Forest Structural White Paper

In support of the Screens Team Analysis

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Introduction and Purpose

In order to provide a landscape context to the current Eastside Screens revision, ecological departure estimates are being provided for the entire project area (five National Forests in eastern Oregon). Once the code is written for this, it is a relatively simple extension to cover the entire Region, so the departure estimates map will be run for the entire Region.

The purpose of previous ecological departure maps in the Pacific Northwest Region focused on departure in forest structure and density. Because fire exclusion and other factors have resulted in landscapes with too much mid-seral closed forest, and not enough late seral open forest, the need for altering this with thinning, prescribed fire, and planning for the judicious use of wildfire has become compelling. A landscape analysis to quantify this need, and show how it varies with seral stage, potential vegetation type, and watershed (landscape) has allowed us to identify and set restoration priorities. Moreover, the method has value as the coarse filter assessment of biodiversity, integrating a number of factors to identify ecological resilience and sustainability.

The purpose of this white paper is to document the map layers involved, the methods used, and the datasets involved in generating these maps.

Methods

Logic Process in Generating Ecological Departure Maps

Overview

Landscapes are both dynamic and stable. They are dynamic through disturbance at all scales, so much so that this disturbance is an intrinsic feature. Typically we are most interested in fire, although wind, soil mass movement, and insects and disease are other important disturbances. These disturbances over time, in the pre-European-settlement landscape, occurred in predictable patterns of fire frequency and severity.

This dynamic nature of landscapes is framed by a stable set of land capability, or potential, factors. These factors of climate, geology, geomorphology, soils, and vegetation can be classified and mapped.

The vegetation expression of this combination of factors, reflecting what is possible ecologically on a site or area, is known as potential natural vegetation (PNV).

PNV at broad scale is useful for framing fire regime. In other words, each potential vegetation zone (and subzone) is associated with a characteristic pre-European settlement set of fire frequencies and severities. (See Table 1). The complete set of Fire Regimes for each Vegetation Subzone and BpS is found in the accompanying spreadsheet Subzones_FRG.

Table 1. How potential natural vegetation (PNV) provides the framework for fire regimes. This is an example from the Pacific Northwest (DeMeo et al. 2018). NRV = Natural range of variation.

Fire Regime	Potential Natural Vegetation Zone	Landscape Size	Fire Frequency (NRV)	Fire Severity (NRV)
I	Ponderosa pine	Subwatershed (10000 ac to 40000 ac)	0-35 yrs	Generally low severity replacing less than 25% of overstory
II	Grasslands	Subwatershed (10000 ac to 40000 ac)	0-35 yrs	Replacement (near 100%)
III	Grand fir (Mixed conifer)	Watershed (40000 ac to 250000 ac)	35-200 yrs	Mixed severity generating patches
IV	Lodgepole pine	Watershed (40000 ac to 250000 ac)	35-200 yrs	High severity
V	Sitka spruce	Subbasin (Average 700 mi2)	200+ yrs	High severity

Corresponding to each potential vegetation map unit on the landscape is a set of seral stages. Seral stages can be many or few, depending on the objectives of the work. For this work we follow the classic "five box" model of Fire Regime Condition Class (Barrett et al. 2010) with early, mid-seral closed, mid-seral open, late seral open, and late seral closed seral stages.

The natural range of variation (NRV) concept allows us to compare the present landscape against a modeled pre-European settlement landscape. It is assumed the pre-settlement, or historic, landscape was fully functional and sustainable. The current condition is either within that range of variation or departed from it.

The historic abundances of seral stages varied within a framework set by the PNV type they occur in. The average values of each seral stage form a coherent set for each PNV type, as in Table 2.

Table 2. Average seral stage abundances for selected potential natural vegetation (PNV) types in the Pacific Northwest. This is an excerpt from the R6RefCon table and is provided as an example. A,B,C,D,E are the seral stages. U=Uncharacteristic; always equals 0 for HRV/NRV. FRG=Fire Regime Group. Landscape Level 1=HUC 5/10, 2=HUC 4/8, 3=ILAP map zones, with boundaries set to HUC 4/8 so that all three landscapes nest within each other.

R6RefCon									
BpS_Model	Name	A	B	C	D	E	U	FRG	LandscapeLevel
R#DFHEdy	Douglas-fir Hemlock-Dry Mesic	5	15	5	15	60	0	III	2
R#DFHEwt	Douglas-fir Hemlock-Wet Mesic	5	15	1	4	75	0	V	3
R#DFWV	Douglas-fir Willamatte Valley Foothills	15	15	10	30	30	0	I	1
R#JUPIse	Western Juniper Pumice	3	12	15	10	60	0	V	3
R#MCONdy	Mixed Conifer - Eastside Dry	15	1	30	40	14	0	I	1
R#MCONms	Mixed Conifer - Eastside Mesic	15	40	15	10	20	0	III	2
R#MCONsw	Mixed Conifer - Southwest Oregon	15	5	10	50	20	0	I	1

The historic (presumed natural) variation in seral stages is developed using state-and-transition modeling software known as ST Sim (reference). This software, originally known as the Vegetation Dynamics Development Tool (VDDT), has been in use for Forest planning in the Region since the 1990s.

Data sources to inform the models include tree ring studies, fire history data, and expert opinion. Documentation for these models is found at https://ecoshare.info/projects/ilap/products/vddt/. Many of these models were developed during the LANDFIRE (2008) project, then refined during ILAP (Halofsky et al. 2014). The output of this work is a set of estimates for the historic (natural) range of variation (HRV/NRV), specifically the estimated average percent cover of seral stages for each PNV type. This is known as the reference condition. The Ecology Program in the Region stewards these models in preparation for Forest Plan revision and other applications.

Over the years the Fire Regime Condition Class (FRCC) method has been refined. Haugo et al. (2015) developed a method to identify specific estimates of the acres in each seral stage that would need restoration, either through treatments of thinning, prescribed fire, or wildland fire use, or by forest growth (succession), or both. These were mapped for all 5th/10th field watersheds in the Region in fire-prone areas. This work was expanded to include the entire Region in DeMeo et al. 2018, and the BioRegional assessment area in 2019.

To recap, then, the data and map layers needed for this departure analysis are:

- Potential natural vegetation (PNV) map at vegetation zone and subzone scales for the Region. Available at https://ecoshare.info/products/potential-natural-vegetation-maps/
- Landscape delineation. Should include the three scales corresponding to fire regimes, as in Table 2. Frequent, low intensity fire regimes are associated with smaller landscape areas than long-interval, severe fire regimes because of smaller average fire patch size. Note that other delineations could potentially be used, such as landtype associations rather than HUCs.
- Reference set (reference conditions) of modeled historic seral stage abundances by PNV vegetation zone and subzone. RefCon6 Access database available on request.
- Current seral stage abundances derived from the 2017 Gradient Nearest Neighbor (GNN) layer for the Region.
- Rule sets for defining forest structure

The rule sets for defining forest structure are defined in detail below. These evolved from a long history of the Region of defining forest structure for planning purposes, including the Northwest Plan of 1994 (USDA and USDI 1994), the 1996 Interim Old Growth Standards (USDA Forest Service 1996), and the 2004 Regional Vegetation Mapping Standards (USDA Forest Service 2004). The 2004 Regional standard diameter class definitions were heavily influenced by Johnson and O'Neil 2001, and in a broader sense by Jennings et al. 2003, Brohman and Bryant 2004 (now replaced by Nelson et al. 2015), and Winthers et al. 2005. Old growth definitions in DeMeo et al. 2018 came from the old growth structural index (OGSI) developed by Ray Davis and others (Davis et al. 2015).

We will now go through each of these steps and explain them more fully.

- Potential natural vegetation (PNV) map at vegetation zone and subzone scales for the Region. Available at https://ecoshare.info/products/potential-natural-vegetation-maps/

  The potential vegetation layer used in the Haugo and DeMeo studies was based on the PVT layer created by ILAP (Integrated Landscape Assessment Project, https://inr.oregonstate.edu/ilap), cross-walked to LANDFIRE National and Rapid Assessment Biophysical Settings (BpS) codes.

  A new Region-wide PNV map at vegetation zone and subzone scales is now available. The LANDFIRE BpS codes crosswalk to the new Subzone scale (see accompanying spreadsheet SubZone_PA_Xwalk_20191030)

- Landscape delineation. Landscape delineation. Should include the three scales corresponding to fire regimes, as in Table 2. Frequent, low intensity fire regimes are associated with smaller landscape areas than long-interval, severe fire regimes because of smaller average fire patch size. Note that other delineations could potentially be used, such as landtype associations rather than HUCs.

The code is written so that the NRV departure is calculated at the appropriate scale for that fire regime (and hence PNV type). More frequent, less severe fires are associated with somewhat smaller landscapes (HUC5/10), mid-severity regimes with HUC 4/8 landscapes and long-interval regimes with ILAP map zones. Results are reported at HUC 5/10 scale.

- Reference set of modeled historic seral stage abundances by PNV vegetation zone and subzone.

  This is found in the Access database R6RefCon, available on request.
- Current seral stage abundances derived from the 2017 Gradient Nearest Neighbor (GNN) layer for the Region.
- Rule sets for defining forest structure

These two components will be described in this section.

Using the accompanying spreadsheet Sclass_LUT_20190403, with these fields:

BpS_Code Code for the BioPhysical Setting (BpS) from LANDFIRE. This is a kind of PNV. This is then related to the new PNV types (vegetation zone and vegetation subzone) in the spreadsheet pvg_xwalk_vegetation_zone_20200608.

SClass The seral stage or succession class (SClass). Although many variations of this can be constructed, for this work the class "5 Box Model" of FRCC (Barrett et al. 2010) is used. The reference abundance (reference condition table, R6RefCon.mdb) (in percent cover) of each seral stage for each PNV type is listed. This is an average based on STSim modeling and reflects the historic (natural) range of variation. The five seral stages used are

A Early seral

B Mid-seral closed

C Mid-seral open

D Late seral open

E Late seral closed

In the reference conditions, each PNV type has an average estimated percent cover of these seral stages.

Cover_min The minimum possible cover value for that seral stage in that PNV type.

Cover_max The maximum possible cover value for that seral stage in that PNV type.

SizeClass_min A forest structural class based on tree diameter. This is the minimum allowed for that seral stage.

SizeClass_max A forest structural class based on tree diameter. This is the maximum allowed for that seral stage. The size classes are

1 Grass/forb/shrub
2 Seedling/Sapling (0 to 4.9 inches DBH)
3 Pole (5 to 9.9 in DBH)
4 Small (10 to 14.9 in DBH)
5 Medium (15-19.9 in DBH)
6 Large (20-29.9 in DBH)
7 Extra Large (30 in + DBH)

Madison Laughlin has written the following on determining the S Class layer:

The methodology for creating the S-Class layer involves two major steps, beginning with the use of a decision tree to define tree size classes from a set of GNN variables and potential vegetation types (PVTs). A lookup table is then utilized to take size classes and canopy cover ranges to the final S-Class. These steps are outlined in the document **GNNandBpS-to-Sclass-Outline.docx** (Appendix 1), and detailed here:

1. Create size class raster "forest size" from GNN layers:
   a. In the process to develop DeMeo et al 2018, as well as the Bioregional Assessment (2019), a decision was made to come up with estimates of large trees per acre for Westside as well as the Forests east of the Cascades. The dbh definition for large trees was larger on the Westside and the TPA threshold of large trees also somewhat higher west of the Cascades, but a similar logic and process was used. In the Size_TH raster it looks like there are no PVTs in any of the east side mapzones that are assigned the R6 guidelines for size class—only the west side mapzones. So the methods outlined in this document should be up to date for the east side map zones, but not for the west side.

   b. The decision tree document **Tree_Size_Class_Decision_Tree_2013_Full_Size.docx** (Appendix 2) defines the process for defining size classes from the various GNN layers, and is partially implemented in the python script **Tree Size Class_2017_GNN.py**. Note that the logic of the decision tree requires the specification of a few parameters: a) a "PVT threshold value" for each PVT, which is the number of trees per acre (TPA) in the large / x-large size classes required to classify the stand in the given size class; and b) CC1 & CC2, the canopy cover threshold for large/x-large size classes, and the threshold for the smaller size classes, respectively. So before running the script, the user needs to know the universe of TPA cutoffs that will be needed to describe the PVTs used. In the most recent implementation (the BioA assessment for the NWFP area in WA/OR/CA), the PVT values used were 30, 60, 80, 100, 120, 150, 200, 250, 300, and 350 (considerably fewer were used in the initial Haugo study). The CC1 & CC2 parameters are single values for all PVTs (10/20 in the Haugo study, 10/10 in DeMeo & the BioA).

      Running the script results in the creation of a separate raster for each of the PVT threshold values, each one representing the size classes across the landscape if the threshold value for large/x-large trees was the one given. So e.g., if all PVTs had a size threshold of 20, the output raster "TH_20" would be the final size class raster. But in practice, different PVTs will be assigned different thresholds, so a selection process is needed to produce the final size class layer. This is described in step c.

   c. To create the final size class threshold raster from the rasters produced in the previous step, a lookup table of PVT-to-TPA cutoffs is needed. The lookup used for the original Haugo study was derived from the spreadsheet "**TPA_Thresholds_FINAL_Haugo.xlsx**". In the "Size_TH" column, a "0" indicates that the vegetation type will use the "Guideline size" (i.e., QMD – see step d) rather than a TPA cutoff to determine the large/x-large size classes. This

lookup table is then joined to the PVT raster, and the “Lookup” tool (ArcGIS Spatial Analyst toolbox) is run to give the final “Size_TH” raster.

d. The next step is to create the “R6_Guideline_Size” raster. The approach is to create it for the entire landscape, although it will only be used for those PVTs for which the QMD approach is used to define large and x-large size classes. The calculation uses two GNN rasters: the total canopy cover (to define size class 1, non-forest), and the QMD (in inches) of the top 20 trees. This step has not currently been committed to code, but can be executed in the ArcGIS raster calculator using the following expression (assuming the two GNN rasters have been added to the map project and have their original names):

```
Con("cancov_all_corr_2017.tif" < 1000, 1, Con("qmd_top_20_in_2017.tif" < 50, 2,
Con("qmd_top_20_in_2017.tif" < 100, 3, Con("qmd_top_20_in_2017.tif" < 150, 4,
Con("qmd_top_20_in_2017.tif" < 200, 5, Con("qmd_top_20_in_2017.tif" < 300, 6, 7))))))
```

Note that the GNN layers as delivered are multiplied by scalars in order to “integerize” them: canopy cover has been multiplied by 100, and QMD by 10.

e. Using the rasters “Size_TH” and “R6_Guideline_Size” created in the previous steps, the final size class raster is created using the ArcGIS raster calculator (again, this step could be committed to code, but hasn’t yet). Using the full set of size thresholds indicated above in step b, the raster calculator expression would look like the following:

The final output of the process thus far is the raster “forest_size”, an integer raster with values 1 - 7

(Note that this process has been altered in practice, but not in substance, from the original Haugo paper due to changes in GNN data delivery formats.)

2. Create S-Class layer from size class and canopy cover:

a. Create canopy cover raster – this is just the GNN total canopy cover layer, converted to percentages (i.e., divide the GNN raster, cancov_all_corr_2006.tif in this case, by 100), to give the raster "forest_cover"

b. The S-Class layer is created from the size classes and PVTs using a lookup table approach, in which each s-class of each PVT is defined using ranges of canopy cover and size class, as in the following example from the BioA assessment:

BpS_Code	Sclass	Cover_min	Cover_max	SizeClass_min	SizeClass_max
10080_1_2_3_7	A	0	100	1	3
10080_1_2_3_7	B	41	100	4	7
10080_1_2_3_7	C	0	40	4	7
10170_6_7_8_9_12_18	A	0	100	1	1
10170_6_7_8_9_12_18	B	0	100	2	3
10170_6_7_8_9_12_18	C	0	100	4	5
10170_6_7_8_9_12_18	D	0	20	6	7
10170_6_7_8_9_12_18	E	21	100	6	7

This lookup table should exist as a geodatabase table, to be input into the python script described in the next and final step.

c. Finally, the S-Class raster is created by the python script "**SClass4.0.py**", which takes as input the PVT raster, the canopy cover raster, the forest size raster, and the S-Class lookup table described in the previous step.

I. Determine reference conditions

In the original Haugo et al. 2015 study, ILAP PVTs were cross-walked to BpSes (some were LANDFIRE National codes, and some were Rapid Assessment codes), so that the existing state-and-transition models could be used to derive reference conditions. Using VDDT (FSim, STSim, Path, etc.), models were run a set number of times for each vegetation type, and ranges of ±2 standard deviations were developed for each S-Class to define the reference conditions. This is in contrast to the standard methodology of simply using the mean values as the reference conditions. In the subsequent departure analysis, an S-Class was only considered "departed" (i.e., outside the natural range of variability) if the percent of the S-Class fell outside this stochastic range in its current condition. The reference condition table used in the Haugo study was called "**R6RefCon**", and is located in the LUTs.gdb geodatabase.

Note that in subsequent studies stochastic ranges were dropped, but the format of the reference conditions table remained the same; when only a single value is used instead of a range, just set the "Minus_2_SD" and "Plus_2_SD" values to the average value.

II. Perform departure analysis

The departure analysis is accomplished by the python script "**CreateDepartureLayer.py**". Inputs needed for this script include those discussed above – the BpS, S-Class, 3 landscape level rasters, and reference conditions table - plus one additional spatial layer, a forest mask. This is simply a raster that ArcGIS will use to restrict the pixels being processed to forested pixels only; the only requirement is that forested pixels are non-NULL and non-forest areas are NULL.

The script computes departed acres for each combination of BpS, S-Class, and landscape level (appropriate to the BpS). The output is a raster used as input to the restoration step, and is typically just named "departures."

The script only calculates acres departed from NRV for each landscape and not percent departure, as its main use is as input into the restoration step. To calculate the percent departure, the field "ACRES_CURRENT" gives the total landscape acres, and so dividing the field "ACRES_DEPARTED" by "ACRES_CURRENT" will give the fraction of the landscape that is departed, which can be mapped if desired. Given that landscapes tend to be quite pixelated, the departures layer is rather difficult to interpret visually, even when displaying percent stand departure.

III. Perform restoration analysis

Finally, restoration need is calculated using the python script "**CalculateRestorationAcres.py**". This script takes as input the departures raster from the previous step, a table of restoration rules for each BpS (called "**ActivePassiveRules**" in the Haugo study, located in the LUTs.gdb), and two empty tables that are used as templates for the output tables. The output tables are 1) a table of the results of the application of each restoration step -- how many acres could be "moved" from one s-class to another, if any ("**ActivePassiveRules_Applied_2SD_HRV**" in the Haugo results), and 2) a table of the net results of all restoration steps, i.e., the total restoration need for each stand ("**Acres_PostRestoration_2SD_HRV**" in the Haugo results).

The latter table can be used to visualize the restoration need for each seral stage (SClass), though as with the departures it can be difficult to visualize at the landscape level. The table can be joined to the departures raster by creating a "stand key" in both this table and the departures raster by concatenating the LLID (Landscape Level ID - i.e., the HUC 5/100, HUC 4/8, or map zone code), BpS code, and S-Class code. This step could easily be committed to code, but has not yet been done.

IV. Downscale results to HUC10s (optional)

To put the restoration results on a common footing, and to make visualization easier, the results are often downscaled to HUC10s. But because many vegetation types are analyzed over much larger landscape units (HUC8, mapzones), downscaling does require the assumption that the restoration need is evenly distributed across the landscape units over which they are analyzed. For this reason, interpretation of downscaled results must be done with a certain amount of caution.

First run the script "**CalculateForestedRestorationAcresByWatershed_DownscaleUsingBpsAndSclass.py**" to downscale the restoration numbers; this produces a raster of overlaid HUC10s and departures/restoration need. To complete the calculations, the raster attribute table can be exported to Excel and a pivot table run to sum up restoration need by HUC10. The resulting table can be joined to a HUC10 feature class to visualize the results. Again, all this could ultimately be committed to code, but this has not been done yet.

References Cited

Barrett S, Havlina D, Jones J, Hann W, Frame C, Hamilton D, Schon K, DeMeo T., Hutter L,Menakis J (2010) Interagency Fire Regime Condition Class Guidebook. Version 3.0[Homepage of the

Interagency Fire Regime Condition Class website, USDA Forest Service,US Department of the Interior, and The Nature Conservancy]. Available on-line at www.frcc.gov

Brohman,R, L.Bryant. 2004. Existing Vegetation Classification and Mapping Technical Guide. USDA Forest Service, Washington Office, Ecosystem Management Coordination Staff.

Davis, Raymond J.; Ohmann, Janet L.; Kennedy, Robert E.; Cohen, Warren B.; Gregory, Matthew J.; Yang, Zhiqiang; Roberts, Heather M.; Gray, Andrew N.; Spies, Thomas A. 2015. Northwest Forest Plan–the first 20 years (1994-2013): status and trends of late-successional and old-growth forests. Gen. Tech. Rep. PNW-GTR-911. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 112 p.

DeMeo, T., R. Haugo, C. Ringo, J. Kertis, S. Acker, M. Simpson, and M. Stern. 2018. Expanding our understanding of forest structural restoration needs in the Pacific Northwest. Northwest Science 92:18–35.

Halofsky, Jessica E.; Creutzburg, Megan K.; Hemstrom, Miles A., eds. 2014. Integrating social, economic, and ecological values across large landscapes. Gen.Tech. Rep. PNW-GTR-896. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 206 p.

Jennings, M., 0. Loucks, R. Peet, D. Faber-Langendoen, D. Glenn-Lewin, D. Grossman, A. Damm.an, M. Barbour, R. Pfister, M. Walker, S. Talbot, J. Walker, G. Hartshorn, G. Waggoner, M. Abrams, A. Hill, D. Roberts, and D. Tart. 2003. Guidelines for describing associations and alliances of the U.S. national vegetation classification.

Johnson, David H, and Thomas A. O'Neil. 2001. Wildlife-habitat Relationships in Oregon and Washington. Corallis, OR: Oregon State University Press.

LANDFIRE, 2008, Reference Conditions Table, LANDFIRE 1.1.0, U.S. Department of the Interior, Geological Survey. Accessed 28 October 2010 at http://landfire.cr.usgs.gov/viewer/.

Nelson, M.L.; Brewer, C.K.; Solem, S.J., eds. 2015. Existing vegetation classification, mapping, and inventory technical guide, version 2.0. Gen. Tech. Rep. WO–90. Washington, DC: U.S. Department of Agriculture, Forest Service, Ecosystem Management Coordination Staff. 210 p.

Ryan Haugo, Chris Zanger, Tom DeMeo, Chris Ringo, Ayn Shlisky, Kori Blankenship ,Mike Simpson, Kim Mellen-McLean , Jane Kertis , and Mark Stern. 2015. A new approach to evaluate forest structure restoration needs across Oregon and Washington, USA. Forest Ecology and Management 335: 37–50.

USDA and USDI 1994. The Northwest Plan. USDA Forest Service Pacific Northwest Region, and USDI agencies. Portland, OR

USDA Forest Service. 1996. Interim Old-Growth Definitions for the Pacific Northwest Region. Regional direction. Portland, OR

USDA Forest Service. 2004. Standards for mapping of vegetation in the Pacific

Northwest Region. Portland, OR: Regional Office direction, report on file, 22 pp.

Winthers, E., Fallon, D., Haglund, J. , DeMeo, T., Tart, D., Ferwerda, M., Robertson, G. Gallegos, A., Rorick, A., Cleland, D. T., Robbie, W. and Shadis, D., 2004. Terrestrial Ecological Unit Inventory Technical Guide. USDA Forest Service, Washington Office- Ecosystem Management Coordination Staff, 125 pp.

Appendices

1 GNNandBPS-to-SClass.docx
2 Tree_Size_Class_Decision_Tree_2013_Full_Size

Accompanying Spreadsheets

Sclass_LUT_20190403

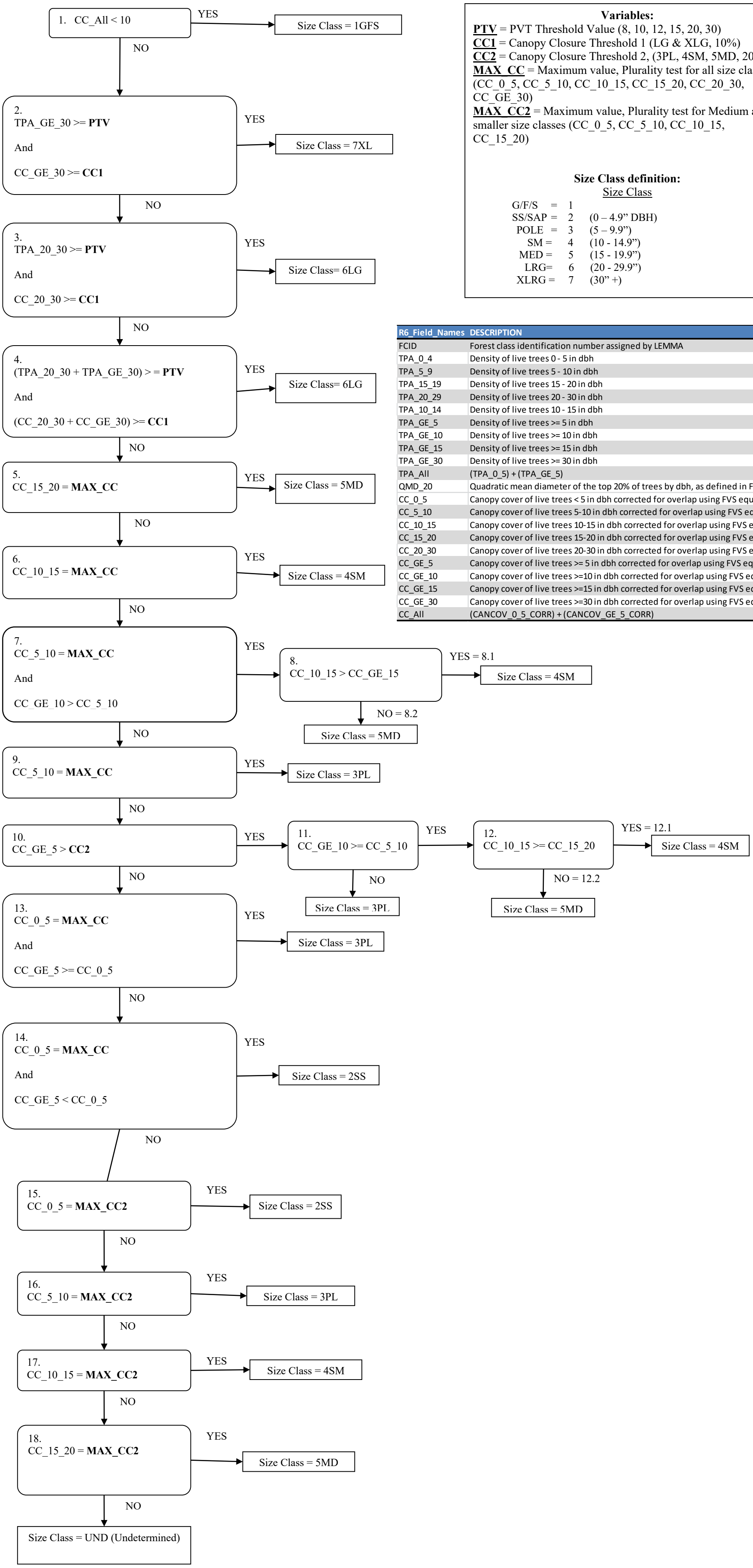
pvg_xwalk_vegetation_zone_20200608

Subzones_FRG

Python Scripts and Access Databases

Available on request

Appendix 2. R6 / TNC Analysis – Tree Size Class Decision Tree for Scripting Code
5/31/2013



Variables:

PTV = PVT Threshold Value (8, 10, 12, 15, 20, 30)
CC1 = Canopy Closure Threshold 1 (LG & XLG, 10%)
CC2 = Canopy Closure Threshold 2, (3PL, 4SM, 5MD, 20%)
MAX_CC = Maximum value, Plurality test for all size classes (CC_0_5, CC_5_10, CC_10_15, CC_15_20, CC_20_30, CC_GE_30)
MAX_CC2 = Maximum value, Plurality test for Medium and smaller size classes (CC_0_5, CC_5_10, CC_10_15, CC_15_20)

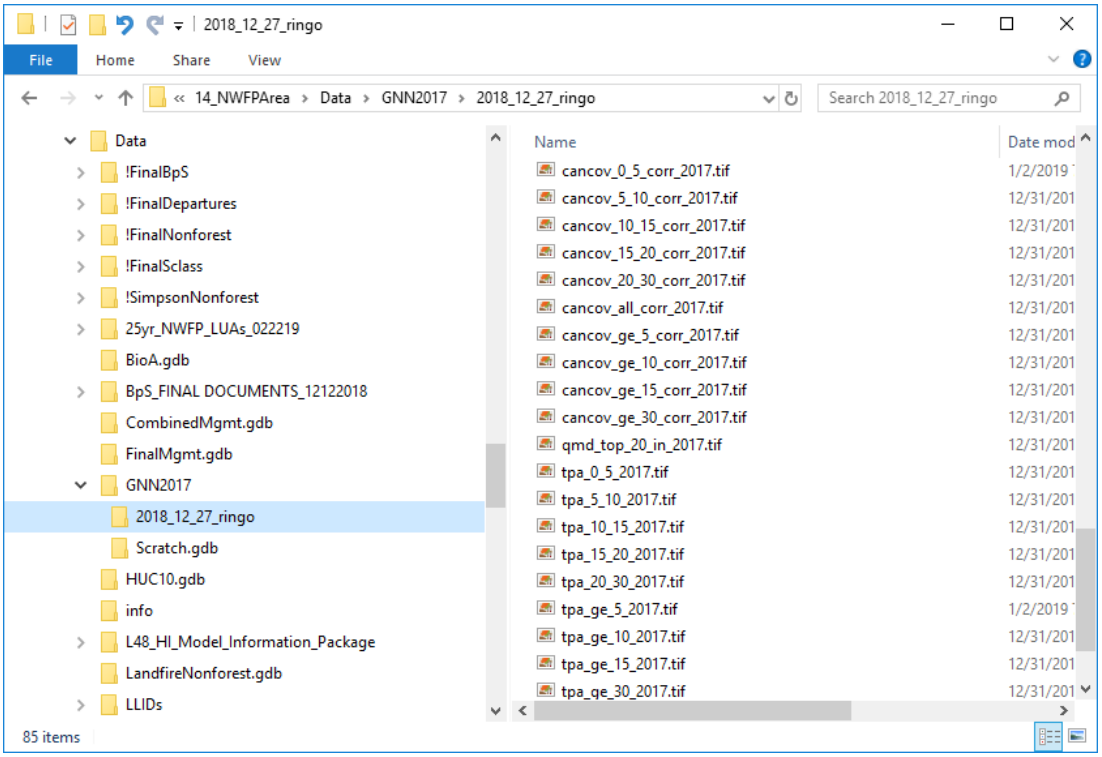
Size Class definition:

	Size Class	
G/F/S =	1	
SS/SAP =	2	(0 – 4.9" DBH)
POLE =	3	(5 – 9.9")
SM =	4	(10 - 14.9")
MED =	5	(15 - 19.9")
LRG=	6	(20 - 29.9")
XLRG =	7	(30" +)

R6_Field_Names	DESCRIPTION
FCID	Forest class identification number assigned by LEMMA
TPA_0_4	Density of live trees 0 - 5 in dbh
TPA_5_9	Density of live trees 5 - 10 in dbh
TPA_15_19	Density of live trees 15 - 20 in dbh
TPA_20_29	Density of live trees 20 - 30 in dbh
TPA_10_14	Density of live trees 10 - 15 in dbh
TPA_GE_5	Density of live trees >= 5 in dbh
TPA_GE_10	Density of live trees >= 10 in dbh
TPA_GE_15	Density of live trees >= 15 in dbh
TPA_GE_30	Density of live trees >= 30 in dbh
TPA_All	(TPA_0_5) + (TPA_GE_5)
QMD_20	Quadratic mean diameter of the top 20% of trees by dbh, as defined in FVS
CC_0_5	Canopy cover of live trees < 5 in dbh corrected for overlap using FVS equations
CC_5_10	Canopy cover of live trees 5-10 in dbh corrected for overlap using FVS equations
CC_10_15	Canopy cover of live trees 10-15 in dbh corrected for overlap using FVS equations
CC_15_20	Canopy cover of live trees 15-20 in dbh corrected for overlap using FVS equations
CC_20_30	Canopy cover of live trees 20-30 in dbh corrected for overlap using FVS equations
CC_GE_5	Canopy cover of live trees >= 5 in dbh corrected for overlap using FVS equations
CC_GE_10	Canopy cover of live trees >=10 in dbh corrected for overlap using FVS equations
CC_GE_15	Canopy cover of live trees >=15 in dbh corrected for overlap using FVS equations
CC_GE_30	Canopy cover of live trees >=30 in dbh corrected for overlap using FVS equations
CC_All	(CANCOV_0_5_CORR) + (CANCOV_GE_5_CORR)

Appendix 1

A. GNN Rasters:



B. Python code implements decision tree → series of size/threshold rasters:

```
# ******
#  DECISION TREE
# ******
printMsg("Starting decision tree...")
#Outputs are size class rasters for various TPA thresholds (TH_8, TH_10, TH_12, …)
for PTV in [30,60,80,100,120,150,200,300,350]:
  PTV_N = int(PTV/10)
   SizeClass = wsOutput + "TH_" + str(PTV_N)
   printMsg("   Creating size class raster for threshold value " + str(PTV_N) + "...")
   outCon = Con(CC_ALL < CC2, 1, \
          Con((TPA_GE_30 >= PTV) & (CC_GE_30 >= CC1), 7, \
                                    Con((TPA_20_30 >= PTV) & (CC_20_30 >= CC1), 6, \
                                    Con(((TPA_20_30 + TPA_GE_30) >= PTV) & ((CC_20_30 + CC_GE_30) >= CC1), 6, \
                                    Con(CC_15_20 == MAX_CC, 5, \
                                    Con(CC_10_15 == MAX_CC, 4, \
                                    Con((CC_5_10 == MAX_CC) & (CC_GE_10 > CC_5_10) & (CC_10_15 > CC_GE_15), 4, \
                                    Con((CC_5_10 == MAX_CC) & (CC_GE_10 > CC_5_10) & (CC_10_15 <= CC_GE_15), 5, \
                                    Con(CC_5_10 == MAX_CC, 3, \
                                    Con((CC_GE_5 > CC2) & (CC_GE_10 >= CC_5_10) & (CC_10_15 > CC_15_20), 4, \
                                    Con((CC_GE_5 > CC2) & (CC_GE_10 >= CC_5_10) & (CC_10_15 <= CC_15_20), 5, \
                                    Con((CC_GE_5 > CC2) & (CC_GE_10 < CC_5_10), 3, \
                                    Con((CC_0_5 == MAX_CC) & (CC_GE_5 >= CC_0_5), 3, \
                                    Con((CC_0_5 == MAX_CC) & (CC_GE_5 < CC_0_5), 2, \
                                    Con(CC_0_5 == MAX_CC2, 2, \
                                    Con(CC_5_10 == MAX_CC2, 3, \
                                    Con(CC_10_15 == MAX_CC2, 4, \
                                    Con(CC_15_20 == MAX_CC2, 5, 0 \
                                )))))))))))))))))
   outCon.save(SizeClass)
```

C. Create R6_Guideline_Size raster (default size classes based on QMD):

```
Con("cancov_all_corr_2017.tif" < 1000, 1, Con("qmd_top_20_in_2017.tif" < 50, 2, Con("qmd_top_20_in_2017.tif" < 100, 3,
Con("qmd_top_20_in_2017.tif" < 150, 4, Con("qmd_top_20_in_2017.tif" < 200, 5, Con("qmd_top_20_in_2017.tif" < 300, 6, 7))))))
```

D. BpS & size threshold rasters → single size-threshold raster "size_TH" (join LUT to BpS):

BPS_CODE	BPS_NAME		TPA TH
10080_1_2_3_7	North Pacific Oak Woodland	**A zero means use guideline size →**	0
10170_6_7_8_9_12_18	Columbia Plateau Western Juniper Woodland and Savanna		6
10180_1_7	East Cascades Mesic Montane Mixed-Conifer Forest and Woodland		20
10190_6_7_9_12_16_17_18_19	Great Basin Pinyon-Juniper Woodland		6
10200_6_9_12_17	Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodland		12
10210_2_3_6_7	Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland		8

E. Create "forest_size" raster with raster calculator:

F. Create S-class layer using lookup table on BpS / canopy cover / size class (py code):

BpS_Code	Sclass	Cover_min	Cover_max	SizeClass_min	SizeClass_max
10080_1_2_3_7	A	0	100	1	3
10080_1_2_3_7	B	41	100	4	7
10080_1_2_3_7	C	0	40	4	7
10170_6_7_8_9_12_18	A	0	100	1	1
10170_6_7_8_9_12_18	B	0	100	2	3
10170_6_7_8_9_12_18	C	0	100	4	5
10170_6_7_8_9_12_18	D	0	20	6	7
10170_6_7_8_9_12_18	E	21	100	6	7