Evaluating A Model To Predict Timber Harvesting In Austria

Hubert Sterba, Michael Golser, and Klemens Schadauer

Abstract.—Between 1981 and 1985, the Austrian National Forest Inventory (ANF) established a set of 5,500 clusters, each with four permanent plots, covering all Austrian forests. After the first remeasurement between 1986 and 1990, models were developed to predict tree growth, mortality, and the behavior of forest owners in harvesting timber. A set of logistic equations describes the probability of a given stand exhibiting intermediate harvesting, single-tree selection, or final clearcutting. The independent variables were partly continuous and partly categorial, describing (1) regional units such as provinces, (2) types of ownership (groups of ownership sizes), (3) site factors (elevation and slope), and (4) stand characteristics (species mixture, density, mean diameter). The removal in the plots is given by five relative dbh classes. These removal percentages differ by elevation, harvesting categories, and tree species groups. A forecast of timber harvests in their spatial arrangement over Austria in the following four 5-year periods was made available to the public on a compact disk. In 1997, data from the second inventory remeasurements were available, and thus the forecasts for this period could be evaluated. Provided the units for which the forecasts were done are large enough, the results indicate that the deviations from the model are either small or can be explained by a then different timber market scenario and/or general socioeconomical scenario.

Austrian forests cover about 3.9 million ha or 47 percent of the country's total area, and 85 percent of these forests are exploitable. The forest owners are typically nonindustrial owners, who sell their timber to the forest industry. The ownerships are usually small (15 ha average), and only 20 percent of the forest area is public forest. Two-thirds of the owners own fewer than 2 ha, and approximately 50 percent of the forest area belongs to owners with fewer than 200 ha (Bundesministerium für Land- und Forstwirtschaft 1995; fig. 1). Forest industries, especially the sawmills, typically (with some exceptions) do not possess their own forests. As with forest owners, the small sawmills outnumber the big ones. Fifty percent of the yearly roundwood is processed by sawmills that process less than 100,000 m^3 per year (fig. 2). In 1996, therefore, the Association of the Austrian Sawmilling Industries ordered the development of software that would enable a single sawmill or any other user to get forecasts of timber harvests for an interactively definable region within Austria by tree species and a number of other categories for four 5-year periods (fig. 3).

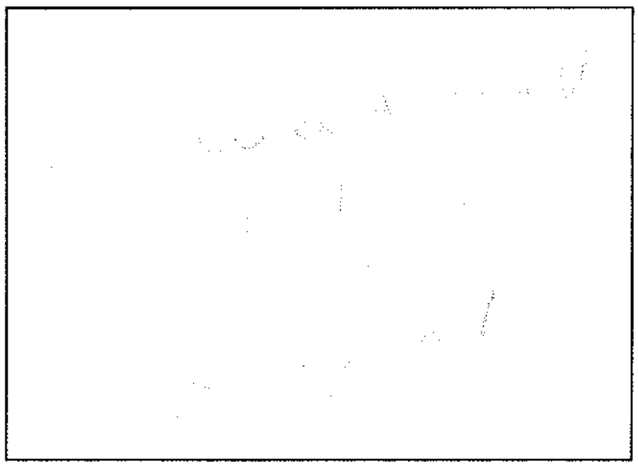

Figure 1.—*Forest ownership structure in Austria (source: Bundesministerium für Land- und Forstwirtschaft 1995).*

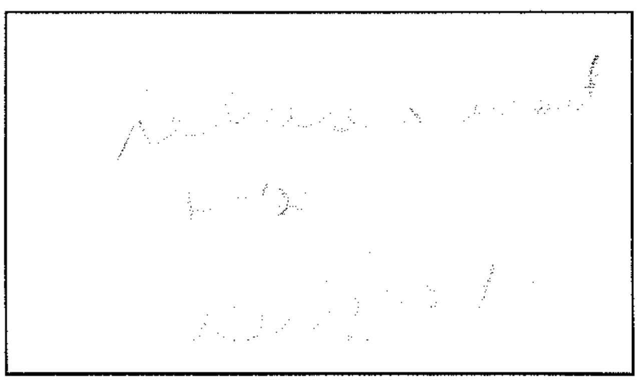

Figure 2.—*Sawmill structure in Austria (source: Fachverband der Sägeindustrie Österreichs 1997).*

Professor and Research Assistant, Institute for Forest Growth and Yield, Universität für Bodenkultur Wien, Peter Jordanstraße 82, A-1190 Vienna, Austria; and Federal Forest Research Center, Seckendorff-Gudent-Weg 8, A-1131 Vienna, Austria, respectively.

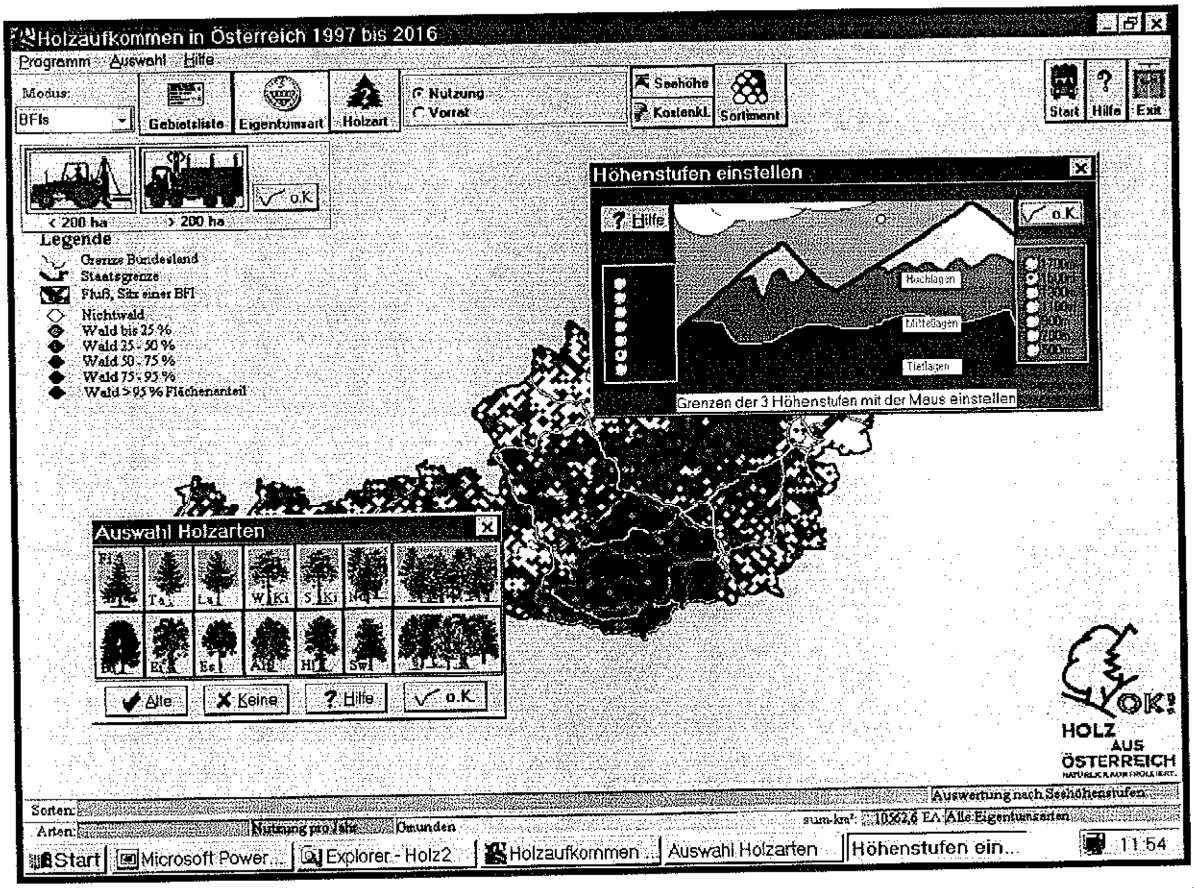

Figure 3.—*Interactive selection of regions, tree species, ownership classes, and other categories for timber harvest forecasts with PROGNAUS.*

DATA

To mimic the behavior of Austrian forest owners, a harvesting model was built, based on the data of the Austrian National Forest Inventory (ANF) from two observation periods, 1981-1985 and 1986-1990. This inventory is a permanent sample over the whole of Austria. The sample plots are clustered at the four corners of a 200- × 200-m square. The clusters themselves are systematically distributed over Austria at a distance of 3.89 km apart. In any given year, every fifth cluster is measured, ensuring a representative sample of all Austrian forests each year. The total inventory comprises 5,500 clusters, consisting of 22,000 sample plots. The center of each plot was marked by a hidden iron stake buried underground. Trees with a diameter at breast height (dbh) larger than 10.4 cm were selected by angle count sampling (Bitterlich 1948) with a basal area factor of 4 m^2 ha^{-1}. Trees with dbh between 5 cm and 10.4 cm were measured only within a circle of 2.6 m radius. Each sample tree was recorded by its polar coordinates and marked by a nail at the base of the tree. These plots were remeasured in five overlapping 5-year intervals, thus covering the period from 1981 to 1990. For the objective of this paper, i.e., the evaluation of the harvest model, data from the second remeasurement of the plots in 1992 to 1996 were used.

THE MODELS

From the first remeasurement of the forest inventory, an individual tree growth simulator of the FVS type, PROGNAUS, (Monserud *et al.* 1997) was built, consisting of a basal area growth model (Monserud and Sterba 1996), a height growth model (Knieling 1994), a crown ratio model (Hasenauer and Monserud 1996) and a mortality model (Monserud and Sterba 1999). To develop software to forecast timber harvests, Moser (1996) added a harvest model, simulating the behavior of forest owners in harvesting trees in their forests. Since all the above-mentioned models were developed for a 5-year period (according to the database) and the forecasts had to be made for 20 years, some additional models, such as to establish ingrowth and to describe the change of the forest development type (youth, thicket, pole stage, mature, uneven-aged), were built to update the data after each 5-year forecast.

For the harvest model at the plot level, a stochastic approach was used, distinguishing between four kinds of harvests:

1. regular final harvests,
   1.1 clearcuts (defined by the ANF as removing all trees on an area larger than 500 m^2)
   1.2 single-tree harvests
2. regular intermediate thinnings, and
3. salvage cuts, i.e., harvests needed because of damage from snow, windthrows, insects, or fungi.

The probability of any of the above harvests taking place on a given inventory plot was depicted by a LOGIT-function of the general form

$$P(harvest) = LOGIT(X) = \frac{1}{1+e^{b^T X}}$$

with X the vector of independent variables and b the associated coefficients. The CATMOD-procedure (SAS Institute 1987) was used to estimate the parameters of the logistic equation using maximum likelihood methods. In detail, there were four such equations, building a system in which only the underlined (fig. 4) probabilities (regular harvest, final harvest, salvage cut, and clear cut) need to be distinguished:

(1) Equation to determine the probability for any regular harvest on a plot,

$$P(\text{regular harvest}) = LOGIT(dg, h_L, BA, CV, ELEV, PF, HC1, HC2, DIST, PROV1, CON, MIX)$$

with dg, the dbh of the mean basal area stem, h_L, Lorey's mean height, BA, basal area per hectare, CV, the coefficient of variation of the dbh distribution, and $ELEV$, the elevation. All the other parameters are dummy variables (Draper and Smith 1981): PF equals 1, if the plot is situated in a protection forest, $HC1$ is equal to 1 if the slope is less than 30 percent, $HC2$ is 1 if the surface at the plot was classified as difficult for harvesting operations (through soil groups), $DIST$ is 1 if the distance to the next rack or forest road is less than 100 m, $PROV1$ is 1 in the province of Tyrol, CON is 1 if the proportion of conifers (by basal area) is larger than 25 percent, and MIX is 1 if the proportion of conifers is between 25 and 75 percent, all otherwise 0.

(2) Equation for salvage cuts, conditioned on no regular harvest

$$P(\text{salvage} \mid \neg\text{regular harvest}) = LOGIT(dg, h_L, BA, CV, OW, HC1, PROV1, PROV2, CON)$$

where OW is 1 if the plot is situated in a forest ownership of less than 200 ha, $PROV2$ is 1 in the province of Salzburg, and the other variables are as given above.

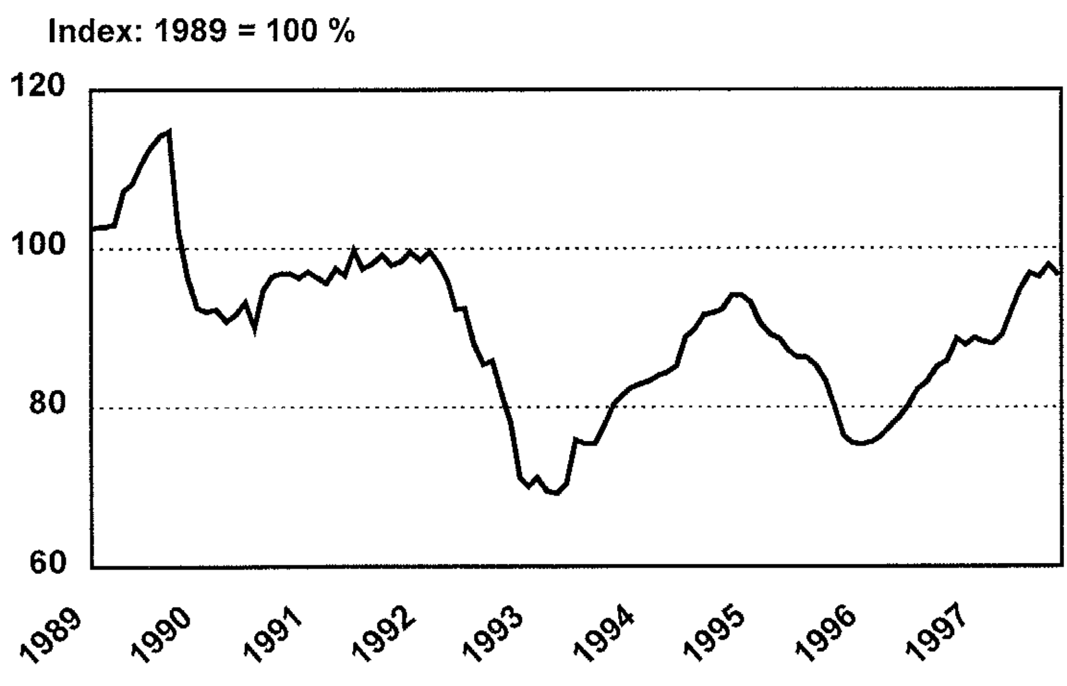

Figure 4.—*Decision tree for simulating harvest at the plot level.*

(3) Equation for final harvest, conditioned on regular harvest

$$P(final \mid regular) = LOGIT(dg,\ h_L,\ BA,\ CV,\ OW,\ PF,\ CON)$$

(4) Equation for clearcuts, conditioned on final harvest

$$P(clear\_cut \mid final) = LOGIT(dg,\ BA,\ ELEV,\ PF)$$

The forecasts, finally made available on a CD, were the results of 500 runs for each period; by random numbers in comparison with the calculated appropriate probability, it was decided which, if any, category of harvest was to take place at the plot level.

After this, harvest at the tree level was simulated by the following procedure. Each sample tree on the plot was related to one of five dbh classes, each comprising about the same number of trees per hectare. Thus, for each tree, the relative dbh was defined as

$$d_{rel} = \frac{dbh - dg}{s_{dbh}}$$

with s_{dbh} the standard deviation of the dbh on a plot.

The allocation of a sample tree into one of the five dbh classes followed the assumption of normal distribution of basal area over dbh; thus, the 20th, 40th, 60th, and 80th percentiles of the normal distribution were the breakpoints for the five dbh classes.

Tables for average basal area removal percentage in these dbh classes were calculated for a total of 60 strata, built according to species groups, elevation classes, groups of provinces, and harvesting categories. The examples (table 1) demonstrate how the removals differed between harvest categories and species. In the clearcuts, nearly all trees in all dbh classes were removed; some shelterwood trees were left, but not concentrated in a certain dbh class. To also retain seed trees of beech (*Fagus silvatica, L.*), the removals of beech on clearcuts were somewhat less than those of Norway spruce (*Picea abies L.* Karst.), except in the smallest dbh class. In the intermediate thinning, the removals clearly decreased with increasing dbh and again were less intensive in beech compared with spruce. In spruce, final single-tree harvests seemed to increase with increasing dbh (target diameter harvest according to Reininger 1989), while in beech, single-tree harvests as well as salvage cuts were about uniformly distributed over the dbh classes. Salvage cuts in spruce were concentrated around the average dbh.

In the final tree-harvest model, the basal area, represented by every tree in the plot, was reduced by the percentages given in the appropriate table.

EVALUATION OF THE HARVEST MODEL

The actual harvest was calculated from the repeated forest inventory of 1992-1996, so the plots last measured in 1986 were measured again in 1992, those measured in 1987 in 1993, and so on. Because this inventory period covered 6 years, while the simulator PROGNAUS was built for 5-year periods, the harvests reported by the inventory had to be multiplied by 5/6 to compare with the forecasts of PROGNAUS.

The various comparisons were made twice, first for the whole of Austria, and second—as the example chosen—for a region that could have been selected by a sawmill situated in eastern Carinthia and wanting to know the

Table 1.—*Example for the harvesting model at the tree level. Norway spruce and common beech in one of the 60 site strata. Percent basal area removal in five relative dbh classes with approximately equal initial tree numbers is given by harvesting categories.*

		Relative dbh-class				
Species	**Harvest category**	**1**	**2**	**3**	**4**	**5**
Norway spruce	Clearcut	72.4	100.0	72.6	86.3	77.6
	Single tree selection	22.4	23.9	18.7	32.5	33.0
	Intermediate thinning	60.2	40.1	27.8	18.0	7.9
	Salvage cut	20.2	30.1	38.8	12.7	9.8
Common beech	Clearcut	92.5	62.2	60.2	77.5	75.2
	Single tree selection	32.4	23.0	22.1	18.5	20.2
	Intermediate thinning	39.9	33.0	19.7	9.4	10.0
	Salvage cut	28.0	20.0	28.1	19.2	30.0

probable timber yield within a circle of approximately 60 km around the sawmill. Compared with the Austrian average, the average elevation of this region is somewhat higher, there are more spruce and fewer broadleaves, protection forests are less, and small forest ownerships are even more frequent in this region (table 2).

Table 2.—*Characteristics of the selected region in comparison with the average of Austria*

	Austria	Selected region
Elevation [m]	905	1,062
Protection forest area [%]	7.4	5.1
Small forest ownership area [%]	53	70
Norway spruce volume [%]	61	72
Broadleaf tree volume [%]	16	9

For both areas, Austria and the selected region, harvests will be compared in terms of fellings in m^3. In the future, the proportions of total harvested volume with respect to management types (protection forest, commercial forests), elevation, harvest categories (intermediate thinning, single-tree selection, final clearcuts), dbh classes, and tree species will be compared. Because of the large number of plots and sample trees, practically any deviation from the forecasts is expected to be significant. Of interest is not the statistical significance, but rather the magnitude of the deviations of predicted volume proportions by categories. Therefore, a simple distance measure (Dirk 1995) for this deviation was defined as

$$\text{Distance}\,[\%] = \sum_{Categories} | f\%_{observed} - f\%_{PROGNAUS} |$$

with $f\%$ the observed and predicted proportion of harvested volume in the given category, and Distance% covering a range between 0 (no deviation, full fit) and 200 percent (maximum deviation).

RESULTS

For the whole of Austria, the total actual timber harvest was about 10 percent smaller than predicted, while for the selected region, the difference was not so large. Nevertheless, in both reference areas, harvests in the small ownerships were distinctly overestimated (table 3). This overestimation is one more reason to later compare relative volume proportions by categories rather than absolute volume in m^3. The distances between the distribution of volume to categories are given in table 4.

Table 3.—*Fellings by ownerships and harvest categories as observed by the Austrian Forest Inventory (ANF92/96) and predicted by PROGNAUS in 1,000 m^3 o.b. Δ% is the overestimation or underestimation of the actual harvests by the model (in percent).*

Harvest category	Size of ownership	Austria			Selected region		
		ANF 92/96	PROGNAUS	Δ%	ANF 92/96	PROGNAUS	Δ%
Regular harvest	< 200 ha	8,425	10,031	+19	2,105	2,215	+5
	> 200 ha	7,559	7,559	+4	910	860	-6
	Σ	15,984	17,871	+12	3,015	3,075	+2
Salvage cuts	< 200 ha	935	687	-26	191	149	-22
	> 200 ha	1,007	1,362	+35	105	124	+18
	Σ	1,941	2,050	+6	296	273	-8
Σ	< 200 ha	9,360	10,718	+14	2,296	2,364	+3
	> 200 ha	8,566	9,202	+7	1,015	984	-3
	Σ	17,926	19,920	+11	3,311	3,348	+1

Table 4.—*Distance (%) between harvest volume distributions*

Grouping		Austria		Selected region	
		Regular harvest	Salvage cut	Regular harvest	Salvage cut
Elevation		7.28	41.17	9.47	39.94
Management type		0.90	3.40	0.98	2.52
Harvest category		10.71	-	11.56	-
Dbh-class		7.26	13.33	8.75	25.98
Tree species within	intermediate thinning	10.88	-	8.19	-
	single tree selection	12.88	-	21.45	-
	clearcut	9.60	-	5.18	-
	total	6.40	10.89	8.77	7.65

Obviously, and not unexpectedly, the predictions were somewhat worse for the salvage cuts and in the selected, and thus smaller, region. To illustrate the magnitude of the deviations between predicted and observed volume distributions, table 5 depicts the respective dbh distribution. For the whole of Austria as well as for the selected region, the regular harvest—dbh distribution was quite well predicted by PROGNAUS, whereas for salvage cuts, the harvests in smaller dbh classes seem to have been underestimated. This shift to smaller dbh classes was even stronger for the selected region than for all over Austria.

Given that distances above 10 indicate some important deviations from the predicted distribution, the distribution of salvage cuts to elevation classes (table 6), the distribution of regular harvests to harvest categories (intermediate thinning, final single-tree selection and clearcuts, table 7), and species distribution, especially in single-tree selections (table 8), exhibited interesting deviations from the model.

DISCUSSION

Total Harvest

The first and most important result to discuss is the overestimation of the total harvests. Nearly all of these 2 million m³ overestimates are located in regular harvests of small forest ownerships (table 3). Severe storm damages in forests, only partly in Austria but mainly in the neighboring German (Bavarian) forests in 1990, were followed

Table 5.—*Harvested volume distribution by dbh classes (percent of volume) as observed (ANF 92/96) and predicted (PROGNAUS)*

			Dbh [cm]							
			< 10	15	25	35	45	55	65	>70
Austria	Regular harvest	ANF 92/96	4.1	14.6	21.2	24.7	18.9	11.0	3.6	2.0
		PROGNAUS	3.1	13.4	23.2	25.9	18.6	10.0	3.6	2.3
	Salvage cuts	ANF 92/96	2.3	12.7	23.1	26.1	19.6	9.3	4.1	2.9
		PROGNAUS	1.7	9.4	20.6	27.8	21.2	11.9	4.5	3.0
Selected region	Regular harvest	ANF 92/96	3.9	14.3	22.8	24.3	18.4	11.5	3.1	1.9
		PROGNAUS	3.0	13.6	24.1	27.3	17.7	9.7	2.9	1.8
	Salvage cuts	ANF 92/96	4.3	18.1	25.5	23.9	10.4	11.9	3.1	2.9
		PROGNAUS	2.1	12.0	23.5	27.8	18.5	10.2	3.5	2.3

Table 6.—*Harvested volume distribution by elevation classes (percent of volume) as observed (ANF 92/96) and predicted (PROGNAUS)*

			Elevation [m]						
			< 500	600	800	1,000	1,200	1,400	>1,500
Austria	Regular harvest	ANF 92/96	23.8	17.6	17.7	13.4	12.5	9.3	5.8
		PROGNAUS	22.2	18.2	16.6	14.0	14.2	9.0	5.9
	Salvage cuts	ANF 92/96	22.2	15.9	22.6	10.5	13.5	11.2	4.3
		PROGNAUS	10.2	13.3	16.6	17.5	17.7	11.6	13.1
Selected region	Regular harvest	ANF 92/96	5.9	15.3	15.7	18.3	19.0	16.0	9.8
		PROGNAUS	7.2	16.6	15.1	19.0	20.0	16.1	6.0
	Salvage cuts	ANF 92/96	12.8	4.7	18.8	24.4	15.6	21.6	2.1
		PROGNAUS	5.1	12.7	14.6	19.2	20.9	18.8	8.8

Table 7.—*Distribution of observed (ANF 92/96) and predicted (PROGNAUS) harvested volume by harvesting categories. Values given are percent of harvested volume. Intermediate thinning, single-tree selection and clearcuts are related to regular harvests, while salvage cuts are related to total harvests.*

	Austria		Selected region	
Harvesting category	**ANF 92/96**	**PROGNAUS**	**ANF 92/96**	**PROGNAUS**
Intermediate thinning	16.9	12.3	17.3	13.6
Single-tree selection	35.5	35.6	31.6	37.2
Clearcut	36.8	41.8	42.1	41.1
Salvage cuts	10.8	10.3	8.9	8.2

Table 8.—*Distribution of observed (ANF 92/96) and predicted (PROGNAUS) harvested volume by species in percent of final single-tree selections*

	Austria		Selected region	
Species	**ANF 92/96**	**PROGNAUS**	**ANF 92/96**	**PROGNAUS**
Norway spruce (*Picea abies* L.)	58.2	59.8	64.8	72.1
White fir (*Abies alba* L.)	6.7	5.4	2.4	2.3
European larch (*Larix europaea* L.)	4.8	4.4	9.9	7.5
Scots pine (*Pinus silvestris* L.)	12.1	8.3	12.5	7.2
Common beech (*Fagus silvatica* L.)	6.9	8.8	1.1	4.3
Oak (*Quercus* sp.)	3.7	2.8	1.4	0.6
Other deciduous	7.1	9.8	7.9	5.8

by a bark beetle outbreak that lasted until about 1996 (Forstliche Bundesversuchsanstalt 1996). Partly for this reason and partly because of low world market sawnwood prices, the timber prices decreased seriously and have not yet fully recovered (fig. 5). Among the forest owners, only those with small land holdings, who do not really depend on the income from forestry, are able to react to such fluctuations of timber market prices (Schwarzbauer 1997). So, the storm damages of 1990, together with the following timber market situation, seem to have led small forest owners to decrease their harvests.

Distribution by Different Categories

As indicated by the average distances (table 4), the relative distribution of harvested volume to most of the different categories was predicted quite well by PROGNAUS. Those less well predicted are discussed in the following sections.

Salvage Cuts by Elevation and Dbh Classes

The bark beetle outbreak may again be the reason why salvage cuts shifted to lower elevations (table 6) to smaller dbh classes than expected from the inventory period 1981-1990 and thus the model. Due to the biology of *Ips typographus* and *Ips chalcographus*, forests in lower elevations and smaller trees there are more susceptible to bark beetle attacks. Since by Austrian law, dead trees have to be removed from the forest, the concentration of salvage cuts in these strata after 1990 may be explained by this effect.

Harvesting Categories

Although the proportion of salvage cuts was predicted quite well (table 7), the observed distribution between intermediate thinning, final single-tree selection, and clearcuts within the regular harvests deviated markedly from the PROGNAUS predictions. In the whole of Austria as well as in the selected region, a shift from final harvesting to thinnings seems evident. This means that the decrease in total harvests, compared with PROGNAUS (table 3) and probably caused by decreasing timber prices, concerns final harvests more than thinnings, which are seen more under the aspect of tending and investment in future stand quality. Final single-tree selection is the preferred harvesting method in smaller forest ownerships. That's why in the region with the higher proportion of small ownerships, the decrease in final harvests is charged to single-tree selection, while in Austria, on average, there are fewer clearcuts—both in favor of intermediate thinnings.

Tree Species in Final Single-Tree Selection

One reason for harvesting single trees in old stands is the fact that due to the central European debate on forest

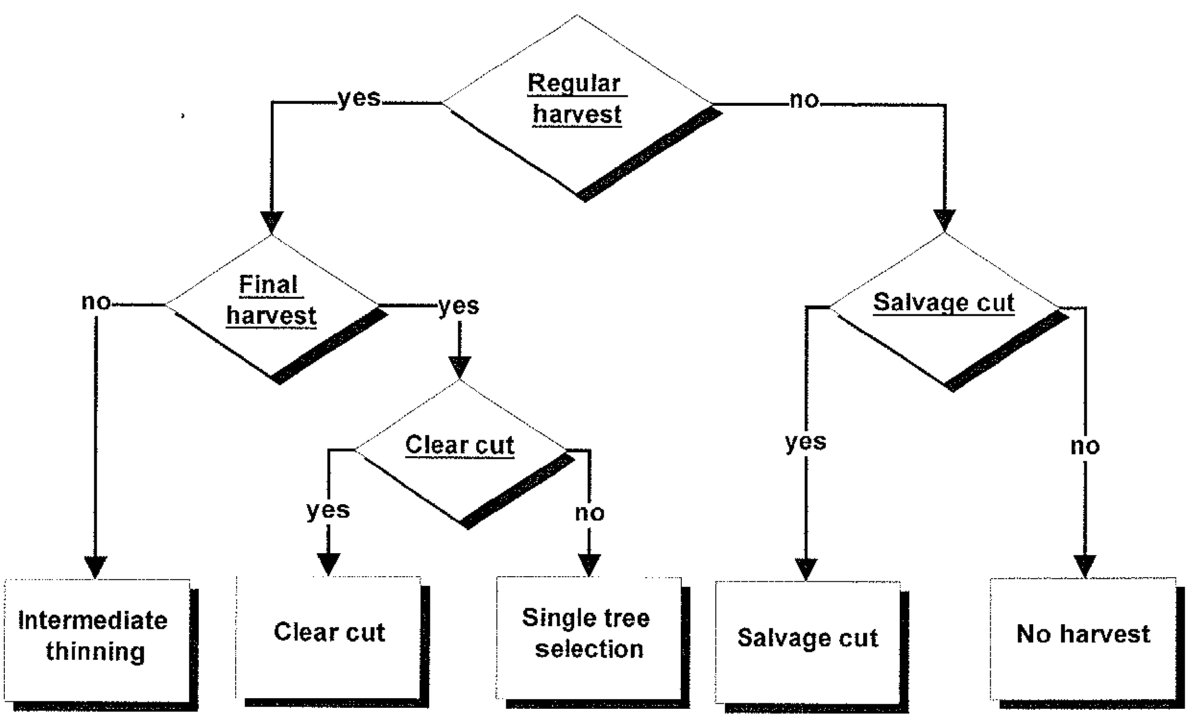

Figure 5.—*Conifer roundwood price development (1988=100%) from Fachverband der Sägeindustrie Österreichs (1997).*

dieback, single trees that by their crown condition seem to indicate poor vigor and probably approaching death are harvested as long as they still live, in the course of "regular" harvesting. If they had already died, they would have been counted as "salvage cuts" in the forest inventory. From the monitoring of crown conditions in Austria, we know that white fir, Scots pine, and oaks are the species with the worst crown conditions over the years (Kristöfel and Neumann 1997). Although the vigor of white fir has improved significantly since 1990, average needle losses of Scots pine and oak have varied strongly, with peaks in 1992 and 1994 (Kristöfel and Neumann 1997). Therefore these species might have been removed more frequently during these periods than predicted by PROGNAUS.

CONCLUSIONS

In general, we conclude that our harvesting model worked quite well. Nevertheless, larger catastrophic events (e.g., windthrows, bark beetle outbreaks, serious changes in crown conditions as a measure of tree vigor) and economic developments cannot be foreseen by PROGNAUS. Including market figures such as roundwood prices in the model, as well as individual tree crown condition, will not be able to improve predictions as long as they themselves cannot be predicted. However, they would enable the model to be used for projections under different scenarios of timber market and "forest dieback" and thus help answer "what-if" questions.

ACKNOWLEDGMENT

The authors want to thank the Association of the Austrian Sawmilling Industries for promoting and sponsoring this work; the Austrian Ministry of Agriculture and Forestry and the Federal Forest Research Center in Vienna, for making the data of the ANF available; and last, but not least, Karl Schieler, head of the ANF, and Peter Schwarzbauer, Professor for Forest Products Market Research at the Universität für Bodenkultur Wien, for valuable review comments.

LITERATURE CITED

Bitterlich, W. 1948. Die Winkelzählprobe. Allg. Forst- u. Holzwirtsch. Zeitung Wien. 59: 4-5.

Bundesministerium für Land- und Forstwirtschaft 1995. Österreichischer Waldbericht 1994. Bundesministerium für Land- und Forstwirtschaft Wien. 266 p.

Dirk W. 1995. Funktionalanalysis. Berlin: Springer Verlag. 446 p.

Draper, N.R.; Smith, H. 1981. Applied regression analysis. 2d ed. New York: John Wiley and Sons. 709 p.

Fachverband der Sägeindustrie Österreichs 1997. Jahresbericht 1997. Informationen des Fachverbandes der Sägeindustrie. (5): 6.

Forstliche Bundesversuchsanstalt 1996. Borkenkäferschäden in Österreich. Forstschutz Aktuell. 17/18: 3-4.

Hasenauer, H.; Monserud, R.A. 1996. A crown ratio model for Austrian forests. Forest Ecology and Management. 84: 49-60.

Knieling, A. 1994. Methodische Beiträge zur Auswertung der Österreichischen Forstinventur nach 1980. Wien: Universität für Bodenkultur. 129 p. Ph.D. thesis.

Kristöfel, F.; Neumann, M. 1997. Ergebnisse der Kronenzustandserhebungen 1996. Österr. Forstzeitung. 107(3): 39-40.

Monserud, R.A.; Sterba, H.; Hasenauer, H. 1997. PROGNAUS. In: Teck, R.; Moer, M.; Adams, J. Proceedings: Forest vegetation simulator conference; 1997 February 3-7; Fort Collins, CO. Gen. Tech. Rep. INT-373. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 50-56.

Monserud, R.A.; Sterba, H. 1996. A basal area increment model for even- and uneven-aged forest stands in Austria. Forest Ecology and Management. 80: 57-80.

Monserud, R.A.; Sterba, H. 1999. Modeling individual tree mortality for Austrian forest species. Forest Ecology and Management. 113(2-3): 109-123.

Moser, M. 1996. PROGNAUS – Simulation des Holzaufkommens für Österreich. Unpublished program description.

Reininger H. 1989. Zielstärken-Nutzung. 3d ed. Wien: Österr. Agrarverlag. 163 p.

SAS Institute. 1987. SAS/STAT Guide for personal computers, Version 6 Edition. Cary, NC. 1028 p.

Schwarzbauer, P. 1997. Demand and supply analysis of roundwood and forest products markets in Europe. EFI Proceedings 17: 7-44.