedar cover showed a surprisingly high result, but likely due in part to the small area of cedar in the state and high number of stems greater than 1". Over half of the seven million trees in cedar cover were 1-3" DBH, most of which were balsam fir.

Summarizing trees per acre for species types and diameter class ranges for a cover type was an example of the most nuanced use of the historic data. In white pine stands, trees shifted in both size and species across stand size classes. Small aspen and white pine dominated young stands that shifted to an overstory of white pine in older stands with small balsam fir replacing aspen. Despite lacking data for unit 4, the restored data provide instructive detail on forest composition.

4.3. Unit comparisons

Summaries of the 1936 data using re-proportioned unit boundaries methodology were less accurate, but may provide an opportunity to compare regional trends over time at the unit level. Proportions used to generate forestland area for each of the four present day FIA units could also be used to re-proportion cover type area, volume, and tree counts per acre. However, any results using this methodology should be interpreted with caution.

4.4. Limitations of the data

Discrepancies in methodologies and naming conventions from different FIA inventories made it difficult in some instances to accurately compare data across the inventory years. Forest cover types and size class designation were made in the field in 1936. Today, FIA forest types and size classes are determined from stocking algorithms. In both cases, and for any single forest cover type or size class, there exists a variety of species and DBH classes. Therefore, changes in forest cover area should be interpreted with caution. A similar conclusion was made by Jaakko Pöyry Consulting, Inc. (1992) and Guilkey et al. (1954), when comparing forest cover change in Minnesota using different FIA inventories. In some cases, it is clear that definition and procedural changes limit the accuracy of data. An example is the black spruce cover type. It is unlikely that a large influx of black spruce forest area occurred in 1977 (see Figure 7b) and that it returned to 1936 levels by 2014. Kilgore et al. (2005) discuss such problems in interpretation with recent FIA inventories.

Several attempts were made to impute unit 4 and some cover types for unit 6 per-acre estimates based on ratios of volume to DBH distribution in neighboring units. It was postulated that if volume was distributed across DBH classes similarly, it could be assumed the number of trees in each DBH class would also be similar. However, when compared, volume of species across size

classes and cover types in each unit were inconsistent, making it difficult to assume any relationship between DBH distribution and volume in a size class and cover type. Without number of plots and thus the area represented by each plot, it was impossible to accurately estimate per acre values for unit 4 using per acre volume and tree counts from nearby units.

The 1936 restored data, as sourced from summary of volume tables, provides only summaries of data, not individual observations. This limits statistical analysis of data, namely assessing sampling errors. Furthermore, the data lacks common forest site quality measures such as site index that can help characterize and compare across differing forest conditions.

4.5. Access to the Study Data

These data are now available on the Interagency Information Cooperative (IIC) website under the heading "IIC Study Areas and Projects." The URL to access these data is: http://iic.umn.edu/project-areas/forest-inventory/historic-data/1936-usfs-survey/. These data are stored in Microsoft Access and sample queries are provided.

5. CONCLUSIONS

This study has provided insight on important details of forest change over a long time period. The general changes from 1936 to the present have been known to experts in the field, but have not been well documented and understood by broader audiences, including many professionals.

Opportunities for further research utilizing the restored data are considerable and extend within and beyond forest summaries at the state and unit level. Examples are examination of long term changes in species composition including shifts among units and linkages to changing environmental conditions. The potential of such analyses using the restored data is enhanced by the usability of trees per acre data when unit 4 area is removed, as demonstrated in section 4.2. Understanding tree species composition change can also help in understanding and managing forest resources in the natural and anthropogenic stressors, singly or in combination.

Further research may also provide insight into the impacts forest resources and land use change have had on society. Ownership changes from private to public; size class distribution from young to older forests; and changes in species composition provide potential insight into the way forest management objectives in the state have shifted over the past eighty years. Historic and recent trends may also be useful in predicting future forest management trends. In brief, this dataset provides considerable missing detail on the history of forest use and management in Minnesota.

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APPENDIX 1: 1936 USDA Forest Service Lake States survey data descriptions with notes.

Table A1.1. Historic records from the 1936 USFS Lake States survey.
Summary of volume books

State	Unit Books	Other books
Minnesota	1-6	All Units Combined; original sheets for units 1-6
Michigan	1-4	
Wisconsin	8-9 (missing 7)	

File boxes stored in Room 305, Green Hall, University of Minnesota, St. Paul Campus

Container Number	Description
Series Title:	***Special Growth and Yield Data Study 1936***
5	field and office work plans, memoranda, and preliminary data compiled from field data (e.g. stand age, annual growth, and volume)
6	growth and yield calculations for Michigan and Wisconsin
7	the original field tally sheets described above
8	growth and yield calculations for Minnesota and Michigan
47	Age and Growth Sample Trees, Michigan and Wisconsin
	Series Title: *RE-LS [Research Lake States] FOREST SURVEY—Michigan, 1936*
13	area calculations, plot summary, and stand tables for Michigan Forest Survey
14	log grades, volume tables, and sample tree summaries
22	calculations for volume tables
Series Title:	***RE-LS FOREST SURVEY—Wisconsin, 1936***
16	area calculations, inventory volume summaries, and stand
Illegible	volume calculations, farm woodland survey study
	Series Title: No official label
None	Minnesota Survey 1959: In the front of this container is a file of USFS documents from the 1930s that mostly deal with land classification and local communities in northern Minnesota. The remaining contents are not well organized; some volume calculations and ownership information for Minnesota from the 1966 Forest Survey

Table A1.2. Two-inch diameter class ranges.

DBH Class	Minimum Diameter	Maximum Diameter	DBH Class	Minimum Diameter	Maximum Diameter
2	1.0	2.9	**24**	23.0	24.9
4	3.0	4.9	**26**	25.0	26.9
6	5.0	6.9	**28**	27.0	28.9
8	7.0	8.9	**30**	29.0	30.9
10	9.0	10.9	**32**	31.0	32.9
12	11.0	12.9	**34**	33.0	34.9
14	13.0	14.9	**36**	35.0	36.9
16	15.0	16.9	**38**	37.0	38.9
18	17.0	18.9	**40**	39.0	40.9
20	19.0	20.9			

Table A1.3. Species common and botanic names.

Second grouping	Species grouping	Species group code	Included species common name	Included species botanic name
Pine	jack pine	JP	jack pine	*Pinus banksiana*
	Norway pine	NP	Norway pine	*Pinus resinosa*
	white pine	WP	white pine	*Pinus strobus*
Other conifers	hemlock	Hem	hemlock	*Tsuga canadensis*
	balsam fir	Bal	balsam fir	*Abies balsamea*
	black spruce	Bsp	black spruce	*Picea mariana*
	white spruce	Wsp	white spruce	*Picea canadensis*
	white cedar	Ced	white cedar	*Thuja occidentalis*
	tamarack	Tam	tamarack	*Larix laricina*
Better hardwoods	sugar maple	SM	sugar maple	*Acer saccharum*
	yellow birch	YB	yellow birch, black birch	*Betula lutea, Betula lenta*
	basswood	BW	basswood	*Tilia glabra*
	elm	Elm	American elm, rock elm, slippery elm	*Ulmus americana, Ulmus racemosa, Ulmus fulva*
	red oak	RO	N. red oak, black oak	*Quercus borealis, Quercus velutina*
	white oak	WO	white oak, burr oak	*Quercus alba, Quercus macrocarpa*
	beech	Be	beech	*Fagus grandifolia*
	miscellaneous better hardwoods	Ms	b.nut, bl. walnut, bl. cherry, hickory spp., w. ash, h.berry, bl. locust, O. buckeye, sycamore, Ky. coffeetree, h. locust, A. chestnut	*J. cinerea, J. nigra, P. serotina, Hicoria spp., F. americana, C. occidentalis, R. pseudoacacia, A. glabra, L. tulipifera, P. occidentalis, G. triacanthos, C. dentate*
Inferior hardwoods	poplar (aspen)	Asp	quaking aspen, big tooth aspen, balm of Gilead, cottonwood	*Populus tremuloides, Populus grandidentata, Populus balsamifera, Populus deltoides,*
	paper birch	PB	paper birch	*Betula papyrifera*
	soft maple	RM	red maple, silver maple, box elder	*Acer rubra, Acer saccharinum, Acer negundo*
	scrub oak	SO	scrub oak	*Quercus ellipsoidalis, Quercus spp. poor form*
	miscellaneous inferior hardwoods	MsI	black ash, green ash, ironwood, willow	*Fraxinus nigra, Fraxinus lanceolate, Ostrya virginiana, Salix nigra*

Table A1.4. Descriptions of forest and non-forest cover types.

Code	Name	Forest Cover Type Description
j	Jack Pine	Stands in which pine predominates, jack pine is most prominent
n	Norway Pine	Stands in which pine predominates, Norway pine is most prominent
w	White Pine	Stands in which pine predominates, white pine is most prominent
e	Bottomland and Swamp Hardwoods	Shallow swamps, overflow land or second bottoms. The characteristic species of this type are black ash, American elm and soft maples. They may occur in different proportions but together they predominate over other species which occur in the mixture. Associates include balsam poplar, yellow birch, green ash, black willow hackberry, black walnut, butternut, silver maple, swamp white oak, white pine, tamarack, cedar hemlock, spruce and occasional other hardwood species. On alluvial bottoms in the southern part of the region, the associated species are black walnut, butternut, black willow, green ash, hackberry, balsam poplar and swamp white oak
m	Northern Hardwoods	Principal species: sugar maple, hemlock, yellow birch, basswood and beech. Associated species: These occur in less proportion. They are white pine, red oak, white ash, balsam fir, spruce, paper birch and ironwood, elm and cedar.
a	Aspen	Areas on which aspen and paper birch make up 60% or more of the stand.
o	Oak	Central Hardwoods. Includes stands in which white, red and burr oak are the chief species in association with maple, basswood and other hardwoods. Occurs chiefly in the southern part of the region.
so	Scrub Oak	The predominating species is jack oak, white oak, burr oak, black oak, scarlet oak and red oak of very poor form.
b	Spruce-Fir	White spruce and balsam fir are the key species, although neither may alone predominate. White cedar, aspen and paper birch are common associates, while black spruce, black ash, yellow birch and hemlock, white pine or even jack pine may occur in the mixture. The type occurs on upland soils and on swamp borders.
s	Black Spruce Swamp	This type is closely confined to acid peat bogs with poor drainage and may thus be distinguished from the spruce-fir type which grows on upland soils. Black spruce may occur in pure stands or mixed with balsam-fir, tamarack and cedar.
t	Tamarack Swamp	This type is very similar to the black spruce type in characteristic associates and site, but tamarack predominates.
c	Cedar Swamp	This type usually occurs on shallow peat. Swamp species including black spruce, balsam fir, tamarack, paper birch are usually associated with it and not infrequently yellow birch, black ash, red maple, white pine, and balsam fir.
s	Non-productive Swamp	Scrubby spruce or tamarack on deep poorly drained peat, usually less than 5" DBH at 100 years.
m(h)	Hemlock	This will be used to designate stands in which hemlock clearly predominate.
		Non-Forest Cover Type Description
wp	Wooded Pasture	Some trees but not enough for forest classification
gr	Grass or Light Brush	Deforested plantable areas--grass, bracken, sweet fern and light bush.
br	Brush	Deforested brush or slash areas which cannot readily be planted, including temporarily deforested land
ms	Marsh or Bog	Includes areas in rushes, sedge or brush such as alder, willow, leatherleaf or Labrador tea

Table A1.5. Stand size class definitions.

Name	Stand size class	Description and diameter range
15+	Old-growth	Old-growth; plots with at least 400 BF; majority of trees >16" (15.0")
9-15	Second-growth	Second-growth; Plots with at least 400 BF; majority of trees 10-14" (9.0-14.9")
3-9	Pole size	Plots with less than 400 BF but at least 0.6 cords of wood; 6-8" (5.0-8.9")
0-5	New growth	Plots with less than above but at least 20 trees 2-4" (1-4.9")

Table A1.6. Volume table data descriptions.
Sample trees and local volume tables.[6]

Sample trees	Sample tree measurements for DBH, height, and merchantability were taken in each well-stocked plot for a tree of average size and species. Sample trees were diagrammed on plot tally sheets to calculate volume per section of tree. Each sample tree was measured for board foot, total cubic foot, and pulpwood cubic foot volume.
Local volume tables	Sample tree measurements were used to generate local volume tables for net volume for an average tree in each species, DBH class, unit, and in two size classes (saw timber-sized trees in 9-15 & 15+ size classes, and small growth 0-5 & 3-9 size classes).
Merchantable board foot	Local board foot volume tables were generated from sample trees of merchantable size using Scribner log scale, curved ($0.79D^2 4$), and Girard form class composite taper tables developed for the region. Volume per tree was based on 16' logs, adjusted for taper, that were at least 9.0" DBH and greater than 8.0" dib in hardwoods and 6.0" dib in softwoods (see Table below).
Total cubic foot	Local volume tables for net cubic foot were generated from all sample trees greater than 5.0" DBH. This included saw log trees, culled saw log trees, pulpwood species and all other species, with the exception of volume of tops and branches of all trees above 4" dib.
Pulpwood cubic foot	Pulpwood volume tables were based on high-grade pulpwood calculated for black spruce, white spruce, balsam fir, jack pine, tamarack, aspen greater than 6" DBH class. Eight-foot lengths occurring in saw timber trees above the merchantable saw log height (6" dib), and trees less than saw timber sized that contained at least two 8-foot sticks of minimum top diameter or larger, were indicated as pulpwood.

[6] Local volume tables for Minnesota were not recovered, but were available for Wisconsin and Michigan. A portion of the hard-bound survey summary books were also available for Wisconsin and Michigan. A calculation of the local tree volume tables multiplied by trees per acre accurately returned the reported tree volumes in the summary books, providing evidence that per-acre volume estimates were based on local volume tables.

Table A1.7. Ownership group descriptions.

Group name	Description
Federal (reserved and unreserved)	All National Forests in Public Domain (e.g. Superior National Forest and Mesaba National Forest); all unreserved and un-allotted Public Domain; all military reservations, wildlife refuges, water level control
State (reserved and unreserved)	Unsold grant lands; delinquency lands (interest not paid on loans); Rural Credits lands acquired by foreclosure of loans by Rural Credits Department; State Forest, game refuge or park lands (only in Kabetogama State Forest in MN); reforestation and Flood Control Lands; delinquency lands (property tax not paid)
Indian	Lands held in trust for the Indians by Interior Department or reservation lands
County & Municipal	Lands belonging to cities, towns or counties
Small Private	Private owners having less than 1800 acres
Large Private	Private owners having 1800 or more acres of land

Table A1.8. Example of stand and stock and summary of volume tables and calculations.

Example of stand and stock table for unit 1, cover type aspen, pole-sized stand, aspen species

Unit	Cover	Stand Size Class	Species	Average per acre				
				D.B.H.	Trees	Board foot	Cubic foot	Pulpwood cubic foot
1, Cloquet	aspen	3-9 (pole size)	aspen	2”	32.26	0	0	0
				4”	41.50	0	0	0
				6”	47.08	0	112.00	20.00
				8”	28.24	0	147.06	78.00
				10”	8.89	151.00	91.00	10.00
				12”	1.89	85.00	29.00	2.00
				14”	0.26	20.00	6.00	0
				16”	0.06	6.00	2.00	0
				18”	0.02	4.00	1.00	0
Total					160.20	266.00	388.06	110.00

Example of summary of volume table for unit 1, cover type aspen, pole-sized stand, aspen species

Unit	Cover	Stand Size Class	Species	Unit Totals				
				Area (acres)	Sawtimber (Scribner board foot)	Total volume (cubic foot)	Pulpwood (cubic foot)	Pulpwood (cords)
1, Cloquet	aspen	3-9 (pole size)	aspen	208,000	50,900,000	80,716,480	22,880,000	292,177.6

Example of how total unit volume and per-acre volumes were calculated

Unit	**Cover**	**Size Class**	**Species**	**Cubic foot volume**
1, Cloquet	aspen	3-9 (pole size)	aspen	388.06 cf/acre * 208,000 acres = 80,716,480 total cf
				80,716,480 total cf / 208,000 acres = 388.06 cf/acre

Example of how total unit number of trees and per-acre trees were calculated

Unit	**Cover**	**Size Class**	**Species**	**Number of Trees**
1, Cloquet	aspen	3-9 (pole size)	aspen	160.2 trees/acre * 208,000 acres = 33,321,600 total trees
				33,321,600 total trees / 208,000 acres = 160.2 trees/acre

APPENDIX 2: Comparisons of digitized data with published figures from 1936.

Table A2.1. Comparisons of statewide totals with USFS Economic Notes Number 10, 1938.
Comparison: Area by stand size class.

Size Class	Summary of Volume Tables (all units)	Economic Notes 10
	Area (acres)	
15+	343,100	343,100
9-15	1,223,400	1,223,400
3-9	4,558,900	4,558,900
0-5	9,366,900	9,366,900
Non-forest	4,123,100	4,123,100
Total	19,615,400	19,615,400

Comparison: Cubic foot volumes by units.

Unit	Summary of Volume Tables	Economic Notes 10
	Total Volume	
	Thousand Cubic Feet	
1	775,590	775,590
2	1,611,190	1,611,190
3	1,323,570	1,323,570
4	1,789,570	1,789,570
5	939,120	939,120
6	464,370	464,370
Total	6,903,410	6,903,410

Comparison: Saw Timber volumes by units. [7]

Unit	Summary of Volume Tables	Economic Notes 10	
	Volume Saw Timber		
	Scribner Thousand BF	International ¼" Thousand BF	% Under
1	886,580	1,052,210	18.68%
2	2,477,730	2,941,560	18.72%
3	1,979,030	2,347,130	18.60%
4	3,379,350	4,008,030	18.60%
5	1,286,582	1,525,920	18.60%
6	478,730	597,890	24.89%
Total	10,488,002	12,454,740	18.75%

[7] Volume totals were converted from Scribner to International ¼" log rule for publication; modal difference of 18.60% (USFS 1938, p.52)

Table A2.1 Continued.
Comparison: Pulpwood volumes by units.

Unit	Summary of Volume Tables	Economic Notes 10	% over
	Volume High-Grade Pulpwood		
	Cordwood		
1	2,142,920.23	2,199,000	0.00%
2	3,777,000.00	3,773,000	0.11%
3	4,136,041.69	4,131,000	0.12%
4	7,143,000.00	7,143,000	0.00%
5	300,070.39	300,000	0.02%
6	697,783.06	694,000	0.55%
Total	18,252,920	18,240,000	0.07%

Table A2.2. Comparison of re-proportioned county data and 1935 MnDNR Land Economic Survey for Hubbard County.

Size Class	Re-growth	Pole stand	Second growth	Old growth	Total
Land Economic Survey (acres)	276,348.00	130,233.00	35,132.00	4,419.00	446,132.00
USFS (acres)	207,813.00	83,397.00	27,468.00	4,904.00	389,181.00
Difference	-25%	-36%	-22%	11%	-13%

APPENDIX 3: Links for 1936 survey attributes to 2014 FIA Database User Guide.

Table A3.1. *EVALIDator* reference tables and attributes.

1936 Name	2014 Name	Reference table from FIA Database User Guide	Attribute/ Name/Number	Notes
Area of forestland	Area of forest land, in acres	9.1.3. Reference Population Attribute Table	2	
Stand size class	Stand size class	2.4.20.Stand-size class code	STDSZCD	Designated based on algorithm
Cover type	Forest type	9.3. Reference Forest Type Table		MnDNR Forest groups
Species	Tree Species	3.1.16. Species Code	SPCD	
Number of trees	Number of live trees (at least 1 inch d.b.h.), in trees, on forest land	9.1.3. Reference Population Attribute Table	4	
Cubic feet volume	Net volume of live trees (at least 5 inches DBH), in cubic feet, on forest land	9.1.3. Reference Population Attribute Table	14	
Board feet volume	Net volume of sawtimber trees, in board feet (International ¼-inch rule), on forestland	9.1.3. Reference Population Attribute Table	20	
Ownership group	Owner Group Code	2.4.13. Owner group code		Four categories