PREDICTION OF FUTURE MANPOWER REQUIREMENTS FOR LOGGING - A DO-IT-YOURSELF GUIDE

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Introduction.

Within this paper I will be dealing with the mechanics of predicting the future manpower requirements for logging in New Zealand. Inevitably this involves covering some of the same subjects addressed by Hamish Levack and Tom Johnson in the 1984 Manpower seminar, and some topics I covered then myself.

This seminar provides the opportunity to assess progress in the prediction methodology since 1984. There have been some useful gains in acquiring necessary information. There have also been some rapid and marked changes in the industry which could only confound the prediction process.

Two of the most significant changes from a modelling viewpoint have been the growing availability of microcomputers, and the provision of improved resource descriptions. These factors have put the capacity to model manpower requirements down to forest planning officer level. If this is not you, it could be the character sitting alongside you.

Suggest to him you'd like the results for your forests by next Friday!

IFS

There will obviously be more than one way to structure a prediction model. This particular version will start with the Interactive Forest Simulator. This is a very useful piece of software which has been around in various forms for approximately 15 years. The latest version (IFS 4.2) is available from the Forest Research Institute for $NZ 1 500.

IFS has the great advantage that some 540 000 ha of NZ plantations (The State Forests at the time of writing) have been described in an IFS compatible form.

IFS, as its name implies, allows you to simulate the development of a forest estate.

An example forest estate is shown below:

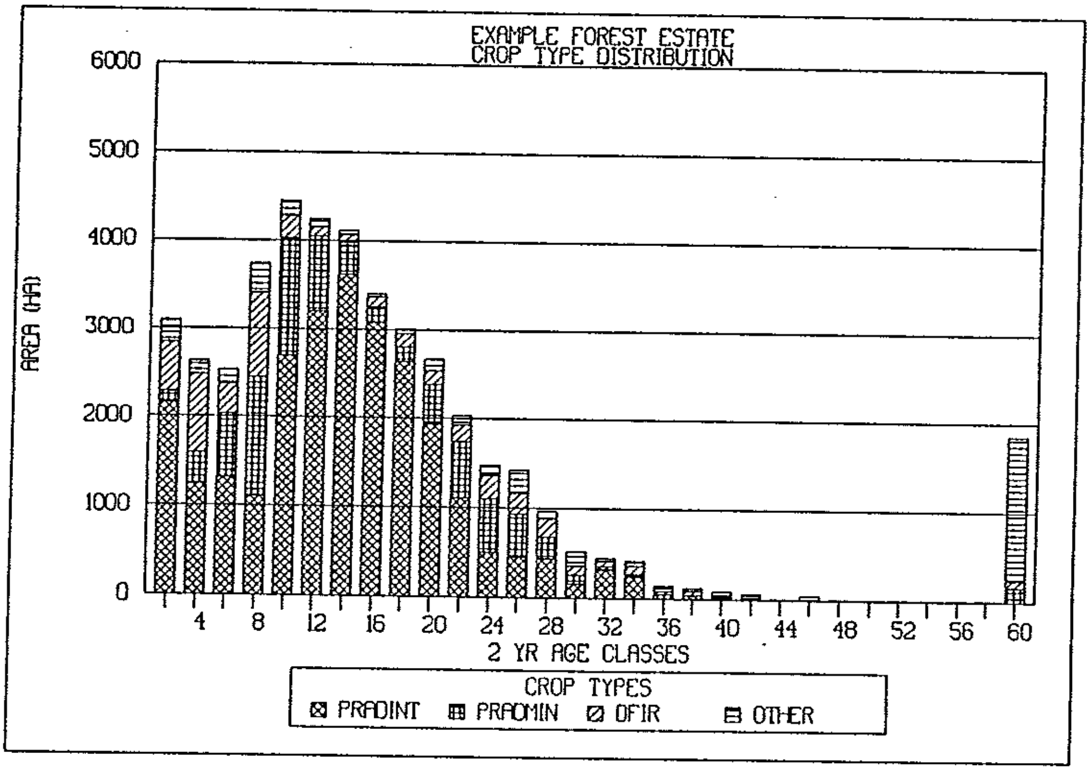

Figure 1

The example forest has a variety of crop types:

PRADINT is intensively tended radiata pine
PRADMIN is minimum tended radiata pine
DFIR is Douglas Fir
OTHER is other minor species.

The forest also has an uneven age class distribution, skewed to younger ages, and in this respect is characteristic of the larger New Zealand resource.

Figure 1 is a static picture of a forest, but as we know forests are anything but static. They may change due to:

Growth
Harvesting stands
Replanting, or new planting

Growth

The growth of the forest is determined by the growth functions of each of the crop types. These characteristically appear as follows:

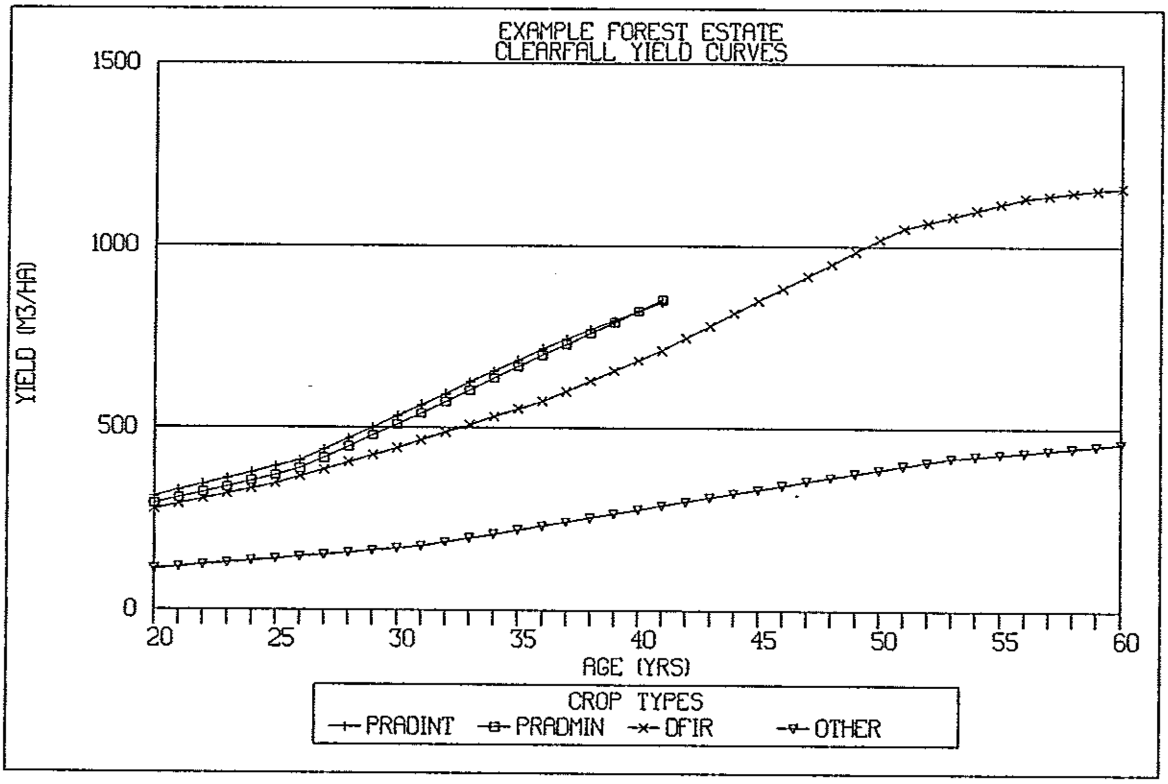

Figure 2

Harvesting Stands

The IFS program, when provided with an area-age class description,and yield curves for each crop type, allows the effect of different cutting strategies to be tested. Various types of cut may be imposed:

- cutting on an area basis
- cutting on a volume basis
- cutting area or volume from a particular crop type or group of crop types.

The most common application is cutting to achieve a total volume output. For the same resource, an unlimited range of alternatives may be available, as shown overleaf (Figure 3).

Generally, by default, it is one of the second group that tends to be developed. The distinguishing feature is that these are "non-declining yield" strategies. As the name implies, once the level of cut is increased, it cannot decline. Ultimately, the level of cut reaches a "long term sustainable yield". Under such a cutting strategy, the forest age class distribution eventually adjusts until it is even, e.g.*

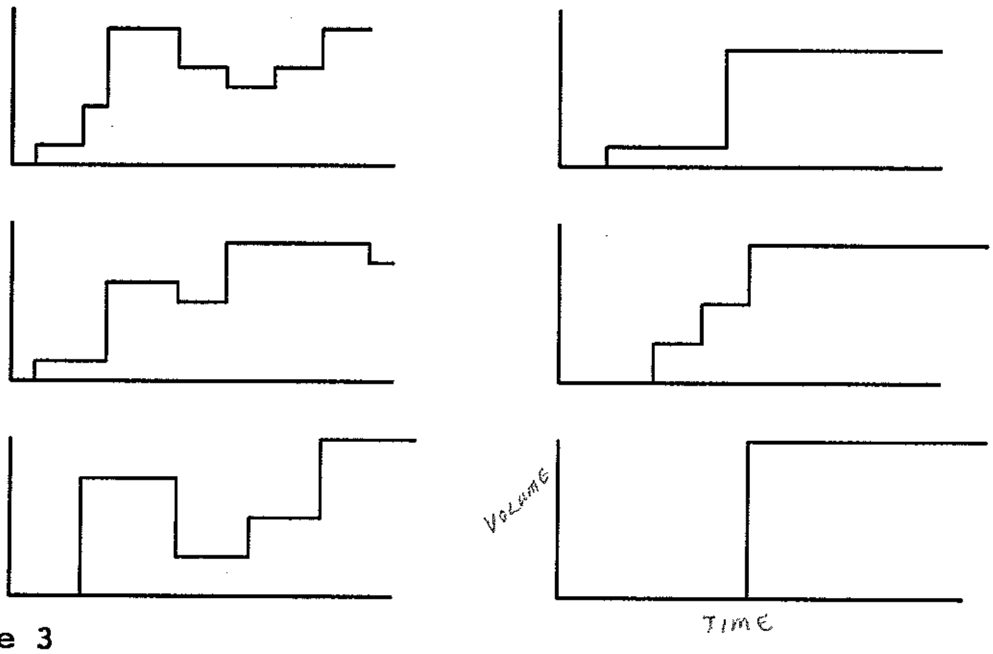

Figure 3

* (Note that it is certainly not mandatory to have an NDY based cut. For a small forest, the cut may be managed to complement that of other small forests to provide an overall NDY. The NDY based cut and associated "normal" forest are nevertheless very useful concepts, and a fundamental cornerstone of the RMS series of estate modelling software)

Features of the Cutting Strategy

Let us examine one possible cutting strategy that the example forest estate would support. (Figure 4).

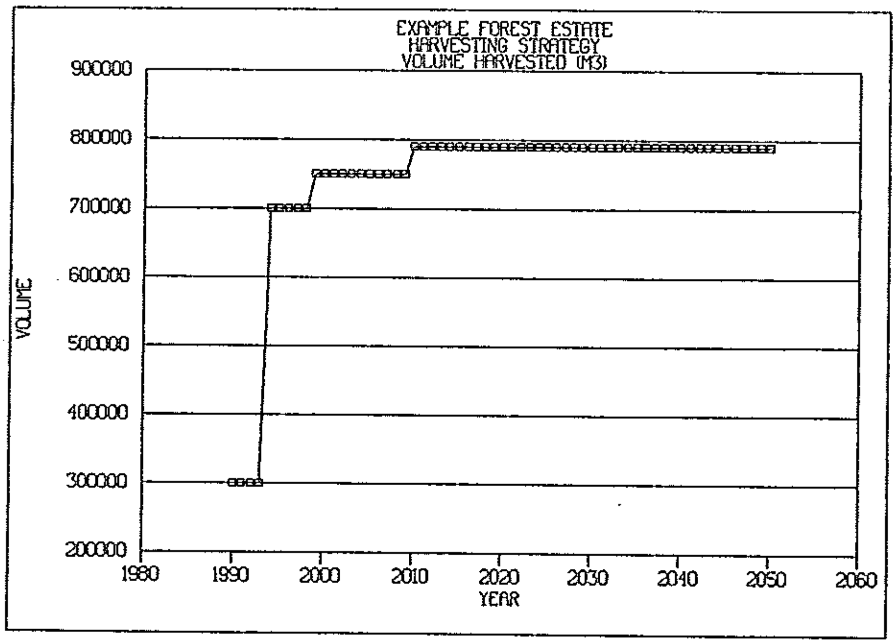

Figure 4

Cutting can begin in the forest in 1992, and then two steps in production are anticipated before a long term sustainable yield of 795 000 m3/annum is reached in 2011.

The total volume graph looks very simple - considering the complex forest structure from which it arises, it is almost too straightforward to be credible. To any enthusiast for graphs, it is downright boring. However, if we look at some of the parameters associated with the strategy (Figure 5), more interesting results emerge:

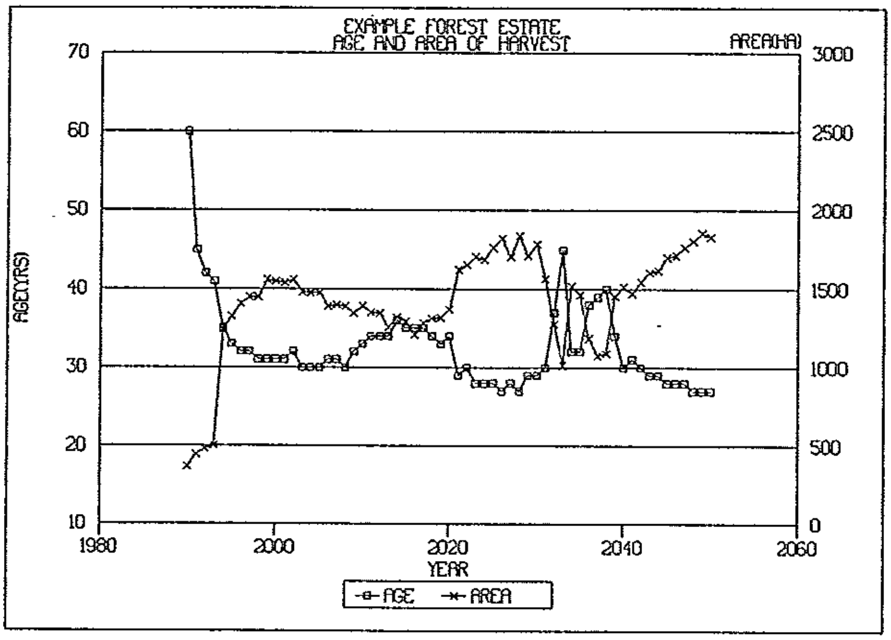

Figure 5

Tree size.

The age of harvest may show some marked variation, as the graph shows. Tree size also varies with age, and we know that tree size, and related piece size, are the most significant factors affecting logging productivity. Any prediction of manpower requirements would be unduly simplistic if we did not consider the variation in tree size, and accordingly it must be included in the model.

For modelling purposes, the most flexible, and effective means of providing for tree size is with a formula.

Such a formula was proposed by Johnson and Levack in the 1984 LIRA Seminar. It stated:

$$\text{Annual gang production} = 32080 * \text{Tree size}^{0.57}$$

This was based on experience at Kaingaroa forest, in the early 1980's, and from the available data, the formula provided a very reliable fit (r^2 = .981).

The shape of the curve is shown below (Figure 6). Curves with some

The shape of the curve is shown below (Figure 6). Curves with some different indices are also shown for comparison.

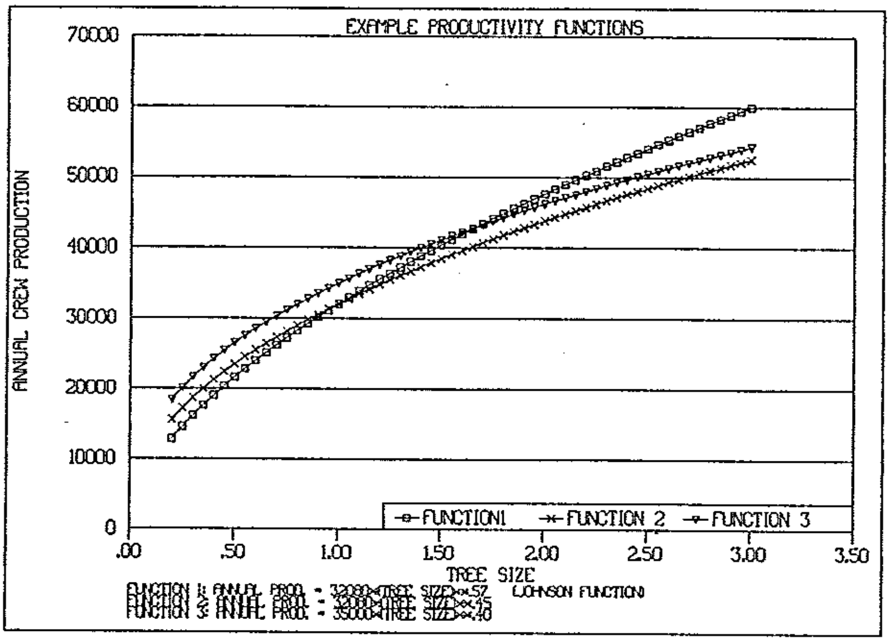

Figure 6

In the course of recent forest modelling and valuation exercises at Groome Pöyry, we have examined a range of empirical data, and tested the fit of the Johnson type function. No strongly identifiable trends have emerged, although there is evidence that for some regions a lower index than 0.57 may prevail. For the example demonstrated in this paper, the following productivity function has been assumed for all crop types:

Annual crew production = 35000*(tree size)**0.40

(The function is for illustrative purposes only. It is strongly recommended that any intending modellers attempt to identify a suitable local coefficients).

The Johnson type function can also be expressed in other forms, e.g. in gang days per hectare for different tree sizes:

$$\text{Gang days/ha} = \frac{(\text{Volume per hectare}) * (\text{Gang days/gang year})}{32080 * \text{Tree size}^{.57}}$$

IFS Products File.

Returning to IFS, we can note that besides an area by age class distribution, and yield data, the program also employs "product files". These indicate the output by product types for the range of potential felling ages. Most commonly such outputs would be log

grades. Figure 7, below, graphs the original contents of the product file for the PRADINT crop type.

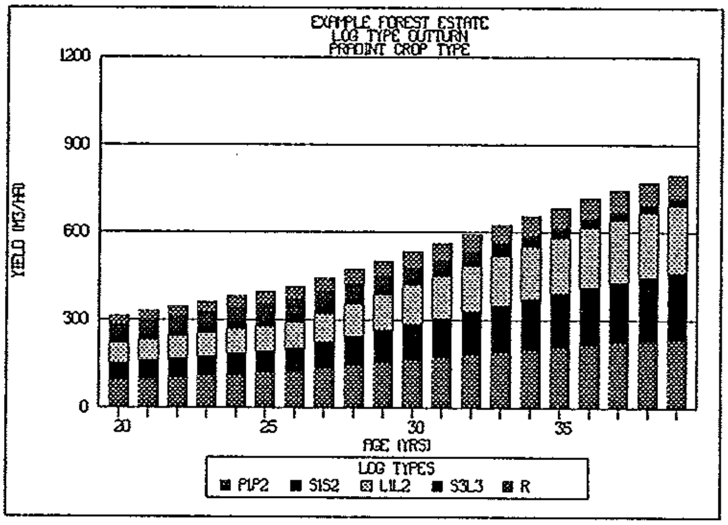

Figure 7

Different types of Product.

A "product" for the IFS program does not have to be something measured in cubic metres. For instance, a flurry of valuation related cash flow generation, dating since the formation of the Forestry Corporation, has seen product files frequently consisting of dollar amounts - either revenues or costs.

A products file may equally well contain gang days per hectare logged.

Below is an excerpt of the PRADINT dataset with the extra product type added. The simplest way to incorporate the extra information is by loading the dataset into a spreadsheet, as illustrated.

	S	T	V	W	X	Y	Z	AA	AB
1	PRADINT	0							
//	(AREA)	(TSV)		(P1P2	S1S2	L1L2	S3L3	S4L4R)	
20	970.2	296	0	89	56	64	57	30	190.2
21	968.1	313	0	94	59	68	61	31	196.7
22	643.6	329	0	99	62	71	64	33	202.7
23	469.4	346	0	104	65	75	67	35	208.9
24	119.5	362	0	109	68	78	70	36	214.7
25	384.2	378	0	114	72	82	73	38	220.3
26	342.7	395	0	119	74	85	77	40	226.2
27	113.5	411	0	124	78	89	80	41	231.6
28	232.4	441	0	135	89	98	75	44	241.6
29	206	471	0	145	99	110	70	47	251.4
30	101.1	501	0	154	111	121	64	50	260.9
31	58.5	532	0	164	122	134	59	53	270.4
32	182.9	562	0	173	134	144	54	56	279.5
33	132	592	0	182	147	155	49	59	288.3
34	191.7	624	0	191	159	168	44	62	297.6
35	50.3	655	0	200	171	179	40	65	306.4
36	0	685	0	207	184	191	34	68	314.7

← Formula for this cell (row 26, 226.2) is:

+T26*23000/(+35000*(+T26/280)**.40)

Where:

- +T26 is the cell containing the total stem volume
- 280 is the assumed stocking(sph)
- .4 is the index
- 35000 is the constant in the productivity equation
- 23000 is the assumed work days in a gang year, multiplied by 100 (to give better resolution in the results)

The trend of logging gangdays per hectare with increasing stand age is shown in the graph below:

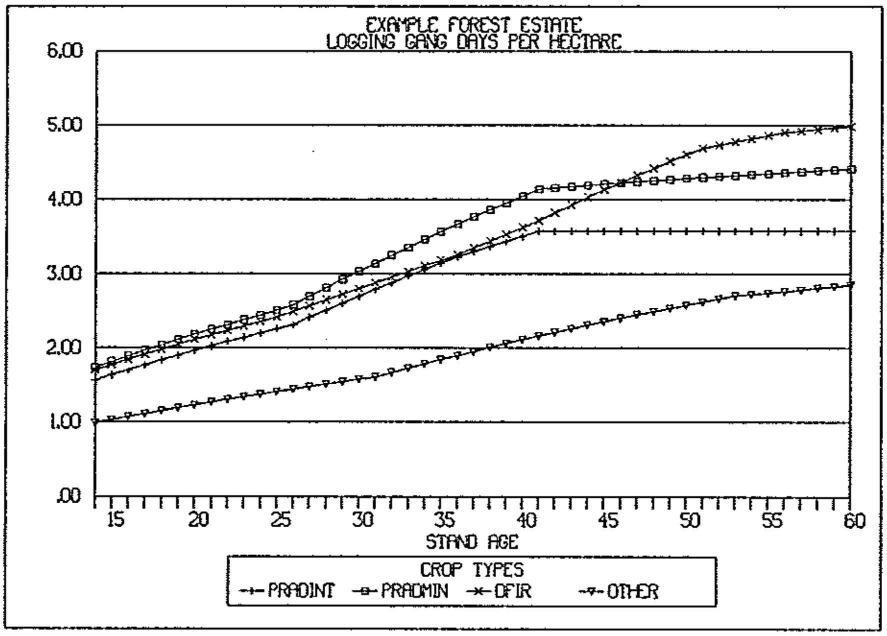

Figure 8

The curves result from the effects of two opposing factors:

- as stand age increases, the tree size increases, and accordingly gang efficiency increases. This would suggest a reduction in gang days per hectare.

- as stand age increases, the volume per hectare increases, which tends to increase the gang day requirement.

In this case the graphed curves indicate that the second effect is dominant.

Product output information from an IFS run.

Figures 9 and 10 illustrate the results of applying the cutting strategy shown in Figure 4 to the Example Forest Estate. Each crop type had been assigned its own product files.

Figure 9 shows the yields by log grade, while Figure 10 shows the number of gangs theoretically required in each year. (The raw IFS output actually gave total number of gang days per year multiplied by the scaling factor of 100 - these have been converted to gang years for this illustration)

Since Figure 10 represents the first of the required end results from the modelling procedure, it is worth careful examination.

- The requirement for logging gangs is naturally dominated by major steps in the level of harvest.
- There is further variation of approximately ± 11% (in this case) associated with changes in the average age of harvest (Figure 5), and the crop type being cut at the time (indirectly indicated by the product mix in Figure 9)....

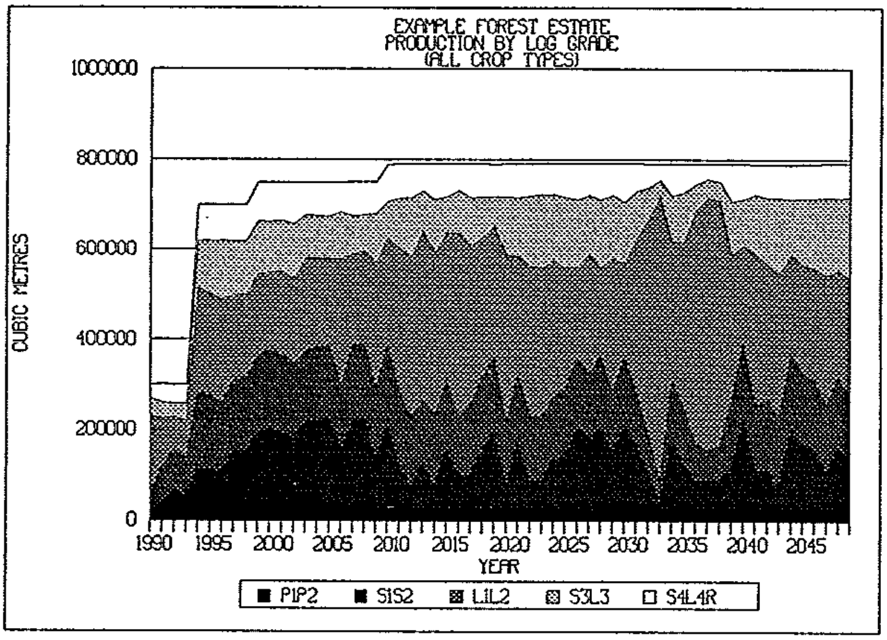

Figure 9

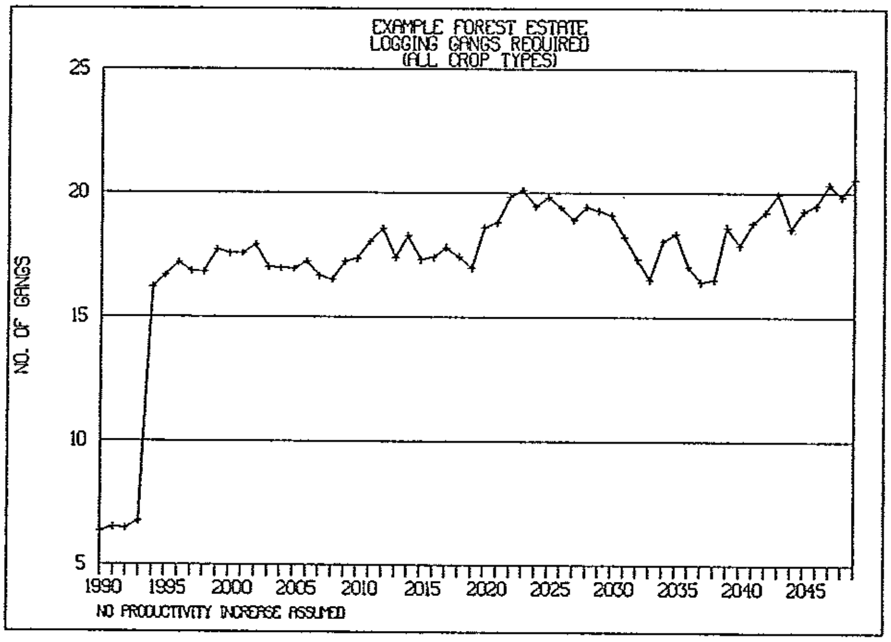

Figure 10

Further Refinements.

Smoothing of Gang Numbers

IFS, like most computer programs, works very mechanically. Within harvest strategies which are only broadly specified, the program is quite indifferent to some of the "spikes" it may produce, whether they be in log grade proportions, or gang numbers. There are two possible approaches to smoothing the results:

1 - assume that some smoothing will almost certainly be possible with fine tuning of the harvest strategy, and approximate the result by applying 2 to 5 year rolling averages.

2. Confirm that the results can indeed be smoothed by actually developing a much more tightly defined harvest strategy. (e.g, applying individual crop type cuts in each year, rather than cuts which are applied collectively.)

Integral number of gangs.

First examination of the prediction results would suggest that in every year decimal fractions of a gang are required. The quickest correction is to round the gang numbers up or down to the nearest whole number. A more diligent approach would involve close examination of the cutting strategy to determine whether by further manipulation the number of gangs can be kept at whole number levels.

Different types of Logging System.

For simplicity, the example of the modelling procedure described here has recognised only one type of crew. Usually, however, more detail will be required, especially for the distinction between hauler and ground based operations. Resolving this requirement is quite simple; since the IFS program will accommodate numerous product types (up to ten), different logging systems should be listed as different product types. The IFS output will then be suitably itemised by crew type.

Future changes in productivity.

Historical experience suggests that continued improvements in logging productivity can be expected. Within an IFS based modelling system the most feasible opportunity to adjust for future changes is by manipulating the program results. Figure 11 illustrates output from the example modelling run loaded into a spreadsheet. Column M represents anticipated future improvements in crew productivity, compared to current levels - in this case an assumed 2.00% per year. Revised estimates are derived by dividing the original estimate of crew requirements by this productivity index. (The example rate of change is of course for illustration purposes only - the anticipated levels of future change are something that other contributors to this seminar will no doubt address.)

Manpower requirements.

Future manpower levels can be obtained by multiplying the number of crews by anticipated crew size. In Figure 11 , column O represents the crew size, and column P the total manpower level.

FIGURE 11

PREDICTION OF FUTURE MANPOWER REQUIREMENTS

A	C	D	E	F	G	H	I	J	L	M	N	O	P	Q	R
YEAR	HARV. VOLUME	HARV. AREA	AVE. AGE	P1P2	S1S2	L1L2 (m3)	S3L3	S4L4R	NO. CREWS	FUTURE PRODUCT-IVITY	REVISED NO. CREWS	AVERAGE CREW SIZE	TOTAL MANPOWER LEVEL	TURNOVER LEVEL	RECRUITMENT TO MEET TURNOVER & EXPANSION
1990	300000	368	60	410	51852	177463	38521	31755	6.34	100%	6.34	5.0	32	20%	6
1991	300000	444	45	39768	79333	105243	35921	40460	6.51	102%	6.38	5.0	32	20%	6
1992	300000	481	42	65971	89788	72215	28756	43236	6.48	104%	6.23	5.0	31	20%	5
1993	300000	501	41	50828	84421	83886	38268	42502	6.76	106%	6.37	5.0	32	20%	7
1994	700000	1238	35	112757	169568	231127	105584	80438	16.21	108%	15.01	5.0	75	20%	58
1995	700000	1325	33	110264	163591	227506	117488	80344	16.68	110%	15.16	5.0	76	20%	16
1996	700000	1408	32	102494	158220	227567	130533	80106	17.17	112%	15.33	5.0	77	20%	16
1997	700000	1448	32	148806	161608	187987	118792	81911	16.84	114%	14.77	5.0	74	20%	12
1998	700000	1450	31	152276	161729	185285	117836	82023	16.81	116%	14.49	5.0	72	20%	12
1999	750000	1558	31	191174	173186	180474	116984	87542	17.71	118%	15.01	5.0	75	20%	18
2000	750000	1549	31	201024	175161	173202	111893	87959	17.55	120%	14.63	5.0	73	15%	9
2001	750000	1542	31	193936	170758	185984	112365	86360	17.57	122%	14.40	5.0	72	15%	10
2002	750000	1558	32	173325	176233	185685	120163	93965	17.89	124%	14.43	5.0	72	15%	11
2003	750000	1483	30	216230	158331	205462	95421	73435	17.01	126%	13.50	5.0	67	15%	5
2004	750000	1476	30	218521	162913	198025	93790	75332	16.97	128%	13.26	5.0	66	15%	9
2005	750000	1476	30	222545	165072	192099	93560	75438	16.95	130%	13.03	5.0	65	15%	9
2006	750000	1389	31	152119	146593	280247	103677	66510	17.23	132%	13.05	5.0	65	15%	10
2007	750000	1398	31	216173	169389	204583	83461	76380	16.65	134%	12.42	5.0	62	15%	6
2008	750000	1391	30	224774	167379	204112	80957	72777	16.52	136%	12.15	5.0	61	15%	8
2009	750000	1345	32	135888	154516	279766	108854	70501	17.22	138%	12.48	5.0	62	15%	10
2010	790000	1393	33	206953	182169	235833	81900	81871	17.35	140%	12.40	5.0	62	15%	9
2011	790000	1348	34	118575	163056	320647	110538	76273	18.03	142%	12.70	5.0	63	15%	10
2012	790000	1345	34	69626	156410	356272	131961	74891	18.55	144%	12.88	5.0	64	15%	11
2013	790000	1256	34	123767	140286	375732	88208	61205	17.39	146%	11.91	5.0	60	15%	5
2014	790000	1320	36	77363	156674	359414	116221	79885	18.27	148%	12.34	5.0	62	15%	11
2015	790000	1293	35	151318	154573	330660	81237	71339	17.30	150%	11.53	5.0	58	15%	5
2016	790000	1209	35	97299	132859	405272	95103	58908	17.40	152%	11.45	5.0	57	15%	8
2017	790000	1282	35	101931	153643	353525	105684	74631	17.79	154%	11.55	5.0	58	15%	10
2018	790000	1312	34	155238	162751	308482	89530	73207	17.42	156%	11.17	5.0	56	15%	6
2019	790000	1317	33	196060	162383	290689	68772	70964	16.98	158%	10.75	5.0	54	15%	6
2020	790000	1370	34	70176	149453	367463	128769	73471	18.61	160%	11.63	5.0	58	15%	13
2021	790000	1624	29	169629	152482	263138	129510	74642	18.80	162%	11.61	5.0	58	15%	9
2022	790000	1655	30	88742	140345	333715	156104	70966	19.83	164%	12.09	5.0	60	15%	11
2023	790000	1706	28	89378	138926	330817	163505	67736	20.10	166%	12.11	5.0	61	15%	10
2024	790000	1686	28	133763	138529	304046	146011	67883	19.45	168%	11.58	5.0	58	15%	6
2025	790000	1763	28	140473	149437	268861	156962	74727	19.82	170%	11.66	5.0	58	15%	9
2026	790000	1822	27	202487	158378	200355	148971	80338	19.41	172%	11.28	5.0	56	15%	6
2027	790000	1706	28	185294	139952	262894	131558	70821	18.91	174%	10.87	5.0	54	15%	6
2028	790000	1839	27	206649	157210	196062	149959	80928	19.42	176%	11.03	5.0	55	15%	9
2029	790000	1712	29	152459	136232	291447	139577	71263	19.27	178%	10.83	5.0	54	15%	7
2030	790000	1784	29	204712	155771	207578	137057	85665	19.08	180%	10.60	5.0	53	15%	7
2031	790000	1566	30	167372	117850	335629	107702	62108	18.22	182%	10.01	5.0	50	15%	5
2032	790000	1276	37	101383	90734	475993	69474	52415	17.32	184%	9.41	5.0	47	15%	4

Within this example, an increase in manpower numbers from 32 to a peak of 77 is indicated. Most importantly, this increase is only part of the number of recruits required - recruitment is also necessary to replace those lost through turnover.

The importance of this factor was described in the 1984 seminar (Liley, 1984), and has since been the subject of very useful investigation by LIRA, in conjunction with the FRI.(Gaskin, Smith, Wilson).

For this example, for demonstration purposes, an initial rate of turnover out of the logging industry of 20% per annum has been assumed, falling to 15% ten years hence. The assumed turnover level is presented in column Q in Figure 11, and the corresponding recruitment requirements in column R. These are also illustrated in Figure 12.

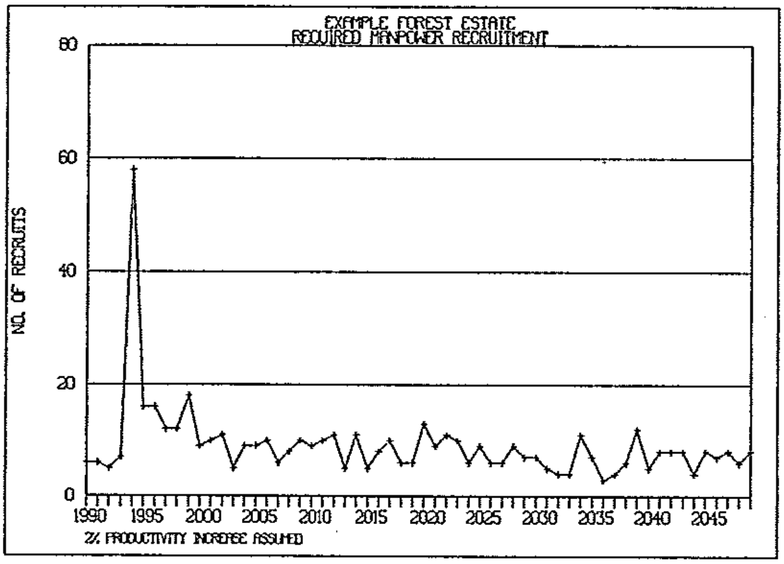

Figure 12

Further Developments

There are numerous potential refinements to the basic modelling procedure, determined mostly by the ingenuity of the spreadsheet user. In this example, the modelling has only been taken as far as the prediction of direct manpower employment in logging - there has been no estimation of the number of supervision and advisory staff required. These can readily be added, in the first instance, through the use of appropriate multipliers, and then these results modified with commonsense.

One further interesting possibility is use of the FOLPI program to enhance the modelling. FOLPI offers Linear Programming capabilities to the basic IFS structure, and with this the capacity to identify an optimum solution within a variety of imposed constraints. An example problem specification would require FOLPI to identify the most profitable harvesting strategy for an example resource provided that the workforce was not to expand by more than 3 crews in any 5 year period. Alternately, or in addition, a limit might be set on the year to year variation in hauler crew requirements.

Input information for the Modelling Procedure.

If the hardware and software, for modelling manpower requirements has become much more readily available than was the case in 1984, what can be said about the necessary model inputs?

- **Resource Information:**
  Thanks to the National Exotic Forest Description Steering Committee, and especially, more recently, the State Forest Asset Sales program, there is resource description information of an unprecedented standard and availability. There is naturally some room for refinement, and there always will be, but in its present form the available information offers a very good platform for further modelling.

- **Cutting strategy:**
  The testing of potential cutting strategies for individual and aggregated NZ forests must have occupied many thousands of man and computer hours in the last few years. Since the forests modelled have in many cases been relatively immature, we have yet to see whether they can realise their projected potential. The modelling software, and sophistication, continue to advance.

- **Crew productivity:**
  In my perception, this area has advanced very little of late. There is a dearth of available information linking productivity to even the most fundamental parameter of piece size for all logging systems. It is certain that a great deal of useful information must exist, but it is not well presented. This remains a worthwhile area for the research organisations to pursue, not only for manpower planning, but for logging planning in general.

- **Future Changes in Gang productivity:**
  This will always involve some conjecture. Some useful indication may be obtained by projecting past trends, but then the trend may not always be smooth. The rapid swings to mechanisation experienced in turn in the US Southwest and then Australia are important examples to bear in mind.

- **Gang Size:**
  As for gang productivity ..

- **Turnover:**
  The ongoing LIRA research into levels of turnover is essential for improving the predictive potential.

Conclusion

Within this paper an example approach to prediction of the future manpower requirements has been presented. It has been emphasized that appropriate software for the purpose is readily available, and that the initial platform for the modelling - the resource description- is well presented.

Logging productivity functions are seen as a critical area within the prediction process, and yet one in which there is considerable room for improvement.

If the eventual aim of the modelling process is the prediction of recruitment requirements, then consideration of turnover is essential. The current research initiatives deserve continued support.

Actual prediction of the manpower requirements for part, or all of New Zealand has not been attempted. For most reliable and authoritative results that responsibility is best placed with the regional forest and logging planners of the industry.