Updating Stand Level Inventory Data Applying Growth Models and Visual Interpretation of Aerial Photographs

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In this study two procedures for updating stand level inventory data were developed and tested. The development of the growing stock of 62 stands over 12 years was simulated in the MELA stand simulator with no prior information of rapid changes, such as clear-cuttings. The acceptability of the simulation was decided standwise with visual interpretation of aerial false-colour photographs. If the simulated data were not accepted, new stand attributes were assessed with photo interpretation in procedure 1. In procedure 2, on the other hand, it was possible to utilise old management proposals. In case a cutting or other operation had been proposed and it looked like the operation had been realised, the interpreters accepted the proposal. Otherwise the last implemented operation and implementation year were interpreted. In case no operation had been carried out during the updating period but the growth model updated data were not acceptable, the same stand characteristics were estimated as in procedure 1. Stands where a proposal had been accepted or an operation interpreted were later updated again in MELA so that the program simulated the operations. The Root Mean Squared Errors of stem volume were 62 and 57 m^3 per ha (34 and 30%) with procedures 1 and 2. With procedure 2 the accuracy of updating was comparable with a stand level field inventory carried out in the study area. The productivity of the photo interpretation procedures was 57 and 84 ha per h, respectively, whereas the productivity of a field inventory has been 3.3–5 ha per h.

List of Symbols

Stand development classes:
T1 = seedling stand
T2 = sapling stand
Y1 = hold-over stand
02 = young stand
03 = middle-aged stand
04 = mature stand

T = age of basal area median diameter tree (a)
D = basal area median diameter (cm)
H = height of basal area median diameter tree (m)
G = basal area (m²ha⁻¹)
N = number of stems (ha⁻¹)
V = mean stem volume (m³ha⁻¹)
$\hat{y}_i$ = estimate of stand attribute in stand i
y_i = true value of stand attribute in stand i
n = number of stands
$s_{\bar{y}}$ = standard error of the mean of stand attribute y
s_y = standard deviation of stand attribute in a stand
m = number of sample plots in stand

1 Introduction

In Finland, privately owned forests cover 60% of the total forested land. The forest management plans for these are based on standwise field inventories. In 1999, 800 000 ha of the privately owned forests were surveyed by Forestry Centres using the so-called Solmu system (Forestry Development Centre Tapio).

In Solmu, stand boundaries are delineated on aerial photographs before carrying out field inventories. The delineation is checked in the field and the stand's basic data (e.g. site description) and information on its growing stock, dead wood, cutting and silvicultural management proposals, biological diversity and other special features are collected on paper forms or in a datalogger (Solmu. Metsäsuunnittelun maastotyöopas 1997). Stand characteristics are estimated subjectively with the aid of some measurements. Each tree species and crown layer of growing stock are described by mean age, mean diameter, mean height, basal area or number of stems, and proportion of saw log. Stem volume and other missing attributes are predicted later with models. In this kind of field inventory the accuracy of stand attributes is dependent on the surveyor. Standard errors for stem volume have been reported to be 14–38% (Table 1).

In 1999 the fieldwork carried out by the Forestry Centres amounted to 20–30 ha per day (Forestry Development Centre Tapio). The total cost of the inventories was 90–120 FIM per ha (i.e. 15.14–20.18 EUR per ha), 61% of which derived from fieldwork. Consequently, there is a strong pressure towards looking for more cost-efficient methods to replace traditional field inventories.

The basic alternatives are

1) Remote sensing, using aerial photographs and other images from airborne and satellite-borne sensors (video camera, imaging spectrometer, profiling radar, laser scanner and optical and radar satellites, to mention a few)
2) Updating former inventory data by simulating the development of a stand
3) A combination of the above.

The combination of aerial photographs and updating former inventory data seems especially attractive, because aerial photos must be purchased for the delineation of stand boundaries and for 70% of the privately owned forest land old inventory data already exists (Forestry Development Centre Tapio).

Research on stand level inventories from aerial photographs has a long tradition in Finland. Nyyssönen (1955), Nyyssönen and Poso (1962), Nyyssönen et al. (1968), Poso (1983) and Pussinen (1992) all carried out visual interpretations of stand attributes from stereo-pairs. The standard errors in volume estimation varied from 28–54% (Table 1). Elsewhere analytical stereoplotters have been utilised in photo-measurements (Åge 1983, Spencer and Hall 1988, Biggs and Spencer 1990, Eid and Næsset 1998). Eid and Næsset (1998) noted that standard errors in volume estimation in practical photo-inventories varied between 10.5–33.6%.

Forestry Centres are using the MELA stand simulator (Siitonen et al. 1996) for simulating stand development for forestry plans, but have not made effective use of the old inventory data, for example by updating it with the MELA simula-

Table 1. Standard errors of stand attributes in previous studies. a) Poso (1983), b) Laasasenaho and Päivinen (1986), c) Pussinen (1992), d) Ståhl (1992), e) Hyyppä et al. (2000), f) Nyyssönen (1955), g) Nyyssönen and Poso (1962), h) Nyyssönen et al. (1968).

	Study	T a	T %	D cm	D %	H m	H %	G m²ha⁻¹	G %	V m³ha⁻¹	V %
Standwise field inventory	a)	12–21	18–29							36–66	29–38
	b)	12–18	15–27	2.2	10	2–3	11–17	3–4	16–21	29–37	15–24
	c)	8	14			2	11	3	13	30	16
	d)										14
	e)					2		3.7		41	26
Aerial photo interpretation	f)										28
	g)									18	46
	h)										33
	a)	24	34							74	54
	c)	15	37	4.3	39	3.3	27	4.6	19	47	42
	d)										14

tor. In MELA, stand development is predicted with mortality, birth and treewise growth models and different management operations can be simulated to stands. However, simulating models include four kinds of uncertainties: the models may be incorrectly specified; there may be random error in the model coefficients; there may be variation not explained by the models; and the initial data may contain errors (Kangas and Kangas 1999). Ojansuu et al. (1991) compared simulation results with measured changes in independent field data. The root mean squared error of volume increment in the mineral soils of Pohjois-Savo was 7.9 m³ha⁻¹(5a)⁻¹. The birth model predicted too many seedlings in natural regeneration.

The old inventory data in the Forestry Centres is mainly in TASO format, which is the planning system used before Solmu (TASO. Maastotyöopas 1993). As for Solmu, the inventory data were collected through standwise field inventories. With respect to inventories, the biggest difference between these systems is the briefer description of the growing stock in TASO, i.e. the mean age, mean diameter, mean height, basal area and distribution of volume by tree species were estimated from the whole stand. Furthermore, sometimes only age, mean volume and distribution of volume by tree species were recorded. Before TASO data can be updated they have to be transferred into the Solmu system and the

initial data for MELA is then formed from the Solmu data.

TASO inventory data are transferred into the Solmu system as follows (Xforest PC – Käyttöohje 1999): mean age, diameter and height of the stand are attached to each tree species. For each tree species, the stand's basal area or number of stems is divided according to the distribution of volume by tree species. Should a mean height be missing, it is predicted as a function of mean age and heat summation. Next, mean height, age and heat summation are used as predictors of a missing mean diameter. If neither basal area nor number of stems has been estimated in the field, basal area is predicted as a function of mean volume, stem form, mean height and the distribution of volume.

To form the initial data for MELA a theoretical diameter distribution (or height distribution in seedling stands) is predicted for each tree species and crown layer in a stand (Mykkänen 1986, Kilkki et al. 1989). For each diameter class a tree is selected as a representative tree, which stands for one or more trees in the stand. Its height is predicted with the models of Veltheim (1987); the mean age of the respective tree species and crown layer is used as the age of all trees in that group.

When updating the old inventory data logging and silvicultural operations must be taken into account; failing to do so causes serious errors
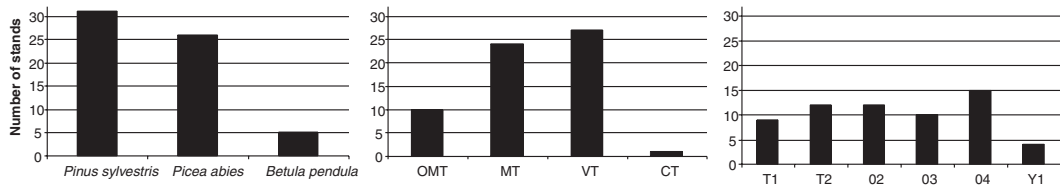
Fig. 1. Number of field checked stands by primary tree species, site type and development class.

in the stand attribute data. Yet Forestry Centres do not have standwise information on operations that have been carried out after the previous field inventory. Rapid changes (such as clear-cuttings) can be detected even with automatic methods from multitemporal aerial or satellite images (Hyppänen 1999, Varjo 1997). Another way to control the effect of rapid changes on the simulations – and thus also avoid errors – would be to visually compare simulated stand attributes with aerial photographs.

The aim of this study was to examine the reliability and time consumption of updating stand level inventory data with a stand simulator and visual aerial photo interpretation. Two updating procedures were developed and tested. In both procedures old stand data were updated with a stand simulator and the acceptability of the updated data was checked visually with aerial photographs. If the updated data were not accepted, new stand attributes were assessed with photo interpretation.

2 Material

The study area is situated in Suonenjoki in eastern Finland (62°40'N, 27°06'E). In 1987, using the TASO system, two forest engineers carried out a stand level field survey, which was applied here as a base for updating. The study area was inventoried again in 1999, now following the Solmu procedure. This time one forest engineer surveyed the whole study area.

After the Solmu inventory, 66 randomly sampled stands were field checked by placing 5–9 sample plots systematically in each stand. The sample plot radius was 3.99–20 m, depending on which development class the stand fell into.

Four stands had to be excluded because between taking the aerial photographs and the field check the seed trees had been removed. With the exception of one stand, which was on spruce mire, all checked stands were situated on forest land and mineral soils. The stands cover the most common tree species, site types and development classes (Fig. 1). The mean area of the stands was 3.1 ha. In younger stands (development classes T1, T2 and seedlings in Y1) the inventory followed the Solmu procedure, but in older stands (development classes 02, 03 and 04) every tree in a plot was measured.

Aerial false-colour photographs of the study area were taken on 26 September 1999. The scale of the photographs was 1:20 000. The negatives were digitised to a resolution of 0.5×0.5 m^2 and the images were saved in JPG-compressed TIF format.

3 Methods

3.1 Updating Inventory Data

The old TASO inventory data were converted into the Solmu system, from which the initial data for MELA were created. The development of the growing stock between 1987 and 1999 was simulated in the MELA96 stand simulator, where the growth of the representative trees taken from the diameter distribution is predicted with growth models of basal area and height (Ojansuu et al. 1991) and the volume of trees is predicted with stem curve models (Laasasenaho 1982). Finally, the mean age, mean diameter, mean height, basal area, number of stems and mean volume of each tree species were calculated and the stand attributes were taken into the Xforest geographi-

cal information system (Xforest PC – Käyttöohje 1999).

Aerial photo interpretation took place in the Xforest application. In Xforest, stand boundaries were displayed on the foreground and three scanned aerial orthophotos covering the study area on the background. The stand boundaries were predefined according to the Solmu inventory so that the stand characteristics could not be affected by any differences in the delineation of stands. Because stereo instruments were not used, tree heights could not be measured. Interpretation was thus solely through visual estimation with no measurements.

Twelve forestry engineers were divided into two groups that had different interpretation instructions. Care was taken to ensure that both groups were on an average equally skilled. Based on photo interpretation, the interpreters in both groups had to decide for each stand whether the simulated development of growing stock was acceptable or not (Figs. 2 and 3). If there had been a cutting or the stand's simulated data did not otherwise correspond to the view, the mean age, diameter, height and basal area or number of stems for each tree species was interpreted in procedure 1 (Fig. 2). In procedure 2, however, it was possible to utilise management proposals given in the field in 1987 (Fig. 3). If a cutting or other operation had been proposed and it looked like the operation had been realised, the interpreters accepted the proposal. Otherwise the last implemented operation and implementation year were interpreted. However, if no operation had been carried out during the updating period and the growth model updated data were nevertheless unacceptable, the same stand characteristics were estimated as in procedure 1. Stands where proposals had been accepted or operations interpreted were later updated again in MELA so that the program simulated the operations.

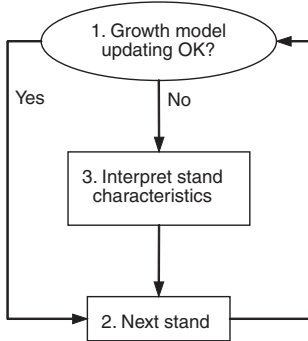On an average, the interpreters had over ten years' experience in delineating stands, but they

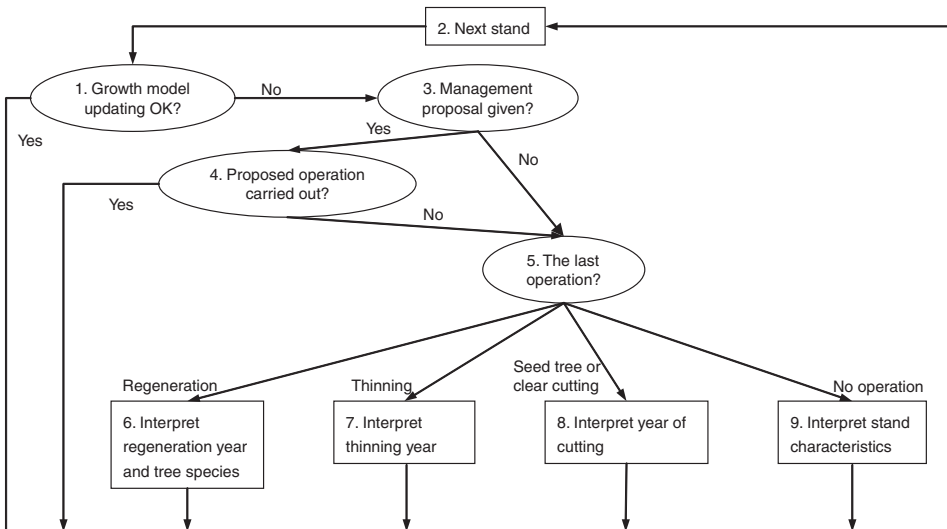**Fig. 2.** Photo interpretation in procedure 1.

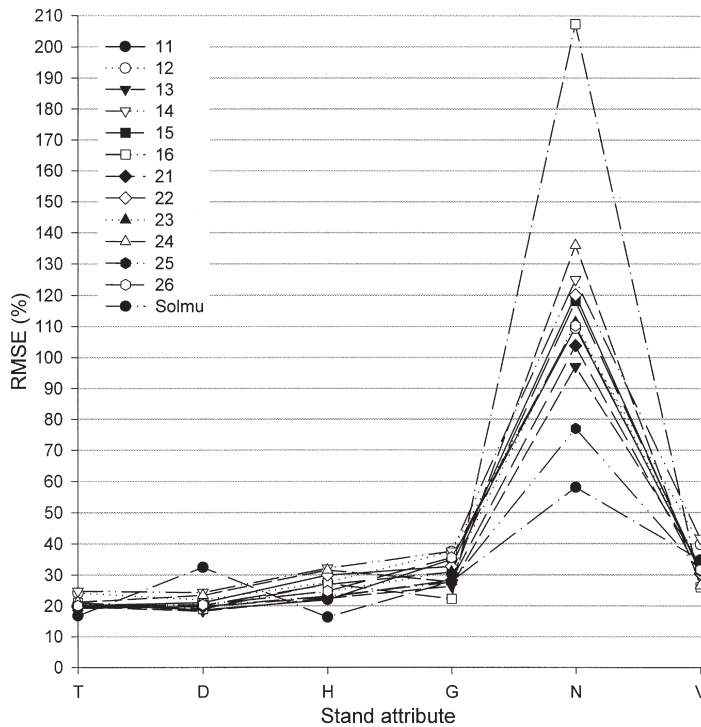**Fig. 3.** Photo interpretation in procedure 2.

Fig. 4. Relative RMSEs by stand attribute for all interpreters and field inventory (Solmu).

had not assessed stand attributes from aerial photos before. Both groups used half a day for training and half a day for the actual interpretation. The correct stand data of the training stands were given to support the actual interpretation.

3.2 Calculating Reliability and Productivity

The reliability of updating stand data was examined with respect to the following attributes: mean age, mean diameter, mean height, basal area, number of stems and stem volume. The reliability of stem number was calculated only for stand development classes T1, T2 and Y1 and the reliability of basal area and volume only for stand development classes 02, 03, 04 and Y1. If the simulated data did not correspond to the view and the stand characteristics had to be interpreted from the aerial photograph, the stem volume was nevertheless calculated in MELA. The accuracy of updating stand characteristics was measured

with Root Mean Square Error (1) and a systematic error with Bias (2). The relative RMSE and Bias were obtained by dividing their absolute value by the estimated mean of a characteristic and multiplying it by 100%.

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n-1}} \tag{1}$$

$$\text{Bias} = \frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)}{n} \tag{2}$$

For each interpreter a gross effective working time was recorded. This includes short delay times that would pertain to the interpretation process if it were in operational use. Longer delay times and break times, however, were excluded. The productivity of an interpreter was calculated by dividing the total area interpreted by the gross effective time.
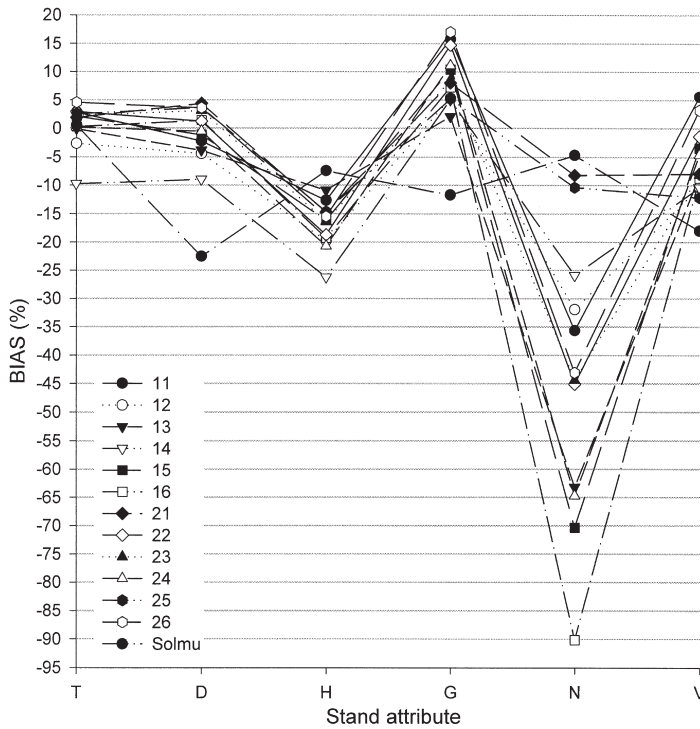
Fig. 5. Relative biases by stand attribute for all interpreters and field inventory (Solmu).

4 Results

The RMSEs and biases of each interpreter are presented in Figs 4 and 5, respectively. Since the interpreters' RMSEs – with two exceptions – were smaller than those found when updating the growth with MELA without taking any cuttings into consideration, visual interpretation improved updating. Age estimates of updatings were on average two years more inaccurate than the estimates given by the Solmu field inventory. On the other hand, there is as much as a 3.5 cm bias in the mean diameter in the field inventory and all estimates of updatings are more accurate than the estimates of the field inventory. The interpreters underestimated the mean height and overestimated the basal area, whereas the field inventory underestimated both. The number of stems has been heavily underestimated by almost all interpreters. Updated stem volumes seem to be comparable with those given by the field inventory. Procedure 2 was more accurate than procedure 1 in updating age, number of stems, mean height and volume.

In seedling and sapling stands the field inventory was much more accurate than updating procedures (Table 2). In older stands the updating of mean diameter and volume was somewhat more accurate than the field inventory (Table 3).

The results of the time study are presented in Table 4. All interpreters did the 66 field checked stands first and the fastest ones continued with the stands that had not been checked. The interpretation time per stand varied from 1 min 28 s to 4 min 5 s. The highest yield was over 110 ha per hour and the lowest about 47 ha per hour. On average the productivity of procedure 2 was 50% higher than the productivity of procedure 1. Fig. 6 illustrates the productivity of interpreters as a function of accuracy.

Table 2. Reliability of updating in younger stands (development classes T1 and T2).

	Attribute	RMSE	RMSE%	Bias	Bias%	Min	Max	Avg	n
Field	T	2.6	26.8	1.1	11.3	3.0	17.0	9.7	21
inventory	D	1.2	36.5	–0.1	–3.7	0.0	7.0	3.4	13
(Solmu)	H	0.9	35.3	0.1	3.8	0.3	6.0	2.5	21
	N	1241.1	42.9	–3.5	–0.1	1000.0	9000.0	2895.2	21
Group 1	T	4.7	59.0	–1.0	–12.2	0.0	18.0	8.0	112
	D	2.4	86.3	–0.9	–31.1	0.0	9.9	2.8	72
	H	1.8	95.2	–0.7	–40.5	0.0	7.3	1.8	112
	N	2196.8	103.0	–741.4	–34.8	0.0	10000.0	2133.5	112
Group 2	T	4.9	55.2	0.3	3.5	0.0	20.0	8.9	123
	D	2.2	122.2	–1.7	–96.0	0.0	5.7	1.8	75
	H	1.9	132.8	–1.0	–73.2	0.0	8.3	1.4	123
	N	2142.3	85.8	–416.5	–16.7	0.0	7800.0	2497.7	123

Table 3. Reliability of updating in older stands (development classes 02, 03 and 04).

	Attribute	RMSE	RMSE%	Bias	Bias%	Min	Max	Avg	n
Field	T	9.4	14.3	–0.6	–1.0	21.0	131.0	65.6	37
inventory	D	5.8	30.2	–4.8	–24.6	7.8	28.0	19.3	37
(Solmu)	H	2.6	14.2	–1.7	–9.5	8.9	24.7	18.1	37
	G	5.0	25.9	–1.9	–9.7	8.0	32.0	19.5	37
	V	57.7	32.8	–28.1	–15.9	44.3	322.4	176.2	37
Group 1	T	11.3	17.4	–1.1	–1.8	15.0	132.0	65.0	222
	D	4.2	17.6	–0.4	–1.8	4.7	36.0	23.6	222
	H	3.5	20.6	–2.7	–15.5	4.0	24.0	17.2	222
	G	5.8	26.0	1.1	5.0	4.0	35.4	22.5	222
	V	55.6	29.5	–15.6	–8.3	11.4	389.4	188.6	222
Group 2	T	10.5	15.7	0.8	1.2	20.0	132.0	67.0	222
	D	4.5	17.7	1.4	5.5	5.9	39.5	25.4	222
	H	3.3	18.9	–2.4	–13.8	4.1	25.8	17.4	222
	G	6.3	27.0	2.2	9.4	5.5	41.7	23.5	222
	V	53.2	27.7	–12.1	–6.3	17.0	335.6	192.2	222

5 Discussion

Two procedures for updating stand level inventory data were developed and tested. Any error in the estimates arises from the following sources: 1) field check, 2) the forming of initial data for the stand simulator, 3) old inventory data, 4) models in the stand simulator and 5) photo interpretation.

Stand attributes obtained from the field check were held as "true" values to which updated estimates were compared. However, a field check contains, for example, sampling, measuring and model errors. Sampling errors in the field check were calculated with the formula for random sampling:

$$s_{\bar{y}} = \frac{s_y}{\sqrt{m}} \tag{3}$$

For systematic sampling the estimator of random sampling usually gives overestimates. Lindgren (1984) has said that the standard error of systematic sampling is about 80% of the random sampling error. Taking this into account the sampling errors in young and mature stands were 4.1% for mean diameter, 2.7% for mean height, 7.5%

Table 4. Mean interpretation time per stand, productivity and total number of interpreted stands of each interpreter.

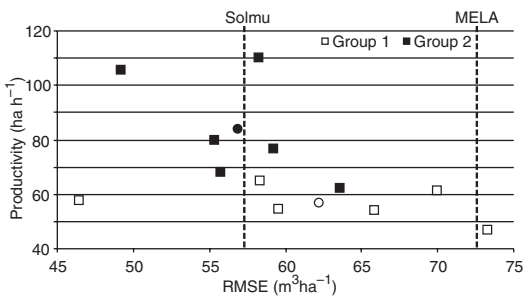|	Interpreter	Time / Stand (h:mm:ss)	Productivity (ha h^{-1})	n
Group 1	11	00:03:32	53.97	66
	12	00:02:59	61.42	72
	13	00:03:29	54.68	66
	14	00:04:05	46.58	66
	15	00:02:49	64.73	74
	16	00:03:18	57.69	66
	Average	00:03:22	56.51	68.3
Group 2	21	00:02:48	67.98	66
	22	00:01:28	110.22	120
	23	00:02:15	76.83	80
	24	00:01:30	105.60	134
	25	00:02:02	79.93	99
	26	00:03:05	61.95	66
	Average	00:02:11	83.75	94.2

Fig. 6. Productivity of interpreters as a function of accuracy of updating stem volume. The accuracy of standwise field inventory (Solmu) and growth model updating with no cuttings simulated (MELA) are marked with dashed lines. Dots are group mean values.

for basal area and 8.1% for volume. Supposing that sampling errors in the field check and variances of updatings are independent, the effect of the sampling error on the updating error is only 0.1–1.0 percentage units. In order to control measurement errors another person remeasured some sample plots. The measurement errors appeared to be consistent with the results of Päivinen et al. (1992). The model errors in calculating tree height and volume are also minor. Thus the effect of field check errors on the total error is low.

An earlier study carried out in the same area looked at the forming of the initial data for the stand simulator. The TASO data were generated for field checked stands, i.e. mean age, mean diameter, mean height, basal area and distribution of volume by tree species were calculated from treewise measurement data. No sampling, measurement or calculation errors were assumed. The initial data for MELA were formed from the generated TASO data. The RMSEs for the mean volumes of pine, spruce and deciduous strata were 11.4, 10.6 and 5.2 m^{3}ha^{-1}, respectively.

The accuracy of old inventory data affects the accuracy of updating with growth models as well as the accuracy of visual interpretation, because simulated stand attributes are used as the basis of the interpretation. Because the accuracy of the old TASO data is not known, error components 3)–5) remain largely unknown. Laasasenaho and Päivinen (1986) noticed that when the error was doubled during growth model updating, the volume also doubled. Consequently, the relative error of volume did not increase.

With 39 stands belonging to development classes 02–04 in the old inventory data, basal area was recorded for 9 and both mean diameter and mean height for 15 stands. Thus most of the advanced stands were described only by mean age, mean volume and tree species distribution, meaning that the error in forming the initial data for the stand simulator may be even higher than previously mentioned. However, the situation will become better in the future when the Solmu data can be used as a basis for updating.

Photo interpretation errors are due to errors in estimating stand attributes and errors in interpreting implemented operations. Because interpreters did not measure any characteristics from the image, attribute estimation was based largely on growth model updating and personal knowledge of dependencies of stand attributes. Measuring height would not have been possible at all from a single image and other attributes were also not directly measurable. Recent thinnings (carried out no more than about 5 years ago) are easily revealed from aerial photographs, but thinnings carried out at the beginning of the updating period are hardly distinguishable. Unfortunately, there was no information of realised cuttings in the updating period. Therefore how well the interpret-

ers really found the thinned stands could not be studied. To speed up the updating procedures, change detection could be done automatically from multitemporal aerial photos (Hyppänen 1999). In conclusion, of the error components the quality of old inventory data plays the greatest role on updating.

What is remarkable in Figs 4 and 5 is that the field inventory (Solmu) was not especially good compared to updating. Sometimes forest engineers intentionally underestimate volume (or basal area and mean height) to make sure the forest owner will not be disappointed at the time of cutting (Poso 1983). In this study a young forest engineer with little field experience carried out the Solmu inventory. Therefore it can be assumed that field work is usually more accurate than in this study (see also Table 1).

Table 1 lists some earlier studies on stand level field and aerial photo inventories. The standard error of mean age estimation in field inventory has been reported to be 14–29%. Compared to this the Solmu inventory was accurate and the updatings are also on the mean level. The age estimation in the old TASO inventory and the Solmu inventory were equally accurate. Interpreting age from aerial photographs without any previous inventory data is clearly more inaccurate (Table 1).

The updating of mean diameter was about twice as inaccurate as in the field inventory reported in the study of Laasasenaho and Päivinen (1986). In the present study the field worker's RMSE was 32%, which is explained by a large underestimate. It suggests that he might have estimated the arithmetic mean instead of the basal area median diameter.

The updating of mean height was as accurate as photo interpretation in the study of Pussinen (1992) although no stereo model was available here. All updatings were negatively biased. This may be due to the growth model of height: Ojansuu et al. (1991) found that the model overestimated the height increment of small trees and underestimated that of large trees. The Solmu estimates were also biased.

The basal area updatings were positively biased. Only recent thinnings can be seen on aerial photos, which means that growth model updated basal areas are on average too large. Stem

number estimation was done only in seedling and seed tree stands. As expected, in those development classes the reliability of updating was very poor with respect to all attributes. When the size of the tree crown is close to the size of the image pixel, the tone value of a particular pixel is an average of the emission from crown and ground, and individual trees cannot be separated due to the mixed pixel effect.

Volume estimates were calculated with MELA from updated stand attributes. The updating procedures seem to give RMSEs of the same order as visual photo interpretation does (Table 1). The large negative bias in the Solmu estimate is caused by underestimates in mean diameter, mean height and basal area.

In the study area there were too few deciduous species dominated stands to explore the effect of them on updating. Scotch pine and Norway spruce dominated stands did not differ from each other. The updating of tree species proportions was also not studied.

With respect to productivity the difference between interpreters was great. The best yield was 2.4 times bigger than the worst. The productivity of a stand level field inventory is 3.3–5 ha h^{-1} (Forestry Development Centre Tapio). Thus updating is at least 10 times faster than a field survey and at best even 25 times faster, while sheer visual photo interpretation is only three times faster (Pussinen 1992). The fastest interpreter did not interpret visually any stand attributes but accepted the growth model updated attributes or management proposals or interpreted operations. Experience in field inventory was not a significant explanation for productivity or accuracy, but it seems rather that suitability for interpretation is a personal feature.

Although the interpretation procedures were quite simple, new working methods may cause errors that decrease when the system becomes more familiar to users. 1–10 stands had to be removed from the interpretations of five people, because the updatings were clearly mistakes and did not describe the real accuracy of the procedure. In the case of most mistakes interpreters had accepted growth model updated attributes in a clear-cut stand, causing huge errors, e.g. over 100 years in age.

Of the two procedures tested, procedure 2 was

faster and also more accurate. Although it was assumed that the interpreters in both groups were equally good, part of the differences between the procedures is due to differences in the photo interpretation skills. In spite of that, it was noted that visual interpretation of stand attributes is time consuming and yet not very accurate. If only quick and accurate interpreters are selected, updating with procedure 2 can reach better results than a conventional field inventory. Numerical interpretation methods of aerial photographs would naturally still be faster than the updating procedures presented here, but the accuracy of such methods has been lower (Hyyppä et al. 2000). However, promising methods based on segmentation of single crowns have been developed (Brandtberg 1999).

Because the data used as a basis for the updating were collected by only two different surveyors and the reliability of the data is not known, one has to be very careful in generalising the results. Unfortunately, from the time of collecting the old inventory data no field check data were available. Nowadays the field inventory estimates of mature stands are compared to exact harvester measurements. In other stand development classes field checks should be carried out to find out the error level of each surveyor. Knowing the error a surveyor makes in a certain development class in a conventional field inventory would form a good basis for the updates.

Although this kind of updating is subjective and may thus easily lead to biased estimates, it is a fast solution to cutting down inventory costs and keeping a stand database up to date. Consequently, it was considered that procedure 2 should be developed further and a follow-up study is underway. Those stands that are hard to interpret from aerial photo, like seedlings, are not interpreted at all, but are surveyed in the field later. Stand delineation is also produced at the same time. Potential applications of updating include carrying out inventories of forest estates not willing to buy a forest plan, marketing forest plans and guiding forest owners. However, the effect of the accuracy of the old inventory data should first be determined.

Acknowledgements

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