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

Theme: Radiata Management

Task No: F10102 **Report No. FFR- R035**
Milestone Number: 1.02.08

Procedures to allow for incomplete Stand Histories when running the 300 Index Growth Model

Author:
M Kimberley

Research Provider:
Scion

Date: January 2011

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The 300 Index radiata pine growth model requires as input either a stand measurement (consisting of age, stocking, height and basal area), or site productivity indices. In addition, the current form of the model requires information detailing significant aspects of the stand history prior to the measurement. The required historical information includes the initial stocking, the age and stocking at each thinning, and the age, height and number of stems of each pruning lift. Without this information, the model will not run correctly, restricting its utility in circumstances when stand history information is unavailable or incomplete.

This report describes a module that has been developed to allow the 300 Index Model to be used when stand history information is incomplete. The module is currently implemented in an experimental VBA version of the model, and will be made available for inclusion in FORECASTER or other implementations of the model. The module acts as a data pre-processor of the stocking/thinning/pruning history data that is provided by the user when running the model. It fills in missing elements in the history required by the model, and these are passed on to the growth model. This allows the user to provide varying levels of information, ranging from a complete history if this is available, to virtually no information. The module uses two calculation procedures combined with simple “expert knowledge” rules based on typical radiata pine regimes to achieve these results.

The calculation procedures are as follows. Firstly, a method of running the 300 Index Model backward in time using the bisection method has been implemented. This technique is used to predict earlier stockings from a specified stocking at a later age. It is used, for example, to estimate the stocking at establishment or following a thinning from a later stocking measurement. Secondly, a procedure for predicting age at a specified height using the height-age model has been implemented. This enables the timings of thinning operations and pruning lifts to be predicted when they are not specified.

The expert knowledge rules used in the procedure are briefly as follows. Firstly, when the age of thinning is not specified, it is assumed to occur at a mean top height of 12 m. Secondly, when the stocking before thinning is not specified, the thinning ratio is predicted using a simple formula. For example, if the stocking following thinning is 350 stems/ha, the module predicts that the initial stocking is 850 stems/ha. Thirdly, when prune heights of a lift are not specified, they are provided from a table of standard prune heights. Finally, when the timing of pruning lifts is not specified, they are predicted using the height-age function assuming a crown length of 4.5 m at each lift.

The module described in this report should improve the utility of the 300 Index growth model in situations where stand history information is not available to the user.

INTRODUCTION

Most forest growth models require as input some information about the stand they are attempting to model. Typically they require a stand measurement (e.g., of age, stocking, height and basal area), possibly some information about the site (e.g., the 300 Index Model[(1)] performs better if it is supplied with latitude and altitude of the stand), and information on silvicultural operations (e.g., thinnings) subsequent to the measurement age.

Similar input information is required by the 300 Index Model, although users can supply site productivity indices as an alternative to the stand measurement. However, the 300 Index Model is more demanding than most models. In addition to the above inputs, it requires information detailing significant aspects of the stand history prior to the measurement. This historical information includes the initial stocking, the age and stocking at each thinning, and the age, height and number of stems of each pruning lift. Without this information, the model will not run correctly.

METHODS

Because stand history information is not always readily available, a module has recently been developed to improve the utility of the model in situations where history information is incomplete. This History Module is currently implemented in an experimental VBA version of the model, and is not currently available in FORECASTER although it is intended to include it in a future version. The module acts as a data pre-processor, taking the history data as input into the user interface, and filling in missing elements in the history before passing the history to the growth model. The growth model itself has not been altered.

RESULTS

Stocking and Thinning History

Information on the stocking and thinning history is currently entered in chronological order into a stocking history table in the user interface of the model. In a complete table, the first row contains stocking at planting and there is one row for each thinning. There can also be one or more intermediate stocking-only measurements specified in the table. A simple example of a complete stocking history is given in Table 1. The first column in the table indicates the type of information in the row, and must be either ‘E’ for Establishment (used for the first row), ‘M’ for Measurement (used for the stand measurement or stocking-only measurements), or ‘T’ for Thinning. The second column in the table specifies the age. The columns headed N1 and N2 contain stocking in stems/ha. For ‘T’ rows, N1 is the pre-thin and N2 post-thin stocking. For ‘M’ and ‘E’ rows, only N1 is entered. Note that in Table 1, the measurement age is 15 years, and the stocking at this age is therefore entered into the table as an ‘M’ row.

Table 1. Example of a complete stocking history.

Type	Age (yrs)	N1 (sph)	N2 (sph)	Thinning ratio
E	0	850		
T	7	800	400	
M	15	370		

The stocking information in the table can be considered to consist of a series of intervals, each beginning either at planting or at a thinning event, and ending at either a thinning or at harvesting. In Table 1, there are two such intervals, the first from age 0-7, and the second from age 7-15 and beyond. In previous versions of the 300 Index Model, the user had to specify the stocking at the beginning of each interval. Thus, in the above example, the stockings at age 0 and 7 (after thinning) were required. The previous version did not require stocking prior to the age 7 thinning, as this could be predicted from the initial stocking using the mortality function by running the model forward from age zero.

The new History Module requires only one specified stocking within any interval. Thus, in the above example, the user would need to specify one stocking between ages 0-7 and another between ages 7-15. The first could be provided either by an initial stocking or the stocking prior to thinning, or by an intermediate measurement at say 2 years. The second is adequately provided by the age 15 measurement. Tables 2 and 3 show two valid examples of stocking histories that fulfil the requirements of the new module.

Table 2. First example of a valid incomplete stocking history.

Type	Age (yrs)	N1 (sph)	N2 (sph)	Thinning ratio
E	0	850		
T	7			
M	15	370		

Table 3. Second example of a valid incomplete stocking history.

Type	Age (yrs)	N1 (sph)	N2 (sph)	Thinning ratio
E	0			
T	7	800		
M	15	370		

How does the new module estimate the missing stocking information? Basically, unlike earlier versions of the model which could only predict stocking forward through time, the new module can run the model either backward or forward. This enables it to predict an earlier stocking from a later supplied value. For example, in Table 2, the model is run forward in time from the establishment stocking to predict N1 at age 7 years. However, to predict N2 at age 7, the model is run backward from the age 15 stocking measurement. Similarly, in Table 3, the model is run backward using the age 7 stocking measurement to predict N1 at age 0, while the model is run backward from the age 15 stocking to predict N2 at age 7.

Because the 300 Index Model is complex and consists of several sub-models (e.g., height and basal area growth models, mortality functions, etc.), it is not possible to run it backward simply by rearranging the underlying equations. Instead, the model is run backward using a numerical technique called the Bisection Method. Essentially, this method repeatedly bisects an interval in which the true solution is known to lie until it finds the solution to a specified level of accuracy. As an example, suppose the stocking is known to be 300 stem/ha at age 20 and it is required to predict the stocking at age 10. It is known that the correct solution must greater than 300 and less than, say 600 stems/ha. To apply the bisection method, the model is run forward from age 10 years using these two stockings and their midpoint (450 stems/ha) as starting values. The predicted stocking at age 20 years is obtained for these three runs. The two starting values that produce predicted age 20 stocking most closely straddling the correct value (300 stems/ha) are then chosen. These must be the midpoint and either the lower or upper value. The remaining starting value is discarded. The procedure is then repeated using these two values and their midpoint. The method is simple to apply and robust, and certain to converge to the correct solution with a given level of precision using a fixed number of iterations.

The History Module also provides a new method for entering thinning stocking information. The user can enter the thinning ratio (the post-thin to pre-thin stocking ratio, N2/N1) into column 5 of any ‘T’ row in the table. When this is done, the two intervals separated by the thinning are linked, and only one stocking is required to be specified anywhere within the linked interval. Thus, the history in our example could be entered using this method as shown in Table 4.

Table 4. Third example of a valid incomplete stocking history.

Type	Age (yrs)	N1 (sph)	N2 (sph)	Thinning ratio
E	0			
T	7			0.5
M	15	370		

There is a further function available in the module which allows for situations where there is almost no stocking history information available. When the user is fairly confident that the stand has been thinned at some time, they can enter a ‘T’ line to indicate this, but supply no further thinning stocking information. In this situation, the module uses a function to predict a reasonable thinning ratio based on the stocking immediately following the thinning. Thus, if the minimal information shown in Table 5 is supplied, the History Module will provide the growth model with a stocking history typical of stands receiving a single thinning in New Zealand. The predicted thinning ratio is obtained using the equation: Thinning ratio = $0.00311*N2^{0.833}$. This equation may be regarded as a simple “expert knowledge” system. It predicts a thinning ratio that increases with stocking so that high values of N2 do not produce extreme values of N1. For example, when N2=350 stems/ha, N1 is predicted to be 850 stems/ha. However, for N2=700 stems/ha, N1 is predicted to be 960 stems/ha. Note that in the example shown in Table 5, the value of N2 at age 7 years would be predicted by running the model backward in time from the age 15 measurement.

Table 5. Fourth example of a valid incomplete stocking history.

Type	Age (yrs)	N1 (sph)	N2 (sph)	Thinning ratio
E	0			
T	7			
M	15	370		

Note also that this thinning ratio prediction function operates only on the first thinning in the stocking table. If there are two thinnings forming three stocking intervals in the table, the user has to specify at least one stocking in each of the 2nd and 3rd intervals but not in the first (e.g., Table 6). Alternatively, if for example the 2nd and 3rd intervals are linked by a thinning ratio, only the measurement stocking would be required (Table 7). Finally, if it is believed that the stand has never been thinned, only the measurement line is required (e.g., Table 8), as the module can derive an estimate of the initial stocking by running the model backwards.

Table 6. Example of a valid incomplete stocking history with two thinnings.

Type	Age (yrs)	N1 (sph)	N2 (sph)	Thinning ratio
E	0			
T	7		600	
T	14			
M	15	250		

Table 7. Second example of a valid incomplete stocking history with two thinnings.

Type	Age (yrs)	N1 (sph)	N2 (sph)	Thinning ratio
E	0			
T	7			
T	14			0.6
M	15	250		

Table 8. Example of a valid incomplete stocking history of an unthinned stand.

Type	Age (yrs)	N1 (sph)	N2 (sph)	Thinning ratio
E	0			
M	15	550		

So far we have considered only how the History Module fills in missing stocking values. However, perhaps just as commonly, there may be uncertainty about the timing of a thinning. To assist the user in this situation, the History Module can predict the thinning age for single-thinning histories. To utilise this function, the user should leave the "Age" column of the single "T" row in the stocking table blank, and the History Module will determine a thinning age typical of New Zealand regimes. Currently the module uses the age when the MTH is 12 m as the estimated thinning age. This age is calculated using the height-age function in the growth model. This can be regarded as a simple "expert knowledge" system, and is based on typical timing of thinning in New Zealand radiata pine stands. Table 9 shows how such a very minimal level of information can be supplied to the model. Note that in stocking histories with two or more thinnings, the user has to specify the age of each thinning.

Table 9. Example of a valid but minimal stocking history.

Type	Age (yrs)	N1 (sph)	N2 (sph)	Thinning ratio
E	0			
T				
M	15	370		

Pruning History

Pruning history information is entered into the prune history table. This contains one line for each pruning lift, and in a complete table the age, mean pruned height, and pruned-tree stocking are specified for each lift. In earlier versions of the 300 Growth Model, complete pruning history information was required (e.g., Table 10).

Table 10. Example of a complete pruning history.

Lift	Age (yrs)	Prune height (m)	Pruned stems (stems/ha)
1	4.5	2.1	400
2	5.5	3.9	375
3	7.0	5.7	325

The History Module has functions for supplying considerable missing information in the prune history table. However it is assumed that a user will at least know whether the stand has been pruned. Also, the mean prune height and pruned-tree stocking achieved in the final lift should be readily available, either from the stand measurement or from stand records. These are therefore still required to be entered into the table. Note that if the pruned stems column is left blank, the model assumes that all stems are pruned. The History Module also currently requires that the user specify the number of pruning lifts applied to the stand. All other information can be generated by simple functions in the module. Table 11 shows an example of a valid but incomplete pruning history that can be processed by the History Module.

Table 11. Example of a valid incomplete pruning history.

Lift	Age (yrs)	Prune height (m)	Pruned stems (stems/ha)
1			
2			
3		5.7	325

To predict missing pruning information, the module proceeds through a series of steps. Firstly, if one or more prune heights are not specified, these are predicted from the following table of standard prune heights: 2.4, 4.6, 6.0, 7.5, and 9.0 m for lifts 1, 2, 3, 4, and 5 respectively. The prune heights are then adjusted if necessary so that they are equal to or less than any specified prune height in a subsequent lift, and greater than any specified preceding lift. Secondly, the module estimates the pruned-tree stocking for each lift as being 5% higher than each succeeding lift, subject to being less than the total stocking of the stand. Finally, if the user is unsure about the timing of one or more pruning lifts, they can leave the “Age” column in the table blank. In this case, the module determines pruning age by using the height-age model to estimate when the mean green crown length following pruning is exactly 4.5 m for each lift. It then checks that this age falls between any specified previous and subsequent lift ages and adjusts it if necessary.

CONCLUSION

A module that has been developed which allows the 300 Index Model to be used when stand history information is incomplete. The module is currently implemented in an experimental VBA version of the model and will be made available for inclusion in FORECASTER or other implementations of the model. The module acts as a data pre-processor of the stocking/thinning/pruning history data that is provided by the user when running the model. It fills in missing elements in the history required by the model, and these are passed on to the growth model. This allows the user to provide varying levels of information ranging from a complete history if this is available, to virtually no information. The module uses two calculation procedures combined with simple “expert knowledge” rules based on typical radiata pine regimes to achieve these results.

The calculation procedures are as follows. Firstly, a method of running the 300 Index Model backward in time using the bisection method has been implemented. This technique is used to predict earlier stockings from a specified stocking at a later age. It is used, for example, to estimate the stocking at establishment or following a thinning from a later stocking measurement. Secondly, a procedure for predicting age at a specified height using the height-age model has been implemented. This enables the timings of thinning operations and pruning lifts to be predicted when they are not specified.

The expert knowledge rules used in the procedure are briefly as follows. Firstly, when the age of thinning is not specified, it is assumed to occur at a mean top height of 12 m. Secondly, when the stocking before thinning is not specified, the thinning ratio is predicted using a simple formula. For example, if the stocking following thinning is 350 stems/ha, the module predicts that the initial stocking is 850 stems/ha. Thirdly, when prune heights of a lift are not specified, they are provided from a table of standard prune heights. Finally, when the timings of pruning lifts are not specified, they are predicted using the height-age function, assuming a crown length of 4.5 m at each lift.

REFERENCES

1. Kimberley, M. O., West, G.G., Dean, M. G., R. Knowles, R. L. 2005. The 300 Index - a volume productivity index for radiata pine. New Zealand. Journal of Forestry 50: 13-18.