Defining the Minimum Age of a Mature Forest in Either Legislation or Regulation

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Abstract

For the purposes of achieving the twin goals of high levels of ecosystem-based carbon storage and sequestration and biological diversity conservation on federal forest lands, the conservation community seeks to protect federal mature and old-growth ("older") forests and trees through national legislation and/or federal regulation.

In proposing such policy, is important to define the age at which a forest stand or tree becomes "mature." This paper makes a case for using the culmination of mean annual increment (CMAI), also known as the age of biological maturity (ABM), as the defining metric the minimum age of a "mature" forest or tree. CMAI is a measurement:

(1) long used;
(2) widely applied;
(3) understood by forestry professionals and federal forestland management agencies; and
(4) applicable to all tree species on all growing sites.

A review of the readily available literature on CMAI found sixty-four forest types and growing sites. CMAI can occur as early as forty years (lodgepole pine) and as late as one hundred and thirty years (Engelmann spruce).

DEDICATED TO THE CONSERVATION AND RESTORATION OF NATURE, THE LARCH COMPANY IS A NON-MEMBERSHIP FOR-PROFIT ORGANIZATION THAT REPRESENTS SPECIES THAT CANNOT TALK AND HUMANS NOT YET BORN. A DECIDUOUS CONIFER, THE WESTERN LARCH HAS A CONTRARY NATURE.

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When Does a Forest Stand (or Tree) Become Mature?

The question of when a forest stand or tree becomes mature is important to answer for purposes of national legislation and/or federal regulation regarding protection of mature and old-growth forests. Using any single age or diameter at breast height as a defining metric for trees or stands of trees cannot encompass the vast variety of forest types in the United States, growing as they are on sites with greatly varying rates of productivity. On better growing sites, trees tend to have a larger diameter at a given age than those growing on poorer sites.

A better metric is culmination of mean annual increment (CMAI), also known as the age of biological maturity (ABM). In lay terms, CMAI is the age of a stand or tree of a given species on a given growing site at which the maximum annual rate of wood (and carbon) growth peaks. While MAI has peaked (culminated), a tree or stand can continue to sequester and store very large amounts of carbon for very long periods of time.

Here is how the USDA Forest Service defines CMAI:

> *For a tree or stand of trees, the age at which the average annual increment is greatest. It coincides precisely with the age at which the current annual increment equals the mean annual increment of the stand and thereby defines the rotation of a fully stocked stand that yields the maximum volume growth.* [2]

The nation's premier forestry textbook notes:

> *Although [culmination of mean annual increment] was considered to represent biological maturity, forests reaching the [mature forest stage] are only just arriving at maturity from an ecological perspective. In fact, high levels of primary productivity generally continue through the [mature forest stage] and result in significant additional accumulations of wood, an important consideration in carbon sequestration.* [3]

Intensive management (fertilization, thinning, and such) can extend the CMAI of a stand several decades into the future. Such stands have far less ecological value, so it is recommended that CMAI for climate and nature policy purposes be defined as what would naturally occur on a growing site.

Advantages of Using CMAI

Using CMAI to define the onset of late-successional (mature and old-growth) forests is superior to alternatives of using age limits, diameter limits, or maps to define the forests and/or trees to be protected by legislation and/or regulation. CMAI accounts for both site- and species-specific conditions. Depending on the species and the quality of the site where the species is growing, CMAI ages differ. CMAI more accurately reflects on-the-ground differences in site and tree species to more accurately identify the point at which "mature" conditions are reached.

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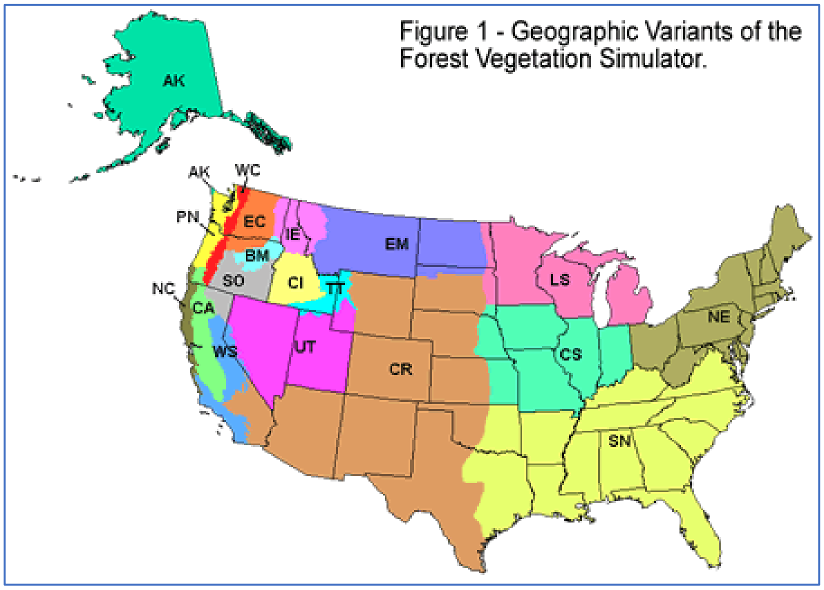
[2] Burns, Russell M., and Barbara H. Honkala (technical coordinators). Silvics of North America, Volume 2: Hardwoods. Agriculture Handbook 654. Washington, DC: USDA Forest Service, 1990.

[33] Franklin, Jerry F., K. Norman Johnson, and Debora Johnson. *Ecological Forest Management*. Long Grove, IL: Waveland Press, 2018, page 61.

The Forest Service's [Forest Vegetation Simulator](#)(FVS), a forest growth simulation model, is a handy tool for determining site-specific and species-specific CMAI.

> *It simulates forest vegetation change in response to natural succession, disturbances, and management. It recognizes all major tree species and can simulate nearly any type of management or disturbance at any time during the simulation. Outputs include tree volumes, biomass, density, canopy cover, harvest yields, fire effects, and much, much more.* [4]

FVS is a suite of software programs and includes training, background documents, and support. It is available for anyone to use. Since its initial development in 1973, FVS has evolved to include twenty-one geographic variants (Map 1).



Map 1. *FVS is geographically tailored, making it easy for foresters to determine CMAI for various species on various growing sites.* Source: USFS.

As long as stand age data is available (and it commonly is), CMAI can be calculated using FVS.[5]

In the field federal foresters could determine specific trees that have reached CMAI by (1) using an increment borer to count rings; or (2) visually assessing tree age.[6]

Examples of CMAI for Various Species on Various Growing Sites

CMAI for a particular species varies greatly by site (growing) conditions. Table 1 compiles various CMAI ages by various species at various sites, taken from various sources. While a published CMAI for every tree species is not readily available, CMAI can be determined for any species on any growing site using FVS.

History of CMAI

National Forest Management Act

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[4] USDA Forest Service. Forest Vegetation Simulator (SVS). Webpage accessed October 20, 2020.
[5] Dixon, Gary. 2020 (rev.). [Essential FVS: A User's guide to the Forest Vegetation Simulator](#). USDA Forest Service.
[6] Van Pelt, Robert. 2007. [Identifying Mature and Old Forests in Western Washington](#). Washington Department of Natural Resources.

CMAI has been used as a defining metric in the National Forest Management Act of 1976 to define the age at which trees could be logged or clearcut. Specifically, Congress directed the Forest Service to establish

> *standards to insure that, prior to harvest, stands of trees throughout the National Forest System shall generally have reached the culmination of mean annual increment of growth (calculated on the basis of cubic measurement or other methods of calculation at the discretion of the Secretary).* [7]

The Forest Service chose to interpret the phrase "generally have reached the culmination of mean annual increment of growth" [emphasis added] to mean that a tree or stand has reached "the minimum age that attains 95 percent of merchantable cubic volume yield at culmination." [8] The chapter "Land Management Planning" in the *Forest Service Manual* operationalizes the definition like this:

> *7. Meet the intent of the culmination of mean annual increment (CMAI) requirement by ensuring the total yield from stands at harvest age is equal to or greater than 95 percent of the volume production corresponding to CMAI. Base CMAI on cubic measure and on the yield from regeneration harvests and any additional yields resulting from intermediate harvests.* [9]

Forest Plans

In the 1993 scientific report that is the basis of the landmark Pacific Northwest Forest Plan, a mature forest is defined as follows:

> *Mature seral stage – The period in the life of a forest stand from culmination of mean annual increment to an old-growth stage or to 200 years. This is a time of gradually increasing stand diversity. Hiding cover, thermal cover, and some forage may be present.* [10]

Pacific Northwest Forest Legacy Act Discussion Draft

CMAI has also been used as a defining metric in a discussion draft of the Pacific Northwest Forest Legacy Act proposed by Representative Peter DeFazio (D-4th-OR) in 2008.

In 2008, Representative Peter DeFazio circulated a "discussion draft" of legislation he was considering introducing in the House of Representatives.[11] The bill was never introduced. From a

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[7] 16 U.S.C. 1604(m)(1).

[8] Curtis, Robert O. "Extended Rotations and Culmination Age of Coast Douglas-fir: Old Studies Speak to Current Issues." USDA Forest Service Pacific Northwest Research Station, Research Paper PNW-RP-485, 1995.

[9] USDA Forest Service. Forest Service Manual Chapter 1920 – Land Management Planning, 2013.

[10] Thomas, Jack Ward, et al. Forest Ecosystem Management: An Ecological, Economic, and Social Assessment (Report of the Forest Ecosystem Management Assessment Team), July 1993. Forest Service, Fish and Wildlife Service, National Marine Fisheries Service, National Park Service, Bureau of Land Management, and Environmental Protection Agency.

[11] DeFazio, Peter. "Pacific Northwest Forest Legacy Act" Discussion Draft. August 6, 2008. (Copy available upon request to author of this memorandum.) Note: The bill was drafted by DeFazio's natural resource counsel Susan Jane Brown, who today serves as an attorney and director of Public Lands and Wildlife at the Western Environmental Law Center.

conservation standpoint, the discussion draft had significant upsides as well as some significant downsides. The bill would have generally protected mature and old-growth forests on Forest Service and Bureau of Land Management lands in the Pacific Northwest Forest Plan (the range of the northern spotted owl), as well as eastside forests of Oregon and Washington and on the Modoc National Forest in California.

In the DeFazio draft, "mature" forest was defined as "forest that has first reached the age of culmination of mean annual increment." The draft went on to say, "Such forests or trees are not yet old-growth forests or trees." The draft defined CMAI as

> *the typical age at which the greatest average annual increment is first reached for a natural, unmanaged stand of trees, which is determined by consulting published scientific references specific to tree species and productivity, as measured by Plant Association Group, site index, or both.*[12]

Recommended Statutory or Regulatory Definition of "Age of Biological Maturity"

The following definition is recommended for either congressional legislation or administrative regulation and can be applied to either natural or managed stands

> *Culmination of Mean Annual Increment*. The "culmination of mean annual increment" means the minimum age that attains 95 percent of merchantable cubic volume yield at which the greatest average annual increment would be first reached for a natural unmanaged stand or trees on the site, which is determined by consulting published scientific references specific to tree species and productivity, as measured by plant association group, site index, or both.

Advocating ABM

Talking points:

- One single age or diameter definition does not scale to the great variety of forest types across the United States.
- Forest scientists have found CMAI to be the best determinant of the beginning of a "mature" forest.
- CMAI is well understood by foresters and can easily be determined for specific forest types on various growing sites using the Forest Service's own modeling software.

[12] Ibid.

Table 1. **Selected CMAI for Various Species at Various Sites**			
Species	*CMAI (Years)*	*Site*	*Source*
	average 84, 80-110	OR, WA, CA	1, 8
Ponderosa pine	90	WA	2
Inland Douglas-fir	80–100, 72-115	WA	2, 8
Grand fir	70	WA	2
Engelmann spruce	130	WA	2
Subalpine fir	100	WA	2
Douglas-fir–ponderosa pine	90	Southwest OR	2
Tanoak	70	Southwest OR	2
Douglas-fir–white fir	60	Southwest OR	2
Western hemlock	60, 50-70	Southwest OR	2, 8
Port Orford cedar	60	Southwest OR	2
Jeffrey pine	80	Southwest OR	2
White fir–Douglas-fir	60	Southwest OR	2
Shasta red fir	80	Southwest OR	2
Western white pine	80	Southwest OR	2
Mountain hemlock	60	Southwest OR	2
Noble fir	115–130	WA, OR	3
White spruce	80–150	MN, WI, MI, NY, VT, NH, ME	3
Jack pine	50–60	MN, WI, MI, ME	3
Lodgepole pine	40–140, typically 50–80	WA, OR, ID, MT, WY, CO, UT, CA, NV	3
Yellow poplar	70	WI to LA to FL to NY	4
Quaking aspen	30, 70-110	WA, OR, CA, NV, AZ, NM, CO, UT, WY, ID, MT, ND, SD, MN, IA, WI, MI, IL, IN, OH, NY, PA, VT, NH, ME, MA, DE	4, 8
Black cottonwood	62–96	AK, WA, OR, ID, MT, CA, NV, UT, ND	4
Sitka spruce	70-100	AK, WA, OR, CA	5, 8
Eastern white pine	90–120	MN, IA, MI, WI, NY, PA, VA, WV, NC, SC, GA, TN, KY, ME, VT, NH, RI, CT	6
Balsam fir	60	MN, WI, MI, NY, VT, NH, ME	6
Oak-hickory type	70	North Central US	6
Longleaf pine	25	TX, LA, AL, MS, GA, FL, SC, NC, VA	6
Virginia pine	30+	PA, NJ, MD, DE, VA, WV, KY, OH, TN, NC, SC, GA, MS, AL	6
Western white pine	100-120	WA, OR, CA, NV, ID, MT	6, 8
Rocky Mountain Douglas-fir	120–140	WA, ID, MT, OR, UT, AZ, NM, CO, WY	6
Lodgepole pine	70–90, 100	WA, OR, CA, NV, ID, MT, WY, CO, UT	6, 8
Sitka spruce	80	OR, WA, AK	6
"True" firs (e.g. Pacific silver fir and noble fir)	130	OR, WA	6
Red pine	60–130	MN, WI, MI, NE, PA, VT, N, ME	7
Aspen (quaking or bigtooth)	40–60	MN, WI, MI, IA, IL, IN, OH, PA, NY, CT, RI, VT, NH, ME, WV, VA, KY, NC, TN	7
Eastern white pine	80–120	MN, WI, IA, IL, IN, MI, OH, NY, PA, VA, NC, GA, SC, KY, TN, VT, CT, NH, ME, RI	7
Red pine	60–120	MN, WI, MI, PA, WV, NJ, VT, NH, ME, CT, RI	7
Jack pine	40	MN, WI, MI, ME	7
Balsam fir	40–60	MN, WI, MI, NY, VT, NH, ME	7
White spruce	80–100	MN, WI, MI, NY, VT, NH, ME	7
Black spruce	60+	MN, WI, MI, NY, VT, NH, ME, CT, MA	7
Tamarack	80–130	MN, WI, MI, OH, NY, VT, NH, ME, CT	7
Black/northern pin oak	70–90	MN to TX to GA to ME (black oak); KS, OK, AR, MO, IA, IL, IN, OH, MI, TN, NC, VA, WV, MD, DE, PA, NJ, NY, CT, MA, RI (pin oak)	7
Red oak	70–100	MN to LA to SC to ME (northern); MO to TX to FL to NJ (southern)	7
White oak	80–100	MN to TX to FL to ME	7
Paper birch	50	MN, WI, MI, NY, VT, NH, ME, MA, CT, RI, PA	7
Red maple	50	MN to TX to FL to ME	7
Green ash	70	MT to TX to FL to ME	7

***Table 1*. Selected CMAI for Various Species at Various Sites (continued)**			
Species	*CMAI (Years)*	*Site*	*Source*
Black cherry	70	MN to TX to FL to ME	7
American elm	80	MN to TX to FL to ME	7
Slippery elm	80	ND to TX to SC to ME	7
Hackberry	70	ND to OK to VA to NH	7
Bitternut hickory	70	MN to TX to SC to NH	7
Shagbark hickory	80	MN to TX to VA to ME	7
White fir	70	OR, CA, NV, ID, UT, CO, NM, AZ	8
Grand fir	121	WA, OR, ID, MT, CA	8
Subalpine fir	120–150	WA, OR, CA, ID, MT, WY, UT, CO, AZ, NM	8
Shasta red fir	140	CA, OR	8
Red alder	35-42	OR	8
Western juniper	100	OR	8
Western larch	70	OR	8
Engelmann spruce	80-150	OR	8
Coast redwood	50-144	OR	8
Loblolly Pine	23-27	TX to DE	9
Oak-pine	38	ME	10

Sources:

1. Appendix A.
2. Appendix B.
3. Burns, Russell M., and Barbara H. Honkala (technical coordinators). Silvics of North America, Volume 1: Conifers. Agriculture Handbook 654. Washington, DC: USDA Forest Service, 1990.
4. Burns, Russell M., and Barbara H. Honkala (technical coordinators). Silvics of North America. Volume 2: Hardwoods. Agriculture Handbook 654. Washington, DC: USDA Forest Service, 1990.
5. USDA Forest Service–Alaska Region. Tongass Land and Resource Management Plan Final Environmental Impact Statement, January 2008.
6. Barrett, John W. (ed.). *Regional Silviculture of the United States*, third edition. New York: John Wiley & Sons, 1995.
7. Wisconsin Department of Natural Resources. Silviculture Handbook, 2431.5.
8. USDA Natural Resources Conservation Service, Portland, OR. Forestry Technical Note No. 2 (Revised), Culmination of Mean Annual Increment for Commercial Trees in Oregon, May 2008.
9. Akridge, Maria and Tom Straka. July-August 2017. Financial Maturity. Forest Landowner.
10. Gallaudet, Denny. 2020. Managing a Maine Woodland. (self-published).

Appendix A
CMAI of Coast Douglas-Fir

Because of the widespread nature and commercial importance of Douglas-fir, CMAI information is widely available. I examine those Douglas-fir numbers in Table A-1, relying on a Forest Service research paper that synthesizes different timber scheduling models and site conditions. For this analysis I relied exclusively on a 1994 paper by Robert O. Curtis. In his paper, Curtis modeled ages of first reaching CMAI ("MAImax" in his paper) for natural stands using four different well-established timber models (DFSIM, SPS, ORGANON, TASS) for three Douglas-fir site classes (II, III, and IV).

To the scientists among you (save for political scientists), I apologize for what I did next. I averaged the site classes within each model, averaged the site classes between each model, averaged the averages of the models, and averaged the averages by model. The results are in Table A-1.

The bottom-line take-home good-enough-for-government-work message is: For Douglas-fir, the average age of CMAI is eighty-four years; on more productive sites it can be as low as sixty years, and on less productive sites as high as one hundred and thirty years—but on average it's eighty-four years.

Table A-1. **Culmination of Mean Annual Increment for Douglas-Fir**					
Douglas-fir Timber Model*	**Site Class**	**Age at Which MAImax* First Reached**	**Lower and Upper Age Limits, 95% of MAImax**		**Notes**
			Lower 95%	**Upper 95%**	
DFSIM	II	74	52	103	
	III	74	58	108	
	IV	84	70	120	
	Average	*77*	*60*	*110*	
SPS	II	71	52	91	
	III	88	64	104	
	IV	92	75	120	***
	Average	*84*	*64*	*105*	
ORGANON	II	90	72	130	***
	III	109	85	130	***
	IV	123	98	130	***
	Average	*107*	*85*	*130*	
TASS	II	75	60	92	
	III	NA	NA	NA	
	IV	60	68	120	***
	Average	*68*	*64*	*106*	
AVERAGE OF SITE CLASSES	*II*	*78*	*59*	*104*	
	III	*90*	*69*	*114*	
	IV	*90*	*78*	*123*	
AVERAGE AVERAGE OF ALL MODELS		*86*	*69*	*114*	***
AVERAGE OF AVERAGES BY MODEL		*84*	*68*	*113*	***
* All “no treatment” (aka natural stands)					
** MAImax = CMAI (culmination of mean annual increment)					
*** Data in Upper 95% column was actually X+. + dropped to allow averaging.					
Data source: Curtis, Robert O. “Some Simulation Estimates of Mean Annual Increment of Douglas-Fir: Results, Limitations, and Implications for Management.” USDA Forest Service Pacific Northwest Research Station, Research Paper PNW-RP-471, 1994.					

Appendix B
CMAI of Typical Eastside Oregon and Washington Species

Process for Calculating Culmination of Mean Annual Increment
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April 2008

Culmination of mean annual increment (CMAI) is calculated by using yield tables derived from actual growth data or by using a growth model (Curtis 1994). Growth rates vary for a particular species depending on many factors including site productivity, stand density, forest composition, age, management pathway, geneotypic variability, etc. Thus there is considerable variation in published yield tables that have been developed for individual species by different authors. The goal of this document is to lay out a process for calculating CMAI that accounts for the variability in natural systems while being easy to use, scientifically credible, and repeatable by multiple parties.

Congressman Peter DeFazio’s draft Pacific Northwest Forest Legacy Act uses CMAI as a means of determining when forests are beginning to develop old forest or late-seral characteristics and thus receive legislative protection. The current language of the draft legislation states that the age of CMAI for a given stand should be based on when CMAI is *typically* and *first* reached in a *natural* stand on that *particular* growing site.

To capture the intent of this language, a process was developed to determine CMAI on specific Plant Associations (PA) in a particular federal forest administrative unit. A number of simplifying assumptions had to be made to design a process that could be applied across the entire NWFP region, while also being easily repeatable and scientifically credible. Different parties may disagree with some of these assumptions. However, this process is similar to what was done to estimate CMAI and rotation ages during the development of many National Forests Land Management Plans prior to the Northwest Forest Plan and the Eastside Screens. Likewise, it is likely very similar to what the Forest Service would propose to estimate CMAI for the purposes of the Pacific Northwest Forest Legacy Act. The process has the following steps.

1. The Forest Vegetation Simulator (FVS) should be used to model stand growth and generate yield tables from which CMAI can be calculated. This is the primary growth model used by the Forest Service. It is publicly available and likely to be maintained and updated for many years to come. http://www.fs.fed.us/fmsc/fvs/software/index.shtml

2. Within FVS, different growth model variants exist for different regions of the PNW and greater US. The appropriate variant should be used for the National Forest or BLM District in question. For areas covered by multiple variants, choose the one that covers the Ranger District or administrative unit in question. Default values embedded within each variant for elevation, aspect, slope, and lat and long should be used. A map and overview information on the different variants can be found at http://www.fs.fed.us/fmsc/fvs/variants/index.shtml.

3. The dominant Plant Association (PA) of the stand or area in question should be used within FVS as the basis of defining productivity and density of natural stands. Site index may be included in the model parameters, but must be the value listed for the specific PA

and site species in the Plant Association Guide for the National Forest or BLM District in question.

4. Yield tables should be based on even-aged stands that receive no intermediate stand entries (precommercial or commercial thinning). Conceptually, CMAI is based on even-aged stands and is problematic to calculate in uneven-aged stands and for specific cohorts. Natural stands in some plant associations are often uneven-aged. However, even in these PA's, natural even-aged stands, or large even-aged patches, also exist. Even if most natural stands for a specific PA are uneven-aged, the even-aged CMAI for that PA is still a good indicator of when mature and old forest characteristics begin to occur. Thus rather than attempting to calculate CMAI for uneven-aged stands, the process sticks with even-aged stands.

5. To generate a yield table, a stand in a specific PA should be planted within FVS and grown out to an age that is very likely beyond the CMAI. Species composition of planted trees should be based on the percent cover of overstory trees for a specific PA listed in the Plant Association Guide for the National Forest in question. For any federal administrative unit that does not have its own Plant Association Guide, a guide from a nearby and ecologically similar National Forest should be used. Species with 5% or less mean relative cover should not be included to simplify modeling.

6. Initial stand density for the year of origin used to generate yield tables should be based on the formula shown below. The sum of overstory cover for all species, derived for specific PA in the respective Plant Association Guide, is used as an approximate measure of the stocking level of natural stands in each PA. Stands with less overstory cover generally have less carrying capacity, as measured by maximum Stand Density Index (SDI). The maximum SDI for each PA used by FVS is shown in the appendix tables of the FVS variant overview files, which are located at: http://www.fs.fed.us/fmsc/fvs/variants/index.shtml. The formula below makes the assumption that PA with more carrying capacity generally have higher stocking under natural stand development, and thus start out at a higher density. Natural regeneration is inherently difficult to predict and stands start out at a wide range of initial densities depending on a large number of factors. While natural regeneration extensions exist for some FVS variants and could be used, they do not yet exist for all FVS variants. Plus, many natural stands go through long periods of stand establishment and/or shrub competition, which is difficult to account for in this FVS modeling process.

   Also, natural stands in some drier PA's typically develop with multiple partial disturbances such as low to moderate intensity fires. These disturbances lower stand density and thus typically prolong CMAI. Instead of trying to estimate the number and intensity of these disturbances, this process assigns lower initial stocking to account for this. These dry forest PA's have lower overstory cover and thus receive lower initial stocking under the formula below.

7. The formula below is meant to provide a simple, common initial density and avoid multiple methodologies of determining initial stand density. The formula is based on low estimates of initial stocking that generally occur under natural regeneration. As lower initial stocking results in a later CMAI, using higher initial stocking numbers will result in a lower CMAI. If agency staff or others argue that higher initial stocking is closer to actual conditions, the CMAI will be lower.

- 0–50% total overstory cover 100 trees per acre (TPA)
- 51–65% total overstory cover 200 TPA
- 66–80% total overstory cover 300 TPA
- 81+% total overstory cover 400 TPA

8. Total stem cubic volume should be used as the basis for determining the age when CMAI is reached.

Due to many factors the same plant association may have different productivity levels and carrying capacity and thus different CMAI in different regions and federal forest administrative units. Thus CMAI should not be calculated for a PA across the entire Pacific Northwest, but instead should be calculated for specific federal administrative units. To demonstrate how the process works, it was used to calculate CMAI for a range of PAs on the Wenatchee National Forest, from a very dry Ponderosa PA to an upper elevation sub-alpine fir PA (Table B-1). In addition, the process was also used to calculate CMAI for a range of PAs on the Rogue-Siskiyou NF (Table B-2) using the Klamath Mountains (NC) variant of FVS.

To further illustrate how the calculation of CMAI was done, the step by step process is explained below for 1 PA on the Wenatchee NF:

1. The Eastside Cascades variant of the Forest Vegetation Simulator (FVS) was used as the growth model.

2. A range of plant associations were chosen to show a range of forest types and tree species. The location code corresponding to the Wenatchee National Forest was entered. No variables for elevation, age, aspect, or site index were entered and thus the model used the default values as described in the East Cascade Variant Overview: http://www.fs.fed.us/fmsc/ftp/fvs/docs/overviews/ecvar.pdf.

3. For each plant association, a stand was planted that contained the proportion of overstory tree species that is listed in Appendix B of the Field Guide for Forested Plant Associations of the Wenatchee NF, http://www.fs.fed.us/pnw/pubs/gtr359.pdf. For example, Appendix B (page 290) lists PSME/PUTR (Douglas-fir/bitterbrush) PA as having 16% mean relative cover of Ponderosa Pine and 10% for Douglas-fir. Given a starting density of 300 TPA, this equates proportionally to 185 TPA of Ponderosa Pine and 115 of Douglas-fir. Any other species with 5% or less mean relative cover would have been ignored.

4. The stands were grown out 150 years at 10-year intervals and a yield table was generated for total stem cubic volume. From this yield table, mean annual increment was calculated at 10 year points. The CMAI was found to be at 70 years for this PA.

References

Curtis, R. O. 1994. Some simulation estimates of mean annual increment of Douglas fir: results, limitations, and implications for management. USDA Forest Service, Pacific Northwest Research Station. Res. Pap. RP-PNW-471:27.

Table B-1. CMAI, Total Overstory Cover, and Species Composition for a Range of Plant Associations on the Wenatchee National Forest									
Plant Association Group	**CMAI Age**	**Total OS Cover (%)**	**Initial TPA**	**Species Composition (%)**					
				PP	**DF**	**LP**	**GF**	**ES**	**AF**
PIPO/CARU-AGSP Ponderosa pine/pinegrass-wheat grass	90	35	100	94	6				
PSME/PUTR Douglas-fir/bitterbrush	90	26	100	62	38				
PSME/CAGE Douglas-fir/elk sedge	100	57	200	21	79				
PSME/SYAL Douglas-fir/common snowberry	80	84	400	25	63	12			
ABGR/SPEBL/PTAQ Grand fir/shiny-LFspirea/bracken fern	70	72	300	21	50	17	13		
PIEN/EQAR Engelmann spruce/horsetail	130	88	400		28			51	20
ABLA2/PAMY-WEN Subalpine fir/pachistima	100	76	300		34	32		16	18
PP: Ponderosa Pine; DF: Douglas-fir; LP: Lodgepole Pine; GF: Grand-fir; ES: Engelmann Spruce; AF: Sub-alpine-fir									

Table B-2. CMAI, Total Overstory Cover, and Species Composition for a Range of Plant Associations on the Rogue-Siskiyou National Forest									
Plant Association Group	**CMAI Age**	**Total OS Cover (%)**	**Initial TPA**	**Species Composition (%)**					
				PP	**DF**	**IC**	**WF**	**RF**	**OS**
PIPO-PSME Douglas-fir-ponderosa pine	90	47	100	34	36	30			
LIDE3/VAOV2-GASH Tanoak/evergreen huckleberry-salal	70	51	200		100				
PSME-ABCO Douglas-fir-white fir	60	63	200		81		19		
TSHE/GASH Western hemlock/salal	60	68	300		74				26
CHLA/GASH Port-Orford-cedar/salal	60	77	300		68				32
PIJE-QUVA Jeffrey pine-huckleberry oak	80	31	100			16			84
ABCO-PSME White fir-Douglas-fir	60	79	300		63		37		
ABMAS/POPU Shasta red fir/skunkleaf polemonium	80	64	200				19	81	
PIMO/XETE Western white pine/beargrass	80	50	100						100
TSME/POPU Mountain hemlock/skunkleaf polemonium	60	66	300					32	68
PP: Ponderosa Pine; DF: Douglas-fir; IC: Incense Cedar; WF: White-fir; RF: Red-fir; OS: Other conifers									