PREDICTING THE SUITABILITY OF SITES FOR FOREST TREES: HELP FROM THE INFER EXPERT SYSTEM

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INTRODUCTION

Predicting the suitability of a site for a forest tree requires knowledge of (a) the environmental conditions at the site and (b) the responses to environmental factors of the species being considered. For agronomic and horticultural crops, such predictions can be reliably made now for at least 20 species, but for forest trees, there is hardly a single species for which the responses to a full range of environmental factors are accurately known.

The reasons for this disparity between crops and forest trees lie in the comparative size of the species, which make experimentation difficult for forest trees, and in the wide geographic dispersal of tree plantings, which makes it difficult to monitor the effects of environmental factors. However, as a result of the first author's interest in predicting the growth of lesser-known plants (Hackett 1988, 1991a, 1991b; Harris and Hackett 1994), species' environmental relationships can be estimated by methods other than formal experimentation. This so because (a) there is not - for practical purposes - an infinite range of possible plant relationships for a factor and (b) the relationships particular factors have recognisable forms, e.g. those for salinity usually start high on the y-axis, are flat for low levels of salinity, and then decline as salinity increases whereas relationships for nitrogen usually start very low, then rise and become level, and finally turn down again as excess nitrogen is experienced.

It follows therefore that a basis exists for believing that the form for a relationship is much the same from plant to plant and that the variation in species' responses arise largely from the positions of the turning-points. Thus if relationships are presented in the form of straight-line segments and turning-points, a simple method emerges for recording estimated relationships, testing them, and improving them.

This inferential approach was first applied with Version 1 of the Plantgro prediction system (Hackett 1991a). The set of rules created, subsequently called Inspired by the first author, drew on forest tree data from the Inspire data (Webb et al. 1984). The results were quite encouraging and were used to help create tree files for Indonesia's National Masterplan for Forest Plantations. However, because the NMFP files were kept confidential, little more emerged from that work at that time.

Fortunately, Inspired had been remembered by one of the agencies which had been monitoring the development of Plantgro and Inspire. This was the PROSEA Organisation (Plant Resources of South East Asia) which is producing 20 volumes on South-East Asian plants, many of which are little known so far as experimentation is concerned. Because Plantgro appeared to be the best system at the time for providing a predictive capability for the plants being dealt with by PROSEA, it funded the creation of a much-improved version of Inspired which was called Infer (Hackett 1996).

The nature and application of Infer

The data sources available for the work on Infer were PROSEA's published articles, the personal knowledge which had not got into the articles, and a set of rules created by the first author of this paper for interpreting the data available from PROSEA.

After substantial planning discussions, it was decided to give a large sample of the PROSEA authors three tick-box data-sheets and a supplementary sheet presented in conventional linear format. The first of the three data-sheets dealt with the bounds of the species (e.g. does it grow in sea-water?, does it grow on walls?, etc). The second dealt with soil conditions experienced - e.g. in the pH range pH 5.5 to 6.4? - while the third dealt with climate conditions - e.g. for any month, does the plant experience rainfall in the range 150-220 mm. The fourth and most convential data-sheet sheet dealt with questions such as whether the species had mycorrhizal associations, fixed nitrogen, etc. (All 21 of the environmental relationships considered in Plantgro were dealt with. For soils, these were aeration, base saturation, cation-exchange capacity, depth, nitrogen, pH, phosphorus, potassium, salinity, slope, and texture. For climates, the relationships were for daylength, solar radiation, brief cold, extended cold, heat damage, thermal units, water availability, waterlogging, flooding, and wind damage.)

The response from PROSEA's authors for help with the project was very satisfying. Two hundred sets of data were sent in, for which, because of the limited resources available, it has only been possible thus far to process a hundred. Of those hundred data-sets, about seventy were useable, and of those seventy, approximately twenty Plantgro files were produced which were ready for serious testing and another further were found to need only small amounts of work before also going to serious testing. (The judgements of quality were based on internal consistency, the quality of the supplementary notes provided by the authors, and the obvious degree of knowledge and care put into the task by the authors.)

The outcome from the trial was very positive. Over the space of about five months, useful start-up files were made for about forty plants, most of which had not been associated with growth-prediction analysis before so far as was known. As for the cost of the whole exercise, that was only about $US 500 per plant as based on the 40 best plant files produced. Compared with conventional research methods, that was an extremely low price for eliciting a plant's environmental responses which, after polishing, can be applied to almost any location in the world.

As to the polishing of the files itself, that too can be performed economically. Considering forest trees now from hereon as the point of reference, much can be done by plain observation instead of using expensive facilities. For example, instead of commonly planting individual species or provenances in sizeable separate blocks, groups of species should be planted side by side. In this way, direct comparisons can be made of critical temperatures such as triggers for heat-damage, cold-damage, and bud-breaking; responses to waterlogging and lack of water; and reactions to different soil depths and textures. If all of such records are used with a prediction system such as Plantgro which can test the inferred relationships, a high predictive capability for a tree can be obtained within three years. Separate files may be required later to deal with changes which occur due to natural development of the the tree, but that would be little different from what is done in Plantgro already for the phases of the development of crops. (As a result of these developments, Infer is now used by the CSIRO Division of Forestry and Forest Products to help produce sets of environmental relationships for acacia and eucalypt species. N.Marcar and T.Vercoe pers. comm.)

An Illustration of Infer's methods

This section of the paper illustrates how Infer works. Within the present text, it is only possible to give an illustration of one tick-box plus an example of use of a set of rules for creating a relationship, in this case for pH. Readers who would like to learn more about Infer and/or collect data for Infer are asked to refer to the appendix to this paper.

Example of a set of Infer tick-boxes

Figure 1 shows Infer's tick-box for recording the soil conditions which a species, provenance, or cultivar is known to experience. All that is required is whether it experienced a nominated condition. The user does not have to consider how well the plant is growing at the site. (At this point the method is not greatly different from the site-matching method. Where Infer does differ greatly is in the use which is made of the data recorded.)

Interpretation of Infer data about the pH conditions experienced by a plant

As explained above, the Plantgro plant files contain two-dimensional environmental relationships which are used to predict the plant's growth (Figure 2).

For the y-axis of these relationships there is a standard range of 9 units which are called suitability ratings (SRs 0 to 9), whilst for the x-axis, the units and range of values vary with the factor considered.

In this example for pH, there are four x-axis values whose values are initially unknown. The first of these is PHA where death occurs and the suitability rating is zero. The next x-axis value is called PHB and equates with maximum suitability (SR9). Following that, there is another pair of variables (PHC and PHD) which relate to SR9 and SR0 respectively. When PHC is greater than PHB, the relationship is a plateau; when PHC = PHB, there is a peak.

Referring back now to the tick-boxes in Figure 1 and imagining that three pH boxes have been marked for a particular species, namely pH 5.5-6.4, 6.5-7.4, and 7.5-8.4, we can begin to see how a set of rules can be applied to estimate a relationship.

Returning now to Figure 2, we can see that Rule 1 does not apply because the lowest pH value recorded is not less than pH 4.5. Rule 2 then says that the estimate for PHB is the middle of the range pH 5.5-6.4, which we shall take as 6.0. Rule 3 then asks us to treat PHA as PHB-1.5, i.e. pH 4.5.

We are then asked about the highest pH value quoted. In this case the maximum recorded pH is in the range pH 7.5 to 8.4. This causes the value of PHC to be set at the mean of this range, which will be taken as pH 8.0. PHD is then estimated as pH 9.5.

These estimates have therefore produced an overall range for the plant from pH 4.5 to 9.5, with a plateau from pH 6.0 to 8.0. In more formal terms, four x,y pairs of values have been established: pH 4.5 & SR 0; pH 6.0 & SR 9; pH 8.0 & SR 9; and pH 9.5 & SR 0. Given these pairs of values, a relationship can be drawn which represents the first estimate of the species' response to acidity and alkalinity.

Had we been considering a real plant, the relationship would then be entered into the relevant species' plant file and would be tested by having Plantgro or another system make predictions for all the sites for which helpful data were available. Until the relationships for all the factors have been satisfactorily tested can the file be considered totally reliable; however, experience has shown that adequate predictions can usually be obtained for a file which has minor uncertainties. (In all cases, users should be extremely careful about making or implying a particular degree of reliability of a file when passing it to another person. Onus of risk should always be accepted by the recipient unless some other mutually acceptable arrangement is in place.)

Because Plantgro deals with 21 environmental relationships, 21 sets of rules can be dealt with in this manner described above. If a system has to be used which does not deal with all of the 21 factors, the user can merely neglect those factors. (With Plantgro, one can bypass relationships by setting them as favourable under all conditions. It is not so safe, however, to pass by input variables because sub-models exist which use a variety of input data - e.g. for estimating water balance.)

Since Infer's rules can only be used in print form at present and most sets of rules are more complicated than those shown for pH, it is unwise to try to make files for more than two species in a day. Because of this, there is a firm intention to produce a software version of Infer which will make the processes much easier. It is hoped that this disk will be available around the end of 1997.

CONCLUSION

For those who might like to collect data for the processing via Infer, copies of the three tick-box sheets are provided in the Appendix along with the supplementary page. Should readers like to use the Infer system before the software version is available, an approach can be made to the first author of this paper. For those who would like merely to collect records of conditions which species experience, the records can be sent to either Dr Jerry Vanclay*, CIFOR, PO Box 6596, JKPWB, Jakarta 10065, Indonesia or to the first author. Where more than one set of records for a species or provenance is supplied, those records may be pooled on fresh blank sheets after being treated independently. The results of such a pooling will be reported to all the primary data-suppliers involved. (All data-sets supplied will be regarded as the property of the supplier, and all suppliers will be told how their records have been used.)

*(Dr Vanclay is the co-author with Dr Hackett of a paper called " Mobilizing expert knowledge of tree growth with the Plantgro and Infer systems" (Hackett and Vanclay 1997?)

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APPENDIX

(The appendix will contain only Figures, which will be supplied separately.)

The Infer Figures are presented here as DOC files concerning habitats, soils, climates, and supplementary data. All of these files should be retained for the appendix. Only that for soil is required for the text.

There is also an XL file showing the basis of a relationship for pH. We have not been able to enter the x-axis letters required. These are variables - PHA, PHB, PHC, and PHD - determined by use of Infer. This figure has been copied from the Plantgro handbook. It needs to be inserted in the text along with the pH rules. I doubt that it will be needed for the appendix.

I hope this is sufficiently clear. Please contact me if you have any difficulties (chackett@ozemail.com.au).

SUPPLEMENTARY INFORMATION

1. Using ratings from 1 to 10, please indicate the plant's **vigour** compared to other plants, assuming favourable environmental conditions for the plant in question. Examples now follow:

1 = cacti 3 = small weeds 4 = garden peas 5 = wheat, clover 6 = Irish potatoes

7 = tropical pasture gressas 8 = rice, soybean 10 = maize, tropical eucalypts

Vigour rating = ...

2. Please indicate: **(a) the potential rooting depth** assuming all other conditions are favourable - this is very important for water balance calculations, **(b) the plant's height, which is important in relation to frost, and (c) the most common setting for the plant:**

(a) Potential rooting depth (cm) .... **(b)** Plant height (m) ....

(c) Mono-cropping ..... Controlled competition (e.g. farm pastures) .....

Uncontrolled competition ..... Other (please describe) ....

3. Please indicate the daylength reponse of the plant, if known (mark more than one if there are within-species differences):

Day-neutral .... Weak long-day.... Strong long-day.... Strong short-day.... Weak short-day.... Not known ....

4. Nitrogen-fixing ability of the plant:

Nil ..... Weak ..... Strong ..... Not known .....

5. Mycorrhizal association concerning phosphorus uptake :

Nil ..... Weak ..... Strong ..... Not known .....

6. The plant's response to winter conditions:

death of plant.... semi-dormancy (retention of leaves).... true dormancy (shedding of leaves) ....

7. The plant's response to prolonged hot conditions:

death of plant.... shedding of leaves.... retention of plant parts except flowers.....

8. Special relationships, if any:

Indoor plant .... Heavily shaded .... Epiphytic .... Parasitic .... Saprophytic ....

9. If an environmental factor affects a **quality** of the plant in a way which is separate from effects of that factor on growth (e.g. an effect on the taste of a fruit), please indicate the factor involved and the impact it has:

....

RELATIONSHIP 6 : pH

The relationship is considered to have:

: a rising slope from acidity towards neutrality (PHA to PHB)

: a plateau (PHB to PHC) where PHB and PHC can be the same to make a peak

: a falling slope from neutrality towards alkalinity (PHC to PHD).

1. Acidity

If the lowest box marked = "< 4.5", PHA = 3 PHB = 5.

Else PHB = the mean of the lowest box marked.

PHA = PHB - 1.5.

2. Alkalinity

If the highest box marked = "> 8.4", PHC = 8 PHD = 10.

Else PHC = mean of the highest box marked.

PHD = PHC + 1.5.

3. Check against 'Habitats - harsh soils - natural' and any other indications available.

.CONDITIONS EXPERIENCED: 1. HINTS ABOUT THE SOIL REQUIREMENTS OF THE SPECIES

Please mark the conditions experienced and use the blank spaces to indicate other conditions or to supply notes or comments.

SOIL						
Depths	< 10 cm ☐	10-20 cm ☐	20-50 cm ☐	50-100 cm ☐	100-200 cm ☐	> 200 cm ☐
Levels of major nutrients	almost nil ☐	very low ☐	low ☐	moderate ☐	high ☐	very high ☐
Total N (%)	almost nil ☐	v.low (0.05-0.1) ☐	low (0.1-0.2) ☐	mod. (0.2-0.3) ☐	high (0.4-0.6) ☐	v. high (>0.6) ☐
Avail. K (meq/100 mg)	almost nil ☐	v.low (0.05-0.1) ☐	low (0.1-0.2) ☐	mod. (0.2-0.3) ☐	high (0.4-0.6) ☐	v. high (>0.6) ☐
Avail. P (ppm Olsen)	almost nil ☐	v. low (1-4) ☐	low (5-9) ☐	mod. (10-15) ☐	high (18-25) ☐	v. high (>25) ☐
pII	< 4.5 ☐	4.5-5.4 ☐	5.5-6.4 ☐	6.5-7.4 ☐	7.5-8.4 ☐	>8.4 ☐
Salinity (dS/m)	0 ☐	traces (1-4) ☐	low (5-10) ☐	mod. (11-20) ☐	high (21-30) ☐	v.high (31-50) ☐
						extreme (>50) ☐
Slopes (deg.)	0 ☐	1-15 ☐	6-30 ☐	31-50 ☐	51-70 ☐	>70
	(incl. akes, sea, etc.)	(tractor limit)	(steady walking)	(hard walking)	(clambering)	
Textures	heavy ☐	medium ☐	light ☐	stony/rocky ☐	leafmould/peat ☐	well-draining
	(e.g. clays)	(e.g. loams)	(e.g. sands)		peat	clays

CONDITIONS EXPERIENCED : 2. HINTS AT THE CLIMATE REQUIREMENTS OF THE SPECIES

*** Please indicate here the approximate optimum temperatures (o C) for the main phase of growth: day . ... night . ... (Don't know ....)**

Please now mark the conditions experienced and use the blank spaces to indicate other conditions or to supply notes or comments.

Temperature units = oC - monthly mean or monthly minimum					**GROWING SEASON**				
Mid-day temps	0-5 ☐	6-10 ☐	11-15 ☐	16-20 ☐	21-25 ☐	26-30 ☐	31-35 ☐	36-40 ☐	> 40 ☐
Night lowest temps	-9 to -5 ☐	-4 to 0 ☐	1-5 ☐	6-10 ☐	11-15 ☐	16-20 ☐	21-25 ☐	26-30 ☐	> 30 ☐
Rainfall/irrgn	< 30 ☐	30-60 ☐	60-100 ☐	100-150 ☐	150-220 ☐	> 220 ☐			
(mm/month)	very low	low	moderate	high	very high	abundant			
Humidity(RH%)	0-20 ☐	20-40 ☐	40-60 ☐	60-80 ☐	80-100 ☐				
Windspeed(km/hr)	20-28 ☐	29-38 ☐	39-49 ☐	50-61 ☐	62-74 ☐	75-88 ☐	89-102 ☐	103-117 ☐	>117 ☐
	dust raised	small trees sway	wires sing	hard to walk	twigs break off	slight damage	trees uprooted	wide damage	severe damage

DORMANT SEASON

Mid-day temps	< -29 ☐	-29 to -20 ☐	-19 to -10 ☐	-9 to 0 ☐	1-10 ☐	11-20 ☐	21-30 ☐	31-40 ☐	41-50 ☐
									> 50 ☐
Night lowest temps	< -39 ☐	-39 to -30 ☐	-29 to -20 ☐	-19 to -10 ☐	-9 to 0 ☐	1-10 ☐	11-20 ☐	21-30 ☐	> 30 ☐
Rainfall/irrgn									
(mm/month)	c. 0 ☐	c. 5 ☐	10-20 ☐	20-50 ☐	50-100 ☐	> 100 ☐			
Humidity(RH%)	0-20 ☐	20-40 ☐	40-60 ☐	60-80 ☐	80-100 ☐				