Foothills Growth and Yield Association

Technical Note 2010-2

RLPn: A Model to Predict the Establishment and Performance of Natural Regeneration Following Harvest of Lodgepole Pine Stands

About RLPn

RLPn is a Microsoft Excel application. It uses results from the Foothills Growth and Yield Association's Regenerated Lodgepole Pine (RLP) trial[1] and inputs provided by the user to predict the development of naturally regenerated lodgepole pine up to 12 years following harvest. The majority of RLP research plots on which the projections are based currently have been measured up to 9-10 years since harvest, and to 9 years since site preparation. Trends in height growth and ingress projected beyond these ages were verified and adjusted against earlier research conducted by Crossley[2] and Johnstone.[3] Projections beyond the current age of the RLP trial have been made with conservative caution pending their replacement over the next few years as the experimental data become available.

Predicted Variables

The variables named in italics and described below are projected for each year (elapsed growing season) from the fifth to the twelfth since harvest.

The following height variables are computed from a height distribution function, the parameters of which depend on ecological site class and years since the disturbance (site preparation, or harvest if no subsequent site preparation was undertaken):

- *Average pine height;*
- *Modal pine height;*
- *Average height of tallest 100 pine stems per ha;*
- *Average pine crop[4] tree height.*

Top height is usually defined as the average height of the largest-diameter 100 trees per ha. In Alberta regeneration performance surveys it is based on the largest diameter tree per 0.01 ha. This convention has been adopted here to make RLPn consistent with and applicable to regeneration surveys. *Top height* of pine is calculated based on the relationship found in the RLP trial between average crop tree height and height of the largest-diameter tree per 0.01 ha. Note that all height predictions are restricted to pine, and do not include other coniferous species that may occur in the stand.

Percent stocking (coniferous trees >10cm) is predicted based on years since disturbance and ecological site class. Projections can be adjusted using percent stocking data input by the user from stocking or establishment surveys. Projection of stocking relying on a 30cm height tree-inclusion threshold (consistent with current establishment survey protocols) as a function of age was found to be problematic because many trees do not reach the threshold until well into, or even past, the establishment survey age

[1] Dempster, W.R. 2010. Regenerated lodgepole pine trial, 2009 crop performance report. *Foothills Growth and Yield Association Technical Report*.

[2] Crossley, D.I. 1976. The ingress of regeneration following harvest and scarification of lodgepole pine stands. *Forestry Chronicle* February 1976.

[3] Johnstone, W.D. 1976. Juvenile height growth of white spruce and lodgepole pine following logging and scarification in west-central Alberta. *Canadian Forestry Service Information Report NOR-X-171*.

[4] A "crop" tree is the tree with the best overall height, diameter and health within a 0.001ha (1.78 m radius) regeneration plot.

window (5 – 8 years since harvest). *Percent stocking (coniferous trees >30cm tall)* is instead estimated from its general relationship by ecological site class to stocking at the 10 cm threshold.

Average number of coniferous trees per stocked regeneration plot is also predicted based on years since disturbance and ecological site class. From this, the *average number of pine trees per stocked regeneration plot* is calculated based on the average pine content by ecological site class observed in the RLP trial, or from species composition data provided by the user. The *average number of pine trees >30cm tall per stocked plot* and the *average number of pine trees >130cm tall per stocked plot* are then calculated by applying the height distribution function to the total number of pine trees per stocked plot.

The following measures of coniferous and pine density are all estimated from percent stocking (coniferous trees >10cm) and the relevant estimate of trees per stocked regeneration plot:

- *Total coniferous trees per ha >10cm tall;*
- *Number of pine trees per ha >10cm tall;*
- *Number of pine trees per ha >=30cm tall;*
- *Number of pine trees per ha >=130cm tall*.

Note that all these estimates are net of mortality i.e. the projections of natural regeneration densities are based on numbers of surviving trees.

Average ground-line diameter is computed from a diameter distribution function. Like the height distribution function, the parameters of this function depend on ecological site class and years since disturbance. The following diameter and basal area variables are calculated from the diameter distribution function, additional functions relating stump and breast-height diameter to ground-line diameter, and densities calculated as described above:

- *Modal ground-line diameter;*
- *Average stump diameter;*
- *Average breast-height diameter;*
- *Ground-line basal area per ha;*
- *Breast-height basal area per ha*.

No statistically significant differentiation in growth or ingress response to vegetation treatment (weeding) is yet detectable for natural (as distinct from planted) regeneration in the RLP trial. This factor is therefore not included in the model output. Consistent with the conservative approach taken for projections past the current stand ages of the RLP trial, stocking and density predictions are capped at the upper 95th confidence interval on average values by site class observed in the latest RLP trial measurements. Both the RLP trial and previous stocking studies[2] suggest that upward trends will continue past these imposed maxima.

Required and Optional Inputs

The following variables are the minimum inputs required to run the model:

- Ecological site class (see Table 1);
- Site preparation delay: the interval between harvest and site preparation (must be between 0 and 4 years – enter zero if either the site was prepared prior to the first growing season following harvest, or if no site preparation was considered necessary)

Additional variables may be input, from establishment surveys and / or other sources if available, to improve predictions. These are:

- Coniferous stocking percent, based on seedlings greater than 10cm tall of any acceptable coniferous species, occurring on a 0.001 ha (1.78m radius) regeneration plot, at a specified survey age (years since harvest);

- Average number of coniferous seedlings per stocked plot at the specified survey age;
- Percent pine (number of pine seedlings expressed as a percentage of all coniferous seedling);
- Average crop tree height (pine) at the specified survey age;

Table 1. Ecological site classes

Class #	Ecosite Names (and Edatope)	Ecosite Codes[5]	
		WC	SW
1	Bearberry / lichen / hairy wild rye (submesic / subxeric, medium – poor)	b, c	b
2	Labrador tea – mesic (mesic – poor)	d	c
3	Billberry / cranberry / sarsaparilla / rhododendron (mesic / medium)	e	d
4	Honeysuckle / fern (subhygric – rich)	f	e
5	Labrador tea – hygric (hygric – poor)	h	f

The survey should have been made at least 4 years after the last site disturbance for the survey results to be used in prediction. The current version of RLPn does not support predictions of diameter and basal area from survey data i.e. these predictions are generated only from default data sources.

How to Install

No installation is required. The model may be run on any computer that has Microsoft Excel installed. Simply open the workbook RLPn_v1alpha.xls in Excel. If you are given the choice to disable or enable macros, select "enable macros".

How to Use

Start at the top of the "Input" worksheet and work your way from top to bottom (see Figure 1). Then proceed to the "Output" worksheet.

1. At the top of the "Input" worksheet you are given a number of run options to choose from. Depending on the options that you select, required inputs will be indicated by red crosses. The run options are:
   - Input data source: choose "Default" or "Survey". Select "Default" if you wish to rely on data only from the RLP trial e.g. for making broad regional or strategic assessments. Select "Survey" if you wish to localize predictions for operational or stand-level assessments and any survey data are available that include percent stocking. (The model will resort to default data sources where the survey data are incomplete.)
   - Ecological site class: select one of the classes numbered in the pull-down menu. (See definitions in Table 1 above. If you hold the cursor over the cell to the right of the pull-down, a comment will open to remind you of these.)

[5] WC = *Field guide to ecosites of west-central Alberta*, J.D. Beckingham, I.G.W. Corns and J.H. Archibald, Can. For. Serv. Special Report 9, 1996.
SW = *Field guide to ecosites of southwestern Alberta*, J.D. Beckingham, G.D. Klappstein, and I.G.W. Corns, Can. For. Serv.

- Vegetation treatment: ignore the request to specify "Weed" or "Leave" – these are not differentiated in the current version.
- If you selected "Survey" as the input data source, you will be asked what survey data you intend to utilize: coniferous stocking, trees per stocked plot, percent pine, and / or crop tree height. Answer yes or no for each.

2. Next provide the required information on stand history. You will always be asked for the interval between harvest and site preparation. If you selected "Survey" as the input data source, you will be prompted for the stand age (years after harvest) at which the survey took place. The "years since last disturbance at time of survey" will be calculated automatically and displayed.

3. Enter any requested survey and climate data (i.e. items flagged with a red cross), adhering to the data ranges and formats specified to the right of the input cells.

4. Check that you have provided all required information in the "Input" worksheet, and proceed to the "Output" sheet.

5. Use the keystroke shortcut Ctrl+E to run the model macro i.e. press "Ctrl+E" on your keyboard while in the "Output" sheet. Tabular results will be displayed in, and may be printed from, this worksheet (see Figure 2). Table and chart contents can be cleared by the keystroke Ctrl+Shift+E, though this is not strictly necessary because they are automatically replaced whenever the model is run. Charts illustrating height, stocking and density trends with age will be displayed in, and may be printed from, the "Graphs-Height", "Graphs-Stocking" and "Graphs-Density" worksheets (see Figures 3 and 4). Do NOT use either of the keystroke shortcuts while in any worksheet except "Output".

Figure 1. Example of a completed run input worksheet

Run Options		
x Input data source	Survey	Select from drop-down
x Ecological site class	1	Select from drop-down
Vegetation treatment	Leave	Select from drop-down
x Survey data to be utilized:		
Coniferous stocking percent?	Yes	(required - select Yes)
Average # of coniferous seedlings per stocked plot?	No	(optional)
Percent pine?	Yes	(optional)
Average crop tree height (pine)?	No	(optional)
Stand History		
x Interval between harvest and site preparation (years)	1	Integer between 0 and 4
x Survey age (years after harvest)	6	Integer between 5 and 12
Years since last disturbance at time of survey	5	Calculated
Survey Data Inputs		
x Coniferous stocking percent	50	Decimal between 0 and 100
Average # of coniferous seedlings per stocked plot		Decimal - minimum value 1
x Percent pine	95	Decimal between 0 and 100
Average crop tree height (pine)		Decimal >10cm

Figure 2. Example of tabular output

Regenerated Lodgepole Pine - Natural

Input data source	Default
Ecological site class	1
Vegetation treatment	Not differentiated
Interval between harvest and site preparation (years)	1

Age (years since harvest)	5	6	7	8	9	10	11	12
Years since latest disturbance (harvest or site prep)	4	5	6	7	8	9	10	11
Average pine height (cm)	18.9	26.5	40.1	59.7	85.5	108.8	132.2	155.6
Average pine crop tree height (cm)	19.3	29.9	48.9	76.3	112.0	144.1	176.3	208.4
Modal pine height (cm)	16.0	25.0	35.0	50.0	73.0	93.0	121.0	145.0
Average height of tallest 100 pine stems per ha (cm)	40.8	58.4	87.6	127.5	178.0	222.4	261.7	301.9
Top height based on largest diameter pine per 100m^2 (cm)	40.8	56.2	78.0	109.5	150.6	187.5	224.5	261.4
Percent stocking (coniferous trees >10cm)	51.2	66.0	77.2	85.0	90.1	93.4	95.5	95.5
Percent stocking (coniferous trees 30cm+)	9.0	36.4	57.1	71.5	81.0	87.2	90.9	90.9
Average number of coniferous trees per stocked regen plot	5.09	7.74	10.38	13.03	15.68	18.32	20.63	20.63
Average number of pine trees per stocked regen plot	5.05	7.67	10.30	12.92	15.55	18.17	20.46	20.46
Average number of pine trees >30cm tall per stocked plot	0.60	2.79	7.22	11.53	15.00	17.91	20.33	20.40
Average number of pine trees >130cm tall per stocked plot	0.00	0.00	0.00	0.03	1.43	5.37	10.51	13.90
Total coniferous trees per ha >10cm tall	2605	5106	8015	11070	14123	17119	19698	19698
Number of pine trees per ha >10cm tall	2584	5064	7950	10979	14007	16978	19536	19536
Number of pine trees per ha >=30cm tall	307	1842	5571	9799	13514	16736	19415	19476
Number of pine trees per ha >=130cm tall	0	0	0	29	1285	5019	10033	13275
Average pine ground-line diameter (cm)	0.42	0.82	1.22	1.62	2.03	2.43	2.83	3.24
Modal pine ground-line diameter (cm)	0.31	0.55	0.82	1.23	1.47	1.54	2.20	1.94
Average pine stump diameter (cm)	0.52	0.84	1.05	1.30	1.61	1.96	2.32	2.68
Average pine breast-height diameter (cm)	-	-	-	0.85	0.87	0.98	1.16	1.41
Pine ground-line basal area per ha (m^2)	0.04	0.33	1.12	2.71	5.32	9.18	14.28	18.62
Pine breast-height basal area per ha (m^2)	0.00	0.00	0.00	0.04	1.37	5.32	11.34	16.87

Figure 3. Example of graphical output - height

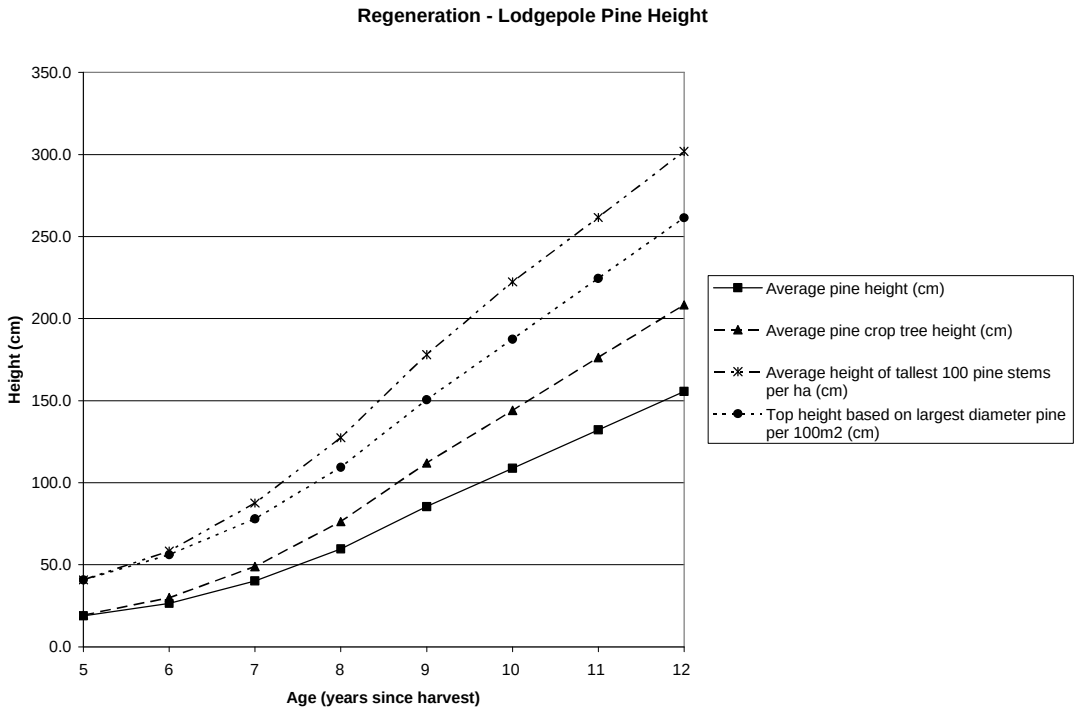

Figure 4. Examples of graphical output – stocking and density