FUTURE FORESTS RESEARCH

PO Box 1127
Rotorua 3040
Ph: + 64 7 921 1883
Fax: + 64 7 921 1020
Email: info@ffr.co.nz
Web: www.ffr.co.nz

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Recommendations to Calibrate Branch Size, Sweep and Forking with FFR Forecaster

Authors:
J Snook

Research Provider:
Scion

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BACKGROUND

For some time now, FFR members have raised concerns about the under-prediction of low quality log grades using the models available in FFR Forecaster (in particular, the under-prediction of larger branch sizes). In addition, Forecaster contains generic models for stem forking and sweep, though aside from one study, there has never been any effort to educate users on how these models should be parameterised. In order to improve user confidence in the models, FFR conducted a calibration study to try to make branch size, sweep and forking predictions within Forecaster align more closely with industry expectations (i.e. based on actual pre-harvest inventory data). The results of this study provide guidance to users around how to better parameterise these models within Forecaster to produce more realistic log grade distributions.

Inputs to Forking Model

1. Probability of stem forking – this is a value between zero and one that indicates the likelihood that a stem will be forked;
2. Probabilities of numbers of leaders – if a stem is forked, this defines the probabilities of the fork producing 2,3,4… leaders (a list of comma-separated values which must sum to 1);
3. Mean of the fork height, expressed as percentage of the interval between pruned height (or breast-height on an unpruned stem) and twice breast-height below the total tree height.
4. Coefficient of variation of the fork height, expressed as percentage of the interval between pruned height (or breast-height on an unpruned stem) and twice breast- height below the total tree height.

A 2007 study by Hamish Marshall[1] found the latter two parameters to be most critical to predicted stand value.

Inputs to Sweep Model

1. Region Count Probabilities – the probabilities of the stem having 0,1,2,3,… sweep-regions (a list of comma-separated values which must sum to 1);
2. Mean length of sweep-regions;
3. Standard deviation of length of sweep-regions;
4. Region Type Probabilities – the probabilities for each of the five different types of sweep (5 comma-separated numbers summing to 1), i.e. specifies the likelihood of any region being of type normal, bend, hockey stick, leader replacement, or wobble;
5. Mean deviation of sweep-regions (as a proportion of the sweep-regions' SED);
6. Standard deviation of the deviation (from straight-line) of sweep-regions (as a proportion of the regions' SED).

Marshall[1] found the sweep parameters 1-3 to be most critical to predicted stand value.

Inputs to BLOSSIM Branching Model

In the development of BLOSSIM (and other branching/BIX models), stems which contained large and/or malformed branches were deliberately excluded from the collected data, so that the models represent branched trees without any occurrence of malformation. However this then causes these models to under-predict branch size relative to a population of trees comprised of both normal-branching and large-branching. To correct this bias, the following two properties were added to BLOSSIM (now updated to version 4.1) in Forecaster[2]:

1. Large Branch Probability. This a value between zero and one that indicates the likelihood that a cluster will include large branches, e.g. > 7 cm.

2. Large Branch Scale Factor. A value greater than or equal to one. The normal cluster potential that BLOSSIM derives is scaled by this factor, if the cluster is selected as “large-branched”

METHODS

Inventory assessment data covering a range of regions throughout New Zealand was provided by several forest management companies (who have chosen to remain anonymous to ensure that their data cannot be identified). This was in the form of:

1. Raw Plotsafe (fi2) files collected using the RAD05, RAD06 or equivalent cruising domains; and
2. YTGen (ytf) files derived from the Plotsafe files.

To enable the analysis of a very large number of inventory files while minimising data handling and analysis costs, the fi2 files were loaded onto the inventory servers managed by Interpine Forestry Ltd, an automated process which loads the inventory data into a SQL database. Interpine technician, Jonathan Dash, then interrogated the data using SQL queries to provide the required summary information. Because raw fi2 files only contain stem heights for a sample of stems, an automated process derived all missing heights for each inventory by applying a Petterson function.

After data screening, the following information was analysed for radiata pine and Douglas-fir in order to parameterise the sweep, forking and branching models within FFR Forecaster:

	Radiata Pine			Douglas-fir		
Region	Populations	Plots	Trees	Populations	Plots	Trees
Northland	525	8,823	364,691	1*	18	1,624
Waikato	131	1,430	55,842	3*	16	561
BOP	229	3,380	183,585	5*	64	3,760
CNI	2,483	38,351	2,595,391	567	9,396	533,999
Hawkes Bay	133	1,801	65,205	3*	8	274
Nelson	94	1,552	43,407	6*	89	3,290
SNI	22	437	18,821	0	0	0
Canterbury	264	2,523	72,442	36	400	9,627
Southland	252	3,471	311,304	26	509	60,142
Grand Total	**4,133**	**61,768**	**3,710,688**	**647**	**10,500**	**613,277**

Table 1 – summary of inventory data analysed by region and species (* ignored – too few inventory populations)

Summarised Information

For each species, and each region, the following variables were calculated:

- Frequency of forked stems (% of stems with at least one fork described).
- Probabilities of numbers of leaders (note that because Forecaster only models a single level of forking, only the lowest fork on a stem was considered).
- Mean and coefficient of variation of fork height, as a percentage of the interval between breast-height and total tree height (either measured or derived using a Petterson function) minus twice breast-height. Note that because Forecaster only models a single level of forking, only the lowest fork on a stem was considered.
- Sweep-Region Count Probabilities.
- Mean and standard deviation of length of sweep-regions.
- Region Type Probabilities – these were derived from a mixture of the inventory sweep domain

information, and specific malformation "features" described within the inventory (e.g. wobble in RAD05/06 = wobble in Forecaster, kink in RAD05/06 is equivalent to leader replacements and hockey sticks in Forecaster).

- Mean and standard deviation of the deviation of sweep-regions – this was derived from the lengths of sweep-regions and sweep severity classes (already aligned with sweep-region SED) within the inventory data.
- Large Branch Probability – this was derived from the frequency (weighted by the length of the branching region) of branch size classes larger than 7 cm, because:
    - A. BLOSSIM currently barely predicts any branches larger than about 7 cm; and
    - B. 7 cm is a common boundary threshold for branch size reflected in both domestic sawlog specifications and inventory assessments.
- Large Branch Scale Factor – derived from the average branch size (weighted by the length of the branching region) of branch size classes larger than 7 cm.

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Results

Results

Model	Input Variable	Previous Default Value	Radiata Pine Recommended Value	Douglas-fir Recommended Value
Forking	Probability of stem forking	0.05	0.11	0.07
	Probabilities of numbers of leaders	0.8,0.2	0.9,0.1*	0.9,0.1*
	Mean of the fork height	50	41	38
	Coefficient of variation of the fork height	1	48	46
Sweep	Region Count Probabilities	0.4,0.1,0.3,0.2	0.77,0.13,0.07,0.02,0.01	0.77,0.14,0.06,0.02,0.01
	Mean length of sweep-regions	4	6.4	5.7
	Standard deviation of length of sweep-regions	2	2†	2†
	Region Type Probabilities	0.3,0.1,0.2,0.3,0.1	0.75,0,0.05,0.05,0.15	0.72,0,0.05,0.05,0.18
	Mean deviation of sweep-regions	0.5	0.5†	0.5†
	Standard deviation of deviation of sweep-regions	0.4	0.4†	0.4†
BLOSSIM	Large Branch Probability	0	0.27	0.23‡
	Large Branch Scale Factor	1	2.8	3.0‡

Table 2 - Recommended values (national averages) for input variables for FFR Forecaster's sweep, forking and branching models.

* This could not easily be extracted from the database. The recommended values were provided as an estimate by staff of Interpine Forestry Ltd.

† Time did not allow for these to be adequately determined. The previous default value has been retained for each input variable.

‡ Note that BLOSSIM is a radiata pine branching model, and should be used as indicative only for other species.

Model	Input Variable	Previous Default Value	Radiata pine Recommended values									D-fir Recommended values		
			North land	Waikato	BOP	CNI	Hawkes Bay	SNI	Nelson	Canter-bury	South land	CNI	Canter-bury	South land
Forking	Probability of stem forking	0.05	0.16	0.09	0.13	0.09	0.11	0.05	0.14	0.15	0.16	0.07	0.08	0.09
	Probability of fork having 2 leaders	0.8	-	-	-	-	-	-	-	-	-	-	-	-
	Probability of fork having 3 leaders	0.2	-	-	-	-	-	-	-	-	-	-	-	-
	Mean of the fork height	50	50	49	47	39	37	48	40	41	35	38	39	39
	Coefficient of variation of the fork height	1	38	35	45	51	52	38	49	46	51	47	31	47
Sweep	Probability of stem having 0 sweep-regions	0.4	0.72	0.68	0.75	0.82	0.74	0.83	0.52	0.62	0.76	0.81	0.56	0.84
	Probability of stem having 1 sweep region	0.1	0.15	0.17	0.13	0.11	0.16	0.12	0.20	0.19	0.1	0.13	0.23	0.05
	Probability of stem having 2 sweep-regions	0.3	0.09	0.1	0.08	0.05	0.07	0.04	0.17	0.12	0.08	0.05	0.14	0.07
	Probability of stem having 3 sweep-regions	0.2	0.03	0.04	0.03	0.02	0.02	0.01	0.08	0.05	0.04	0.01	0.05	0.02
	Probability of stem having 4 sweep-regions	0	0.01	0.01	0.01	0	0.01	0	0.03	0.02	0.02	0	0.02	0.02
	Mean length of sweep-regions	4	6.1	7.6	6.9	6.4	8.4	6.2	7.4	6.9	4.2			
	Standard deviation of length of sweep-regions	2	-	-	-	-	-	-	-	-	-	-	-	-
	Probability of region type being 'normal'	0.3	0.9	0.84	0.86	0.66	0.76	0.79	1	1	0.69	0.71	1.00	0.70
	Probability of region type being 'bend'	0.1	0	0	0	0	0	0	0	0	0	0	0	0
	Probability of region type being 'hockey stick'	0.2	0.04	0.06	0.06	0.06	0.05	0.08	0	0	0.07			
	Probability of region type being 'leader replacement'	0.3	0.04	0.06	0.06	0.06	0.05	0.08	0	0	0.07			
	Probability of region type being 'wobble'	0.1	0.02	0.04	0.02	0.22	0.14	0.05	0	0	0.17			
	Mean deviation of sweep-regions	0.5	-	-	-	-	-	-	-	-	-	-	-	-
	Standard deviation of deviation of sweep-regions	0.4	-	-	-	-	-	-	-	-	-	-	-	-
BLOSSIM	Large Branch Probability	0	0.27	0.24	0.22	0.28	0.28	0.36	0.39	0.23	0.22			
	Large Branch Scale Factor	1	3.1	3.3	3.4	2.5	3.7	3.0	2.5	2.8	3.6			

Table 3 - Recommended values (regional averages) for input variables for FFR Forecaster's sweep, forking and branching models.

Limitations, Conclusions and Potential Future Studies:

- While branching information is collected in inventory data in terms of maximum branch size classes over stem lengths, Forecaster's branch models predict the size of each modelled branch. Thus the data available is not entirely consistent with Forecaster's needs – however, the results may provide valuable insight, particularly if log grade out-turn results from Forecaster are compared to that from inventory analysis software such as YTGen.
- The BLOSSIM parameters investigated are also not directly comparable with branch measurements for inventory, because BLOSSIM predicts the maximum branch size possible for each cluster, and then scales this based on stocking and stem dominance. Thus, using the recommended large branch scale factor of 2.8 (for radiata pine) will cause each modelled "large branch" to become 2.8 times larger, but the absolute value of the branch's size will subsequently also be adjusted for the stem's dominance and the stocking of the whole stand.
- Stocking has not been included in these calibrations, although it is known to influence branch size. However, BLOSSIM internally adjusts branch size for stocking, so it may not necessarily be necessary to calibrate. A future study could examine the parameterisation of BLOSSIM across the range of stockings likely to be found in stands being harvested.
- While the widespread uptake of the RAD05/RAD06 cruising domains provides a great deal of standardisation in this data, differences in cruising policies/standards between different inventory companies and crews operating throughout the country were ignored – however this is likely to introduce differences in the resulting data summaries. A future study could focus on examining these differences – there is certainly enough data to support this.
- Analysis of inventory data is not without its pitfalls – however it should be noted that this dataset represents an enormous wealth of information which is routinely being collected across the New Zealand forest-growing environment. Handling such large volumes of data presents its own set of computational problems, but such analysis is heavy on machine time and light on personnel time, representing good value for money.

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NEXT STEPS:

In order to better validate the recommended parameter values for branching, forking and sweep, it would be pertinent to directly compare log grade output from Forecaster with that from YTGen for a sample of pre-harvest inventories across different regions. This could be achieved relatively easily by:

1) Creating a Forecaster-compatible stemlist from the YTGen population (ytf) file (an automated method has been developed by Scion to handle this conversion);

2) Generating a yield table within Forecaster using this stemlist by simulating a clearfell event immediately following the measurement event, and using a cutting strategy which reflects the major value boundary thresholds for common New Zealand log grades;

3) Generating a yield table within YTGen using the inventory population and an equivalent cutting strategy.

Results from such a reconciliation would determine whether any changes need to be made to the recommended Forecaster parameter values. If the cutting strategy is designed to isolate the effects of forking, sweep, and branching, then it will be possible to independently validate the models for each of these properties. It is suggested that this exercise be undertaken jointly by Scion and each of the various industry data contributors.

Additional work could also recommend sets of default property values which represent “low”, “medium” and “high” incidence of large branching, forking, and sweep.

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