ICASCA Variant

(INLAND CALIFORNIA / SOUTHERN CASCADES)

FOREST VEGETATION SIMULATOR

Compiled by

Gary Dixon
Forest Management Service Center
Fort Collins, Colorado

October 23, 1999

INTRODUCTION

The Forest Vegetation Simulator (FVS) is an individual tree, distance independent growth and yield model with linkable modules, called extensions, to simulate various insect and pathogen impacts, and development of understory vegetation. The FVS model was originally called Prognosis (Stage, 1973) and developed for use in the Inland Empire area of Idaho and Montana. New "variants" of the FVS model result when tree growth and mortality equations for a particular geographic area are imbedded in the FVS framework. Geographic variants of FVS have been developed for most of the forested lands in the western, upper midwest, northeast, and some parts of the southeast U.S.

A FVS variant was completed in 1998 for the forest types of the northern Inland California and Southern Cascades regions of California and Oregon. This variant, called ICASCA, includes all or part of the Klammath, Lassen, Mendocino, Plumas, and Shasta-Trinity National Forests in California, the Illinois Valley (east) Ranger District of the Siskiyou National Forest in Oregon, and the Applegate and Ashland (west) Ranger Districts of the Rogue River National Forest in Oregon. Figure 1 shows the general geographic area covered by this variant.

The model includes forty seven individual species and additional species are accomodated through "other softwoods" and "other hardwoods" categories. Since FVS is an individual tree model, a wide variety of forest types can be simulated, as can any stand structure ranging from even-aged to uneven-aged, and pure to mixed species stands.

Geographic Area of Application:

Figure 1 Map indicating the approximate geographic area covered by the Inland California / Southern Cascades (ICASCA) variant of the Forest Vegetation Simulator.

Location and species codes are used to enter appropriate data for a given FVS run. Location codes and species codes used in the ICASCA variant are as follows:

Forest Codes

Region 5:
505 = Klammath
506 = Lassen
508 = Mendocino
511 = Plumas
514 = Shasta-Trinity

Region 6:
610 = Rogue River
611 = Siskiyou

Species Order

FVS SEQ NUM	FVS ALPHA CODE	PLANTS CODE	FIA CODE	COMMON NAME	SCIENTIFIC NAME
1	PC	CHLA	041	Port Orford cedar	Chamaecyparis lawsoniana
2	IC	LIDE	081	Incense cedar	Libocedrus decurrens
3	RC	THPL	242	Western redcedar	Thuja plicata
4	WF	ABCO	015	White fir	Abies concolor
5	RF	ABMA	020	California red fir	Abies magnifica (magnifica)

6	SH	ABSH	021	Shasta red fir	Abies magnifica (shastensis)
7	DF	PSME	202	Douglas-fir	Pseudotsuga menziesii
8	WH	TSHE	263	Western hemlock	Tsuga heterophylla
9	MH	TSME	264	Mountain hemlock	Tsuga mertensiana
10	WB	PIAL	101	Whitebark pine	Pinus albicaulis
11	KP	PIAT	103	Knobcone pine	Pinus attenuata
12	LP	PICO	108	Lodgepole pine	Pinus contorta
13	CP	PICO3	109	Coulter pine	Pinus coulteri
14	LM	PIFL2	113	Limber pine	Pinus flexilis (flexilis)
15	JP	PIJE	116	Jeffrey pine	Pinus jeffreyi
16	SP	PILA	117	Sugar pine	Pinus lambertiana
17	WP	PIMO3	119	Western white pine	Pinus monticola
18	PP	PIPO	122	Ponderosa pine	Pinus ponderosa
19	MP	PIRA2	124	Monterey pine	Pinus radiata
20	GP	PISA2	127	Gray pine	Pinus sabiniana
21	JU	JUOC	064	Western juniper	Juniperus occidentalis
22	BR	PIBR	092	Brewer spruce	Picea breweriana
23	GS	SEGI2	212	Giant sequoia	Sequoiadendron giganteum
24	PY	TABR2	231	Pacific yew	Taxus brevifolia
25	OS		001	Other softwoods	
26	LO	QUAG	801	Coast live oak	Quercus agrifolia
27	CY	QUCH2	805	Canyon live oak	Quercus chrysolepsis
28	BL	QUDO	807	Blue oak	Quercus douglasii
29	EO	QUEN	811	Engelmann oak	Quercus engelmanni
30	WO	QUGA4	815	Oregon white oak	Quercus garryana
31	BO	QUKE	818	California black oak	Quercus kelloggii
32	VO	QULO	821	Valley white oak	Quercus lobata
33	IO	QUWI2	839	Interior live oak	Quercus wislizenii
34	BM	ACMA3	312	Bigleaf maple	Acer macrophyllum
35	BU	AECA	330	California buckeye	Aesculus californica
36	RA	ALRU2	351	Red alder	Alnus rubra
37	MA	ARME	361	Pacific madrone	Arbutus menziesii
38	GC	CACH6	431	Golden chinkapin	Castanopsis chrysophylla
39	DG	CONU4	492	Pacific dogwood	Cornus nuttallii
40	FL	FRLA	542	Oregon ash	Fraxinus latifolia
41	WN	JU__	600	Walnut	Juglans sp.
42	TO	LIDE3	631	Tanoak	Lithocarpus densiflorus
43	SY	PLRA	730	California sycamore	Platanus racemosa
44	AS	POTR5	746	Quaking aspen	Populus tremuloides
45	CW	POBAT	747	Black cottonwood	Populus trichocarpa
46	WI	SA__	920	Willow	Salis sp.
47	CN	TOCA	251	California nutmeg	Torreya californica
48	CL	UMCA	981	California laurel	Umbellularia californica
49	OH		004	Other hardwoods	

Site index

The FVS ICASCA variant uses site index as a growth predictor variable. If site index information is available, a single site index for the whole stand can be entered, a site index for each individual species in the stand can be entered, or a combination of these can be entered.

Region 5 forests can enter site index as a Dunning site class (0-5) or as a site index value from TABLE 1 of the FOREST INVENTORY AND ANALYSIS USER'S GUIDE (1995). This table was adapted for Region 5 by Jack Levitan from Duncan Dunning's (1942) site index curves and is a base age 50, total age site index.

If a Dunning site class is entered, it is immediately converted to a site index for each species within the model using a two-step process. First the Dunning site class is converted to a 50-year site index as follows:

DUNNING SITE CLASS	(BREAST HT AGE) 50-YEAR SITE INDEX
0	110
1	95
2	80
3	60
4	50
5	40

Second, site index for an individual species is determined by multiplying the 50-year site index obtained in the first step by a species specific adjustment factor. These factors are shown in Table 1.

In other words, the 50-year site index derived from a Dunning code is directly assigned to white fir, California red fir, shasta red fir, Douglas-fir, Jeffrey pine, sugar pine, ponderosa pine, and giant sequoia, and a reduced site index is assigned to the remaining species. For example, if a Dunning site class 2 is entered, the 50-year site index is 80 and would be assigned to all the species with an adjustment factor of 1.00, while incense cedar would be assigned 61 (i.e. 80 * 0.76), western hemlock would be assigned 72 (i.e. 80 * 0.90), and pacific madrone would be assigned 46 (i.e. 80 * 0.57).

For Region 5 forests, the default site species is DF and the default site index is 80.

Region 6 forests can enter a site index from a King (1966) curve if the site species for a given ecoclass is either Douglas-fir or Jeffrey pine, or they can enter a site index from a Dolph (1987) curve if the site species for a given ecoclass is either white fir or shasta red fir. Both of these curves are base age 50, breast high age curves.

For Region 6 forests, the default site species and site index are determined by ecoclass codes as discussed in the Ecoclass Codes section.

Site index values for individual species in Region 6 which are not set via keywords are obtained by multiplying the site index for the site species by the species adjustment factors shown in Table 1.

Stand Density Index (SDI) maximum

Stand Density Index (SDI) is used in the mortality and crown ratio change portions of the ICASCA variant. Default SDI maximums, by species, for Region 5 forests are shown in Table 1. These defaults were determined from scattergrams of sdi by pure or majority species for Region 5 forest inventory cluster plots. Users can enter their own SDI maximum values, by species, using the SDIMAX keyword.

Ecoclass codes

The ICASCA variant does not use ecoclass code (aka habitat type, plant association) as a predictor variable. However, for Region 6 forests, default site species, site indices, and sdi maximums are determined by ecoclass code. Users can override these defaults with appropriate keywords. Valid ecoclass codes for the ICASCA variant are shown in Table 2. The default ecoclass code for Region 6 users of the ICASCA variant is 46 = XCWC221.

Table 1. Site index adjustment factors and Region 5 default SDI values, used in the ICASCA variant.

FVS SEQ NUM	FVS ALPHA CODE	COMMON NAME	SITE INDEX ADJUSTMENT FACTOR	DEFAULT REGION 5 SDI MAXIMUM
1	PC	Port Orford cedar	0.90	690
2	IC	Incense cedar	0.76	690
3	RC	Western redcedar	0.90	690
4	WF	White fir	1.00	800
5	RF	California red fir	1.00	765
6	SH	Shasta red fir	1.00	765
7	DF	Douglas-fir	1.00	580
8	WH	Western hemlock	0.90	600
9	MH	Mountain hemlock	0.90	600
10	WB	Whitebark pine	0.90	580
11	KP	Knobcone pine	0.90	460
12	LP	Lodgepole pine	0.90	590
13	CP	Coulter pine	0.90	460
14	LM	Limber pine	0.90	460
15	JP	Jeffrey pine	1.00	460
16	SP	Sugar pine	1.00	460
17	WP	Western white pine	0.90	580
18	PP	Ponderosa pine	1.00	735
19	MP	Monterey pine	0.90	460
20	GP	Gray pine	0.90	460
21	JU	Western juniper	0.76	460
22	BR	Brewer spruce	0.76	800
23	GS	Giant sequoia	1.00	730
24	PY	Pacific yew	0.76	460
25	OS	Other softwoods	0.90	460
26	LO	Coast live oak	0.76	550
27	CY	Canyon live oak	0.76	550
28	BL	Blue oak	0.76	550
29	EO	Engelmann oak	0.76	550
30	WO	Oregon white oak	0.76	550
31	BO	California black oak	0.76	400
32	VO	Valley white oak	0.76	550
33	IO	Interior live oak	0.76	550
34	BM	Bigleaf maple	0.76	550
35	BU	California buckeye	0.76	550
36	RA	Red alder	0.76	550
37	MA	Pacific madrone	0.76	525
38	GC	Golden chinkapin	0.76	525
39	DG	Pacific dogwood	0.76	525
40	FL	Oregon ash	0.76	550
41	WN	Walnut	0.76	550
42	TO	Tanoak	0.76	550
43	SY	California sycamore	0.76	550
44	AS	Quaking aspen	0.76	550
45	CW	Black cottonwood	0.76	550
46	WI	Willow	0.76	550

47	CN	California nutmeg	0.76	550
48	CL	California laurel	0.76	550
49	OH	Other hardwoods	0.76	550

Table 2. Plant Association (Ecoclass) codes used in the Inland California /Southern Cascades (ICASCA) variant of the Forest Vegetation Simulator

Example: If the ecoclass code XCDC412 was entered in field 2 of the STDINFO keyword, the default site species would be Douglas-fir, the default site index for Douglas-fir would be 87, and the default Stand Density Index (SDI) for Douglas-fir would be 1155. Default values for all other species would be generated from these Douglas-fir values. Douglas-fir is species number 7 in the ICASCA variant.

ALPHA ECO CLASS	SCIEN SITE SPEC	MAX SDI	ALPHA SITE SPEC	SITE INDX	NUM IN ECO	SITE SPP FLAG	FVS SEQ NUM	PLANT ASSOCIATION REFERENCE
1 = XCDC411 = PSME-ABCO-PIJE Douglas-fir-white fir-Jeffrey pine								
XCDC411	PSME	899	DF	85	1	1	7	
2 = XCDC412 = PSME-ABCO-PIPO Douglas-fir-white fir-ponderosa pine								
XCDC412	PSME	1155	DF	87	1	1	7	
3 = XCDC421 = PSME-ABCO Douglas-fir-white fir								
XCDC421	PSME	786	DF	72	1	1	7	
4 = XCDC431 = PSME-ABCO/HODI Douglas-fir-white fir/creambush oceanspray								
XCDC431	PSME	845	DF	96	1	1	7	
5 = XCDC432 = PSME-ABCO/BENE Douglas-fir-white fir/dwarf Oregongrape								
XCDC432	PSME	1193	DF	93	1	1	7	
6 = XCDC511 = PSME-PIPO Douglas-fir-ponderosa pine								
XCDC511	PSME	1235	DF	101	1	1	7	
7 = XCDC521 = PSME-PIJE Douglas-fir-Jeffrey pine								
XCDC521	PSME	516	DF	71	1	1	7	

ALPHA ECO CLASS	SCIEN SITE SPEC	MAX SDI	ALPHA SITE SPEC	SITE INDX	NUM IN ECO	SITE SPP FLAG	FVS SEQ NUM	PLANT ASSOCIATION REFERENCE
8 = XCDF911 = PSME/DEPAUPERATE Douglas-fir/depauperate								
XCDF911	PSME	887	DF	70	1	1	7	
9 = XCDH111 = PSME-LIDE3/GASH Douglas-fir-tanoak/salal								
XCDH111	PSME	845	DF	86	1	1	7	
10 = XCDH112 = PSME/RHMA Douglas-fir/Pacific rhododendron								
XCDH112	PSME	979	DF	92	1	1	7	
11 = XCDH121 = PSME-LIDE3-PILA Douglas-fir-tanoak-sugar pine								
XCDH121	PSME	989	DF	97	1	1	7	
12 = XCDH131 = PSME-LIDE3 Douglas-fir-tanoak								
XCDH131	PSME	1098	DF	81	1	1	7	
13 = XCDH141 = PSME-LIDE3-QUCH Douglas-fir-tanoak-canyon live oak								
XCDH141	PSME	804	DF	86	1	1	7	
14 = XCDH142 = PSME-LIDE3/RHDI Douglas-fir-tanoak/poison oak								
XCDH142	PSME	845	DF	82	1	1	7	
15 = XCDH511 = PSME-QUSA Douglas-fir-Sadler oak								
XCDH511	PSME	1087	DF	95	1	1	7	
16 = XCDS111 = PSME/RHDI-BEPI Douglas-fir/poison oak-Piper's Oregongrape								
XCDS111	PSME	683	DF	77	1	1	7	
17 = XCDS112 = PSME/RHDI Douglas-fir/poison oak								
XCDS112	PSME	490	DF	67	1	1	7	

ECO CLASS	SITE SPEC	MAX SDI	SITE SPEC	SITE INDX	IN ECO	SPP FLAG	SEQ NUM	ASSOCIATION REFERENCE
18 = XCDS511 = PSME/BENE Douglas-fir/dwarf Oregongrape								
XCDS511	PSME	856	DF	93	1	1	7	
19 = XCDS521 = PSME/BERE Douglas-fir/creeping Oregongrape								
XCDS521	PSME	899	DF	85	1	1	7	
20 = XCHC111 = TSHE-CHLA Western hemlock-Port-Orford-cedar								
XCHC111	PSME	1334	DF	117	1	1	7	
21 = XCHC412 = TSHE-THPL/HIGH ELEV Western hemlock-western redcedar/high elevation								
XCHC412	PSME	1152	DF	108	1	1	7	
22 = XCHC461 = TSHE-THPL Western hemlock-western redcedar								
XCHC461	PSME	1392	DF	146	1	1	7	
23 = XCHC611 = TSHE-ABCO Western hemlock-white fir								
XCHC611	PSME	1332	DF	119	1	1	7	
24 = XCHH111 = TSHE-UMCA Western hemlock-California laurel								
XCHH111	PSME	956	DF	106	1	1	7	
25 = XCHH511 = TSHE-QUSA Western hemlock-Sadler oak								
XCHH511	PSME	1152	DF	108	1	1	7	
26 = XCHS131 = TSHE/GASH (SWO) Western hemlock/salal								
XCHS131	PSME	751	DF	61	1	1	7	
27 = XCHS331 = TSHE/RHMA (SWO) Western hemlock/Pacific rhododendron								
XCHS331	PSME	1147	DF	102	1	1	7	

ALPHA ECO CLASS	SCIEN SITE SPEC	MAX SDI	ALPHA SITE SPEC	SITE INDX	NUM IN ECO	SITE SPP FLAG	FVS SEQ NUM	PLANT ASSOCIATION REFERENCE

```
-----------------------------------------------------------------------
   28 = XCMF211 = TSME/POPU
    Mountain hemlock/skunkleaf polemonium

      XCMF211    ABMAS   1371  SH      74    1    1    6
-----------------------------------------------------------------------
   29 = XCPC411 = PIPO-PSME
    Ponderosa pine-Douglas-fir

      XCPC411    PSME     720  DF      76    1    1    7
-----------------------------------------------------------------------
   30 = XCPC511 = PIJE-PIMO
    Jeffrey pine-western white pine

      XCPC511    PIJE     351  JP      52    1    1   15
-----------------------------------------------------------------------
   31 = XCPG141 = PIJE/FEID
    Jeffrey pine/Idaho fescue

      XCPG141    PIJE     340  JP      57    1    1   15
-----------------------------------------------------------------------
   32 = XCPH411 = PIJE-QUVA
    Jeffrey pine-huckleberry oak

      XCPH411    PIJE     304  JP      60    1    1   15
-----------------------------------------------------------------------
   33 = XCPS321 = PIJE/CEPU
    Jeffrey pine/dwarf ceanothus

      XCPS321    PIJE     364  JP      58    1    1   15
-----------------------------------------------------------------------
   34 = XCPS611 = PIJE/GRASS
    Jeffrey pine/grass

      XCPS611    PIJE     340  JP      57    1    1   15
-----------------------------------------------------------------------
   35 = XCQF111 = PIMO/XETE
    Western white pine/beargrass

      XCQF111    ABCO     436  WF      33    1    1    4
-----------------------------------------------------------------------
   36 = XCRF211 = ABMAS/POPU
    Shasta red fir/skunkleaf polemonium

      XCRF211    ABMAS   1065  SH      57    1    1    6
-----------------------------------------------------------------------
   37 = XCRF311 = ABMAS/SHEEP
    Shasta red fir/sheep    (grazing destroyed understory plants)

      XCRF311    ABMAS    319  SH      50    1    1    6


      ALPHA     SCIEN          ALPHA        NUM  SITE FVS  PLANT
       ECO       SITE     MAX  SITE  SITE  IN   SPP  SEQ  ASSOCIATION
      CLASS      SPEC     SDI  SPEC  INDX  ECO  FLAG NUM  REFERENCE
-----------------------------------------------------------------------
   38 = XCRH111 = ABMAS-QUSA
```

```
    Shasta red fir-Sadler oak

      XCRH111    ABMAS   1335  SH      81    1    1    6
----------------------------------------------------------------------
   39 = XCRS211 = ABMAS/SYMO
    Shasta red fir/creeping snowberry

      XCRS211    ABMAS   1508  SH      91    1    1    6
----------------------------------------------------------------------
   40 = XCTH111 = CHLA-QUVA
    Port-Orford-cedar-huckleberry oak

      XCTH111    PSME    1309  DF      87    1    1    7
----------------------------------------------------------------------
   41 = XCTH211 = CHLA-ACMA
    Port-Orford-cedar-bigleaf maple

      XCTH211    PSME    1309  DF      87    1    1    7
----------------------------------------------------------------------
   42 = XCTS111 = CHLA/BENE/ACTR
    Port-Orford-cedar/dwarf Oregongrape/vanillaleaf

      XCTS111    PSME    1348  DF      85    1    1    7
----------------------------------------------------------------------
   43 = XCTS112 = CHLA/BENE/LIBOL
    Port-Orford-cedar/dwarf Oregongrape/western twinflower

      XCTS112    PSME    1505  DF      92    1    1    7
----------------------------------------------------------------------
   44 = XCTS211 = CHLA/GASH
    Port-Orford-cedar/salal

      XCTS211    PSME    1075  DF      83    1    1    7
----------------------------------------------------------------------
   45 = XCTS311 = CHLA/GABU
    Port-Orford-cedar/box-leaved silktassle

      XCTS311    PSME    1309  DF      87    1    1    7
----------------------------------------------------------------------
   46 = XCWC221 = ABCO-PSME
    White fir-Douglas-fir

      XCWC221    PSME    1052  DF      92    1    1    7
----------------------------------------------------------------------
   47 = XCWC231 = ABCO-PSME/BENE
    White fir-Douglas-fir/dwarf Oregongrape

      XCWC231    PSME    1008  DF      95    1    1    7


      ALPHA     SCIEN         ALPHA        NUM  SITE FVS  PLANT
       ECO       SITE     MAX  SITE  SITE  IN   SPP  SEQ  ASSOCIATION
      CLASS      SPEC     SDI  SPEC  INDX  ECO  FLAG NUM  REFERENCE
----------------------------------------------------------------------
   48 = XCWC232 = ABCO-PSME/HODI
    White fir-Douglas-fir/creambush oceanspray
```

```
      XCWC232    PSME    1136  DF       89    1    1    7
---------------------------------------------------------------------
   49 = XCWC233 = ABCO-PSME/DEPAUPERATE
    White fir-Douglas-fir/depauperate

      XCWC233    PSME     988  DF       78    1    1    7
---------------------------------------------------------------------
   50 = XCWC241 = ABCO-PIPO
    White fir-ponderosa pine

      XCWC241    PSME    1251  DF       84    1    1    7
---------------------------------------------------------------------
   51 = XCWC521 = ABCO-PIBR/VAME
    White fir-Brewer spruce/thin-leaved huckleberry

      XCWC521    PSME     899  DF       57    1    1    7
---------------------------------------------------------------------
   52 = XCWC522 = ABCO-PIBR/GAOV
    White fir-Brewer spruce/slender salal

      XCWC522    PSME     874  DF       95    1    1    7
---------------------------------------------------------------------
   53 = XCWC523 = ABCO-PIBR/CHUM
    White fir-Brewer spruce/western prince's-pine

      XCWC523    PSME     751  DF       69    1    1    7
---------------------------------------------------------------------
   54 = XCWC611 = ABCO-CHLA
    White fir-Port-Orford-cedar

      XCWC611    PSME    1399  DF       99    1    1    7
---------------------------------------------------------------------
   55 = XCWC612 = ABCO-CHLA/DEPAUPERATE
    White fir-Port-Orford-cedar/depauperate

      XCWC612    PSME    1399  DF       99    1    1    7
---------------------------------------------------------------------
   56 = XCWC721 = ABCO-ABMAS/RIBES
    White fir-Shasta red fir/currant

      XCWC721    ABCO    1414  WF       77    1    1    4
---------------------------------------------------------------------
   57 = XCWC722 = ABCO-ABMAS/ROGY
    White fir-Shasta red fir/baldhip rose

      XCWC722    PSME    1349  DF       89    1    1    7


      ALPHA     SCIEN         ALPHA         NUM  SITE FVS  PLANT
       ECO       SITE     MAX  SITE  SITE  IN   SPP  SEQ  ASSOCIATION
      CLASS      SPEC     SDI  SPEC  INDX  ECO  FLAG NUM  REFERENCE
---------------------------------------------------------------------
   58 = XCWC723 = ABCO-ABMAS/SYMO
    White fir-Shasta red fir/creeping snowberry

      XCWC723    PSME    1287  DF       81    1    1    7
---------------------------------------------------------------------
```

```
   59 = XCWC811 = ABCO-TABR
    White fir-Pacific yew

      XCWC811    PSME    1096  DF      96    1    1    7
-----------------------------------------------------------------------
   60 = XCWC911 = ABCO-CHNO
    White fir-Alaska cedar

      XCWC911    ABCO    1641  WF      65    1    1    4
-----------------------------------------------------------------------
   61 = XCWF911 = ABCO/HERB
    White fir/herb

      XCWF911    PSME    1202  DF      89    1    1    7
-----------------------------------------------------------------------
   62 = XCWH312 = ABCO-LIDE3
    White fir-tanoak

      XCWH312    PSME    1255  DF      93    1    1    7
-----------------------------------------------------------------------
   63 = XCWH413 = ABCO-ACGL
    White fir-Rocky Mountain maple

      XCWH413    PSME     654  DF     108    1    1    7
-----------------------------------------------------------------------
   64 = XCWH511 = ABCO-QUSA/CHUM
    White fir-Sadler oak/western prince's-pine

      XCWH511    PSME    1337  DF      93    1    1    7
-----------------------------------------------------------------------
   65 = XCWH521 = ABCO-QUSA/BENE-PAMY
    White fir-Sadler oak/dwarf Oregongrape-Oregon boxwood

      XCWH521    PSME    1371  DF      96    1    1    7
-----------------------------------------------------------------------
   66 = XCWH522 = ABCO-QUSA/BENE
    White fir-Sadler oak/dwarf Oregongrape

      XCWH522    PSME    1432  DF     105    1    1    7
-----------------------------------------------------------------------
   67 = XCWH531 = ABCO-QUSA-CACH
    White fir-Sadler oak-golden chinquapin

      XCWH531    PSME    1226  DF      94    1    1    7


      ALPHA     SCIEN          ALPHA        NUM  SITE FVS  PLANT
       ECO       SITE     MAX  SITE  SITE  IN   SPP  SEQ  ASSOCIATION
      CLASS      SPEC     SDI  SPEC  INDX  ECO  FLAG NUM  REFERENCE
-----------------------------------------------------------------------
   68 = XCWS331 = ABCO/SYMO
    White fir/creeping snowberry

      XCWS331    PSME    1649  DF      92    1    1    7
-----------------------------------------------------------------------
   69 = XCWS523 = ABCO/BENE
    White fir/dwarf Oregongrape
```

```
      XCWS523    PSME    1249  DF      101    1    1    7
-----------------------------------------------------------------------
   70 = XHTC111 = LIDE3-SESE2
    Tanoak-coast redwood

      XHTC111    PSME    1550  DF      125    1    1    7
-----------------------------------------------------------------------
   71 = XHTC211 = LIDE3-TSHE
    Tanoak-western hemlock

      XHTC211    PSME    1037  DF      103    1    1    7
-----------------------------------------------------------------------
   72 = XHTC311 = LIDE3-CHLA
    Tanoak-Port-Orford-cedar

      XHTC311    PSME    1269  DF       98    1    1    7
-----------------------------------------------------------------------
   73 = XHTC411 = LIDE3-ABCO-ACCI
    Tanoak-white fir-vine maple

      XHTC411    PSME    1264  DF       90    1    1    7
-----------------------------------------------------------------------
   74 = XHTC412 = LIDE3-ABCO
    Tanoak-white fir

      XHTC412    PSME     969  DF       99    1    1    7
-----------------------------------------------------------------------
   75 = XHTH111 = LIDE3-QUCH
    Tanoak-canyon live oak

      XHTH111    PSME    1005  DF       96    1    1    7
-----------------------------------------------------------------------
   76 = XHTH112 = LIDE3-QUCH/BENE
    Tanoak-canyon live oak/dwarf Oregongrape

      XHTH112    PSME     728  DF       83    1    1    7
-----------------------------------------------------------------------
   77 = XHTH211 = LIDE3-UMCA
    Tanoak-California laurel

      XHTH211    PSME     944  DF      110    1    1    7


      ALPHA     SCIEN         ALPHA        NUM  SITE FVS  PLANT
       ECO       SITE     MAX  SITE  SITE  IN   SPP  SEQ  ASSOCIATION
      CLASS      SPEC     SDI  SPEC  INDX  ECO  FLAG NUM  REFERENCE
-----------------------------------------------------------------------
   78 = XHTH311 = LIDE3-ACCI
    Tanoak-vine maple

      XHTH311    PSME     997  DF      104    1    1    7
-----------------------------------------------------------------------
   79 = XHTS111 = LIDE3/VAOV2-GASH
    Tanoak/evergreen huckleberry-salal

      XHTS111    PSME     881  DF      107    1    1    7
```

```
-----------------------------------------------------------------------
   80 = XHTS112 = LIDE3/VAOV2
    Tanoak/evergreen huckleberry

      XHTS112    PSME    2384  DF     116    1    1    7
-----------------------------------------------------------------------
   81 = XHTS221 = LIDE3/RHMA
    Tanoak/Pacific rhododendron

      XHTS221    PSME    1089  DF     111    1    1    7
-----------------------------------------------------------------------
   82 = XHTS222 = LIDE3/RHMA-VAOV2
    Tanoak/Pacific rhododendron-evergreen huckleberry

      XHTS222    PSME     839  DF      93    1    1    7
-----------------------------------------------------------------------
   83 = XHTS223 = LIDE3/RHMA-GASH
    Tanoak/Pacific rhododendron-salal

      XHTS223    PSME    1073  DF      68    1    1    7
-----------------------------------------------------------------------
   84 = XHTS311 = LIDE3/BENE
    Tanoak/dwarf Oregongrape

      XHTS311    PSME    1288  DF      95    1    1    7
-----------------------------------------------------------------------
   85 = XHTS312 = LIDE3/BENE-RHDI
    Tanoak/dwarf Oregongrape-poison oak

      XHTS312    PSME    1005  DF      96    1    1    7
-----------------------------------------------------------------------
   86 = XHTS321 = LIDE3/GASH
    Tanoak/salal

      XHTS321    PSME    1036  DF     102    1    1    7
-----------------------------------------------------------------------
   87 = XHTS331 = LIDE3/GASH-RHMA
    Tanoak/salal-Pacific rhododendron

      XHTS331    PSME    1002  DF      90    1    1    7


      ALPHA     SCIEN          ALPHA         NUM  SITE FVS  PLANT
       ECO       SITE     MAX  SITE  SITE  IN   SPP  SEQ  ASSOCIATION
      CLASS      SPEC     SDI  SPEC  INDX  ECO  FLAG NUM  REFERENCE
-----------------------------------------------------------------------
   88 = XHTS341 = LIDE3/GASH-BENE
    Tanoak/salal-dwarf Oregongrape

      XHTS341    PSME    1022  DF     109    1    1    7
-----------------------------------------------------------------------
   89 = XHTS411 = LIDE3/RHDI-LOHI
    Tanoak/poison oak-hairy honeysuckle

      XHTS411    PSME     768  DF      79    1    1    7
-----------------------------------------------------------------------
   90 = XHTS511 = LIDE3/RHCA
```

```
     Tanoak/California coffeeberry

       XHTS511    PSME     138  DF      50    1    1    7
 -----------------------------------------------------------------------
```

Height Dubbing

If height is not present on a tree data input record, a height will be estimated by internal equations.

Two types of default equations are provided: (1) a non-linear functional form we call Curtis-Arney equation (Curtis 1967, Arney 1985), and (2) a logistic functional form we call a Wykoff equation (Wykoff et al. 1982). The Curtis/Arney equation is used if a User does not have a NOHTDREG keyword in their keyword set, or if a NOHTDREG keyword is present and contains a blank or 0 in field two. In this case, FVS does not attempt to calibrate the height-diameter model to the input data. The Wykoff equation is used if a User has a NOHTDREG keyword in their keyword set and it contains a non-zero entry in field two. In this case, FVS will calibrate the Wykoff equation to the input data for any species having at least 3 tree records in the input data with recorded heights.

The default Curtis-Arney equation for trees greater than or equal to a "spline" dbh is shown in equation {1}. The default equation for trees less than the "spline" dbh is shown in equation {2}. Equation coefficients and the spline dbh for each species in the ICASCA variant are shown in Table 3.

The default Wykoff equation is shown in equation {3}, with coefficients by species also shown in Table 3. When heights are given in the input data, the value of b1 in equation 3 is recalculated and replaces the default value shown in Table 3. In the event that measured heights would lead to illogical coefficients, the values may be disregarded and the defaults used. This can happen, for example, when the larger diameter trees in a stand are shorter than smaller diameter trees.

{1} $HT = 4.5 + p2 \exp(-p3 * DBH^{p4})$

{2} $HT = ((4.5 + p2 \exp(-p3*(Z^{p4}))-4.51) * (DBH-0.3)/(Z-0.3)) + 4.51$

{3} $HT = \exp(b0 + b1 / (DBH + 1.0)) + 4.5$

where:

HT = the tree height in feet
DBH = diameter at breast high
Z = spline dbh
b1, b2, p2, p3, p4, and Z are shown in Table 3.

Data were available to fit Curtis-Arney and Wykoff height-diameter coefficients for IC, WF, RF/SH, DF, KP, LP, JP, SP, WP, PP, GP, WO, BO, & MA). Curtis-Arney coefficients for the other species were fit from inventory data from other forests in Region 6. Wykoff coefficients for other species are from the Klammath Mountains FVS variant.

Table 3. Coefficients for the height dubbing function in the Inland California / Southern Cascades FVS variant

FVS SEQ NUM	FVS ALPHA CODE	------COEFFICIENTS-------- p2	p3	p4	SPLINE DBH	--COEFFICIENTS-- b0	b1
1	PC	8532.9026	8.0343	-0.1831	3.	4.7874	-7.3170
2	IC	695.4196	7.5021	-0.3852	6.	5.2052	-20.1443
3	RC	487.5415	5.4444	-0.3801	3.	4.7874	-7.3170
4	WF	467.3070	6.1195	-0.4325	3.	5.2180	-14.8682
5	RF	606.3002	6.2936	-0.3860	3.	5.2973	-17.2042
6	SH	606.3002	6.2936	-0.3860	3.	5.2973	-17.2042
7	DF	408.7614	5.4044	-0.4426	3.	5.3076	-14.4740
8	WH	263.1274	6.9356	-0.6619	3.	4.7874	-7.3170
9	MH	233.6987	6.9059	-0.6166	3.	4.7874	-7.3170
10	WB	89.5535	4.2281	-0.6438	3.	4.7874	-7.3170
11	KP	101.5170	4.7066	-0.9540	2.	4.6843	-6.5516
12	LP	99.1568	12.1300	-1.3272	5.	4.8358	-9.2077
13	CP	514.1013	5.5983	-0.2734	3.	4.7874	-7.3170
14	LM	514.1013	5.5983	-0.2734	3.	4.7874	-7.3170
15	JP	744.7718	7.6793	-0.3779	5.	5.1419	-19.8143
16	SP	944.9299	6.2428	-0.3087	5.	5.3371	-19.3151
17	WP	422.0948	6.0404	-0.4525	3.	5.2649	-15.5907
18	PP	1267.7589	7.4995	-0.3286	2.	5.3820	-20.4097
19	MP	113.7962	4.7726	-0.7601	3.	4.7874	-7.3170
20	GP	79986.6348	9.9284	-0.1013	2.	4.6236	-13.0049
21	JU	60.6009	4.1543	-0.6277	3.	4.7874	-7.3170
22	BR	91.7438	17.1081	-1.4429	3.	4.7874	-7.3170
23	GS	8532.9026	8.0343	-0.1831	3.	4.7874	-7.3170
24	PY	127.1698	4.8977	-0.4668	3.	4.7874	-7.3170
25	OS	79986.6348	9.9284	-0.1013	3.	4.7874	-7.3170
26	LO	105.0771	5.6647	-0.6822	3.	4.6618	-8.3312
27	CY	105.0771	5.6647	-0.6822	3.	4.6618	-8.3312
28	BL	59.0941	6.1195	-1.0552	3.	4.6618	-8.3312
29	EO	59.0941	6.1195	-1.0552	3.	4.6618	-8.3312
30	WO	40.3812	3.7653	-1.1224	3.	3.8314	-4.8221
31	BO	120.2372	4.1713	-0.6113	3.	4.4907	-7.7030
32	VO	126.7237	3.1800	-0.6324	3.	4.6618	-8.3312
33	IO	55.0	5.5	-0.95	3.	4.6618	-8.3312
34	BM	143.9994	3.5124	-0.5511	3.	4.6618	-8.3312
35	BU	55.0	5.5	-0.95	3.	4.6618	-8.3312
36	RA	94.5048	4.0657	-0.9592	3.	4.6618	-8.3312
37	MA	117.7410	4.0764	-0.6151	3.	4.4809	-7.5989
38	GC	1176.9704	6.3245	-0.2739	3.	4.6618	-8.3312
39	DG	403.3221	4.3271	-0.2422	3.	4.6618	-8.3312
40	FL	97.7769	8.8202	-1.0534	3.	4.6618	-8.3312
41	WN	105.0771	5.6647	-0.6822	3.	4.6618	-8.3312
42	TO	679.1972	5.5698	-0.3074	3.	4.6618	-8.3312
43	SY	55.0	5.5	-0.95	3.	4.6618	-8.3312
44	AS	47.3648	15.6276	-1.9266	3.	4.6618	-8.3312
45	CW	179.0706	3.6238	-0.5730	3.	4.6618	-8.3312
46	WI	149.5861	2.4231	-0.1800	3.	4.6618	-8.3312
47	CN	55.0	5.5	-0.95	3.	4.6618	-8.3312
48	CL	114.1627	6.0210	-0.7838	3.	4.6618	-8.3312
49	OH	40.3812	3.7653	-1.1224	3.	4.6618	-8.3312

Small Tree Submodel

The growth estimation sequence in the small tree model is height growth first, followed by diameter growth, and then crown ratio change. Crown ratio change will be discussed later in the Crown Ratio section.

A. Small Tree Height Growth

Data was not available to fit small tree height growth models for the ICASCA variant. As a result, the ICASCA variant uses small tree height growth equations fit for the Western Sierras variant. Height growth is estimated with one of four equations, then modified to account for differences in species, site index, and geographic area. The four equations are as follows:

{4} pines $HTG1 = 1.75 * EXP[0.7452 - 0.003271*BAL - 0.1632*CR + 0.0217*CR*CR + 0.00536*SI]$

{5} firs $HTG1 = 1.25 * EXP[-0.2495 - 0.00111*BAL + 0.0100*CR*CR]$

{6} black oak $HTG1 = EXP[3.817 - 0.7829 * Ln(BAL)]$

{7} tanoak $HTG1 = EXP[3.385 - 0.5898 * Ln(BAL)]$

where HTG1 = predicted height growth in feet
BAL = total stand basal area in trees with a larger diameter than the tree for which growth is being estimated ($5 < BAL$)
CR = crown ratio expressed as a percent crown ratio divided by 10
SI = site index
Ln = natural logarithm base e

Height growth for an individual tree is then estimated as:

{8} $HTG = HTG1 * (0.8 + 0.004*(SI-50.)) * FACTOR$

where HTG1 and SI are as defined above, and FACTOR is from Table 4. Which equations are used for each species are also shown in Table 4.

Finally, a small random deviation, bounded between (-0.2, 0.05), is added to the predicted height growth to assure a good distribution of estimated height growths.

Height growth estimates from the small tree submodel are weighted, using equation {9}, with height growth estimates from the large tree submodel to assure a smooth transition between the two submodels.

{9} Predicted HTG = (small tree HTG)*(1.0-weight) + (large tree HTG)*weight

where weight = (diameter - minimum DBH) / (maximum DBH - minimum DBH)
= 0.0 if diameter is less than minimum DBH
= 1.0 if diameter is greater than maximum DBH
and minimum DBH = 2.0 for all species
maximum DBH = 4.0 for all species

Table 4. Small tree submodel height growth equation surrogates and adjustment factors.

FVS FVS

SEQ NUM	ALPHA CODE	COMMON NAME	SURROGATE EQUATION	ADJUSTMENT FACTOR
1	PC	Port Orford cedar	2	1.0
2	IC	Incense cedar	2	1.0
3	RC	Western redcedar	2	0.9
4	WF	White fir	2	1.1
5	RF	California red fir	2	1.1
6	SH	Shasta red fir	2	1.1
7	DF	Douglas-fir	2	1.1
8	WH	Western hemlock	2	0.8
9	MH	Mountain hemlock	2	0.9
10	WB	Whitebark pine	1	0.9
11	KP	Knobcone pine	1	1.0
12	LP	Lodgepole pine	1	1.0
13	CP	Coulter pine	1	1.0
14	LM	Limber pine	1	1.0
15	JP	Jeffrey pine	1	1.0
16	SP	Sugar pine	1	1.1
17	WP	Western white pine	1	1.1
18	PP	Ponderosa pine	1	1.0
19	MP	Monterey pine	1	1.1
20	GP	Gray pine	1	0.9
21	JU	Western juniper	1	1.0
22	BR	Brewer spruce	2	0.9
23	GS	Giant sequoia	1	1.0
24	PY	Pacific yew	2	0.8
25	OS	Other softwoods	1	1.0
26	LO	Coast live oak	3	1.1
27	CY	Canyon live oak	3	0.9
28	BL	Blue oak	3	1.1
29	EO	Engelmann oak	3	1.1
30	WO	Oregon white oak	3	1.0
31	BO	California black oak	3	1.1
32	VO	Valley white oak	3	1.0
33	IO	Interior live oak	3	1.1
34	BM	Bigleaf maple	4	1.0
35	BU	California buckeye	3	1.0
36	RA	Red alder	3	1.0
37	MA	Pacific madrone	4	1.0
38	GC	Golden chinkapin	3	1.0
39	DG	Pacific dogwood	4	1.0
40	FL	Oregon ash	3	1.0
41	WN	Walnut	3	1.1
42	TO	Tanoak	4	1.0
43	SY	California sycamore	3	1.1
44	AS	Quaking aspen	3	1.2
45	CW	Black cottonwood	3	1.2
46	WI	Willow	3	1.1
47	CN	California nutmeg	2	0.8
48	CL	California laurel	4	1.0
49	OH	Other hardwoods	3	1.0

B. Small Tree Diameter Growth

Small tree diameter growth is calculated as the difference of predicted diameter at the start of the projection period and the predicted diameter at the end of the projection period, using the species specific height-diameter relationship discssed in the Height Dubbing section. This difference is adjusted for bark ratio since diameter growth is an inside bark value in FVS.

Large Tree Submodel

The growth estimation sequence in the large tree submodel begins with diameter growth, followed by height growth, and then crown ratio change. Crown ratio change will be discussed in the Crown Ratio section.

A. Large Tree Diameter Growth

The basic function form is similar to that described by Wykoff (1986). In this model form the dependent variable is the logarithm of change in diameter growth squared. Since this is a regression with a log transformation, the prediction is adjusted for bias to to the log transform.

The specific equation for the ICASCA variant is as follows:

{10} Ln(dds)= CONSPP + b1 * ln(SITE) + b2 * ln(BA)

+ b3 * alog(DBH) + b4 * CR + b5 * CR2 + b6 * BAL

+ b7 * EL + b8 * cos(ASP)*SL

+ b9 * sin(ASP)*SL + b10 * SL + b11 * SL2

+ b12 * BAL/ln(DBH+1) + b13 * PCCF

+ b14 * DBH2 - B15 + b16 * RELHT

where:

b1-b16 = species dependent regression coefficients

BA = basal area of the subject tree

BAL = basal area in trees larger than the subject tree

CONSPP = a species specific adjustment constant derived from diameter growth measurements in the input data (0. if equations are not being calibrated to the input data, or diameter growth estimates are not present in the input data)

CR = ratio of crown length to total tree height

DBH = diameter of the subject tree at breast height

DDS = 10-year change in squared DBH

PCCF= crown competition factor on a sample subplot

RELHT = height of the subject tree divided by the average height of the 40 biggest trees by DBH

Values for the coefficients b1c through b16 by species are shown in Table 5.

Table 5. Coefficients for large-tree diameter increment model

Vari-able		Incense cedar	White fir	Ca/Shasta red fir	Douglas-fir	Knobcone pine	Lodgepole pine
b1		0.820451	0.365679	0.492695	0.759305	0.	0.566946
b2		-0.000016	-0.058039	-0.122905	-0.028564	0.	-0.267873
b3		0.950418	1.182104	1.186676	0.716226	1.077154	1.218279
b4		1.815305	2.856578	2.763519	3.272451	-0.276387	3.167164
b5		0.	-1.093354	-0.871061	-1.642904	1.063732	-1.568333
b6		0.	0.	0.	0.	-0.000893	0.
b7		0.	0.000301	0.000248	-0.000141	0.	0.
b8		0.	-0.315227	-0.444594	-0.151727	0.649870	0.
b9		0.	0.097350	0.139180	0.018681	0.951834	0.
b10		0.	-0.206267	0.	-0.339369	0.	0.
b11		0.	0.	0.	0.	0.	0.
b12		-0.005433	-0.005992	-0.003728	-0.008787	0.	0.
b13		-0.000779	-0.001014	0.	-0.000224	0.	-0.000338
b14		-0.0002385	-0.0006362	-0.0004572	-0.0002723	0.	-0.0014178
b15	a.	-3.428338	-2.108357	-2.073942	-1.877695	-0.564402	-2.058828
	b.	-3.428338	-2.108357	-2.073942	-2.099646	-0.564402	-2.058828
	c.	-3.428338	-2.108357	-2.073942	-2.099646	-0.564402	-2.058828
	d.	-3.428338	-2.108357	-1.943608	-1.877695	-0.564402	-1.596998
	e.	-3.966547	-2.108357	-2.073942	-2.211587	-0.564402	-2.058828
	f.	-3.428338	-2.108357	-2.073942	-1.955301	-0.564402	-2.058828
	g.	-3.428338	-2.108357	-2.073942	-2.078432	-0.564402	-2.058828
b16		0.	0.	0.	0.	0.	0.

a = Klammath, b = Lassen, c = Mendocino, d = Plumas, e = Shasta-Trinity
f = Rogue River, g = Siskiyou

Table 5. continued:

Oaks
LO/CY/BL/

Vari-able		Sugar pine	W. white pine	Ponderosa pine	EO/WO/WO/ BO/VO/IO	Pacific madrone	Tanoak
b1		0.963375	0.724300	1.011504	0.213526	1.334008	0.00659
b2		-0.129146	-0.203636	-0.131185	0.	-0.408462	0.
b3		0.886150	0.825682	0.738750	1.310111	0.955569	0.99531
b4		1.478650	1.675208	3.454857	0.271183	0.	2.08524
b5		0.	0.	-1.773805	0.	0.	-0.98396
b6		0.	0.	0.	0.	0.	0.
b7		0.	0.	-0.000038	0.000049	0.	0.
b8		-0.280294	-0.179510	0.	0.	0.	-0.19935
b9		-0.014463	-0.562259	0.	0.	0.	-0.03587
b10		-0.581722	-0.544867	0.	0.	0.	0.73530
b11		0.	0.	0.	0.	0.	-0.99561
b12		-0.006263	-0.002133	-0.013091	0.	-0.005893	-0.00147
b13		0.	0.	-0.000593	-0.000473	0.	-0.00018
b14		-0.0002528	-0.0000731	-0.0004708	-0.0003048	0.	-0.000373
b15	a.	-2.397678	-1.626879	-2.922255	-1.958189	-3.344700	-0.94563
	b.	-2.397678	-1.626879	-2.922255	-1.958189	-3.344700	-0.94563
	c.	-2.397678	-1.626879	-2.922255	-1.958189	-3.344700	-0.94563
	d.	-2.397678	-1.626879	-2.922255	-1.958189	-3.344700	-0.94563
	e.	-2.397678	-1.626879	-2.922255	-1.958189	-3.344700	-0.94563
	f.	-2.397678	-1.626879	-2.922255	-1.958189	-3.344700	-0.94563
	g.	-2.397678	-1.626879	-2.922255	-1.958189	-3.344700	-0.94563
b16		0.	0.	0.	0.	0.	0.50155

a = Klammath, b = Lassen, c = Mendocino, d = Plumas, e = Shasta-Trinity
f = Rogue River, g = Siskiyou

The equation for Tanoak predicts 5-year diameter growth rather than 10-year diameter growth. There weren't enough tanoak growth sample trees in the data set used for this variant to fit a tanoak equation. This equation was derived from data used to fit the Klammath mountains FVS variant.

There are many species represented in this variant which did not have enough data to fit diameter growth relationships. These species are grown with the following surrogates:

Equation Also used for:

Incense cedar	Port Orford cedar, Western red cedar
White fir	Brewer spruce
Knobcone pine	Coulter pine, Limber pine, Gray pine, Western juniper, Pacific yew
Lodgepole pine	Whitebark pine
Sugar pine	Western hemlock, Mountain hemlock
Ponderosa pine	Jeffrey pine, Monterey pine, Other softwoods
Oaks	Bigleaf maple, California buckeye, Red alder, Oregon ash, Walnut, California sycamore, quaking aspen, Black cottonwood, Willow, California nutmeg, California laural, Other hardwoods
Pacific madrone	Golden chinkapin, Pacific dogwood

Giant sequoia also lacked sufficient data to fit a diameter growth equation, so one was used from the Western Sierra Nevada FVS variant: The equation is:

{11} $$\ln(dds) = CONSPP - 0.4297 + 0.01401 * SITE + 1.26883 * \ln(DBH) - 0.35325 * DBH2 / 1000. + 0.27986 * CRID - 0.79922 * PBAL / \ln(DBH + 1) / 100.$$

where:

CRID = CR2 / ln(DBH + 1) / 1000. (limited to CRID > 1.8)

PBAL = Basal area in trees larger than the subject tree on the sample point the subject tree was measured on

All other variables as defined previously.

B. Large Tree Height Growth

Height growth functions used in the ICASCA variant are the site index reference curves. For Region 5 forests the Dunning/Levitan site curves are used, and for Region 6 forests either the King or Dolph site curves are used. Species differences in height growth are accounted for by entering the appropriate curve with the species specific site index value.

A two step process is used. First, the site curve is entered with the tree's current height, and the tree's age is estimated. Second, the cycle length is added to the estimated age, and a predicted height is determined from the site curve. Height growth is then the predicted height minus the current height.

Dunning/Levitan site curves

The Dunning/Levitan site curves are of the form:

{12} Height = A + B * Ln(Age + 1.)   for age greater than or equal to 40

A linear function is assumed for trees less than 40 years old:

{13} Height = C * Age   for age less than 40

The A, B, and C coefficients for the various Dunning site codes (0-5) are shown in Table 6.

Table 6. Coefficients for the Dunning/Levitan site curves, nominal site index by site class, and range of Region 6 site values for which the coefficients are used in the ICASCA variant.

Dunning site class	Nominal Site Index	R6 Range Used	A	B	C
0	110	103+	-88.9	49.7067	2.375
1	95	88 - 102	-82.2	44.1147	2.025
2	80	71 - 87	-78.3	39.1441	1.650
3	60	55 - 70	-82.1	35.416	1.225
4	50	45 - 54	-56.0	26.7173	1.075
5	40	10 - 44	-33.8	18.64	0.875

Crown Ratio

Crown Dubbing

Crown ratio is often missing from the input data and must be estimated (dubbed) for those tree records for which it was not recorded. Two methods of estimating crown ratio are used in the ICASCA variant depending on the size of the tree.

For trees less than 1.0" dbh, crown ratios are estimated as follows:

{14} ECR = a0 + a1*H + a2*H + a3*BA + e

{15}   CR = ([(ECR - 1)*10] + 1) / 100

where ECR = predicted crown ratio code
CR = predicted crown ratio proportion bounded between (0.05 - 0.95)
H = tree height
BA = stand basal area
a0 - a3 = species specific coefficients
e = random error term based on the regression standard deviation bounded between (-Std Dev, Std Dev) which is shown below

Coefficients used in the ICASCA variant are shown in Table 7.

Table 7. Coefficients used to estimate missing crown ratios on trees less than 1.0" dbh in the ICASCA variant.

Species   Species   Species   Species   Species   Species

Coefficient	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
a0	8.042774	8.477025	7.558538	6.489813	5.0	9.0
a1	0.007198	-0.018033	-0.015637	-0.029815	0.0	0.0
a2	-0.016163	-0.018140	-0.009064	-0.009276	0.0	0.0
Std. Dev.	1.3167	1.3756	1.9658	2.0426	0.5	0.5

where Group 1 = WF, RF, SH, BR
Group 2 = DF
Group 3 = PC, IC, RC, WH, MH
Group 4 = WB, KP, LP, CP, LM, JP, SP, WP, PP, MP, GP, GS, PY, OS
Group 5 = all the hardwoods
Group 6 = JU

For trees with a diameter of 1.0" dbh or larger, crown ratios are dubbed from the Weibull distribution described in the next section.

Crown Ratio Change

For trees whose diameter at the end of the growth projection cycle is less than 1.0" dbh, the crown ratio change is zero. In other words, the crown ratio stays the same value it was recorded in the input data or dubbed as described above.

For trees whose diameter at the end of the growth projection cycle is 1.0" dbh or greater, crown change is determined using a Weibull distribution. The Weibull distribution is also used to estimate initial crown ratios on trees 1.0" dbh or greater if crown ratio was missing from the input data.

Crown ratio is predicted at the end of each projection cycle. The distribution of crown ratios within a stand are assumed to follow a Weibull distribution. First, the mean stand crown ratio is estimated from Stand Density Index. Next, Weibull distribution parameters are estimated from mean stand crown ratio. Finally, individual trees are assigned a crown ratio from the specified Weibull distribution based on their rank in the diameter distribution, and scaled by a density dependent scale factor. A detailed description of this technique can be found in Dixon (1988). Change in crown ratio from one projection cycle to the next is obtained by subtracting the crown ratios picked from the appropriate Weibull distributions. This change value is bounded to 1 percent per year in the projection cycle to avoid drastic changes from one cycle to the next. So, for a 10 year projection cycle, the crown change will be 10 percent or less of the original crown ratio. Coefficients for the ICASCA variant are from equations fit for either the Klammath Mountains or West Cascades variants, with the species matched as closely as possible with the species for which the equations were fit..

Mean stand crown ratio is estimated using equation {16} and the coefficients shown in Table 8.

{16} $MCR = d0 + d1*RSDI$

where RSDI = current stand SDI / SDI maximum for the stand

Table 8. Coefficients for estimating mean stand crown ratio, by species group, for the ICASCA FVS variant.

Species Group	d0	d1	Species
1	7.48846	-0.02899	DF, JU, BR, GS, PY, OS
2	6.92893	-0.04053	SP, WP
3	7.44422	-0.04779	WF
4	3.64292	-0.00317	MA
5	5.12357	-0.01042	PC, IC, RC
6	6.82187	-0.02247	LO, CY, BL, EO, WO, BO, VO, IO
7	5.95912	-0.01812	TO
8	6.14578	-0.02781	RF, SH
9	6.04928	-0.01091	JP, PP, MP, GP
10	5.48853	-0.00717	WH, MH
11	6.48494	-0.02325	WB, KP, CP, LM
12	4.42000	-0.01066	BM
13	4.12048	-0.00636	RA
14	4.62512	-0.01604	BU, GC, DG, FL, WN, SY, AS, CW, WI, CN, CL,OH
15	4.89032	-0.01884	LP

The Weibull distribution is described bye the probability density function shown in equation {17}.

{17} $$f(x) = \frac{c}{b}\left(\frac{x-a}{b}\right)^{(c-1)} e^{-\left(\frac{x-a}{b}\right)^{c}}$$

To estimate the functions parameters, the "a" (location) coefficient was set to a constant and the "b" (scale) and "c" (shape) coefficients were estimated as linear functions of mean stand crown ratio, equations {18} and {19}. Resulting coefficients for estimating these parameters are shown in Table 9. Estimates of the "b" parameter are bounded to values 3.0 or greater, and estimates of the "c" parameter to values of 2.0 or greater.

{18} $b = b0 + b1*MCR$

where MCR = estimated mean stand crown ratio

{19} $c = c0 + c1*MCR$

Coefficients for the ICASCA variant are from equations fit for either the Klammath Mountains or West Cascades variants, with the species matched as closely as possible. Species groups shown in the table are the species groups used in Table 8.

Table 9. Coefficients for estimating the Weibull parameters, by species group, for the ICASCA FVS variant.

Species Group	a	b0	b1	c0	c1
1	0.	0.52909	1.00677	-3.48211	1.38780
2	0.	0.25115	1.05987	0.33383	0.63833
3	0.	0.48464	1.01272	-2.78353	1.27283
4	0.	0.08402	1.10297	0.91078	0.45819
5	0.	0.29964	1.05398	-1.09270	0.80687
6	0.	0.06607	1.10705	2.04714	0.15070
7	0.	0.25667	1.06474	0.11729	0.61681
8	0.	0.16601	1.08150	0.91420	0.45768
9	0.	0.03685	1.09499	4.01340	0.04946

10	0.	0.49085	1.01414	3.16456	0.
11	0.	0.16267	1.07340	3.28850	0.
12	1.	-0.81881	1.05418	-2.36611	1.20241
13	1.	-1.11274	1.12314	2.53316	0.
14	0.	-0.23830	1.18016	3.04413	0.
15	0.	-0.13121	1.15976	2.59824	0.

Once the Weibull distribution is specified, crown ratios are assigned to individual trees based on the tree's rank in the diameter distribution. The lower truncation point for choosing crowns from the Weibull distribution is the .05 percentile point. The upper limit is the .95 percentile point, unless a density dependent scale factor is invoked.

The density dependent scale factor {20} is a function of the stand's crown competition factor. Values of this factor are bounded between 0.3 and 1.0, inclusive.

{20} Scale factor = [1 - 0.00333*(SCCF-50)]

where SCCF = stand crown competition factor

Mortality

The mortality model used in the ICASCA variant is based on Stnad Density Index (SDI), and techniques developed by Dixon (1986). Two types of mortality are present: (1) a background mortality rate, and (2) a density related mortality rate. The background rate accounts for the occasional mortality which occurs in stands up to the time where density related mortality starts to occur. Density related mortality begins when the stand SDI is about 55 percent of maximum SDI, and stand density peaks at about 85 percent of maximum SDI (Smith 1984, Long 1984).

Maximum SDI values by species can be set by the user, or default values are assigned as discussed earlier. Default SDI values by species for Region 5 are shown in Table 1, and default SDI values by plant association for Region 6 are shown in Table 2.

When dealing with a species mix, maximum values for a single species can become distorted. The ICASCA variant uses a weighted SDI {21} where weights are based on the proportion of basal area an individual species represents in the stand.

{21} $$\text{Weighted SDI} = \frac{S1SDI*S1BA + S2SDI*S2BA + ... + SnSDI*SnBA}{\text{TOTAL STAND BA}}$$

where S1SDI = maximum SDI for the first species in the stand
S1BA = total basal area of species 1
S2SDI = maximum SDI for the second species in the stand
S2BA = total basal area of species 2
SnSDI = maximum SDI for the nth species in the stand
SnBA = total basal are of the species n

The weighted SDI is calculated each growth cycle and mortality is determined based on a stands position relative to the weighted SDI. Over time, this weighted SDI changes as the species mix in the stand changes. During a projection, density related mortality begins at 55 percent of the weighted SDI value and the stand SDI cannot exceed 85 percent of the weighted SDI value.

As stated above, users may specify their own maximum SDI values by species using the SDIMAX keyword. In addition, if the stand SDI initially exceeds 90 percent of the weighted SDI maximum, a new maximum value will be calculated. The new maximum is set so the current stand SDI corresponds to 85 percent of the new maximum.

Once the number of mortality trees has been determined (i.e. how many to kill), the mortality has to be dispersed among the tree records in the projection (i.e. which ones to kill). Mortality in FVS is achieved by adjusting the number of trees per acre a tree record represents. Tree records are processed, each receiving a calculated mortality, until the total number of mortality trees has been reached. All tree records eventually receive some mortality in a projection.

Mortality rates in the ICASCA variant are partially dependent on the shade tolerance of individual species. More intolerant species receive heavier mortality than tolerant species. The mortality rate is also dependent on a trees rank in the basal area distribution. Smaller trees (understory) receive heavier mortality than larger trees (overstory).

The proportion of a tree record to be killed is computed using equation {22}.

{22} $$EFF = 0.084525 - 0.001074*PCT + 0.00000002*PCT^3$$

where EFF = the proportion of a tree record to be killed bounded to (0. - 1.0)
PCT = the tree's percentile ranking in the basal area distribution (1-100)

Next the EFF value is adjusted by multiplying EFF by the relative shade tolerance adjustment factor for the given species. The relative shade tolerance adjustment factors are shown in Table 10.

Table 10. Mortality adjustment factors representing relative shade tolerance for species in the ICASCA variant.

Species	Factor	Species	Factor
Port Orford Cedar	0.60	Coast Live Oak	1.00
Incense Cedar	0.60	Canyon Live Oak	1.00
Western Redcedar	0.60	Blue Oak	1.00
White Fir	0.55	Engelmann Oak	1.00
Calif Red Fir	0.50	Oregon White Oak	1.00
Shasta Red Fir	0.50	Calif Black Oak	1.00
Douglas-fir	0.65	Valley White Oak	1.00
Western Hemlock	0.65	Interior Live Oak	1.00
Mountain Hemlock	0.75	Bigleaf Maple	0.80
Whitebark Pine	0.90	Calif Buckeye	0.80
Knobcone Pine	0.90	Red Alder	1.00

Lodgepole Pine	0.90	Pacific Madrone	0.80
Coulter Pine	1.10	Giant Chinkapin	0.80
Limber Pine	0.90	Pacific Dogwood	0.80
Jeffrey Pine	0.85	Oregon Ash	0.80
Sugar Pine	0.70	Walnut	0.80
Western White Pine	0.75	Tanoak	0.55
Ponderosa Pine	0.85	Calif Sycamore	0.80
Monterey Pine	0.85	Quaking Aspen	0.80
Gray Pine	1.10	Black Cottonwood	0.80
Western Juniper	1.10	Willow	1.00
Brewer Spruce	0.65	Calif Nutmeg	1.00
Giant Sequoia	0.80	Calif Laurel	1.00
Pacific Yew	0.55	Other Hardwoods	1.00
Other Softwoods	0.65		

The mortality model makes multiple passes through the tree records multiplying the tree's trees-per-acre value times the adjusted EFF value, accumulating the results, and reducing the tree's tree-per-acre value until the desired mortality level has been reached. This process has an enherent interaction between species and tree size; a larger intolerant tree may be killed before a tolerant smaller sized tree.

Volume Estimation

By default, the ICASCA variant uses volume estimation procedures from the National Cruise System volume library. National Cruise System volume equation numbers, by species are shown in Table 11. Users can also enter their own volume equations using the CFVOLEQU and BFVOLEQU keywords, and can make other volume adjustments using the VOLUME, BFVOLUME, BFFDLN, BFDEFECT, MCFDLN, and MCDEFECT keywords.

Table 11. National Cruise System volume equation numbers used in the FVS ICASCA variant.

REGION 5

Species	Equation	Species	Equation
Port Orford Cedar	556	Coast Live Oak	517
Incense Cedar	556	Canyon Live Oak	515
Western Redcedar	556	Blue Oak	514
White Fir	554	Engelmann Oak	514
Calif Red Fir	555	Oregon White Oak	521
Shasta Red Fir	555	Calif Black Oak	513
Douglas-fir	551	Valley White Oak	514
Western Hemlock	554	Interior Live Oak	518
Mountain Hemlock	554	Bigleaf Maple	512
Whitebark Pine	558	Calif Buckeye	514
Knobcone Pine	558	Red Alder	511
Lodgepole Pine	558	Pacific Madrone	520
Coulter Pine	558	Giant Chinkapin	516
Limber Pine	558	Pacific Dogwood	514
Jeffrey Pine	557	Oregon Ash	514
Sugar Pine	553	Walnut	513
Western White Pine	553	Tanoak	522

Ponderosa Pine	552	Calif Sycamore	513
Monterey Pine	558	Quaking Aspen	513
Gray Pine	558	Black Cottonwood	513
Western Juniper	510	Willow	514
Brewer Spruce	554	Calif Nutmeg	514
Giant Sequoia	524	Calif Laurel	519
Pacific Yew	558	Other Hardwoods	519
Other Softwoods	558		

REGION 6

Species	Equation
All Species	632BEHW000

Crown competition factor and crown width

The ICASCA variant uses crown competion factor (CCF) as a predictor variable in some of the growth relationships. Crown competion factor for an individual tree (CCFT) is calculated from crown width by: (1) first computing the area of a circle of diameter equal to the trees' crown width, and (2) expressing the area of the circle in terms of percentage of an acre covered.

{23} $CCFT = 3.14159 * (\text{Crown Width} / 2)^2$

{24} $CCFT = \frac{3.14159}{4} * (\text{Crown Width})^2$

{25} $CCFT = \frac{3.14159}{4} * \frac{1}{43560} * 100 * (\text{Crown Width})^2$

{26} $CCFT = 0.001803 * (\text{Crown Width})^2$

To compute a per-acre CCF estimate for a given area (point or stand), take the CCFT value for the individual tree times the trees-per-acre representation for that tree, and sum these products over all trees on that given area.

Crown width equations for trees larger than the join dbh are of the form:

{27} CW = b1 + b2 * DBH equation type 1
{28} CW = b1 * (DBH ** b2) equation type 2
{29} CW = b1 + b2 * DBH + b3 * DBH**2 equation type 3

where CW = estimated crown width
DBH = diameter outside bark at breast height

Crown width equations for trees 4.5 feet tall up to the join dbh are of the form:

{30} CW = c1 + c2 * DBH

Crown with equations for trees less than 4.5 feet tall are of the form:

{31} $CW = d1 * Height$

For Region 5, crown width equations are the same ones shown in the FIAS User's Guide (Section V. C. of Appendix L.). ICASCA species which do not have a specific crown width equation developed for them, use the "other softwoods" or "other hardwoods" equations. Species specific constants for Region 5 forests are shown in Table 12.

For Region 6, crown width equations are the same ones used in the CVS program. ICASCA species which do no have a specific crown width equation developed for them, were assigned a surrogate equation based on crown descriptions in Harlow and Harrar (1968) and Burns and Honkala (1990). Species specific constants for Region 6 forests are shown in Table 13.

Table 12. Crown width equations used in the ICASCA variant for Region 5 forests.

FVS SEQ NUM	FVS ALPHA CODE	----COEFFICIENTS----- b1	b2	b3	EQN TYPE	JOIN DBH	COEFFICIENTS c1	c2	COEFFICIENT d1
1	PC	----------------- use OS equation --------------------------							
2	IC	7.11	0.470	0.	1	5.0	3.5	1.192	0.7778
3	RC	4.00	1.60	0.	1	5.0	3.5	1.700	0.7778
4	WF	5.82	0.591	0.	1	5.0	3.26	1.103	0.7778
5	RF	6.71	0.421	0.	1	5.0	3.5	1.063	0.7778
6	SH	6.71	0.421	0.	1	5.0	3.5	1.063	0.7778
7	DF	6.81	0.732	0.	1	5.0	3.62	1.370	0.7778
8	WH	4.57	1.41	0.	1	5.0	3.5	1.624	0.7778
9	MH	4.72	0.608	0.	1	5.0	3.5	0.852	0.7778
10	WB	2.37	0.736	0.	2	5.0	3.5	0.8496	0.7778
11	KP	----------------- use OS equation --------------------------							
12	LP	1.91	0.784	0.	2	5.0	3.5	0.6492	0.7778
13	CP	----------------- use OS equation --------------------------							
14	LM	----------------- use OS equation --------------------------							
15	JP	1.52	0.891	0.	2	5.0	3.5	0.5754	0.7778
16	SP	-1.476	1.01	0.	1	7.4	3.5	0.338	0.7778
17	WP	-0.997	0.92	0.	1	7.6	3.5	0.329	0.7778
18	PP	2.24	0.763	0.	2	5.0	3.77	0.7756	0.7778
19	MP	----------------- use OS equation --------------------------							
20	GP	----------------- use OS equation --------------------------							
21	JU	4.31	0.628	0.	2	5.0	3.5	1.6684	0.7778
22	BR	6.50	1.80	0.	1	5.0	3.5	2.400	0.7778
23	GS	----------------- use OS equation --------------------------							
24	PY	4.2	1.42	0.	1	5.0	3.5	1.560	0.7778
25	OS	6.0	0.6	0.	1	5.0	3.5	1.1	0.7778
26	LO	----------------- use OH equation --------------------------							
27	CY	5.0	1.69		1	5.0	2.5	2.190	0.5556
28	BL	4.49	0.688	0.	2	5.0	2.5	2.2175	0.5556
29	EO	----------------- use OH equation --------------------------							
30	WO	3.08	1.92	0.	1	5.0	2.5	2.036	0.5556
31	BO	10.0	1.2	0.	1	5.0	2.5	2.700	0.5556
32	VO	----------------- use OH equation --------------------------							
33	IO	----------------- use OH equation --------------------------							
34	BM	----------------- use OH equation --------------------------							
35	BU	----------------- use OH equation --------------------------							
36	RA	8.0	1.53	0.	1	5.0	2.5	2.630	0.5556
37	MA	1.0	1.43	0.	1	5.0	3.11	1.008	0.5556

38	GC	2.98	1.55	-0.014	3	5.0	2.15	1.646	0.5556
39	DG	----------------- use OH equation --------------------------							
40	FL	0.50	1.62	0.	1	5.0	2.5	1.220	0.5556
41	WN	----------------- use OH equation --------------------------							
42	TO	10.0	1.05	0.	1	13.4	2.23	1.630	0.5556
43	SY	----------------- use OH equation --------------------------							
44	AS	0.5	1.62	0.	1	5.0	2.5	1.220	0.5556
45	CW	0.5	1.62	0.	1	5.0	2.5	1.220	0.5556
46	WI	----------------- use OH equation --------------------------							
47	CN	----------------- use OH equation --------------------------							
48	CL	----------------- use OH equation --------------------------							
49	OH	2.0	1.5	0.	1	5.0	2.5	1.4	0.5556

Table 13. Crown width equations used in the ICASCA variant for Region 6 forests.

FVS SEQ NUM	FVS ALPHA CODE	----COEFFICIENTS----- b1	b2	b3	EQN TYPE	JOIN DBH	COEFFICIENTS c1	c2	COEFFICIENT d1
1	PC	5.3864	0.4213	0.	2	0.	0.	0.	0.608
2	IC	4.0920	0.4912	0.	2	0.	0.	0.	0.412
3	RC	6.2318	0.4259	0.	2	0.	0.	0.	0.698
4	WF	3.8166	0.5229	0.	2	0.	0.	0.	0.452
5	RF	3.1146	0.5780	0.	2	0.	0.	0.	0.345
6	SH	3.1146	0.5780	0.	2	0.	0.	0.	0.345
7	DF	4.4215	0.5329	0.	2	0.	0.	0.	0.517
8	WH	5.4864	0.5144	0.	2	0.	0.	0.	0.533
9	MH	2.9372	0.5878	0.	2	0.	0.	0.	0.253
10	WB	2.1606	0.6897	0.	2	0.	0.	0.	0.255
11	KP	2.1451	0.7132	0.	2	0.	0.	0.	0.248
12	LP	2.4132	0.6403	0.	2	0.	0.	0.	0.298
13	CP	----------------- use PP equation --------------------------							
14	LM	----------------- use PP equation --------------------------							
15	JP	3.2367	0.6247	0.	2	0.	0.	0.	0.406
16	SP	3.0610	0.6201	0.	2	0.	0.	0.	0.385
17	WP	3.4447	0.5185	0.	2	0.	0.	0.	0.476
18	PP	2.8541	0.6400	0.	2	0.	0.	0.	0.407
19	MP	----------------- use PP equation --------------------------							
20	GP	----------------- use PP equation --------------------------							
21	JU	----------------- use PY equation --------------------------							
22	BR	3.6802	0.4940	0.	2	0.	0.	0.	0.451
23	GS	----------------- use DF equation --------------------------							
24	PY	4.5859	0.4841	0.	2	0.	0.	0.	0.468
25	OS	----------------- use PP equation --------------------------							
26	LO	----------------- use WO equation --------------------------							
27	CY	----------------- use WO equation --------------------------							
28	BL	----------------- use WO equation --------------------------							
29	EO	----------------- use WO equation --------------------------							
30	WO	2.4922	0.8544	0.	2	0.	0.	0.	0.140
31	BO	----------------- use WO equation --------------------------							
32	VO	----------------- use WO equation --------------------------							
33	IO	----------------- use WO equation --------------------------							
34	BM	7.5183	0.4461	0.	2	0.	0.	0.	0.815
35	BU	----------------- use WO equation --------------------------							
36	RA	7.0806	0.4771	0.	2	0.	0.	0.	0.730
37	MA	----------------- use AS equation --------------------------							
38	GC	----------------- use WO equation --------------------------							
39	DG	----------------- use WO equation --------------------------							

40	FL	----------------- use AS equation --------------------------							
41	WN	----------------- use BM equation --------------------------							
42	TO	----------------- use AS equation --------------------------							
43	SY	----------------- use AS equation --------------------------							
44	AS	4.0910	0.5907	0.	2	0.	0.	0.	0.351
45	CW	----------------- use BM equation --------------------------							
46	WI	----------------- use PY equation --------------------------							
47	CN	----------------- use AS equation --------------------------							
48	CL	----------------- use BM equation --------------------------							
49	OH	----------------- use WO equation --------------------------							

Bark Ratio Equations

Bark ratio estimates are used to convert between diameter outside bark and diameter inside bark in various parts of the model. Bark ratios are either (1) set to a constant value, (2) estimated from DIB equations, or (3) estimated from double bark thickness equations, depending on species. Equation forms used in this variant are shown below and coefficients for these equations used in the ICASCA variant are shown in Table 14.

Equation forms:

```
{1} DIB = b1 * (DOB ** b2);              BRATIO = DIB / DOB
{2} DIB = b1 + b2 * DOB;                 BRATIO = DIB / DOB
{3}                                      BRATIO = b1
{4} DBT = b1 + b2 * DOB + b3 / DOB;      BRATIO = (DOB - DBT) / DOB
{5}                                      BRATIO = b1 + b2 * DOB
```

where:

```
DIB    = diameter inside bark at breast height
DOB    = diameter outside bark at breast height
DBT    = double bark thickness
BRATIO = bark ratio
b1,b2  = equation coefficients
```

Table 14. Bark ratio coefficients used in the ICASCA variant.

FVS SEQ NUM	FVS ALPHA CODE	COMMON NAME	---------COEFFICIENTS--------- b1	b2	b3	EQN NUM	EQN SOURCE
1	PC	Port Orford cedar	(use RC equation)				
2	IC	Incense cedar	-0.0549	0.8374	0.	2	8
3	RC	Western redcedar	0.949670	1.0	0.	1	3
4	WF	White fir	-0.1593	0.8911	0.	2	5
5	RF	California red fir	(use WF equation)				
6	SH	Shasta red fir	(use WF equation)				
7	DF	Douglas-fir	0.903563	0.989388	0.	1	1
8	WH	Western hemlock	0.933710	1.0	0.	1	3
9	MH	Mountain hemlock	(use WH equation)				
10	WB	Whitebark pine	(use LP equation)				
11	KP	Knobcone pine	0.8709	0.0031	0.	5	9
12	LP	Lodgepole pine	0.9	0.	0.	3	3
13	CP	Coulter pine	(use PP equation)				
14	LM	Limber pine	(use LP equation)				

15	JP	Jeffrey pine	-0.4448	0.8967	0.	2	5
16	SP	Sugar pine	-0.1429	0.8863	0.	2	5
17	WP	Western white pine	(use SP equation)		.		
18	PP	Ponderosa pine	-0.4448	0.8967	0.	2	5
19	MP	Monterey pine	(use PP equation)				
20	GP	Gray pine	0.7735	0.0043	0.	5	6
21	JU	Western juniper	(use RC equation)				
22	BR	Brewer spruce	0.9	0.	0.	3	3
23	GS	Giant sequoia	(use RC equation)				
24	PY	Pacific yew	(use LP equation)				
25	OS	Other softwoods	(use PP equation)				
26	LO	Coast live oak	-0.75739	0.93475	0.	2	2
27	CY	Canyon live oak	-0.19128	0.96147	0.	2	2
28	BL	Blue oak	-0.17324	0.94403	0.	2	2
29	EO	Engelmann oak	-0.78572	0.92472	0.	2	2
30	WO	Oregon white oak	-0.30722	0.95956	0.	2	2
31	BO	California black oak	2.0754	0.0204	-14.0088	4	7
32	VO	Valley white oak	-0.38289	0.93545	0.	2	2
33	IO	Interior live oak	0.04817	0.92953	0.	2	2
34	BM	Bigleaf maple	0.08360	0.94782	0.	2	2
35	BU	California buckeye	(use BO equation)				
36	RA	Red alder	0.075256	0.94373	0.	2	4
37	MA	Pacific madrone	-0.3386	0.0438	2.5626	4	7
38	GC	Golden chinkapin	0.15565	0.90182	0.	2	2
39	DG	Pacific dogwood	(use BO equation)				
40	FL	Oregon ash	(use BO equation)				
41	WN	Walnut	(use BO equation)				
42	TO	Tanoak	1.9064	0.172	-8.4312	4	7
43	SY	California sycamore	(use BO equation)				
44	AS	Quaking aspen	(use RA equation)				
45	CW	Black cottonwood	(use BO equation)				
46	WI	Willow	(use BO equation)				
47	CN	California nutmeg	(use BO equation)				
48	CL	California laurel	-0.32491	0.96579	0.	2	2
49	OH	Other hardwoods	(use BO equation)				

Equation Sources:

1) Walters et. al. Res Bull 50 Table 2
2) Pillsbury and Kirkley Res Note PNW-414 Table 2
3) Wykoff et. al. Res Paper INT-133 Table 7
4) Average of 312, 361, and 431 values from Pillsbury and Kirkley Res Note PNW-414 Table 2, plus info from Harlow and Harrar
5) Dolph PSW-368
6) Forest Management Service Center --- Ralph Johnson analysis
7) McDonald PSW-362
8) From Klammath Mtns variant
9) Forest Management Service Center --- Renate Bush analysis

Regeneration/establishment submodel

The FVS regeneration/establishment model is used to simulate stand establishment from bare ground, or to bring seedlings into a simulation with existing trees. Table 15 shows the bud width and minimum seedling heights by species for the

ICASCA variant.

The ICASCA variant has fifteen species which will automatically sprout when cut, unless a NOSPROUT keyword is used. These fifteen include the eight oak species, bigleaf maple, pacific dogwood, walnut, California sycamore, quaking aspen, black cottonwood, and willow. Establishment of all other species must be user specified using the PLANT or NATURAL keywords.

Table 15. Minimum seedling heights and bud widths for the FVS regeneration/establishment submodel in the ICASCA variant.

FVS SEQ NUM	FVS ALPHA CODE	COMMON NAME	TERMINAL BUD WIDTH (INCHES)	MINIMUM HEIGHT (FEET)	SPROUTS WHEN CUT
1	PC	Port Orford cedar	0.2	0.5	
2	IC	Incense cedar	0.2	0.5	
3	RC	Western redcedar	0.2	0.3	
4	WF	White fir	0.2	0.8	
5	RF	California red fir	0.2	0.8	
6	SH	Shasta red fir	0.2	0.8	
7	DF	Douglas-fir	0.2	0.8	
8	WH	Western hemlock	0.2	0.3	
9	MH	Mountain hemlock	0.2	0.5	
10	WB	Whitebark pine	0.5	1.2	
11	KP	Knobcone pine	0.5	1.0	
12	LP	Lodgepole pine	0.4	1.0	
13	CP	Coulter pine	0.5	1.0	
14	LM	Limber pine	0.5	1.0	
15	JP	Jeffrey pine	0.5	1.0	
16	SP	Sugar pine	0.5	0.8	
17	WP	Western white pine	0.3	0.8	
18	PP	Ponderosa pine	0.5	1.0	
19	MP	Monterey pine	0.5	0.8	
20	GP	Gray pine	0.5	1.2	
21	JU	Western juniper	0.3	1.0	
22	BR	Brewer spruce	0.3	0.5	
23	GS	Giant sequoia	0.3	1.0	
24	PY	Pacific yew	0.3	0.3	
25	OS	Other softwoods	0.3	0.8	
26	LO	Coast live oak	0.2	1.0	YES
27	CY	Canyon live oak	0.2	0.5	YES
28	BL	Blue oak	0.2	1.0	YES
29	EO	Engelmann oak	0.2	1.0	YES
30	WO	Oregon white oak	0.2	0.8	YES
31	BO	California black oak	0.2	1.0	YES
32	VO	Valley white oak	0.2	0.8	YES
33	IO	Interior live oak	0.2	1.0	YES
34	BM	Bigleaf maple	0.2	0.5	YES
35	BU	California buckeye	0.3	0.8	
36	RA	Red alder	0.1	0.8	
37	MA	Pacific madrone	0.1	0.5	
38	GC	Golden chinkapin	0.2	0.8	
39	DG	Pacific dogwood	0.1	0.5	YES
40	FL	Oregon ash	0.3	0.8	
41	WN	Walnut	0.4	1.0	YES
42	TO	Tanoak	0.2	0.5	
43	SY	California sycamore	0.2	1.0	YES

44	AS	Quaking aspen	0.1	1.2	YES
45	CW	Black cottonwood	0.1	1.2	YES
46	WI	Willow	0.1	1.0	YES
47	CN	California nutmeg	0.2	0.3	
48	CL	California laurel	0.2	0.5	
49	OH	Other hardwoods	0.2	0.8	

Literature Cited

Arney, J. D. 1985. A modeling strategy for the growth projection of managed stands. Canadian Journal of Forest Research 15(3):511-518.

Burns, Russell M. and Barbara H. Honkala. 1990. Silvics of North America: Volume 1, Conifers; Volume 2, Hardwoods. Agriculture Handbook 654. USDA Forest Service, Washington, D.C.

Curtis, Robert O. 1967. Height-diameter and height-diameter-age equations for second-growth Douglas-fir. Forest Science 13(4):365-375.

Dixon, Gary E. 1986. Prognosis mortality modelling. USDA-Forest Service, Washington Office, Forest Management Service Center in Fort Collins, CO. Internal Report on file.

Dixon, Gary E. 1988. Crown ratio modeling using stand density index and the weibull distribution. USDA-Forest Service, Washington Office, Forest Management Service Center in Fort Collins, Co. Internal Report on file.

Dolph, Leroy K. 1987. Site index curves for young-growth California white fir on the western slopes of the Sierra Nevada. Res. Paper PSW-185, USDA Forest Service, Pacific Southwest Forest and Range Expt. Stn., Berkeley, CA.

Dunning, Duncan. 1942. A site classification for the mixed-conifer selection forests of the Sierra Nevada. Res. Note No. 28. Berkeley, CA: USDA Forest Service, California Forest and Range Expt. Stn. 21p.

Forest Inventory and Analysis User's Guide. 1995. USDA Forest Service. Pacific Southwest Region. San Francisco, CA.

Harlow, William M. and Ellwood S. Harrar. 1968. Textbook of Dendrology, 5th Ed.McGraw-Hill Book Company. 512p.

King, James E. 1966. Site index curves for Douglas-fir in the pacific northwest. Weyerhaeuser Forestry Paper No. 8. Centralia, Washington. Weyerhaeuser Forestry Research Center. 49p.

Long, Jim. 1984. Personal communication. Utah State Univ., Logan, UT.

Smith, Frederick (Skip). 1984. Personal communication. Colorado State Univ., Fort Collins, CO.

Stage, A. R. 1973. Prognosis model for stand development. USDA Forest Service Res. Paper INT-137. Ogden, UT: Intermountain Forest and Range Expt. Stn. 32p.

Wykoff, William R, Nicholas L. Crookston, and Albert R. Stage. 1982. User's

Guide to the Stand Prognosis Model. USDA-Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. General Technical Report INT-133. 112 pages.

Wykoff, William R. 1986. Supplement to the user's guide for the stand Prognosis Model version 5.0. Gen. Tech. Report INT-208. Ogden, UT: Intermountain Forest and Range Expt. Stn. 36p.