Use and implementation of FIA Data

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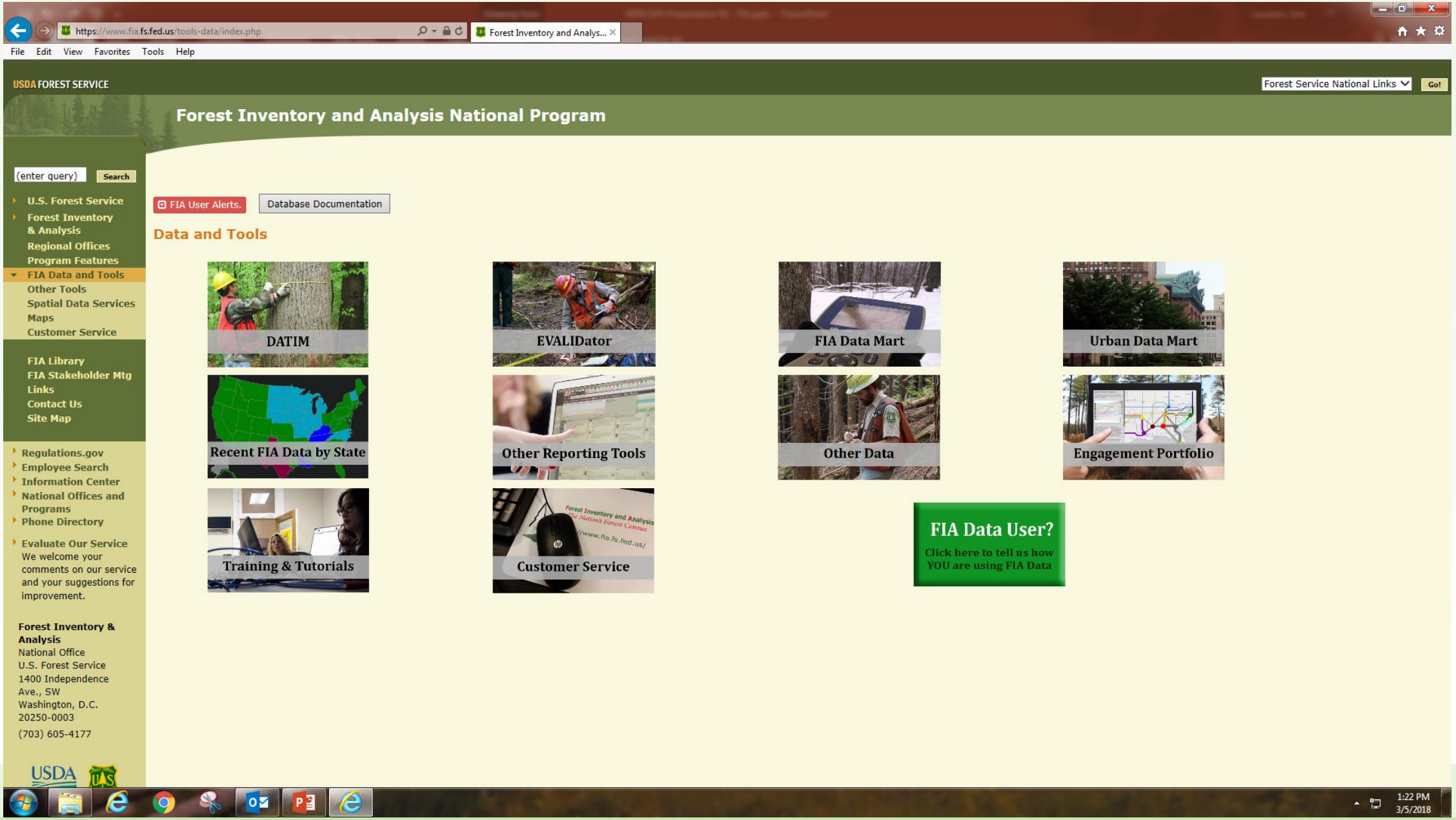
My typical analysis year

October, 2016 to September, 2017 Biometrician Analysis Projects			
Group Type	Resource Assessment	Risk Assessment	Total
Academia (University, High & Middle School) & Research	17	2	19
Consulting Foresters	40	1	41
Due Diligence - Investment	11		11
Due Diligence - Manufacturing	6		6
US Federal, US States, Local Government; Canada Federal & Provinces	40	7	47
Landowner/Manager	13	2	15
NGO	11	2	13
Public (incl. reporters)	12	1	13
Total	150	15	165

Use and Implementation of FIA Data

- Distinction between inventory and change estimates
  - Spatial Scale – Multiple state, single state, groups of counties (FIA Unit), single counties, circular wood baskets/drains, polygons. All are currently doable back to 1995.
  - Temporal Scale – Making sure estimates are comparable across time?
- Hierarchical structure of FIA data
  - Land – acres of uses/cover, by classification variables
  - Trees – how many by species, dbh class, tree class (quality), status (live, standing dead, dead and down)
  - Volume – how much by species, dbh class, tree class, cubic feet vs. board feet, tree grade
  - Components of change
- Show Me the Numbers - Charts vs. Tables

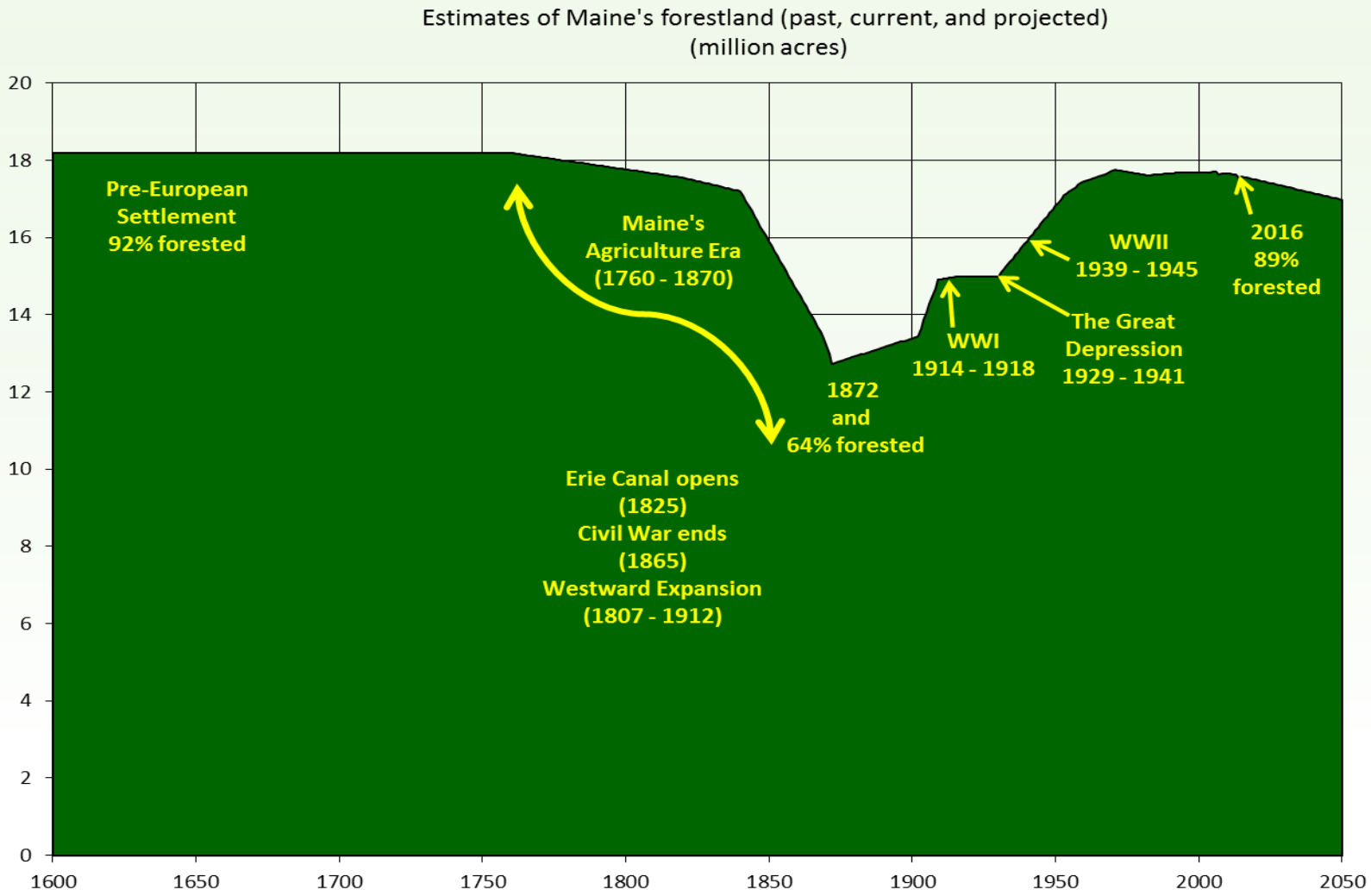
Where to go? https://www.fia.fs.fed.us/tools-data/index.php



Inventory Estimates – A Forest Census

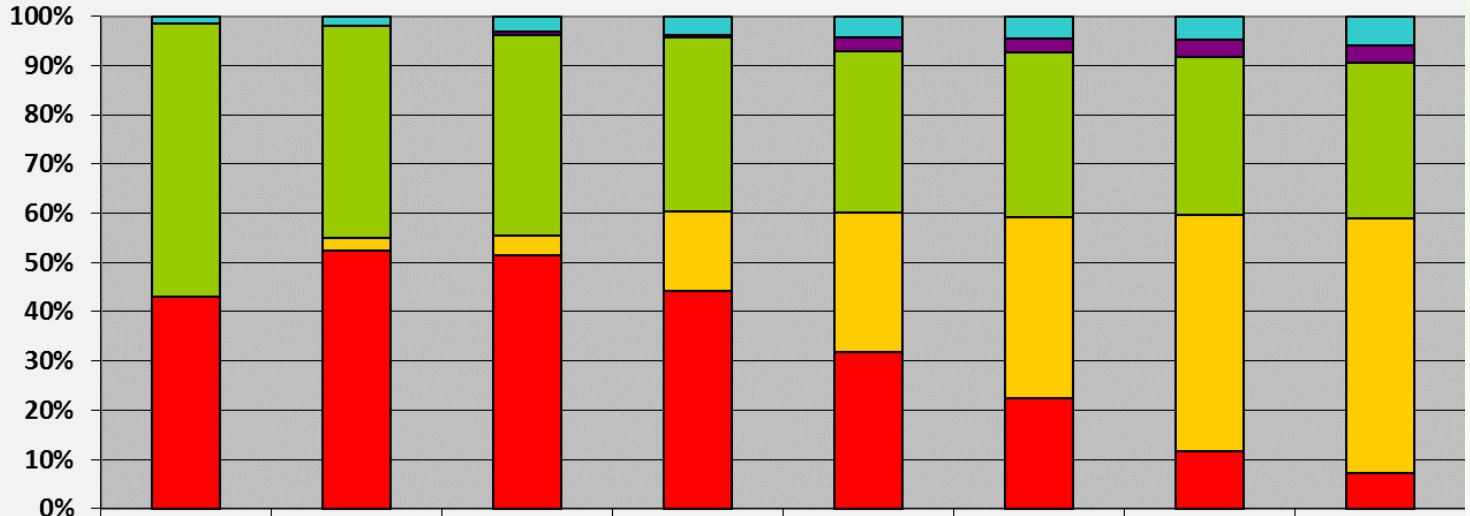
- The historic1959, 1971, 1982, and 1995 Periodic surveys were great inventory estimates of Maine's forest resources at a variety of scales (State, FIA Unit, County)
- But because of the many years between inventory measurements, changes in plot design, changes in definitions, and changes in classification algorithms - They are not great indicators of direct change. DO NOT connect the dots with a line and graphically infer that this is the actual and real trend over the interval (see next slide!)
- Even with the implementation of the National Core Design in 1999; there have been continued and substantial changes in definitions, techniques, and protocols. To their credit, FIA for the most part silently implements these in a backcast correction to 1995 (the oldest digital dataset) so that all respective databases are essentially on the same basis.

Land – depicting acres of forests



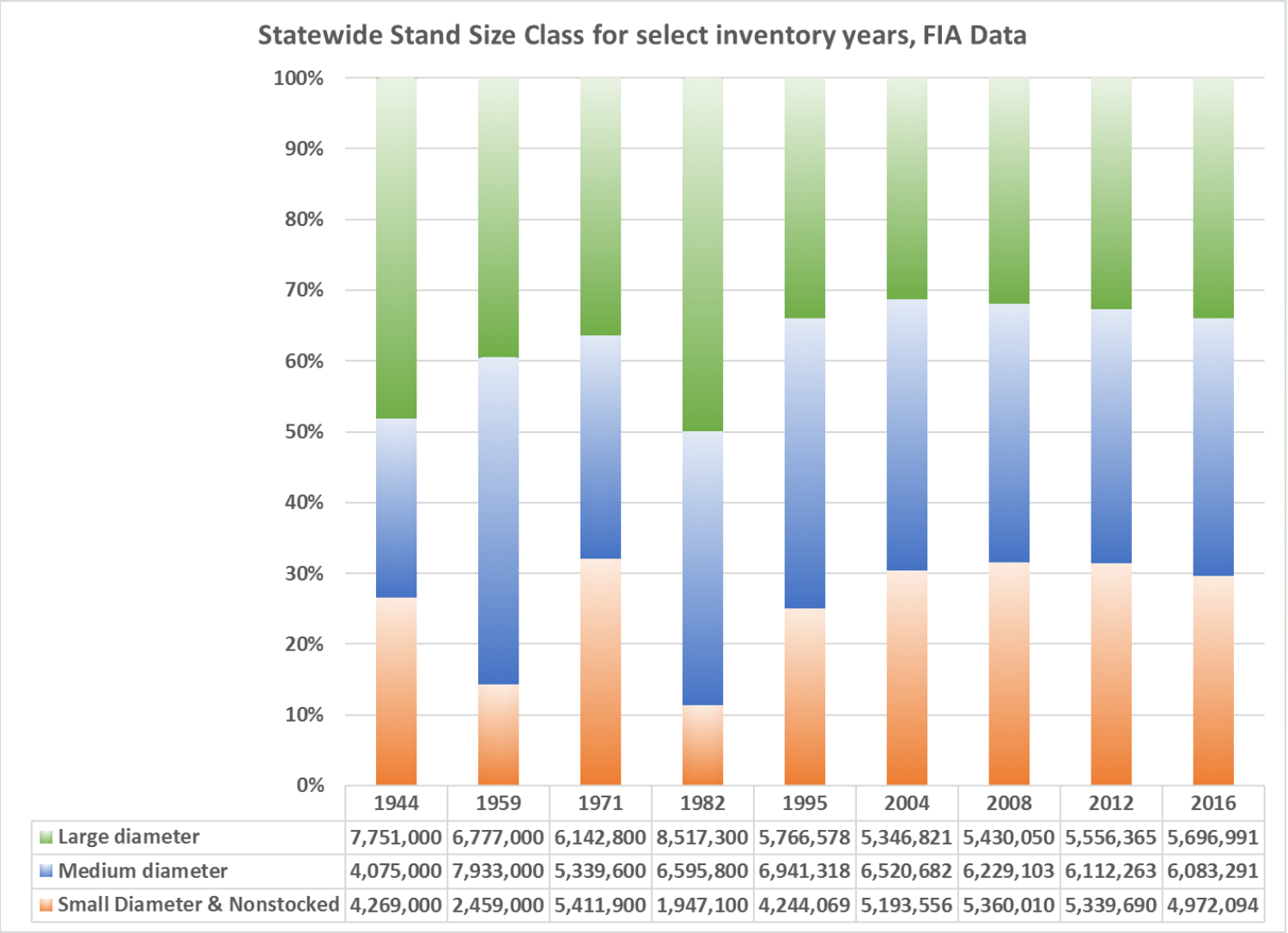
Land – depicting acres by owner group

Timberland, by major owner group,
percentage in chart and acres in table, by inventory year



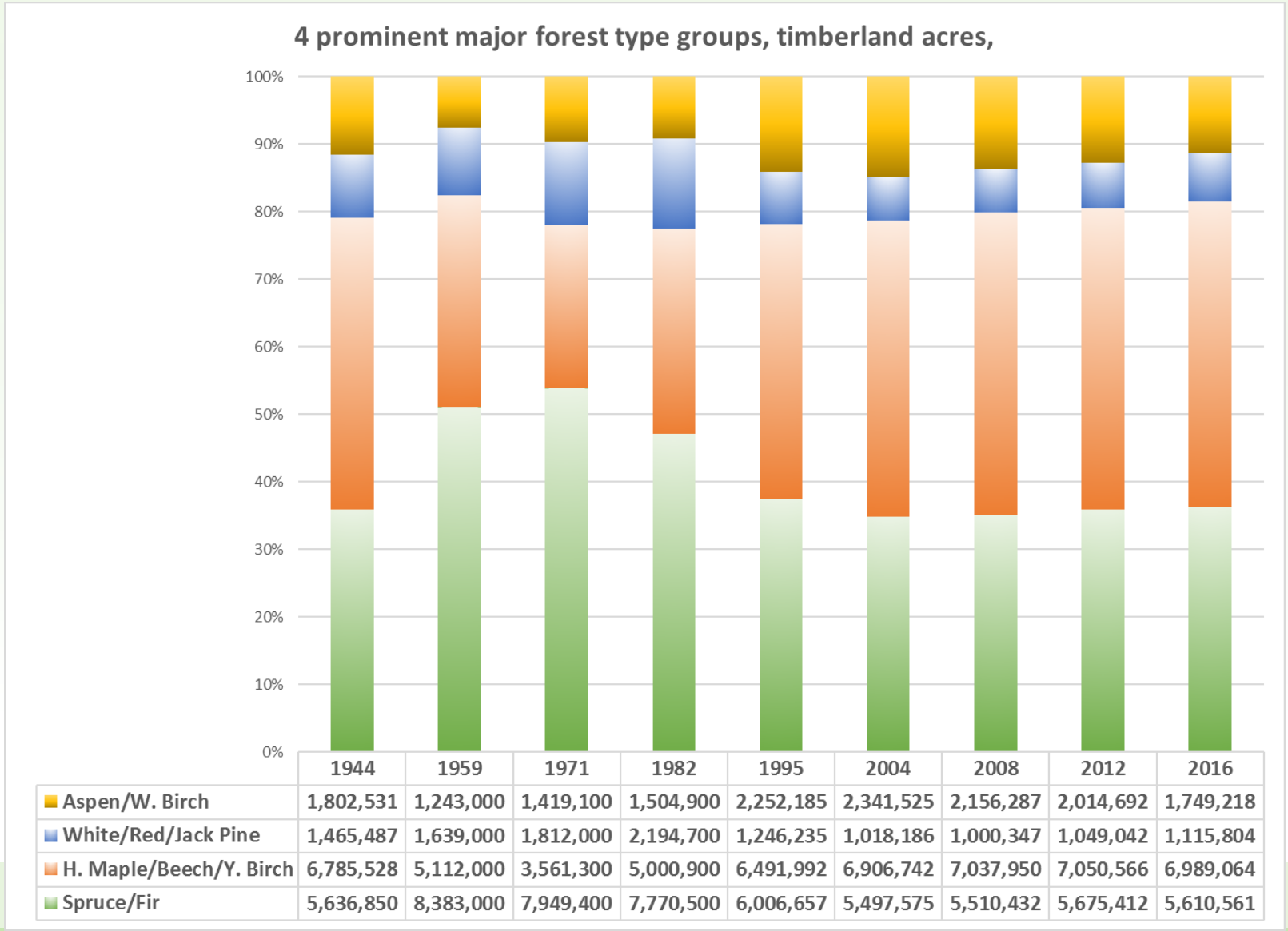
	1959	1971	1982	1995	2003	2006	2012	2015
Public	216,000	311,500	495,746	627,957	743,542	771,236	827,899	1,002,700
Misc. Large Private	-	-	118,153	100,399	475,208	504,061	607,210	611,438
Family Forests	8,440,000	6,797,200	6,579,406	5,935,261	5,648,088	5,705,685	5,507,296	5,337,507
Private Investor	-	408,500	656,756	2,702,735	4,865,170	6,302,971	8,216,250	8,760,134
Forest Industry	6,521,000	8,255,000	8,286,336	7,446,258	5,470,094	3,865,592	2,017,882	1,215,809

Land – depicting acres by stand size class



	1944	1959	1971	1982	1995	2004	2008	2012	2016
Large diameter	7,751,000	6,777,000	6,142,800	8,517,300	5,766,578	5,346,821	5,430,050	5,556,365	5,696,991
Medium diameter	4,075,000	7,933,000	5,339,600	6,595,800	6,941,318	6,520,682	6,229,103	6,112,263	6,083,291
Small Diameter & Nonstocked	4,269,000	2,459,000	5,411,900	1,947,100	4,244,069	5,193,556	5,360,010	5,339,690	4,972,094

Land – depicting acres in the 4 prominent major forest type groups



	1944	1959	1971	1982	1995	2004	2008	2012	2016
Aspen/W. Birch	1,802,531	1,243,000	1,419,100	1,504,900	2,252,185	2,341,525	2,156,287	2,014,692	1,749,218
White/Red/Jack Pine	1,465,487	1,639,000	1,812,000	2,194,700	1,246,235	1,018,186	1,000,347	1,049,042	1,115,804
H. Maple/Beech/Y. Birch	6,785,528	5,112,000	3,561,300	5,000,900	6,491,992	6,906,742	7,037,950	7,050,566	6,989,064
Spruce/Fir	5,636,850	8,383,000	7,949,400	7,770,500	6,006,657	5,497,575	5,510,432	5,675,412	5,610,561

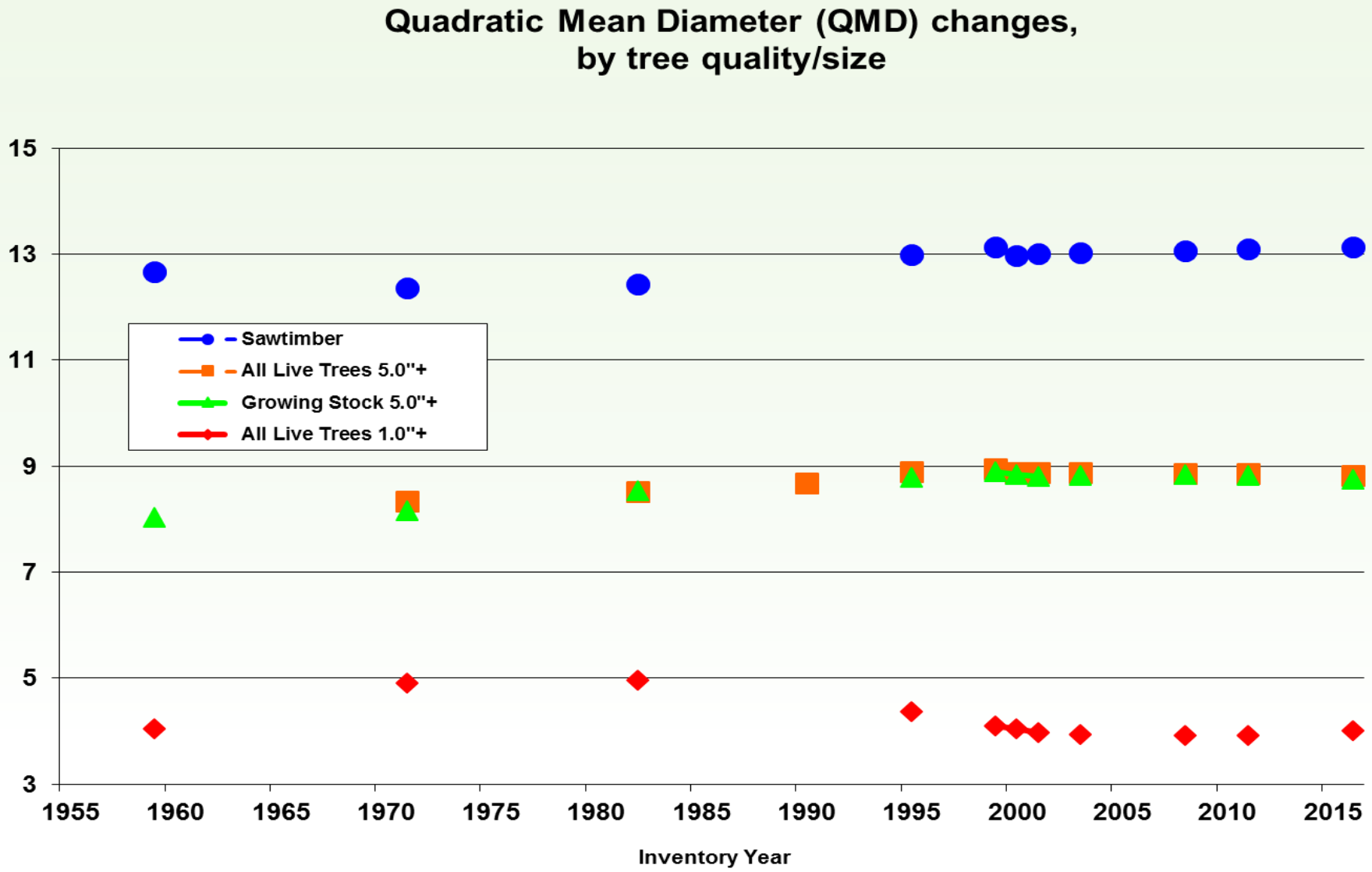
Quiz #1: Trees – composition, size, quality

1. What are the top 3 most prevalent tree species, 1.0”+ DBH?
2. What are the top 3 most prevalent tree species, 5.0”+ DBH?
3. What are the top 3 most prevalent tree species, 11.0”+ DBH?
4. How has the Quadratic Mean Diameter (QMD) changed across Maine’s inventories, i.e. is the purported average tree getting smaller?
5. Which 3 Softwood/Hardwood tree species have the highest proportion of quality, i.e. growing stock?

Trees – composition, size, quality

1. What are the top 3 most prevalent tree species, 1.0"+ DBH?
   - Out of an estimated 22.9 Billion trees
     - Balsam Fir (8.3 Billion, 36%)
     - Red Maple (2.7 Billion, 12%)
     - Red Spruce (2.3 Billion, 10%)
2. What are the top 3 most prevalent tree species, 5.0"+ DBH?
   - Out of an estimated 3,129 Million trees
     - Balsam Fir (621 Million, 20%)
     - Red Maple (416 Million, 13%)
     - Red Spruce (339 Million, 11%)
3. What are the top 3 most prevalent tree species, 11.0"+ DBH?
   - Out of an estimated 486 Million trees
     - Northern White Cedar (67 Million, 14%)
     - Eastern White Pine (59 Million, 12%)
     - Red Maple (59 Million, 12%)

Changes in Quadratic Mean Diameter?



Which 3 Softwood/Hardwood tree species have the highest proportion of quality, i.e. growing stock?

- All Growing Stock (5.0"+ DBH)

Softwood

- Balsam Fir (97%)
- Red Spruce (98%)
- Eastern Hemlock (90%)

Hardwood

- Aspen (97%)
- Northern Red Oak (95%)
- White Ash (93%)

- Just Sawtimber Growing Stock (11.0"+ DBH)

Softwood

- Balsam Fir (98%)
- Red Spruce (98%)
- Eastern White Pine & Hemlock (88%)

Hardwood

- Aspen (94%)
- Northern Red Oak (94%)
- White Ash (93%)

Volume – types defined

- All Live vs. Commercial Species (tree species currently or prospectively suitable for industrial wood products; excludes species of typically small size, poor form, or inferior quality.)
- Gross volume (cubic feet) is calculated for all live trees (5.0"+ DBH) from a 1 foot stump height to a minimum 4.0"DOB minimum top diameter, or where merchantability ends due to excessive limbs.
- Gross volume (board feet) is calculated for live commercial species at least 9.0"+ DBH to a 7.0" DOB for softwoods and 11.0"+ DBH to a 9.0" DOB for hardwoods, that contain at least one 12-foot sawlog in the first 16 feet or two non-contiguous 8-foot sawlogs, and meet regional specifications for freedom from defects.
- Cull Defect (cubic and board foot) – assigned deduction for sound and unsound volume.
- Net volume = Gross volume – cull defect

Volume – Tree Class

- All Live – net volume of all live trees 5.0"+ DBH, and is the sum of these 3 tree classes
  - Growing Stock – net volume of live commercial tree species 5.0"+ DBH, that have the potential (poletimber or pulpwood w/potential) to become or are sawtimber quality, meeting regional specifications for freedom from defect.
  - Rough Cull – net volume of any live tree, 5.0"+ DBH that does not meet regional specifications for freedom from defect, primarily due to poor form (sweep, crook, forks). Volume is considered to be pulpwood quality.
  - Rotten Cull – net volume of a live tree species that does meet regional specifications for freedom from defect, primarily because of rot; i.e. more than 50% of the cull defect volume is rotten, i.e. unsound. Not pulpwood quality, suitable for biomass.

Volume – Tree Grade

- A classification of sawtimber quality based on guidelines of actual throughput and yield from a sawmill, ***specifications have not essentially changed since 1959***. Based on the first 16 feet of the bole. In Maine, there are 4 tree grade groupings and specifications.
  - All commercial hardwood tree species (Grade 1–5)
    - Grade 1 (16.0"+ DBH, Max. 9% Cull)
    - Grade 2 (13.0"+ DBH, 9 to 40% Cull)
    - Grade 3 (11.0"+ DBH, Max. 50% Cull)
    - Grade 4 (Meets minimum log length, not grade 3 quality i.e. Tie and Timber Grade)
    - Grade 5 (Meets grade3 specifications, does not contain the minimum log length)
  - Eastern White Pine (Grade1–5) (Critical defect is diameter of red and black knots and their number)
  - All other Pines (Southern Pine Tree Grade 1–3)
  - All other Softwoods (Grade 1 or Grade 5)

Quiz #2: Volume – size, quality, and grade

1. What are the top 4 tree species, 5.0”+ DBH by All Live volume (cubic feet)?
2. What are the top 4 tree species, 5.0”+ DBH by Growing Stock volume (cubic feet)?
3. What are the top 4 tree species, 11.0”+ DBH by Sawtimber volume (board feet)?
4. Highest proportion of Tree Grade 1 in 15.0”+ DBH, out of all 11.0”+ DBH sawtimber volume?

Volume – All Live & Growing Stock quality

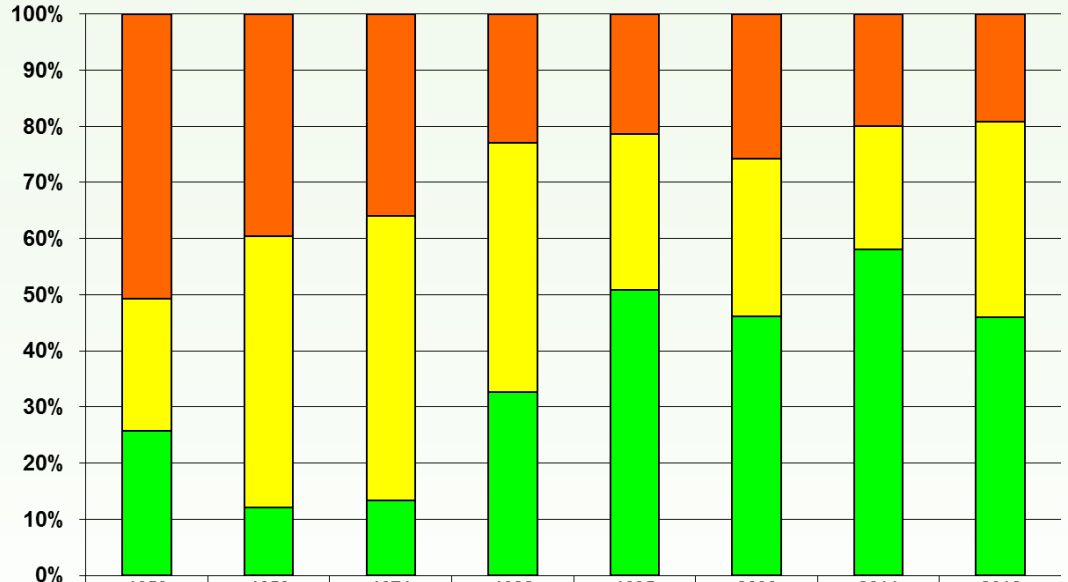
1. What are the top 4 tree species, 5.0"+ DBH by All Live volume?
   - Out of an estimated 25.5 Billion Cubic Feet (300 Million Cords)
     - Red Maple (3.1 BCF, 12%)
     - Eastern White Pine (2.9 BCF, 11%)
     - Red Spruce (2.9 BCF, 11%) 10%)
     - Balsam Fir (2.7 BCF, 10%)
2. What are the top 4 tree species, 5.0"+ DBH by Growing Stock volume?
   - Out of an estimated 23.3 Billion Cubic Feet (274 Million Cords)
     - Red Spruce (2.9 BCF, 12%)
     - Red Maple (2.7 BCF, 12%)
     - Balsam Fir (2.6 BCF, 11%)
     - Eastern White Pine (2.6 BCF, 11%)

Volume – sawtimber quality

- What are the top 4 tree species, 11.0"+ DBH by Sawtimber volume?
  - Overall there is an estimated 57.1 Billion Board Feet (BBF) and 50.1 BBF in 11.0"+ DBH, and of that -
    - Eastern White Pine (10.0 BBF, 20%)
    - Red Spruce (6.0 BBF, 12%)
    - Sugar Maple (4.9 BBF, 10%)
    - Eastern Hemlock (4.9 BBF, 10%)
- Proportion of Tree Grade 1 in 15.0"+ DBH trees, out of all 11.0"+ DBH sawtimber volume, i.e. Veneer?
  - Eastern White Pine – 9%
  - Red Maple – 8%
  - Sugar Maple – 26%
  - Yellow Birch – 23%
  - Paper Birch – 7%
  - Aspen – 15%
  - Northern Red Oak – 25%

Changes in Eastern White Pine & Major Hardwood Grade Quality

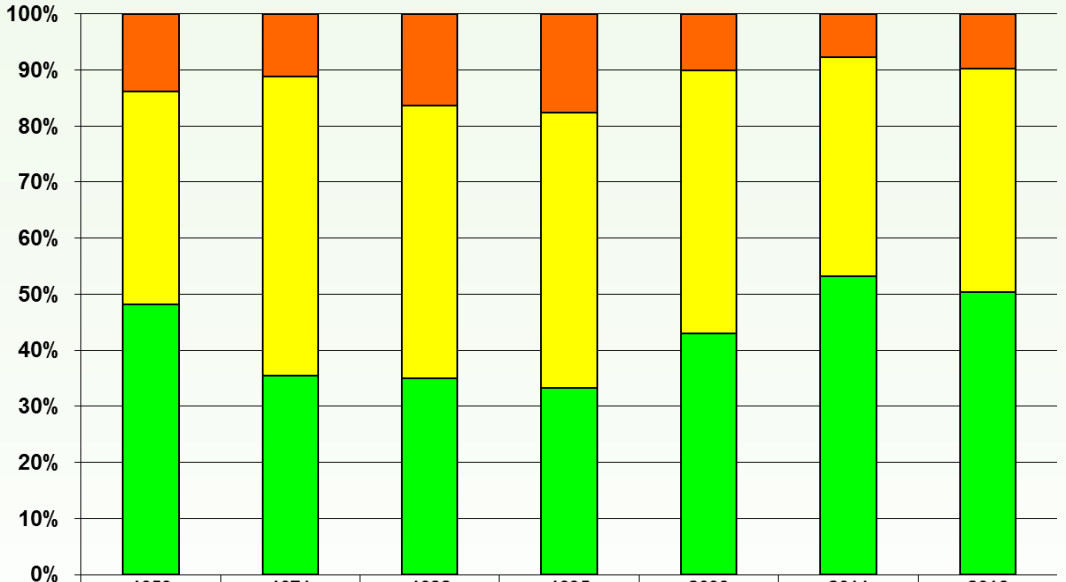
Distribution of sawtimber quality for eastern white pine, by select inventory years



	1950	1959	1971	1982	1995	2003	2011	2016
Grades 4 & 5 (Pulpwood)	51%	40%	36%	23%	21%	26%	20%	19%
Grade 3 (Pallet)	24%	48%	51%	44%	28%	28%	22%	35%
Grades 1 & 2 (Selects)	26%	12%	13%	33%	51%	46%	58%	46%

Inventory Year

Distribution of sawtimber quality for the 6 major hardwood species (Hard and Red Maple, Yellow and Paper Birch, Aspen, and Northern Red Oak) by select inventory years



	1959	1971	1982	1995	2003	2011	2016
Grades 4 & 5 (Pulpwood)	14%	11%	16%	18%	10%	8%	10%
Grade 3 (Pallet)	38%	53%	49%	49%	47%	39%	40%
Grades 1 & 2 (Selects)	48%	35%	35%	33%	43%	53%	50%

Inventory Year

Change in volume

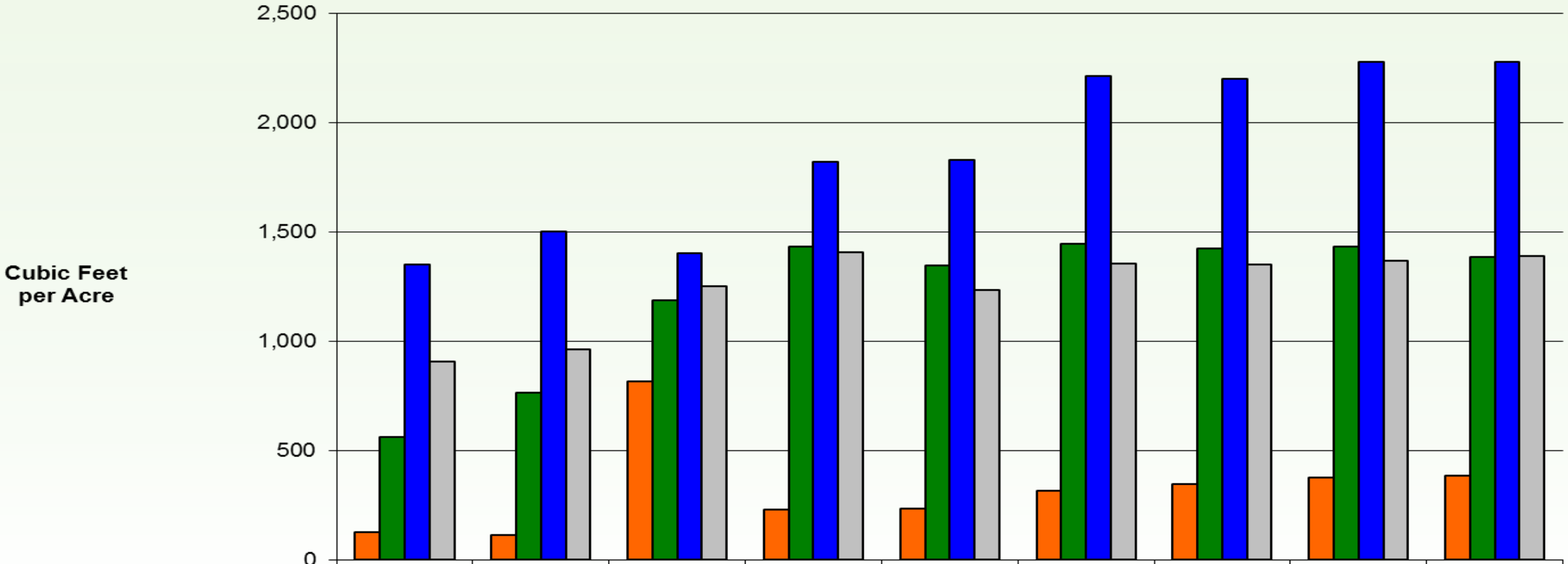
Table 2A. - Top 10 species' net volume of pulpwood quality and percent changes on timberland acres, Maine, 2016

Species	Net pulpwood quality volume (Million Cords)	Percent Change Since 2011	Percent Change Since 2006
red maple	35.8	-2%	2%
eastern white pine	34.2	9%	15%
red spruce	34.1	4%	-4%
balsam fir	31.3	19%	26%
eastern hemlock	23.5	2%	10%
northern white-cedar	23.2	-6%	-3%
sugar maple	21.3	-8%	-14%
yellow birch	17.9	1%	0%
paper birch	11.8	-5%	-11%
northern red oak	11.4	12%	29%
All Other Softwoods	17.2	4%	5%
All Other Hardwoods	33.1	-3%	-5%
Total	294.9	2%	3%

Table 2B. - Top 10 species' net prime sawtimber volume and percent changes on timberland acres, Maine, 2016

Species	Net prime sawtimber volume (Billion BF)	Percent Change Since 2011	Percent Change Since 2006
eastern white pine	8.8	6%	21%
red spruce	7.8	4%	-1%
eastern hemlock	5.0	-5%	13%
sugar maple	4.5	-14%	-17%
northern white-cedar	4.0	-8%	3%
red maple	3.9	-8%	-2%
yellow birch	2.9	-11%	-14%
balsam fir	2.7	10%	9%
northern red oak	2.7	19%	48%
white spruce	1.7	5%	15%
All Other Softwoods	1.6	9%	7%
All Other Hardwoods	5.3	-13%	-13%
Total	50.9	-2%	3%

Growing stock volume on timberland, average cubic feet per acre, by stand size class, by inventory year



	1950	1959	1971	1982	1995	2003	2006	2011	2016
Seedling/Sapling	125	115	816	231	233	315	346	375	384
Poletimber	562	764	1,188	1,431	1,348	1,444	1,422	1,434	1,383
Sawtimber	1,349	1,501	1,402	1,818	1,829	2,213	2,199	2,278	2,275
Overall Average	906	962	1,252	1,408	1,232	1,355	1,349	1,367	1,390

Historic Components of Change

- 1959 – 2003, you could get a full suite of growing stock components, by FIA Unit and major species, including:
  - Ingrowth – trees since the previous measurement that became merchantable, ingrowth volume was the net volume of the tree.
  - Accretion – change in volume on live trees measured at both occasions.
  - Gross Growth = Ingrowth + Accretion
  - Mortality – tress that died due to natural causes since the previous measurement. Mortality volume was based on tree measurements at the previous occasion, i.e. it died right after I left
  - Cull Decrement – a rough tree at the previous measurement, now classified as a growing stock tree, treated as an change addition.
  - Cull Increment – a growing stock tree at the previous measurement, now classified as a rough /rotten tree, treated as a change loss.
  - Net Growth = Gross Growth – Mortality + Cull Decrement – Cull Increment

Historic Components of Change, cont.

- Harvest Removals – trees harvested or killed in logging, cultural (TSI/PCT), or land clearing activities, i.e. trees are either severed at the stump or physically removed. This has nothing to do with the utilization of that tree!
- Land Use Removals – trees harvested, killed, or still growing on land reclassified from timberland to reserve or nonforest
- Total Removals = Harvest Removals + Land Use Removals (Removal volumes were calculated using the previous tree measurement, right after I left at the previous measurement)
- Net Change = Net Growth – Total Removals
- These volume estimates were converted to annualized (cubic feet/acre/year) by dividing by the remeasurement period (REMPER), which has had at least 3 different mathematical calculation methods, trying to capture the correct total growing seasons (years) between measurements.

Modern Components of Change and Comparison

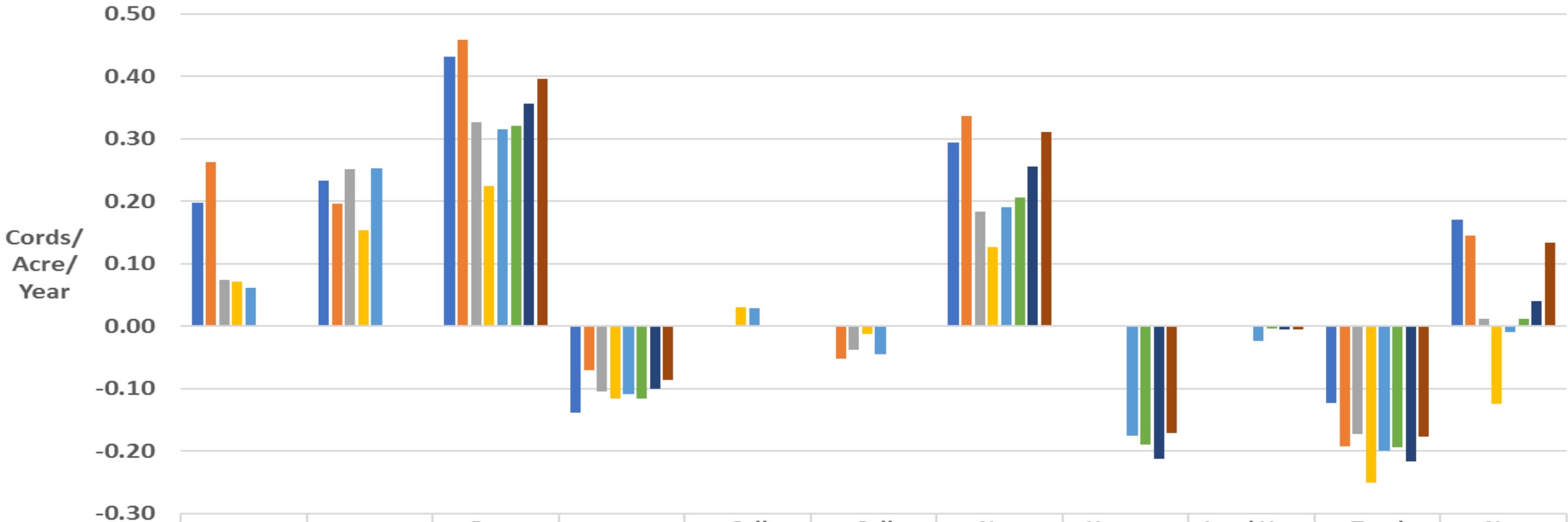
- Ingrowth – volume represented by the tree just at 5.0" DBH. New version is deflated to old.
- Accretion Total – is inflated, now the sum of two components
  - Accretion on Ingrowth – increase in volume between 5.0" minimum DBH and actual volume based on current tree measurements
  - Accretion – same as before
- Gross Growth (New) = Gross Growth (Historic)
- Mortality – trees are now modeled forward to the mid-point of the remeasurement period, mortality volume based on modeled parameters, inflated compared to historic.
- Cull Decrement/Cull Increment – are pretty well hidden from view, but are based on modeling the tree to the measurement mid-point for the component estimate.
- Growth on Removals – all removal trees are grown to the midpoint of the measurement period, and this incremental gain is treated as new piece of net growth.
- Net Growth = Gross Growth (No Change) – Mortality (Inflated) + Net Growth on Removals (New Added Piece).

**** If I typically remove more trees than dying, then net growth gets inflated relative to historic***

Modern Components of Change and Comparison

- Removals (both Harvest and Land Use) – are modeled to the midpoint of the measurement period and the volume represented by these modeled parameters is treated as the removal volume (Inflated compared to historic)
- Net Change (New) = Net Change (Historic) or as they say it is "Zero net sum."

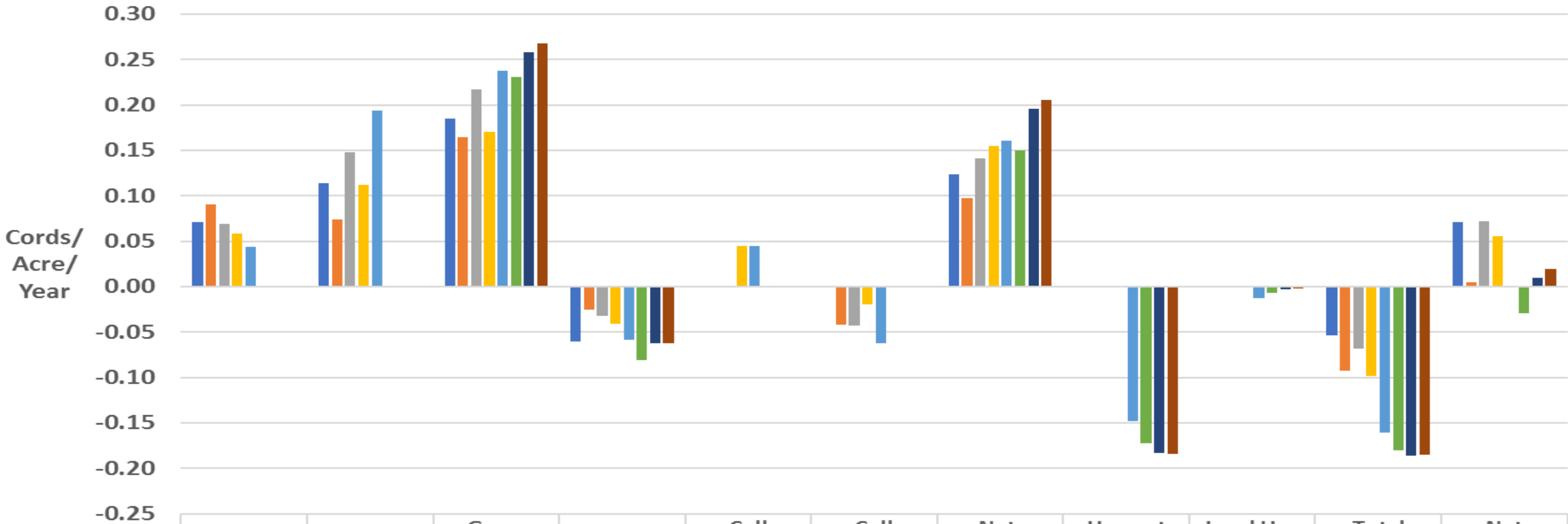
Historic Softwood Growing Stock Components of Change for select inventory years



	Ingrowth	Accretion	Gross Growth	Mortality	Cull Decrement	Cull Increment	Net Growth	Harvest Removals	Land Use Removals	Total Removals	Net Change
1959	0.20	0.23	0.43	-0.14		0.00	0.29			-0.12	0.17
1970	0.26	0.20	0.46	-0.07		-0.05	0.34			-0.19	0.15
1981	0.07	0.25	0.33	-0.10		-0.04	0.18			-0.17	0.01
1995	0.07	0.15	0.23	-0.12	0.03	-0.01	0.13			-0.25	-0.12
2003	0.06	0.25	0.31	-0.11	0.03	-0.04	0.19	-0.18	-0.02	-0.20	-0.01
2006			0.32	-0.12			0.21	-0.19	0.00	-0.19	0.01
2011			0.36	-0.10			0.26	-0.21	-0.01	-0.22	0.04
2016			0.40	-0.09			0.31	-0.17	-0.01	-0.18	0.13

Backwards Math

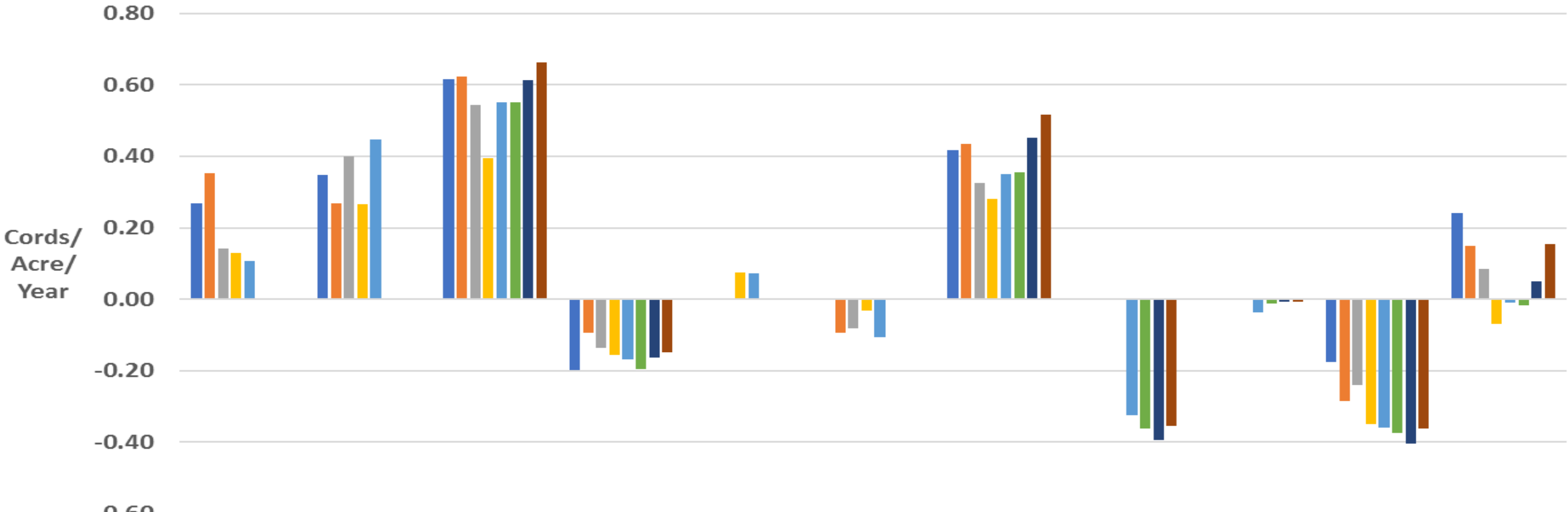
Historic Hardwood Growing Stock Components of Change for select inventory years



	Ingrowth	Accretion	Gross Growth	Mortality	Cull Decrement	Cull Increment	Net Growth	Harvest Removals	Land Use Removals	Total Removals	Net Change
1959	0.07	0.11	0.18	-0.06		0.00	0.12			-0.05	0.07
1970	0.09	0.07	0.16	-0.03		-0.04	0.10			-0.09	0.00
1981	0.07	0.15	0.22	-0.03		-0.04	0.14			-0.07	0.07
1995	0.06	0.11	0.17	-0.04	0.04	-0.02	0.15			-0.10	0.06
2003	0.04	0.19	0.24	-0.06	0.04	-0.06	0.16	-0.15	-0.01	-0.16	0.00
2006			0.23	-0.08			0.15	-0.17	-0.01	-0.18	-0.03
2011			0.26	-0.06			0.20	-0.18	0.00	-0.19	0.01
2016			0.27	-0.06			0.21	-0.18	0.00	-0.19	0.02

Backwards Math

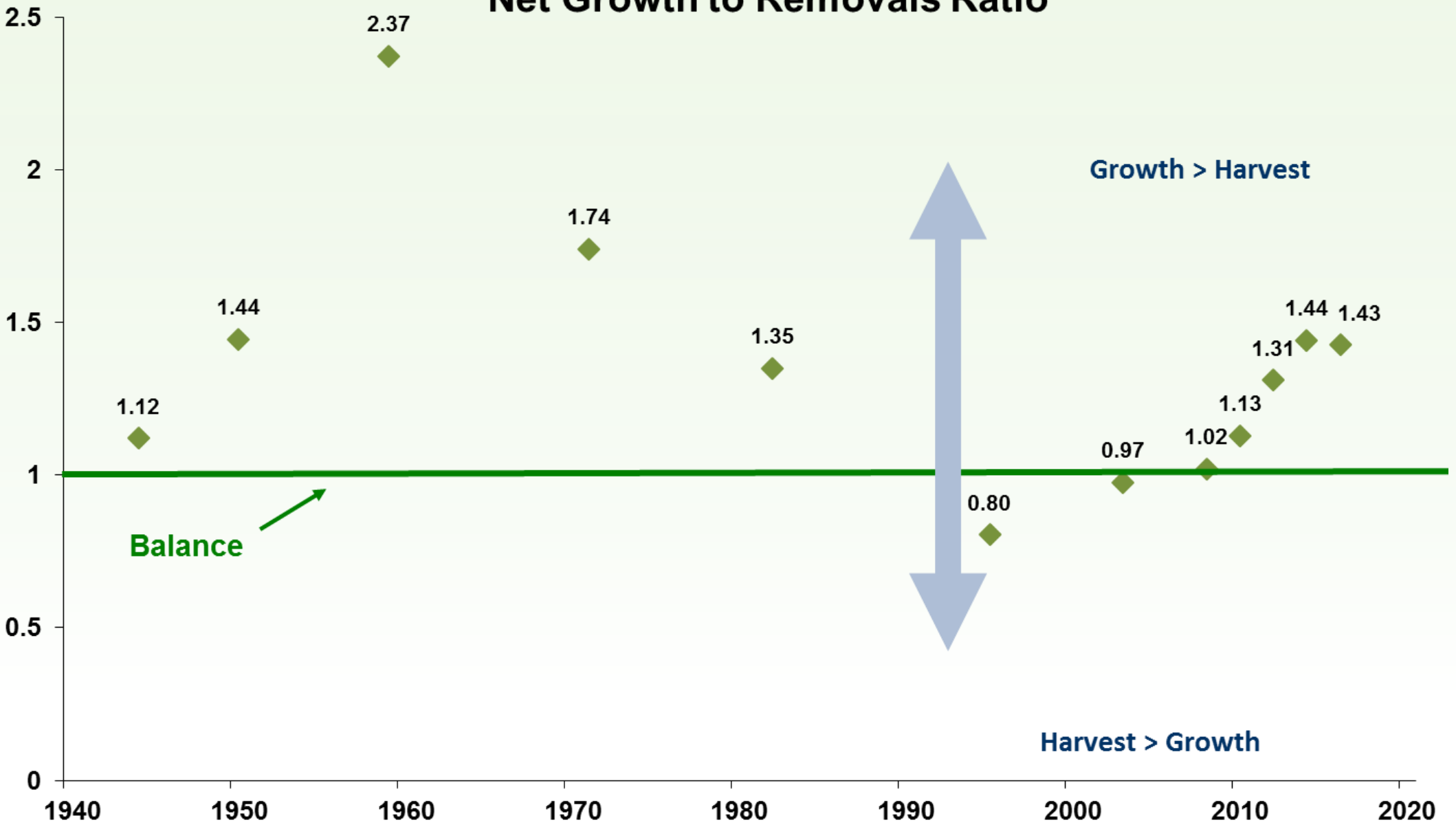
Historic All Species Growing Stock Components of Change for select inventory years



	Ingrowth	Accretion	Gross Growth	Mortality	Cull Decrement	Cull Increment	Net Growth	Harvest Removals	Land Use Removals	Total Removals	Net Change
1959	0.27	0.35	0.62	-0.20		0.00	0.42			-0.18	0.24
1970	0.35	0.27	0.62	-0.09		-0.09	0.43			-0.28	0.15
1981	0.14	0.40	0.54	-0.14		-0.08	0.33			-0.24	0.08
1995	0.13	0.27	0.40	-0.16	0.07	-0.03	0.28			-0.35	-0.07
2003	0.11	0.45	0.55	-0.17	0.07	-0.11	0.35	-0.32	-0.04	-0.36	-0.01
2006			0.55	-0.20			0.36	-0.36	-0.01	-0.37	-0.02
2011			0.61	-0.16			0.45	-0.39	-0.01	-0.40	0.05
2016			0.66	-0.15			0.52	-0.36	-0.01	-0.36	0.15

Backwards Math

Historic Trends in the Growing Stock
Net Growth to Removals Ratio



Source: Department of Agriculture, Conservation, and Forestry - Maine Forest Service

Change Estimates – The Holy Grail of CFI in FIA

The Question - If Time #2 Inventory - Time #1 Inventory = Net Change in Inventory (NCI) and if (Ingrowth + Accretion – Mortality – Removals) = Net Change in Components (NCC)

Does NCI = NCC for 3 Maine Counties?

Step #	Ending Inventory (MMCF)	Beginning Inventory (MMCF)	Net Change in Inventory (NCI) (MMCF)	Net Change in Components (NCC) (MMCF)	Actual MCF Difference	% Difference NCI from NCC
York County						
Start	949.80	835.06	114.74	103.94	10,800.0	10.39%
Post Step 1	949.80	835.06	114.74	109.66	5,080.0	4.63%
Post Step 2	949.80	836.05	113.75	109.66	4,090.0	3.73%
Post Step 3	949.80	845.94	103.86	102.54	1,320.0	1.29%
Post Step 4	949.80	845.43	104.37	104.82	(451.6)	*-0.43%*
Lincoln County						
Start	375.63	359.16	16.47	17.82	(1,350.0)	-7.58%
Post Step 1	375.63	359.16	16.47	15.91	560.0	3.52%
Post Step 2	375.63	359.15	16.48	17.37	(890.0)	-5.12%
Post Step 3	375.63	358.91	16.72	16.83	(110.0)	-0.65%
Post Step 4	375.63	358.80	16.83	16.83	0.003	*0.00%*
Knox County						
Start	251.09	264.03	(12.94)	(11.75)	(1,190.0)	10.13%
Post Step 3	251.09	263.92	(12.83)	(11.75)	(1,080.0)	9.19%
Post Step 4	251.09	263.92	(12.83)	(12.83)	(0.002)	*0.00%*

- ***Some Lessons Learned***

- *The exact same plots must be used to calculate both NCI and NCC*
- *Components of Change have to be uncoupled from an annual estimate (CF/Year) to CF per remeasurement period.*
- *Trees in inventory @ Time #1 must have both a inventory record at Time #2 and a viable component of change transition.*
- *A tree now called "Out" at Time #2 needs to be also deleted from Time #1*
- *Dead trees @ time #1 cannot become alive again at Time #2 without a correction to Time #1*
- *Trees cannot change species from Time #1 to Time #2, volume equations are species dependent*
- *Correcting a previous DBH measurement at Time #2 requires correcting the original DBH at Time #1*
- *In simple words, rigorous reconciling of data*

Questions/Comments

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