COMMERCIAL IN CONFIDENCE
Client Report No. XXXX

DEVELOPMENT OF A NATIONAL HEIGHT MODEL FOR SCOTCH BROOM - PRELIMINARY RESULTS AND RECOMMENDATIONS FOR FURTHER RESEARCH

Authors: Karina Potter, Mike Watt, Michelle Watson, Agathe Leriche-Guichard and Brian Richardson

Date: 3 April 2007
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THE JOINT FORCES OF CSIRO & SCION

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EXECUTIVE SUMMARY

Objective
The objective of this study was to augment the existing data set of Scotch broom height growth used to model the competition intensity between Scotch broom and plantation trees in the VMAN model. Additional measurements of broom height and age were required from a range of additional sites varying in soil type, climate and altitude.

Key Results
Broom height age data were collected from the stand edge and within the forest stand from three forest estates: Kaingaroa (Central North Island), Pan Pac (surrounds of Napier) and Weyerhauser (near Nelson). Age had by far the greatest influence on Scotch broom height for plots in both stand positions. The Schumacher sigmoidal equation accurately modelled changes in height with age. Although Scotch broom height appeared to be very insensitive to environment, this may be partially attributable to the relatively narrow climatic range covered by the sampling to date.

Application of Results
The additional measurements of broom height and age at a range of locations are valuable in the development of a national height model for Scotch broom. This information will improve the predictive ability of the VMAN model for different New Zealand locations.

Further Work
In view of the relatively narrow climatic range covered by the sampling to date, it is recommended that further sampling should focus on identifying sites with environmental extremes which have not been previously covered. Potential candidate areas would include dryland sites (Canterbury) and areas representing extremes in solar radiation and temperature such as Southland and areas north of CNI.

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Table of Contents

Information for Ensis abstracting:

Contract number	
Report ID number	
Weed species worked on	Scotch broom (*Cytisus scoparius*)
Key words	Height, age, Scotch broom, VMAN, competition, environment

INTRODUCTION

In the late 1990s a crude model of Scotch broom (and other weeds) height growth (Figure 1) was developed based on measurements at a small number of sites in Southland, Canterbury, and Bay of Plenty. This information is important for modelling the competition intensity between Scotch broom and plantation trees and is crucial for applying the VMAN model.

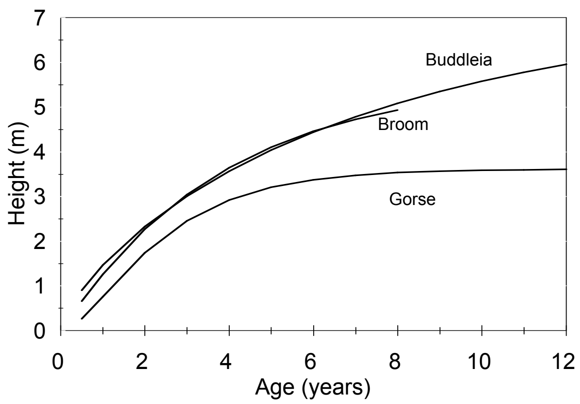


Figure 1: Predicted height growth curves for Scotch broom, buddleia, and gorse.

Element 2 of the New Zealand Site Management Cooperative project “A case study of Scotch broom management in forestry” proposed to augment the existing data with measurements of Scotch broom height growth from a range of additional sites. Ideally, sites were to vary in soil type, climate and altitude. The number and location of sites to be assessed depended on the ability and willingness of forestry companies to contribute data (collected according to Ensis protocols) through in-kind support.

MATERIALS AND METHODS

Site selection

Three companies were involved in data collection for this report; Kaingaroa Timberlands located in the Central North Island, Pan Pac in the Napier region and Weyerhauser in the Nelson region. While other companies did offer their assistance, analytical problems with selecting stands using the estate maps provided, limited field assistance and high travel costs required for protocol training limited the number of companies involved at this stage of the project.

Site selection for each company was tailored according to the presentation style of forest estate maps (GIS layers or paper maps), the range of stand ages and staff availability for field work. Kaingaroa and Weyerhauser provided maps of plantations in a GIS format while Pan Pac provided 1:25,000 NZMG printed maps showing forest, block, stand, species and year of planting.

Appendix A, Figure 7 provides an example of the site selection protocol when supplied with digital data in the form of GIS layers. Each stand/polygon was grouped into 4 age classes, delineated as 0-3 years (2005-2002), 4-7 years (2001-1998), 8-11 years (1997-1994) and "other". This dataset was then stratified using Land Environment New Zealand (LENZ3). LENZ is a nationally consistent classification of New Zealand environments with mapping based on climate, landform and soil attributes. At this point, the data were examined and it was found that there were too many combinations of LENZ and age class within the one forest to sample representatives of all combinations. In order to reduce this, a calculation of the total surface area in each LENZ/age class combination was made and combinations for which the sum was less than <500ha were excluded from the site selection process. The sum of the remaining LENZ/age class combinations were divided by 500ha to provide the number of polygons to be sampled from each combination (up to 5). Due to the high number of LENZ/age class combinations, only 2 of the maximum 5 polygons were actually sampled. Priority was given to polygons that contained whole stands and those in different regions of the forest estate. A total of 21 sites were sampled from the Kaingaroa estate and 33 sites from the Weyerhauser estate.

In the case of the Pan Pac maps, stands within each forest (Gwavas, Kaweka Forest, Tangoio Forest, Esk, Mohaka) were allocated an age class: 0-3 years (2005-2002), 4-7 years (2001-1998), 8-11 years (1997-1994) and "other". A transparent numbered grid was then laid over each map and a random numbers table was used to select a total of 25 stands across the range of forests and age classes for sampling. If a neighboring stand to a selected stand was chosen, this selection was ignored and the next random number was utilized.

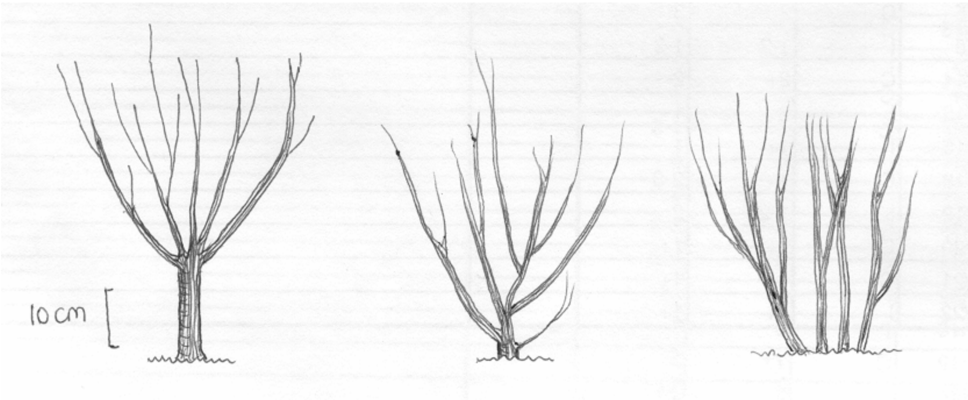
Sample collection

Each selected stand was visited and data recorded on a separate score sheet. For each stand, the boundary was driven and the presence or absence of Scotch broom recorded. In this study only Scotch broom was sampled. If only Montpellier (French) broom (*Genista monspessullana*) or Spanish broom (*Spartium junceum*) were found when driving around the stand boundary Scotch broom was recorded as absent. The presence of the other broom species was noted on the score sheet.

Scotch broom was sampled from two different locations at each stand visited; a) the stand edge and b) inside the stand. Edge plants were defined as those plants on the roadside or under the first row of trees, relatively unshaded from the plantation trees. Within stand plants were at least four rows into the plantation and exposed to the shading environment within the stand. Three growth forms of Scotch broom were commonly observed in the forest. The different forms were identified by examining the plant stem between 0 and 10cm above ground level. The three forms were: a) single stemmed, b) multi-stemmed above ground and c) multi-stemmed below ground (Figure 8). Sampling protocols differed slightly depending on the different plant forms.

A GPS coordinate was taken at each stand. If Scotch broom was present, the tallest plants on the stand edge, or below the first row of trees, were sampled. Five of the tallest Scotch broom plants, in one area, that had a single stem between 0 and 10cm above ground level were chosen. Where five single stemmed plants were not available, multi-stemmed plants were sampled.

For each of the five edge plants, several seed pods were collected, if present, otherwise a 30 centimetre sample of young growth was cut and put in a labelled clip-lock bag. This sample was used to confirm the identity of the broom species sampled. The maximum height of the plant was measured with a height pole and recorded on the score sheet. The plant was then cut off at about 10cm above ground level and a stem section 5-10cm long was cut with a chainsaw or pruning saw from the stump. A metal tag, labelled with location and plant details, was securely attached to each section. For plants with multiple stems below 10cm, stem sections of all major stems were taken at the same height (ground to 5 -10cm) and the branching type noted (ie. multi-stemmed *above* ground or multi-stemmed *below* ground). The largest stem section was labelled with a metal tag and all sections bundled together with a rubber band. This process was repeated for a further four plants, allocating them each a number. All sections from the five edge plants were placed in a labelled plastic bag. If there were fewer than five Scotch broom plants in one area, five edge plants and five within-plantation plants were sampled from the entire compartment.



single-stemmed Scotch broom | multi-stemmed *above* ground | multi-stemmed *below* ground

Figure 8. The three commonly encountered growth forms of Scotch broom

From the edge plants sampled, field staff walked into each stand, perpendicular with the road, for approximately 20 m or until they were at least four rows into the plantation. While walking, the tallest Scotch broom within eyesight was found. If no Scotch broom was seen on the way into the stand a 90 degree turn right or left was made and a further 50 m walked (Appendix A, Figure 9). The location of the largest patch of Scotch broom encountered within the stand was recorded using GPS. Five Scotch broom plants were sampled as for the edge plants. If no Scotch broom was found this was recorded on the score sheet. All within-stand Scotch broom samples were placed in a labelled bag. Both the edge plant samples and within stand samples, along with the site score sheet, were placed in a large labelled bag.

Sampling was reliant on each forestry company having time to conduct the work and occurred over a nine month period. The score sheets and Scotch broom samples from each company were sent to Ensis. The diameter of each Scotch broom section was measured. Sections were then dried at 60 °C for at least 62 hours. One surface of each of the sections was sanded to assist in defining the annual growth rings. The number of annual growth rings was counted to estimate the age of each Scotch broom plant.

Analysis

Given the lack of independence between Scotch broom heights measured on the edge and within the stand separate height models were developed for both populations. Development of separate models also enabled key environmental influences on height within and at the stand edge to be separately identified, and allowed a comparison of the relationship between age and height between these two stand positions.

Both the Chapman Richards and the Schumacher sigmoidal equations were used to model height growth. However as the Schumacher fitted the data better in all instances further equation forms are only stated for this sigmoidal type.

Initially the Schumacher equation was used to model Scotch broom height as a function of age using,

$$H = \exp(\mathrm{a} - \frac{\mathrm{b}}{age^{\mathrm{c}}}) \tag{1}$$

where a, b and c are empirically determined parameters. Residuals from this model were then plotted against environmental data. The most significant variable from these plots, denoted, *x*, was initially incorporated into the Schumacher equation using the following form,

$$H = \exp(d + xa - \frac{b}{xage^{c}}) \tag{2}$$

where a, b, c and d are empirically determined parameters. The environmental variable, *x*, was also incorporated into the Schumacher equation using a more complex form given by,

$$H = \exp^{(\mathrm{a} + \mathrm{b}x + \frac{\mathrm{c}x^2}{100000} - \frac{\mathrm{d}}{age^{\mathrm{e}+\mathrm{f}x}})} \tag{3}$$

where a, b, c, d, e and f are empirically determined parameters. Model selection between Equation 2 and 3 was based on predictive power, assessed by the mean square error, and bias of residuals against predicted values and independent variables. Residuals from the final models were also regressed against environmental variables to ensure they were unbiased with respect to other potential predictive variables.

RESULTS AND DISCUSSION

Influence of age on Scotch broom height

Equation 1 fitted the data well, accounting for 70% of the variance in the data, for Scotch broom growing on the stand edge and 74% of the variance in the data for plants growing within the stand (Figure 2). Predictive relationships between age and Scotch broom height were very similar between plants within the stand and at the stand edge (Figure 2). Plots of residual values against predicted values or age exhibited very little apparent bias for either stand position (data not shown).

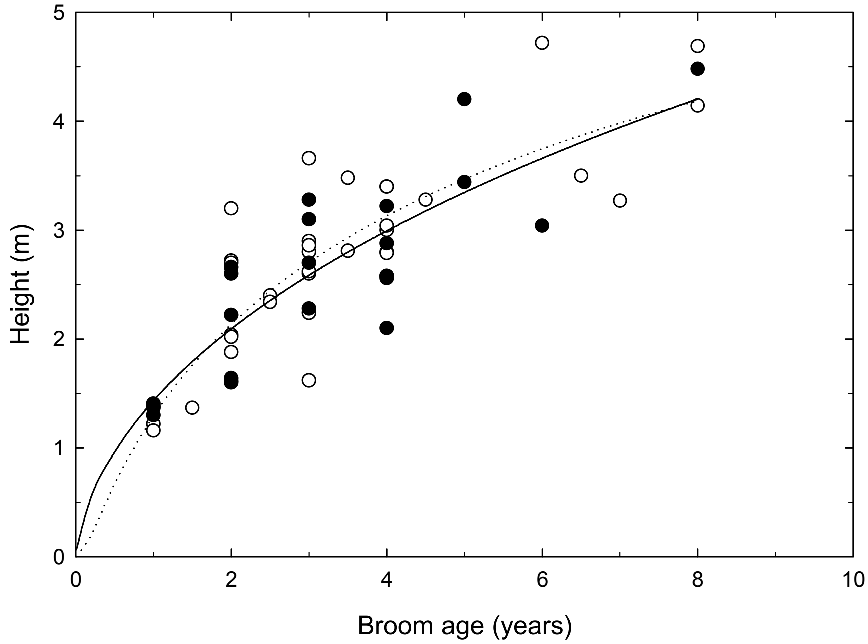


Figure 2. Relationship between Scotch broom age and height for plants growing within (solid circles) and at the edge (open circles) of the stand. Modelled values of height are shown for Scotch broom growing within (dotted line) and at the edge (solid line) of the stand.

Influence of environment on Scotch broom height

For plants growing within the stand residual values obtained from Equation 1 were not significantly related to any of the environmental variables tested. Visual inspection confirmed there was no residual pattern against temperature, rainfall, solar radiation or overstorey stand age. For the model describing height of Scotch broom growing within the stand final parameter values for Equation 1, were 7.69, 7.33, 0.0763 for a, b and c, respectively.

For plants growing on the stand edge, residual values obtained from Equation 1, were significantly related to several long-term average monthly values of solar radiation. Of these variables, residual values were most strongly related to solar radiation during April (r^2 = 0.21; P<0.01). The relationship between residual values and solar radiation during April was positive (Figure 3).

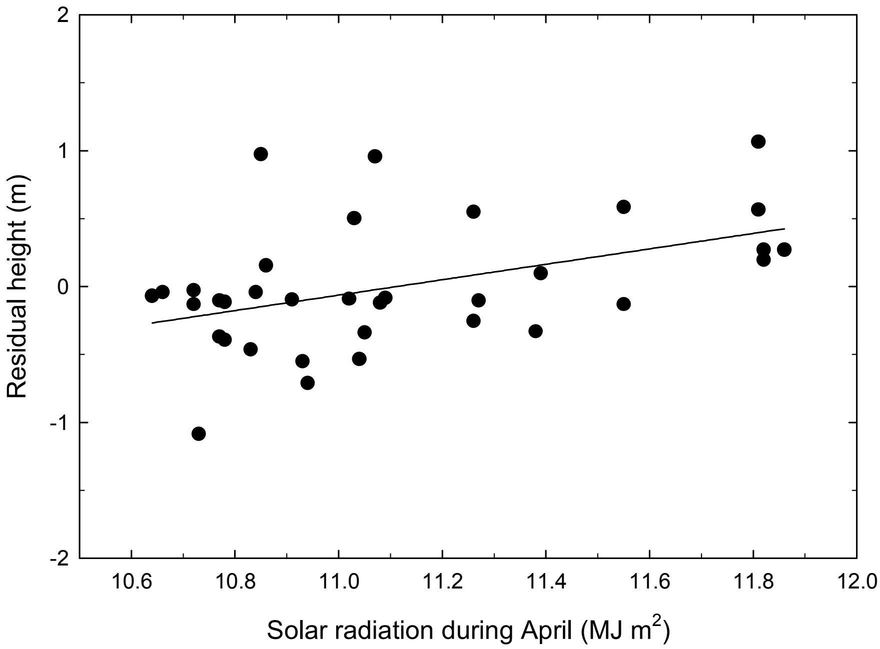


Figure 3. Relationship between solar radiation during April and residual height for plants growing at the stand edge.

Incorporation of solar radiation during April and age into Equation 2 reduced the mean square error from 0.238 to 0.1990. Inclusion of these two variables into Equation 3 further reduced the mean square error to 0.194, and increased the coefficient of determination from 0.70 (using Equation 1) to 0.77. Plots of residual values against predicted values, solar radiation and age exhibited little apparent bias. Residual values from this model were not significantly related to any of the other environmental variables examined (eg. Figures. 4 and 5). The final parameter values for this model were 158.4, -321.9, 16482026, 2.02, 25.41 and 28.64 for a, b, c, d, e, and f respectively.

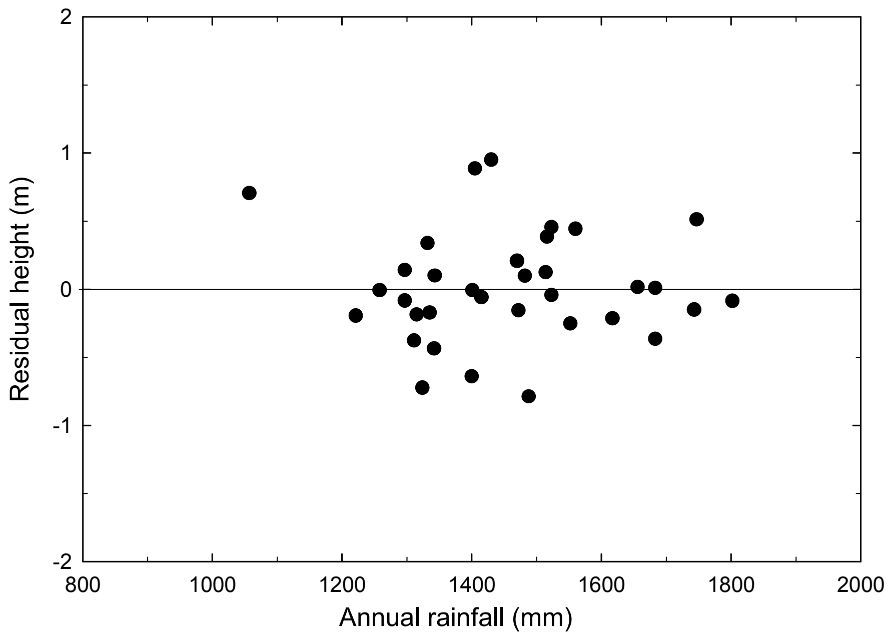


Figure 4. Plot of annual rainfall against residual height for plants growing at the stand edge.

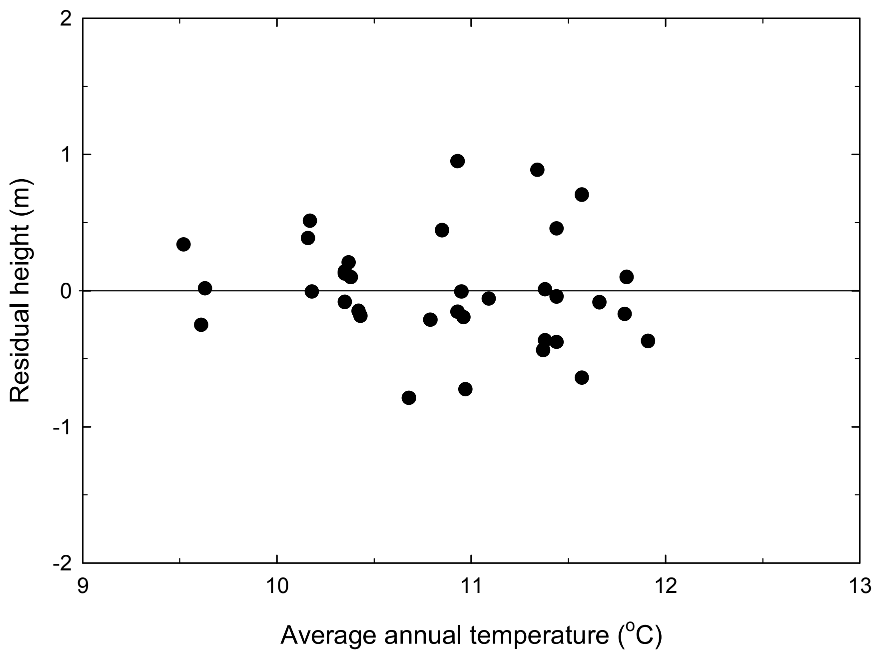


Figure 5. Plot of average annual temperature against residual height for plants growing at the stand edge.

Age had by far the greatest influence on Scotch broom height for plots in both stand positions. The Schumacher sigmoidal equation accurately modelled changes in height with age. The form of this equation was very similar between stand positions. In addition the relationship between age and height for plants within stands corresponded well to a previous relationship found by Kimberley et al. (2003)[1], for Scotch broom plants growing within the Central North Island (Figure 6).

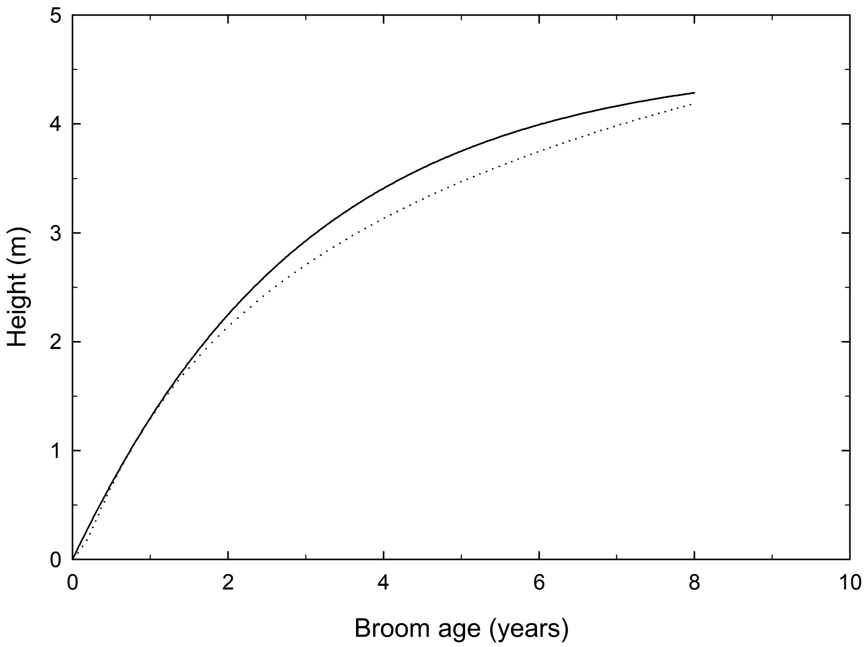


Figure 6. Comparison of Scotch broom height prediction using equations developed in this study (dotted line) and an equation developed by Kimberley et al. (solid line).

Although Scotch broom height appeared to be very insensitive to environment, this may be partially attributable to the relatively narrow climatic range covered by the sampling to date. For instance the range in solar radiation during April (10.6 to 11.9 MJ m^{-2}) is far lower than the New Zealand range, which may reach values as low as 7 MJ m^{-2} in Southland. Similarly dryland sites have not been sampled as the lowest annual rainfall of any site is 1057 mm. The sampled range in annual average temperature of 9.5 to 12˚C is far lower than the national range of 8.6 to 15.3˚C.

[1] Kimberley, M., Richardson, B., Gous, S. (2003) Modelling weed height growth using CHH and Forest Research weed height growth data, Forest Research Internal Report.

RECOMMENDATIONS AND CONCLUSIONS

Age had by far the greatest influence on Scotch broom height for plots in both stand positions. The Schumacher sigmoidal equation accurately modelled changes in height with age. Although Scotch broom height appeared to be very insensitive to environment, this may be partially attributable to the relatively narrow climatic range covered by the sampling to date. Further sampling should focus on identifying sites with environmental extremes which have not been previously covered. Potential candidate areas would include dryland sites (Canterbury) and areas representing extremes in solar radiation and temperature (Southland and areas north of CNI). Ideally stands covering a wide range of ages should be selected within each of these areas.

ACKNOWLEDGEMENTS

The authors would like to thank Nigel Herron, Mark Bryant, Dave Coe and their associated staff for their assistance in the collection of field data. This study was undertaken as part of the project titled “A Case Study of Broom Management in Forestry” funded by the New Zealand Site Management Cooperative and with funding from the Foundation for Research, Science and Technology.

APPENDICES: APPENDIX A

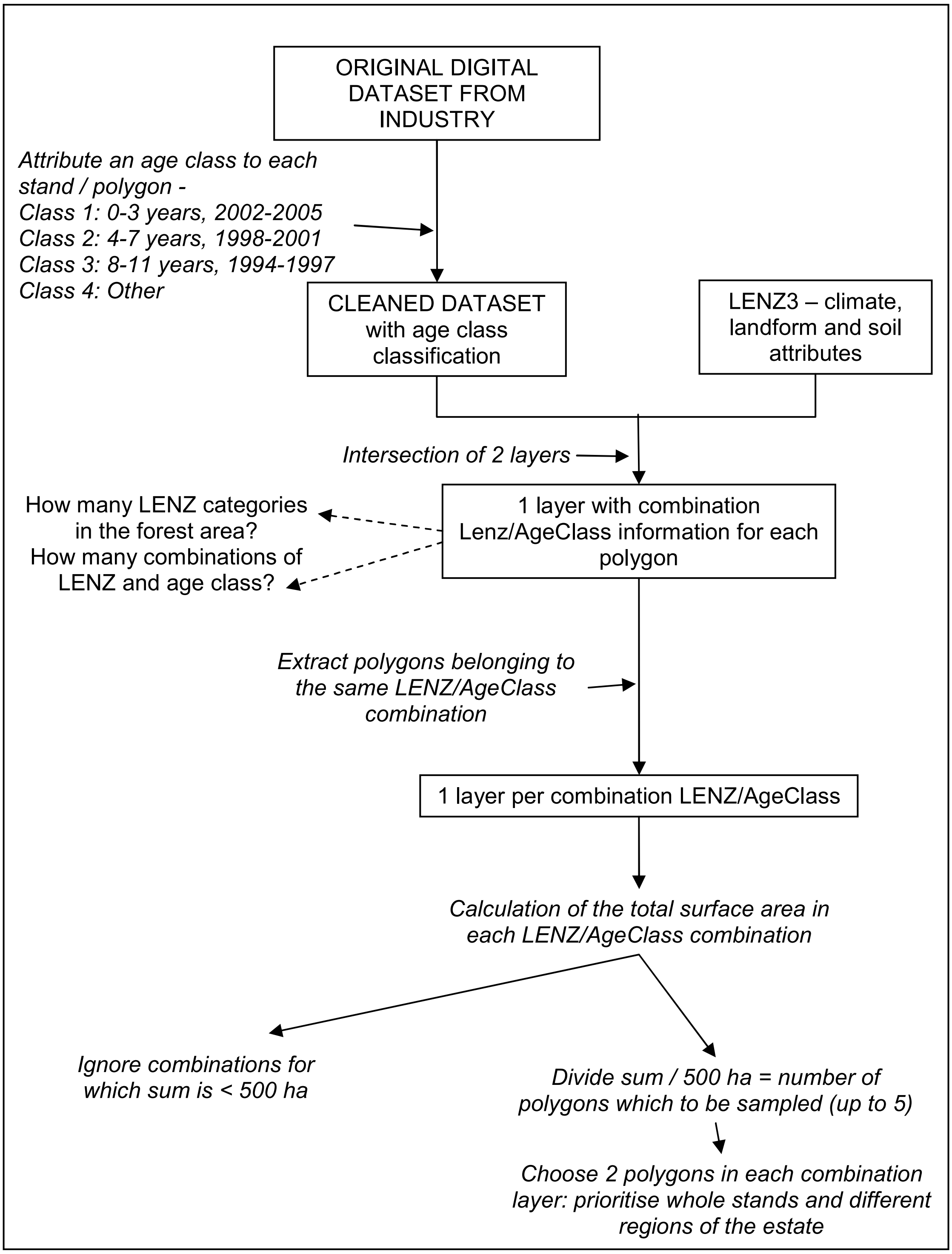


Figure 7: An example of the process involved in site selection when supplied with digital data in the form of GIS layers of the forest estate.

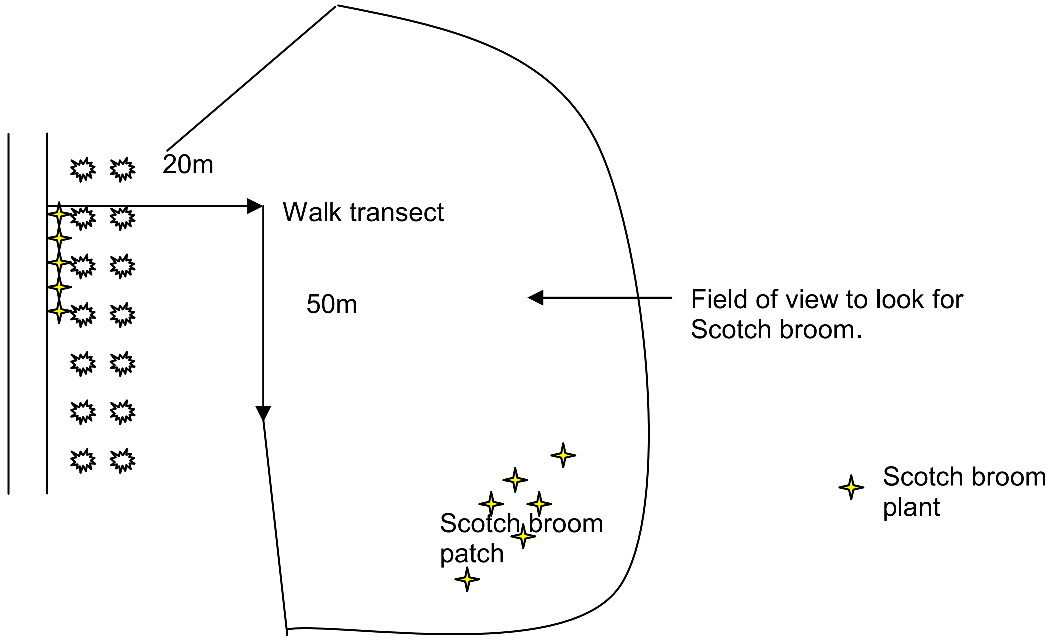


Figure 9. Sampling within stand plants for Scotch Broom