Swedish Gross Felling Statistics and harvesting season determination in the National Forest Inventory

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Abstract:

As part of the official Swedish statistics, a figure of the annual gross felling is presented which provides the volume of felled trees within the country for each year. Two figures are annually produced in Sweden: one official figure produced by the Swedish Forest Agency (SFA) and one by the National Forest Inventory (NFI). The annual felling estimates provided by the SFA and the NFI have differed to some extent during the past decades. In this report, the two methods for estimating the national annual gross fellings are described. Possible avenues for improving the gross felling statistics produced by those two methods are suggested. In particular, one of the possible errors in the NFI data is the determination of felling season. An evaluation is made of a method to assess the accuracy of the NFI felling season determination. The test suggests that NFI classification of treatment type is good, that final fellings are usually noticed, but that both thinnings and cleanings are not noticed as often as expected from forest company stand registers. Using stand registers as the truth, unnoticed plots could amount to an underestimate of NFI's felling statistics by approximately 26%.

Key words:

National Forest Inventory, Gross felling statistics, harvesting volumes, season determination.

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Preface

In the continuous work of improving methods of data capture used by the Swedish NFI, improvement of the data used for estimates of the annual harvested volume has been in focus during the last few years. This was also why Cornelia Sandström (now married with the family name Roberge) in the autumn of 2003 was given the task of looking into details of both the NFI-method and the SFA-method for estimating the annual harvested volume.

Due to positive employment circumstances, Cornelia started to work for one of the major forest companies in Sweden in 2004, therefore, the finishing of this report has been delayed. However, preliminary results from this report have already been used by the NFI.

Large differences in the season-determination from the NFI-teams and data from the stand-registers have been observed, therefore, we realised that this type of comparison cannot be used in isolation.

To help with this we have introduced data from pre-visited (by the NFI-HQ staff) harvesting sites (cleaning, thinning and final felling sites from season 0, 1, 2 and older) where the harvesting time has been very precisely determined using information from the land owner, forest company or contractor. During 2007, 30 such sites have been visited by the 15 NFI-teams in early spring, mid-summer and late autumn (10 different sites each time), this allows us to validate the accuracy of subsequent felling season determination. This data is not fully analysed, but together with this report from Cornelia I am sure that the NFI can develop a better understanding of how to improve the methods used in the delivery of data for annual harvested volume estimates.
This report also gives a good overview of the two different methods, SFA and NFI, which hopefully can improve understanding and cooperation within the two organisations, and of course other authorities and organisations interested in these matters.

Finally I would like to thank Cornelia for not “throwing in the towel”, and best wishes to both of you!

Umeå in October 2007
Jonas Fridman, supervisor

1 Introduction

1.1 Background

The Swedish forest is important due to its economic, social and environmental values. The forest is a major source for renewable raw material, which generates employment and income as well as material goods. Humans ascribe it a large cultural and recreational value. Moreover, it harbours a large part of the country's biodiversity. It is therefore well accepted that society should develop tools and policies to protect this resource in order for it to continue to be just that, a resource, to future generations as well (Anon., 2002).

Around the world there is an increasing interest in countries accounting for their consumption of fossil fuels and their environmental work. The signatory countries of the Kyoto Protocol will start accounting for their sinks and sources in carbon dioxide. Changes in the land use class will also be an important part in these reports (Ståhl et al., 2003).

One tool for ensuring forest sustainability is the elaboration of a forest policy to influence land owners in their management decisions, the degree of environmental consideration and the degree of exploitation of the forest resource. The Swedish Forestry Act (*Skogsvårdslagen*) together with the Swedish Environmental Code and the Heritage Conservation Act (*Miljöbalken* and *Kulturminneslagen*) constitute the formal framework for our use of the Swedish forest resource. There are also various other means of influencing forest owners' choices. These mostly work through influencing the economic profitability of certain forest management activities and thereby influencing the choices made. These incentives are called an informal framework and include everything from tax policy to market terms, wood prices, property legislation, regional politics and the infrastructure surrounding the specific woodlot (Anon., 2002).

An important role of the forest policy is to regulate the fellings as regards the volumes harvested and the methods used. To substantiate debate and to make decisions on these instruments of control it is important to have knowledge on the actual fellings. In order to understand the influencing factors it is crucial to have a means of detecting the changes in silvicultural treatments and final fellings made due to changes in these influencing factors. Knowledge on the actual fellings is useful when analysing trends in the use of different forest management and silvicultural measures. These data, particularly if available annually during a long period, are essential for evaluating the actual results of changes in the incentives, e.g. changes in legislation. In order to assess the effectiveness of the forest policy and its incentives, it is important that the different variables can be measured and compared. The accuracy is important as well as the possibility to compare the newly gathered data with historical ones (Ranneby et al., 1987).

1.2 The Swedish felling statistics

In Sweden, two organisations produce and present statistics on the Swedish Forests. These organisations are the Swedish Forest Agency (*Skogsstyrelsen*; SFA) and the National Forest Inventory (*Riksskogstaxeringen*; NFI). Since 1955, the estimated annual fellings have varied from about 46 million m^3sk (SFA estimate, 1959) to about 84 million m^3sk (SFA estimate, 2002). The annual felling estimates provided by the NFI and the SFA have differed to some extent during the past decades (Fig. 1.1). From the mid 50's to the mid 60's, the NFI figures were consistently higher than the ones provided by the SFA. From the mid 60's to the mid 70's, on the opposite, the NFI estimates were lower than those of the SFA. From the late 70's

to the mid 90's, the absolute differences between the two estimates were relatively low. Finally, in recent years (1997-2001), the difference increased again, with SFA figures approximately 10-20 million m^3sk higher than NFI figures. According to Skogsdata 2000 (Anon., 2000a), the NFI figures would represent an underestimate of the actual annual fellings by approximately 5%.

Today only the SFA's gross felling statistics are presented as official felling statistics for Sweden, the NFI felling statistics are included inofficially in their annual report Skogsdata.

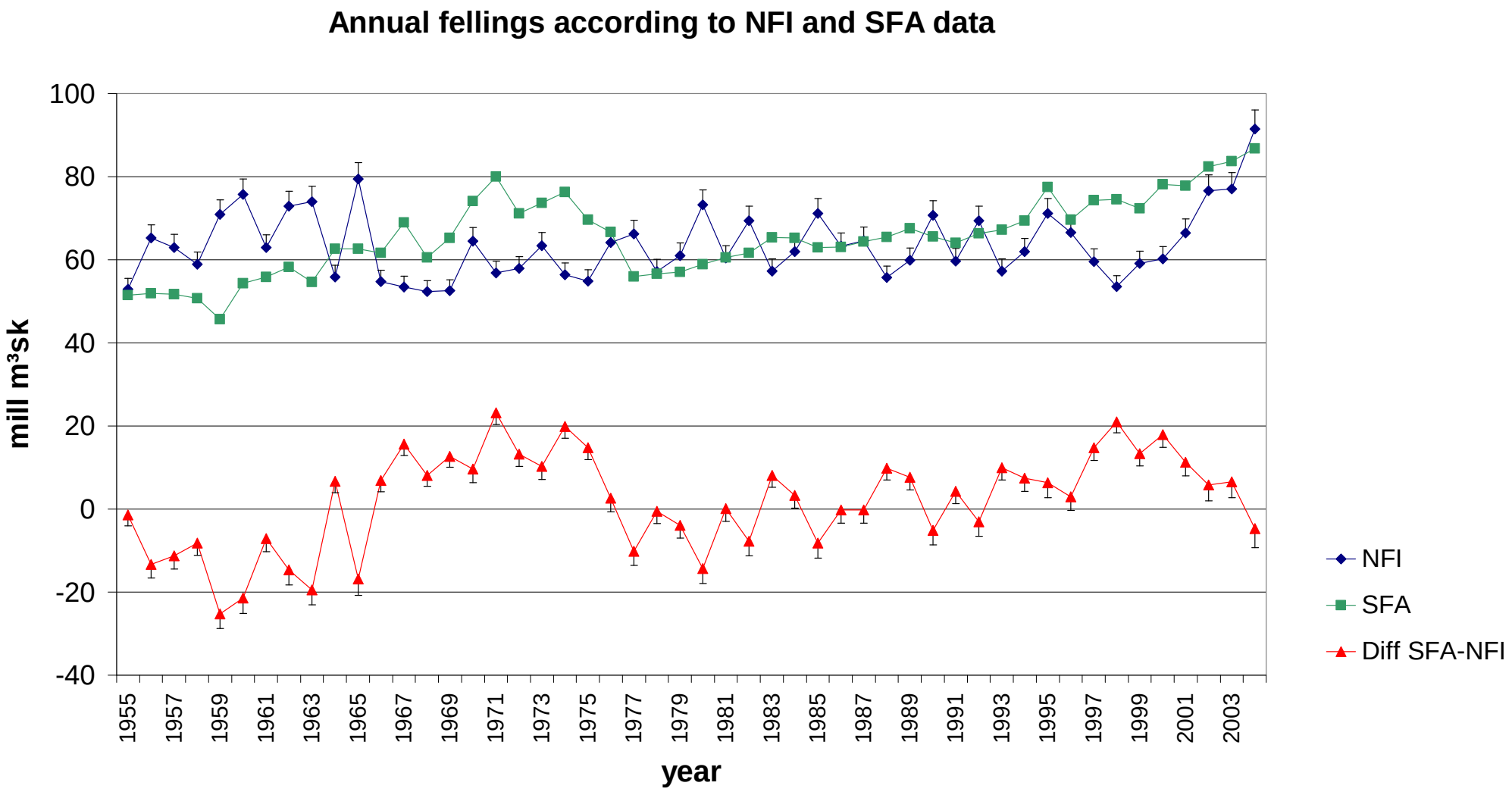

Figure 1.1. Annual fellings according to NFI and SFA data. Up until recently the NFI data has been considered to underestimate the actual volumes by approximately 5% (error bars on NFI points; Anon., 2003a).

1.3 The objective of this report

The objective of this report is to give an overview of the Swedish felling statistics through:
1. Describing the methods used by the NFI and the SFA for estimation of national annual fellings through interviews and the summarising of available documentation.
2. Describing possible improvements to both methods.
3. Evaluating a method for assessing the accuracy of NFI felling season determination by comparing NFI season determination with two forest companies' registers.

2 Definitions of units used in this report

The term “felling” refers to cut trees with a diameter larger than 50 mm at their stump cut height (NFI definition). The main concepts related to fellings (i.e., total drain, gross felling, net felling, removal and wood consumption) are described in a schematic manner in Fig. 2.1.

Volume units:

m^3 – Cubic metre

m^3f – Cubic metre: solid volume

m^3f pb – Cubic metre: solid volume including bark

m^3f ub – Cubic metre: solid volume under bark

m^3s – Cubic metre: loose volume

m^3sk – Cubic metre: standing volume (stem volume over bark from stump to tip)

m^3t – Cubic metre: piled volume

$m^3$to – Cubic metre: by top measurement

m^3sv - Cubic metre sawn wood

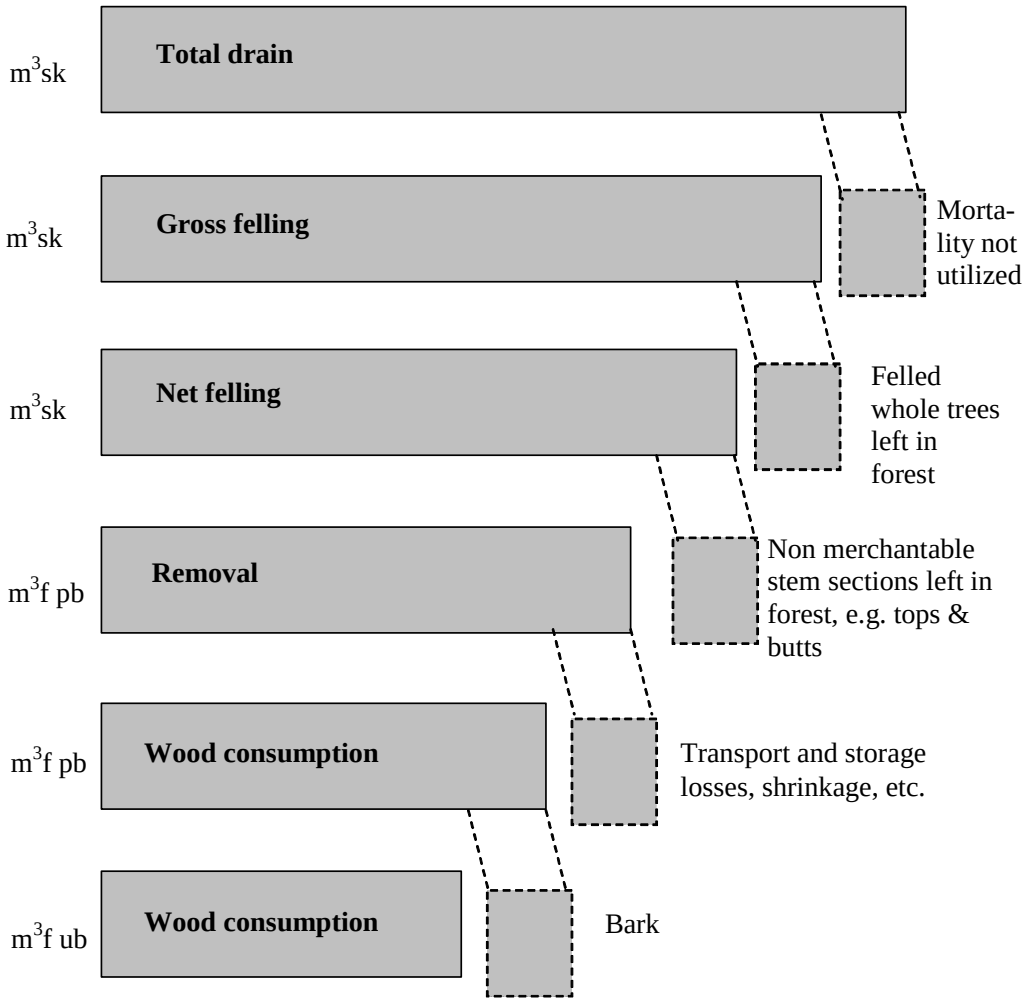

Figure 2.1. The relation between the concepts of different fellings (schematic diagram) adapted from Anon. 2003b.

3 The Swedish National Forest Inventory's felling statistics

The first Swedish National Forest Inventory (NFI) was conducted in 1923. During the planning process, the estimation of the annual felling was considered as important as the standing volume estimates and the growth estimates. However, producing accurate estimates on the annual fellings soon proved difficult, for many different reasons all related to a single factor – too high costs. After 30 years (1953) the NFI had long since changed to become countrywide each year, making it possible to estimate "true" annual felling estimates, and this was the first year when the NFI included the "stump plots" on which felling, and silvicultural measures were described and stumps were callipered (von Segebaden., 1998 and Englund., 1994).

The Department of Forest Resource Management at the Swedish University of Agricultural Sciences (SLU) in Umeå conducts the NFI and annually produces a report called Skogsdata (Forest statistics). Here regional and national statistics are presented for the state of the forest, the annual increment and drain. Data from the NFI is also presented in the annual Statistical Yearbook of Forestry. NFI data are used in research projects and to provide a basis for long-term consequence analyses.

3.1 The inventory

The NFI is based on an annual stratified systematic cluster sampling with a partial replacement of plots. Each cluster has a rectangular shape and is called a "tract" (Fig. 3.1). On each tract there are a number of sample plots, where data is collected on a radius of 7, 10 or 20 m. There are two different kinds of tracts: temporary tracts (hereafter TT) and permanent tracts (hereafter PT). The detailed design is different in different parts of Sweden due to the difference in autocorrelation. Tracts are situated further apart in the north than in the south. Moreover, the distance between the plots increases northwards. The length of the side of the rectangle varies from 300 m to 1800 m (Anon., 2003c)

On all tracts there are two different sample plots: area plot (hereafter AP) and stump plot (hereafter SP). On APs, a number of registrations are made on tree-, stand- and site-level, whereas on SPs data concerning the felling are recorded. SPs are always temporary, i.e. visited once, APs, however, are permanent on PTs, i.e. visited every 5^{th} year, but temporary on TTs.

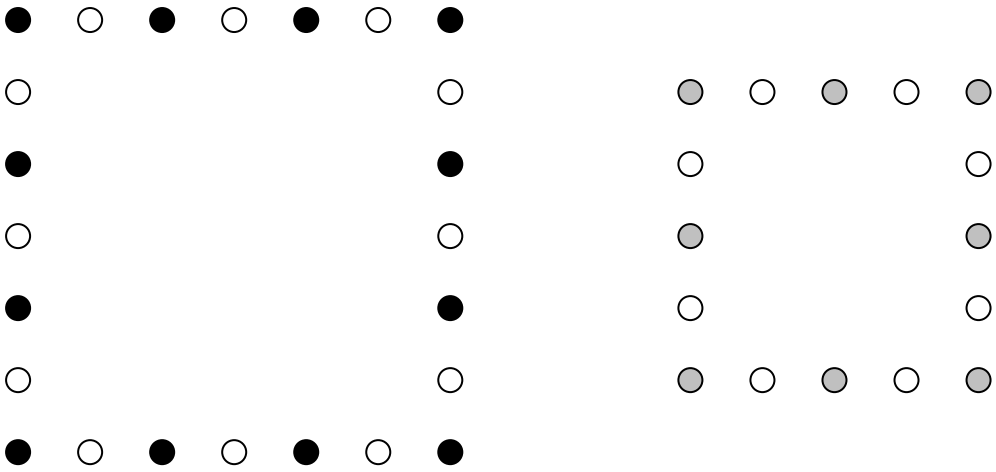

Figure 3.1. Examples of a temporary tract (left) and a permanent tract (right), both seen from above and in proportional scale to one another. Each circle represents a sample plot. White denotes stump plot (SP), grey area plot (AP), and black denotes both SP and AP.

A typical field season starts in the beginning of May and ends in September. To illustrate the numbers of plots covered by the inventory, one can look at the data from 2003. During that field season, a total of 18 401 plots were inventoried in the field, 8 641 of them were SPs (white in Fig. 3.1) and of those about 40% on TT and 60% on PT. In 2003 the NFI changed the frequency for revisiting PT compared to the period 1993-2002, from every ten years to every five years. (B. Westerlund, 2003, pers. com.)

The variables inventoried vary with the land-use class assigned to the sample plot. The NFI land-use classes are: forest land, arable land, sub-alpine woodland, mire, rock surface, high mountains, pasture land, military wasteland, urban land, other land areas, saltwater, freshwater, power line on forest land, road and railway, and other climate impediment (Anon., 2003c).

3.1.1 Season determination

On SPs, data are collected for fellings conducted during the present growth season, the last growth season and the preceding season. These periods are called season 0, 1 and 2, respectively. For example, season 1 as assessed during the field season of 2003 is not the same season as season 1 recorded during the field season of 2004. A ‘season’ starts with the opening of the buds and ends right before the opening of buds on the following year, i.e. is defined by the start of the growth season.

It is not an easy task to determine the season when a felling was conducted. The field workers base their decision on a number of clues, including the status of the buds, needles and leaves of the treetops and branches left behind, the status of the bark on the stumps, and the vegetation. To indicate the presence of uncertainty, two new categories were added in 2003: “either season 0 or 1” and “either season 1 or 2”. If choosing one of these two categories, the team then has to judge which season is the more probable of the two. Thus, these new categories indicate the team’s uncertainty in determination and therefore give information for eventual post-processing of the data. For example, the landowner can later be contacted for further investigation of the actual felling-season.

A number of training sites for season determination have been established by the NFA's local office staff. These sites are identified on detailed maps which are available to the teams. In those felled areas, the stumps are marked and the exact felling-time is given. Each NFI-team practises at least two times during the field season. This is done in order to observe the changes that the stumps, tops and branches left behind undertake over time. Hence, the teams can calibrate their felling-season determination on these sites.

3.1.2 Stump calliperation

On SPs that are not on high mountains, urban land, military waste land, freshwater or saltwater, a stump calliperation is conducted if a felling is attributed season 1. The following variables are also recorded: silvicultural treatment class, estimated stand age, mean height, basal area, tree species composition, canopy cover, executed silvicultural treatment, reason for felling (if sanitary the reason is stated), degree of extraction of branches, and also the state before felling in terms of canopy cover, tree species composition and stand age. (Anon., 2003c)

The stump calliperation involves diameter measurement of all stumps with at least 50 mm minimum horizontal diameter at "normal saw kerf" within a 7-m radius plot. The species is identified and one determines whether the tree was alive or not at the time of the felling. For each measured stump it is also recorded whether the stem has been left behind or taken out of the forest (Anon., 2003c).

3.1.3 Handling of the data

During the field-work, the data are entered into hand-held field computers. When a tract is completed, the data is transferred to a computer and data from approximately one week's field-work is stored on a CD which is sent by mail to the NFI office in Umeå. There, the data is checked for apparent errors and incompleteness. If deemed necessary, the field-teams may have to correct or complete data entries. The field data from the CDs are then stored in a SQL-server-database unique to each field-season, where the data is checked again. When the quality checks are finalised, data is finally stored in an Ingres-database that is the production-database, where data from 1983 and onwards is stored. The latter database also contains calculated variables, e.g. the volume for each callipered stump from the SPs (B. Westerlund, 2003, pers. comm.).

3.1.4 Calculating single tree volume from stump data

Many variables needed for further analyses are calculated variables, or calculated estimates of variables based on the collected field data. Single tree volumes for example, are calculated by an algorithm using the measured diameter at breast height and the height of the trees. Through a three-phased process, the volume of a felled tree is then estimated:
Estimation of breast height diameter y (f(y)=x(stump diameter, latitude and distance to coastline)
Estimation of tree height z (f(z)=f(f(y))
Estimation of tree form fh (f(fh)=f(f(z))

These three steps yield possibilities to obtain a simulated volume. In order to do each of these simulations, the NFI have conducted extensive studies on sub-sample trees during many years. Stump height diameter, breast height diameter and height have been measured on actual

trees all over the country. With this data it has been possible to develop (through multiple regression) the algorithms needed for volume estimation of the callipered stumps (B. Westerlund 2004, pers. comm.).

3.1.5 Estimation of harvested volume

Since the NFI is a stratified sample inventory with two different samples, i.e. PT and TT-tracts, the formulas are quite complex. As an example the simple formula for the total harvested volume for the harvest season 2002/2003 in one county, using only one tract type (TT), is presented below. For details see Fridman (2000).

$\hat{T}^*$ = estimate of the annual total harvested volume in a county for harvesting season 2002/2003

$$\hat{T}^* = \frac{\sum_{i=1}^{K} y_i^*}{\sum_{i=1}^{K} a_i} \times A$$

A = the total area of the county of interest (official area from the Swedish Land survey)
a_i = total plot area of SPs on tract i
y_i^* = total tree volume of callipered stumps on tract i
i = indicator for tract
K = total number of TT tracts in the county of interest inventoried in 2003

3.1.6 Sources of error

The results of the NFI are affected by a number of potential sources of error, which can be separated into two main types: statistical sample errors and other errors. Statistical sample errors are related to the fact that the NFI is based on data from a limited number of plots which are assumed to represent all of Sweden's forests (Daamen, 1980). No matter how good the sampling design, there will always remain some error due to differences between the sampled forests and the total "population" of forest stands (Mead et al., 1993). The "other errors" can be errors such as: measuring errors, omissions to register stump individuals that should have been registered, subjective judgement errors and typing errors during data registration. Those "other errors" can be subdivided into systematic errors and random errors (Daamen, 1980).

Errors connected to stump calliperation are most likely: missing a stump, taking one too many/one too few on the verge of the plot, measurement errors due to the shape of the stumps or incorrectly used equipment. A problem connected to the SP is the fact that stumps are only callipered if attributed to season 1. This could result in errors of missing whole plots or measuring too many plots if the season is misjudged. This, in turn, may lead to problems related to area and volume estimates. The limited number of callipered plots means that errors in season determination may have serious consequences, especially when it comes to the estimation of the annually felled area, and hence to the volume estimates.

4 The Swedish Forest Agency's[1] felling statistics

The Swedish Forest Agency (*Skogsstyrelsen*, SFA) is assigned to work for a sustainable utilisation of the Swedish forests. The SFA is the national authority on forests and forestry. The SFA has offices all over the country and advises on forest-related matters, supervises compliance with forestry act. The SFA works to carry out the policies put forth by the Swedish government. The SFA is responsible for annually presenting forestry related statistics. This is primarily done in a publication called Statistical Yearbook of Forestry (*Skogsstatistisk årsbok*) and on the SFA homepage where a whole section with statistics (tables and figures) can be found (*cf*. www.svo.se).

The following account is based mainly on compilations and personal communications from a visit at the SFA headquarters in Jönköping in November 2003, if no other reference is given. During this day I met with Sven A. Svensson (manager of Forest statistics department), Magnus Fridh (about to become manager of Forest statistics department), Katarina Ekberg (responsible for the Swedish Felling Statistics) and Hans Banck (IT-department, ENFORMA and later with the Swedish Felling Statistics).

4.1 The Forest statistics department

In November 2003 there were thirteen employees at the Statistics department of the SFA. The department was organised in three sections, one section to handle the SFA inventories and the surveys, one to produce the Statistical Yearbook of Forestry as well as other presentations and compilations of statistical data and the third section to work on different analyses and on environmental work.

4.2 Components of the Gross Felling Model

The SFA produces gross felling statistics based on information from many different sources. This section lists and describes those sources as well as the methods used to gather the data.

4.2.1 Forest industries wood consumption statistics by the Swedish Timber Measurement Council

The Swedish Timber Measurement Council (*Virkesmätningsrådet*, VMR) is a collaboration body between the different parties of the Swedish wood market working to achieve efficient measurements, accounting and control measurements according to standardised rules and regulations. Three wood measurement organizations (VMF Nord, VMF Qbera, VMF Syd), are mandated to carry out the work.

Each year the VMR publishes a report on the Swedish wood consumption and the production of forest goods, containing felling statistics for four regions for the last five-year period. These reports are the result of an annual survey, conducted by the VMR, where all Swedish pulp- and board industries report on their wood consumption. The VMR also takes in wood consumption reports from all sawmills with an annual production above 1000 m^3sv $year^{-1}$. The data collected and the resulting statistics represent the actual figures of the Swedish industry as they are based on the totals for all of the industrial actors fulfilling the minimum production criterion (and not on a statistical sample thereof).

[1] The Swedish Forest Agency changed their organisation on 1/1 2006. Their name was previously the National Board of Forestry.

In the VMR report of 2003 (data for the period 1998 – 2002), there was an uncertainty concerning the accounts of refused logs (i.e., logs that were transported to the sawmill, but not accepted as timber-quality logs). They are considered to be a part of the production and are therefore included in the statistics. However, there is some uncertainty due to the fact that different companies account for this in different ways, which may result in an underestimation of the sawmills' wood consumption by about 1% (Anon., 2003d). This translates into a figure of 342 690 m^3f ub (34 269 000 m^3f ub × 0.01) which represents 0.41% of the total gross felling calculated by the VMR for 2002 (83.7 mill. m^3sk).

The statistics reported by the VMR are in m^3f ub while the measuring and accounting is usually done in $m^3$to for timber saw-logs. In the survey, the mills were asked to apply conversion figures that are appropriate for their product and region. When missing, the conversion figure of 1.22 was used from $m^3$to to m^3f ub. Chips, sawdust and bark were reported in m^3s and slabs and other wood fibre products were reported in m^3t. The following conversion figures were used for m^3f: chips – 0.37, sawdust – 0.32, bark – 0.45, slabs, etc. – 0.50. Both the VMR and the SFA use the conversion figure of 1.2 for conversions from m^3f ub to m^3sk. (Anon., 2003d).

4.2.2 Statistics Sweden's surveys and statistics

Statistics Sweden (SCB) performs annual surveys which are used in the SFA Gross Felling Model. Data in this section is mainly from www.scb.se.

4.2.2.1 Stock volumes of coniferous timber saw-logs

Data on stock volumes of coniferous timber saw-logs have been gathered since 1955. Stock volume data is interesting for assessing the national gross felling volumes, but also for evaluating the market conditions of forestry and forest industry. The data is used by, among others, government authorities and researchers. 'Stock volumes of coniferous timber saw-logs' is defined as timber saw-logs that are stored somewhere in the chain between road-side storage and sawmill storage. Such storages can be found for example in port and rail-road terminals. Imported timber saw-logs and timber saw-logs intended for exportation are included in the figure.
A survey is sent to all members of Svenskt Trä (www.svenskttra.org) and to a sample of other sawmills. The data is grouped according to year and for four regions. Sawmills with a total turnover under 500 000 SEK are not included in the survey. Their influence on the data is considered negligible. However, this limitation of the survey material may lead to an underestimation of the stock. The sample is made by two-step stratification by turnover classes using cumrot-method and Neyman allocation on regions. Sawmills with very high turnover are all asked to fill a survey. Data is collected and presented in m^3f ub (www.scb.se).

4.2.2.2 Stock volumes of pulpwood and chips

As for coniferous timber saw-logs, data on stock volumes of pulpwood and chips have been gathered since 1955 and are used by, among others, authorities, researchers and forest owners associations. The 'stock of pulpwood and chips' is defined as pulpwood and chips stored in Sweden, somewhere between road-side storage and industry storage. Imported volumes and volumes stored in Sweden destined for exportation are included in the volume. A survey is sent by SCB to a number of actors selected by the SFA.
The population consists of three parts:
1- Pulp and paper mills
2- Wood purchasing, trading and importing or exporting companies
3- Forest management companies

Data is gathered by means of a quarterly survey and the volumes of pulp wood and chips are given in m^3f ub. Four groups are defined:
1- Pine (including pine pulp logs and coniferous pulp logs)
2- Spruce
3- Other
4- Pulp chips

The quality of the data is considered good by SCB as there is a close to total reply rate to the surveys. One insecurity factor, however, is that the selection process needs to be done with extremely good knowledge of where pulpwood and chips are stored, and by whom (www.scb.se).

4.2.2.3 Foreign Trade

The SCB produces monthly statistics for all trade with foreign countries. Since Sweden entered the European Union the statistics for Swedish import and export are divided into EU-trade and non-EU-trade. For trade with non-EU countries complete information is collected through customs registers (i.e., whole population study). For trade within the EU, companies report on their trade monthly. This survey is a cut-off study and only includes companies with an annual EU-trade of at least 1 500 000 SEK. Therefore, there is a systematic source of error connected to the fact that companies whose EU-trade represents less than 1 500 000 SEK $year^{-1}$ are not included. Moreover, there is some amount of error related to non-response and incomplete answers. To account for non-response and incomplete answers, the figures are then corrected by using the companies' tax declarations. Corrections/adjustments of this kind amounted to 1.4% of the total exports for 2003 and 2.7% for the imports of the same year. These figures are for all imports and exports; the specific corrections for wood raw material or wood products were not available for this study.
It should be noted however that these data are not completely comparable over a long series of years due to (i) entry into EU, (ii) classification changes (e.g., pulp wood and saw-logs were in the same category between 1995-2002), (iii) changes in requirements about what to report (from statistical value to invoiced value).

As regards foreign trade, the following figures are used in the Gross Felling Model:

Imports of wood raw material:

- Coniferous saw-logs
- Deciduous saw-logs
- Pulpwood

Exports of wood raw material:

- Coniferous saw-logs
- Deciduous saw-logs
- Pulpwood

4.2.3 Sawmill Inventory of the Swedish University of Agricultural Sciences

Every fifth year, the Department of Forest Products at the Swedish University of Agricultural Science (SLU) conducts an extensive survey and analysis of the Swedish sawmill industry.

One of the results of this survey is a presentation of the industry's annual consumption of saw-logs. The SLU 2000 Sawmill Inventory was the first report where SLU presented data also for sawmills with a production below 1 000 m^3sv $year^{-1}$. The reply frequency of the questionnaires was 89% for the higher production category. A 100% rate of answer for this category was then obtained by using complementary information provided by VMR's questionnaire. For sawmills with a production below 1 000 m^3sv $year^{-1}$ the reply frequency was 80% and with the help of VMR the reply rate increased to 89%. Means have been used to evaluate missing figures. Sawmills producing less than 1 000 m^3sv $year^{-1}$ only represent 2% of the total sawn volume in Sweden. The SLU Sawmill Inventory was in part financed by the SFA (Staland et al., 2002).
(http://www2.spm.slu.se/publikat/Sagf2k.pdf 2007-10-19).

4.2.4 Fuel wood consumption

Since 1998 the SFA uses the figure 5.9 million m^3f ub as round wood used as fuel. This represents 7.2% of the annual gross felling of 2002. This figure stems from a review for SKA99 (Anon., 2000b), the report was however not finalized. (S. Holm. 2006. pers com.)

4.2.5 Survey on wood consumption

The SFA annually makes a survey to a sample of actors in each region concerning their wood consumption. That study is made in order to weigh the values from the Gross Felling Model and produce regional data. The results of their survey are not used in the Gross felling statistics for the entire country, but only in order to distribute the findings to the regions. For this reason that survey is not described any further here.

4.2.6 Consumption of other round wood

'Other round wood' includes poles and wood for matches. This was inventoried during Virkesbalanser 92 (Anon., 1992). Other round wood is estimated to a figure of 500 000 m^3sk $year^{-1}$ which represents 0.6% of the annual gross felling of 2002.

4.2.7 Data on felled wood left in the forest

As a part of the stump calliperation performed by the NFI, the field staff notes whether the felled tree has been extracted or not (see section 3). This gives a figure of the annually felled, non-extracted volume. As with all NFI felling data it only applies to trees left in the forest that are over 50 mm at stump height. In terms of the national annual felling, felled wood left in the forest makes up a small contribution to the total felled volume (between 2% and 4% for years 1990-2002). Therefore, the error related to that measurement should not have any major influence on the SFA's gross felling statistics.

4.3 The Gross Felling Model

Using data from all of the different sources mentioned above, the SFA produce the national statistics through their Gross Felling Model (Fig. 4.1). The data are handled, gathered and saved in SFA's computer system.

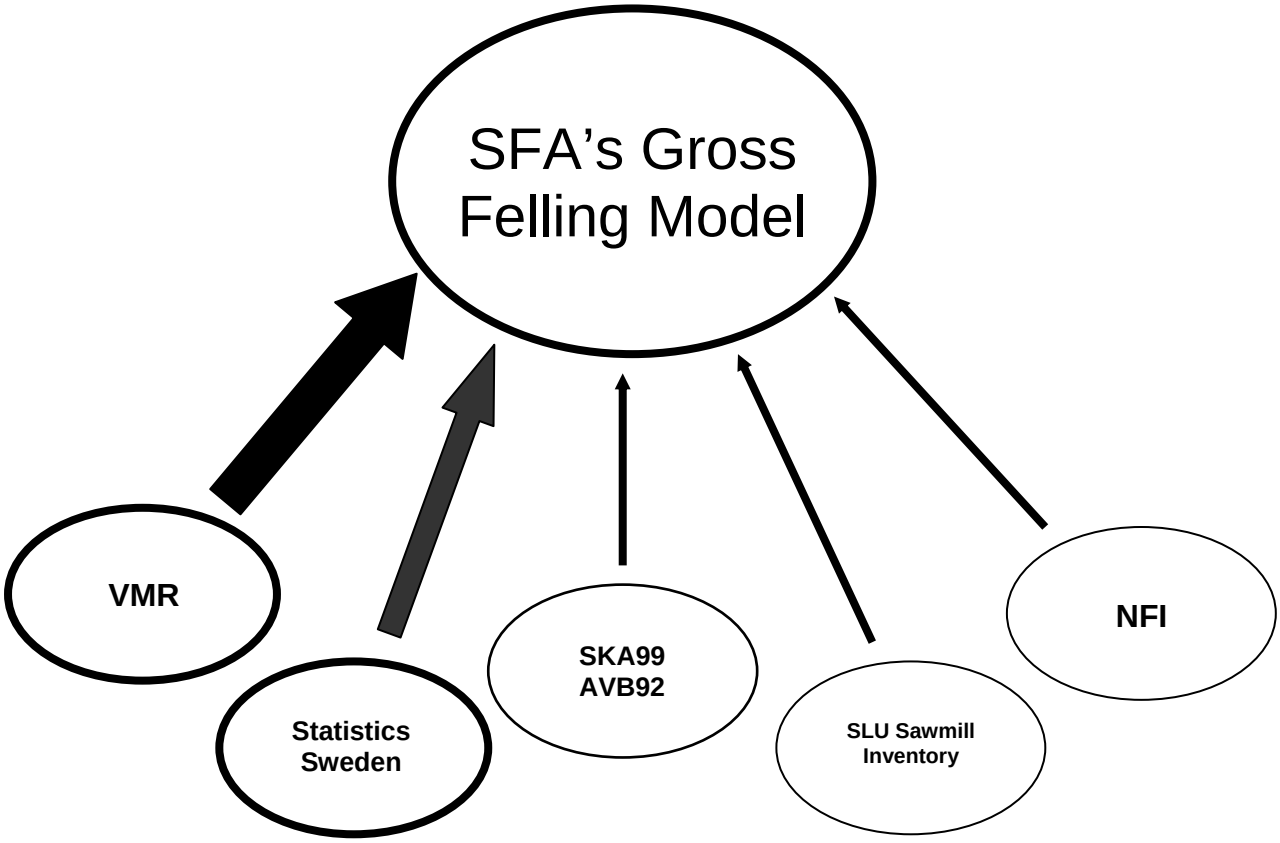

Figure 4.1. The SFA's Gross Felling Model's data sources. The relative sizes of the arrows symbolise the respective importance of the different sources.

4.3.1 Description of the Gross Felling Model

The SFA has recently changed the Gross Felling Model, so that it now relies more heavily on the VMF's annual reports on wood consumption. Before this change, the calculations were based on produced volumes of wood-derived goods and a wood consumption conversion figure for each product. The new model seems more straightforward and should be easier to control and improve (Fig. 4.2).

	Coniferous timber sawlogs	
	Deciduous timber sawlogs	
	Pulpwood (deciduous and coniferous)	
	Roundwood for the plywood industry	
	Roundwood to the particle- and fibreboard industry	
	Fuelwood	
+	Other roundwood	
=	Removals (net fellings), total	m^3f ub
*	Conversion figure (1.2) from m^3f ub to m^3sk	
=	Removals (net fellings), total	
+	Felled whole trees, left in the forest	
=	Gross fellings, total	m^3sk

Figure 4.2. Calculations in the SFA's Gross Felling Model.

4.3.1.1 Coniferous timber sawlogs

The first component in the model is the volume of coniferous sawlogs. In order to obtain this figure, the net import is subtracted from the consumed coniferous sawlogs and then the change in coniferous sawlog timber stock is added. The VMF survey gives the produced coniferous sawlogs, Statistics Sweden provide the import/export information as well as the volume changes in stocks (Fig. 4.3).

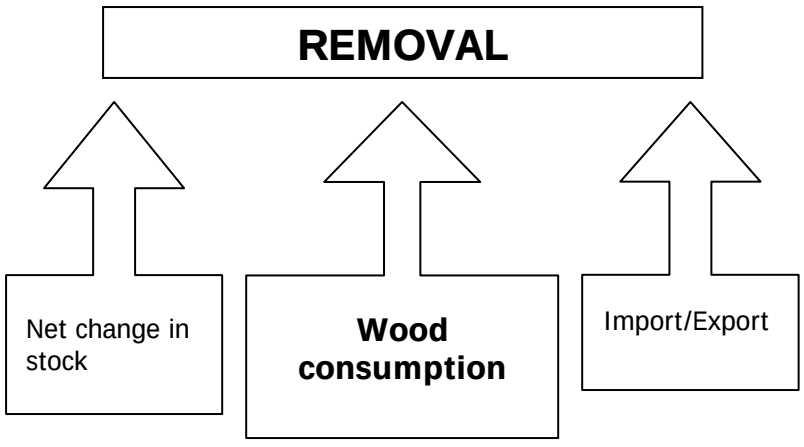

Figure 4.3. The variables used in SFA's Gross Felling Model to estimate the annual removal.

4.3.1.2 Deciduous timber sawlogs

The next variable is the volume of deciduous sawlogs, which is obtained by subtracting the net import from the consumed deciduous sawlogs and then adding the changes in deciduous

wood stock. The 2000 Sawmill Inventory from SLU gives the consumed deciduous sawlog volumes, and Statistics Sweden provide the import/export data as well as the changes in stock volume. It might be interesting to note that in relative terms, small-capacity sawmills (< 1 000 m3sk year-1) included in the SLU survey contributed to a much larger proportion of the sawed timber for deciduous species than for coniferous species, i.e., neglecting those small sawmills would have led to an underestimate of the consumption of deciduous wood.

4.3.1.3 Pulpwood

The volume of wood consumed for pulp production, called 'pulpwood volume', is calculated by subtracting the chip- and sawdust consumption as well as the consumption of other wood fibres from the total volume of consumed wood in the pulp industry. Then, just as for the sawlog volumes, the net import was subtracted and the net change in stock was added (Fig. 4.3).

4.3.1.4 Roundwood for the plywood, particle- and fibreboard industry, fuel-wood and other roundwood

For the volume of roundwood for the plywood, particle- and fibreboard industry, the figure used is the volume reported to the VMR by those industries, and then published in the VMF report. It is a rather low figure and it is not corrected with import/export figures nor adjusted with the changes in stock.
The use of roundwood for energy production is increasing and the last survey was published in the year 2000 as a part of the forest impact assessment SKA99. The figure used for other roundwood comes from a survey in Virkesbalanser 1992. These two are not adjusted for import/export or changes in stock either since they are based on an estimate of annual consumption and do not change from year to year.

4.3.1.5 From net fellings to gross fellings

The NFI volumes give the SFA a basis from which to calculate the annual gross felling from the annual net felling. By taking a five-year mean of NFI's volume of felled wood left behind and dividing it with the NFI's gross felling volume, a weight is calculated, i.e. the percentage of the felled volume that is left behind. This weight was then applied to the SFA's calculated net felling. In this way the SFA only uses the relative amount of wood left compared with the harvested volume. A summary of the SFA's Gross Felling Model is presented in Fig. 4.4.

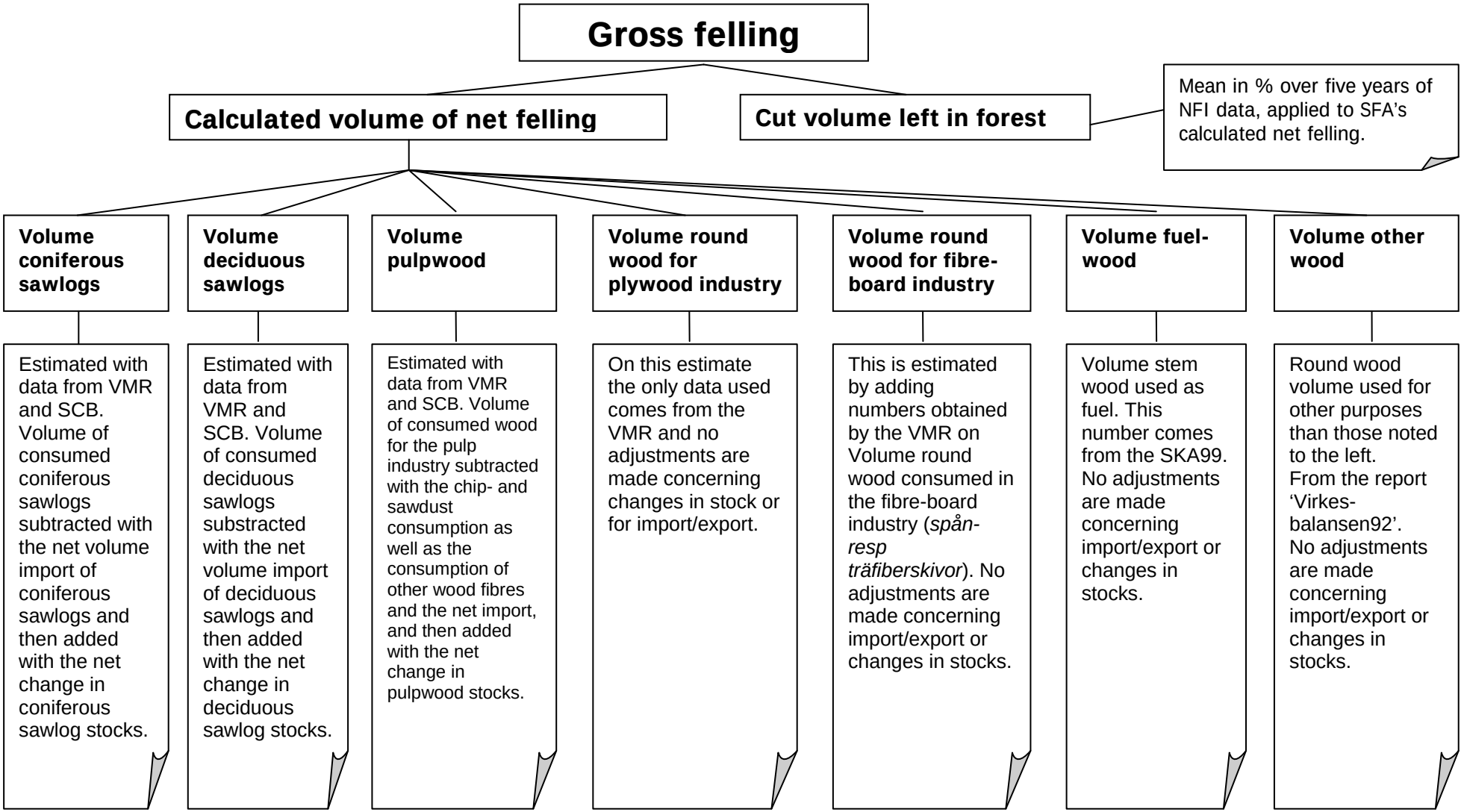

Figure 4.4. The SFA's Gross Felling Model

5 Suggestions for possible improvements to the data

With increasing interest in the forest resource, the reliability of the national statistics on forests becomes more important. This also applies to statistics on annual felled volumes.

Sven A. Svensson, Magnus Fridh, Katarina Ekberg and Hans Banck from the Swedish Forest Agency were interviewed in November 2003. Göran Ståhl (Professor of Forest Inventory) and Mats Nilsson (researcher and manager of the Remote Sensing Laboratory), both at the Department of Forest Resource Management at the Swedish University of Agricultural Sciences (SLU), were interviewed in March 2004. All of these persons were interviewed on the topic of possible improvements to the National Gross Felling Statistics.

5.1 Felling Statistics of the National Forest Inventory

5.1.1 Improvements to the volume simulations and stump calliperation

There are a number of possibilities for improving the volume estimates based on stump calliperation. Through increasing the measurements of stumps to include stump height measurements, measurements of the smallest diameter, measurement at normal stump height and height at actual place of cut, there will be material to evaluate and improve the volume estimates. Moreover, an estimation of how much the stumps shrink on average from the time of harvest to the time of measurement could further improve the simulated volumes. Investigating bark thickness, whether it usually is equal from one side of the stump to the other or if its thickness can be estimated from the diameter alone would potentially provide improved volume estimates.

5.1.2 Remote sensing technology

There are ongoing projects with regional authorities in order to have an operational tool for estimating stand age, tree species composition and standing volumes in the Swedish forests using satellite data.

With remote sensing final fellings can be detected (Saksa et al. 2003). If there were satellite data available at a reasonable cost and from the same day each year during the vegetation season it would be possible to generate an estimate of the annual harvested area through change detection. However, the possibilities of acquiring high quality images covering the whole country year after year at the same date are rather slim, mainly due to weather conditions.

Potentially, a volume estimate of the standing forest before harvesting could be obtained by the *k*NN-method and when a change is noted this can be compared with the standing volume of the previous *k*NN estimate. This would however most likely underestimate the annual fellings, as the *k*NN-method tends to underestimate volumes in high volume stands, ie. final felling stands. The *k*NN estimates, are only possible to attain with extensive field inventories as a basis for the analysis. Another difficulty is the geo-referencing, the image pixel values linked to the plot might not represent the same area as the plot due to geometric errors.

Tests of estimating the standing volume by post-stratifying the NFI plots using *k*NN maps have shown an improvement of the estimation accuracy of approximately 10-30% at county level, as compared to using NFI plots alone. A more likely improvement to the final felling statistics would be using post-stratification.

5.1.3 Other possibilities

Using five-year means from harvested APs on PTs it would be possible to
evaluate the level of the estimates from the stump calliperation
calibrate the level of the annually felled volumes.

Knowing whether all NFI teams really visit all SPs would remove some uncertainty; this could be attained through requesting a GPS waypoint for every plot.

The season determination is an important factor, therefore additional training sites and time to practice could potentially be beneficial, especially if combined with increased emphasis on their importance to all involved field staff.

By sending out questionnaires to land owners whose forest the inventory plots fall within, additional knowledge about the accuracy of the season determination could be collected. Potentially, these landowners also could have information about the harvested volumes and areas.

5.2 The Gross Felling Model

The SFA data has several parts and different sources, each with their own associated uncertainties. To improve data quality in a cost-efficient way, a good starting point would be to identify which of the input figures that have the strongest influence or potential error. From the descriptions presented in section 4.2, the following priority list could constitute a guide for further work:
Increasing co-operation with the VMR on the Forest industries wood consumption survey (due to the fact that it involves the largest volumes added into the Gross Felling Model)
Fuel wood survey (based on rather old data today paired with media attention indicating increasing activity)
Imports and exports within the EU (the SCB-questionnaire (INTRASTAT) does not cover trade with an annual value below 1 500 000 SEK)
“Other wood”-survey (the last was performed as a part of AVB92)

Regarding point #1, the SFA were already increasing their collaboration with the VMR in 2003. As to #2 and #4, they were also planning to conduct a survey aimed at improving the data for other wood and fuel wood variables in the Gross Felling Model.

Finally, it would be very beneficial, especially when comparing with other sources, to provide an estimate of the level of uncertainty, in addition to the presented figure for the Swedish gross felling.

5.3 Summary of possibilities

Current projects of improvements are under way for both methods. Both in the SFA and at the Remote Sensing Laboratory of SLU, projects are proceeding towards the combination of field data and remote sensing techniques. The SFA is working with a tool for remote sensing called ENFORMA. These projects, naturally, have applications beyond felling statistics.

6 Assessing the accuracy of National Forest Inventory's felling season determination: Evaluation of a method.

6.1 Introduction

As described in section 3.1.4, there is a multitude of errors in inventory work in general and stump calliperation is no exception. One possible large contribution to errors in the data is the determination of felling season. This is also a factor that is rather difficult to verify, especially on a large scale. It is not all forest owners that would recall exactly where and when they went and cut some firewood, or remember exactly where and when, the company they had contracted came to harvest. As in all work it is important to evaluate the stump calliperation and season determination from time to time, to see where there are possible improvements to be made. In addition, errors in season determination have a big impact on the gross felling estimate of the NFI.
This is the background for this section, testing a method of assessing the accuracy of NFI felling season determination and then more importantly evaluating the chosen method.

6.2 Material

The location of NFI plots have been recorded in the field, using the Global Positioning System (GPS). Using this data and digital borders of the forest management companies Holmen Skog and Stora Enso Skog, all NFI SPs from the fieldwork conducted in 2003 were coupled with information from the company stand registers using a Geographical Information System (GIS).

The total number of SP's visited during the field season of 2003 was 8641 and the number of plots falling on Holmen's or Stora Enso's forests was 661, which gives a percentage of 7.7 % of the total number of SPs. On these SPs, according to the stand registers of the two companies, cuts have been made on 85 (12.9%) SPs during seasons 0 through 2.

6.3 Method

With a geographical position of each NFI plot the stand data for affected forest stands in the stand registers of each forest company could be selected using GIS and connected to each SP. The recorded treatments in each stand touched by a SP were then sorted into (a) not relevant (i.e., no trees cut) or (b) fellings. The recently recorded fellings were then organised as below:

1. Final Felling (clear-cuts and final fellings with seed tree retention)
2. Thinning (all thinnings)
3. Cleaning (pre-commercial thinning and cleaning)

They were then arranged into their felling seasons as described in Figure 6.1. The seasons, as defined by the NFI and thereby used by the field staff, are not separated by a fixed date, but rather by the time when the buds open in the spring. However, for this particular study we assumed that the buds open on the first of May each year.

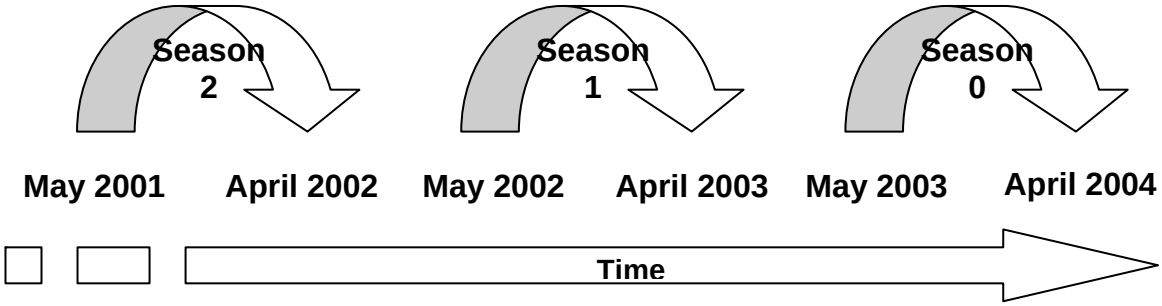

Figure 6.1. The seasons as they are defined for the field season of 2003, i.e. the data used in this survey. Note that the field season of 2003 ended in October 2003, consequently, season 0 from this particular field-season is incomplete and not possible to use for estimates of annual harvesting.

6.4 Results and discussion

Table 6.4.1 shows the distribution of the determined seasons compared with the seasons according to the forest companies' registers. The diagonal depicts the number of SPs where the NFI field staff has determined the same felling season as recorded in the forest companies' registers. As can be seen in table 6.4.1, there are a number of discrepancies, e.g. plots on which the company has registered treatments, but that were not registered by the NFI field staff.

Table 6.4.1. All hits on the companies' forest properties, distributed by season (0, 1 and 2) and whether there was a felling (NF – no felling season 0,1 or 2). Figures in the diagonal (italics) represent matching season classifications.

Number of hits	NFI Season				
Company Season	NF	0	1	2	Total
NF	*572*			4	576
0	13	*5*	2		20
1	14		*10*	2	26
2	21		3	*15*	39
Total	620	5	15	21	661

Of the SPs which fall on woodlands owned by the two companies, fellings have been conducted, according to the stand registers of the two companies, on 85 plots (12.9%) during seasons 0 through 2. The NFI however registered 41 plots affected by cuts during the last three seasons (6.2 %) (Table 6.4.1). Fifteen cuts (2.3%) were attributed to season 1 by the NFI.

As shown in Table 6.4.2, there was a good match between the treatment type as interpreted by the NFI field crew and that noted in the forest companies' stand registers.

Table 6.4.2. All hits on the forest companies' forest properties with a noted treatment by both the NFI crew and the forest companies. Italic figures in diagonal represent matching treatment-classifications.

Number of hits	NFI Season			
Company Season	Final Felling	Thinning	Cleaning	Total
Final Felling	*14*	1		15
Thinning	1	*8*		9
Cleaning			*13*	13
Total	15	9	13	37

6.4.1 Season 1

For the estimates of the annual gross fellings, season 1 is important because the NFI field crew measures the stumps only on fellings that they attribute to that season.

Table 6.4.3. The treatments during season 1, as registered by the companies and by the NFI field crews. The figures in the middle diagonal (bold italics) represent matching classifications.

	NFI Season and Treatment										
Number of hits	NF	0			1			2			
Company Treatment Comp Season 1	No Treatment reg. by NFI	FF	T	C	FF	T	C	FF	T	C	Total
Final Felling (FF)	1	0	0	0	***4***	0	0	0	0	0	5
Thinning (T)	11	0	0	0	0	***2***	0	0	2	0	15
Cleaning (C)	2	0	0	0	0	0	***4***	0	0	0	6
Total	14	0	0	0	4	2	4	0	2	0	26

As illustrated in Table 6.4.3, when the NFI field crew noticed a treatment, they were able to determine successfully what kind of a cut the companies had intended. However, if one considers only the treatments registered by the NFI, the season differs from that of the companies stand registers in 17% of the plots (2/12). If we then add the number of registered treatments that were not noted by the NFI field staff, this figure increases to 16/26 (62%). On these occasions the stump calliperation would not have been made.

6.4.2 Potential impact on the gross volume estimate

For season 1 the NFI found and measured 10 SPs that were also assigned to season 1 in the companies' registers. They also noted and measured 5 SPs that, according to the companies' registers, were not cut during the period. The NFI did not measure 16 plots that were attributed to season 1 according to the two companies' registers (Table 6.4.4).

Table 6.4.4. All treatments registered as season 1, both by NFI and the forest companies.

Number of hits all treatm	NFI season 1	NFI reg other	Total
Comp reg season 1	***10***	16	26
Comp reg other	5	***630***	635
Total	15	646	661

According to the companies' registers there are 26 fellings potentially falling into season 1. The NFI field staff has measured 10 of these, and an additional 5 SPs that were not attributed to season 1 according to the companies' registers.

Concerning Final fellings (FF) the NFI have registered and measured 6 SPs whereas the companies have registered FF on 5 areas with SP plots. This may be considered as an indication that the annually felled volume estimate by the NFI could have been overestimated (Table 6.4.5).

Table 6.4.5. Final fellings (FF) registered during season 1, either by the forest companies or the NFI.

Number of hits FF	NFI season 1	NFI reg other	Total
Comp reg season 1	***4***	1	5
Comp reg other	2	***654***	656
Total	6	655	661

The NFI have registered and measured 4 SPs with thinning, whereas the companies have noted thinnings on 15 areas affected by NFI SPs. This makes for a difference of 11 SPs and may imply an underestimate of the annually thinned volume (Table 6.4.6).

Table 6.4.6. Thinnings (T) registered during season 1, either by the forest companies or the NFI.

Number of hits T	NFI season 1	NFI reg other	Total
Comp reg season 1	***2***	13	15
Comp reg other	2	***644***	646
Total	4	657	661

The NFI have registered and measured 5 SPs with cleaning, whereas the companies have noted a cleaning on 6 areas with NFI SPs. This makes for a difference of one SP and may imply an underestimate of cleaning in the annually cleaned volume (Table 6.4.7).

Table 6.4.7. Cleanings (C) registered during season 1, either by the forest companies or the NFI

Number of hits C	NFI season 1	NFI reg other	Total
Comp reg season 1	***4***	2	6
Comp reg other	1	***654***	655
Total	5	656	661

Tables 6.4.5 to 6.4.7 only contain plots where the NFI and the companies have registered the same treatment. Something worth mentioning is that all the SPs where the NFI has attributed a felling to season 1 have some felling registered during season 0 to 2 by the companies.

Using estimated mean volumes per hectare for final fellings, thinnings, and cleanings, one could translate the differences listed above from numbers of SPs to wood volumes. To obtain those mean volumes, the total volumes harvested in Sweden within each of those three treatments were divided by their respective areas (Anon. 2003a). This yielded values of 181.1, 63.5 and 5.3 m^3sk/ha for final felling, thinning, and cleaning, respectively. The number of SPs classified differently for each treatment type was first divided by the total number of SPs on the two companies' land (661) and multiplied by the total area of their forest holdings (2 617 000 ha). This yields a potential difference in terms of harvested area for those two companies' holdings as a result of differences in determined harvesting season. This area-based difference was then multiplied by the respective mean volumes for the three treatments to give the difference in the total felling volume estimate. These difference estimates were 717 172, -2 765 850, and -20 948 m^3sk for final fellings, thinning and cleanings, respectively, giving a total of -2 069 626 m^3sk.

Based on an assumption that the companies harvest an annual growth of 3 m^3sk/ha, the annual felling would amount to approximately 7 851 000 m^3sk. Thereby the difference in season determination may result in an underestimation of the felled volume by 26%.

This guesstimate is presented in figure 6.4.8 below in order to permit comparison with the figures presented by NFI and SFA.

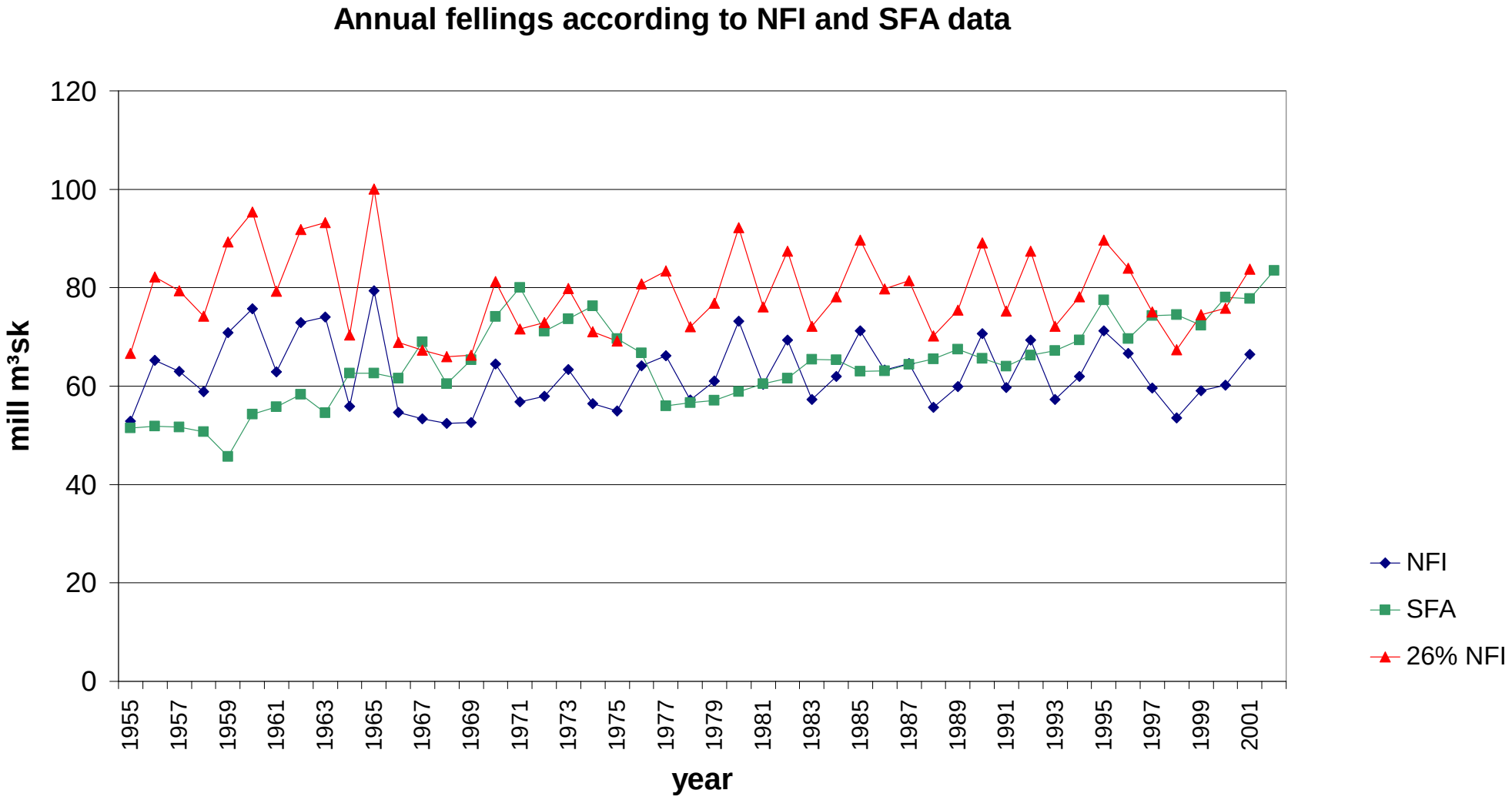

Figure 6.4.8. Annual gross fellings according to NFI and SFA data. Red line "26% NFI" provides an illustration of the results of an underestimate of 26% by the NFI. (The NFI data is considered to be an underestimate of the actual volumes by approximately 5% (Anon. 2003a)).

The actual error in felled volume might be quite different from the 26% underestimate presented above. However it is rather interesting to see the similarities between the SFA and 26% NFI lines in figure 6.4.8. Especially for the periods 1967 to 1975 and then from 1997 and forward the two lines seem somewhat more similar than that of the NFI line compared with the same SFA line. There have been changes over the years, both in NFI and SFA methods and data, i.e. there are certainly other things weighing in to the differences between the curves over the years than season determination in the NFI.

6.4.3 Limitations in study

The main interest is to find out how well the NFI field staff is able to determine the season of cut. As a result of this study came the realization that maybe the NFI field teams miss SPs to a larger extent than expected. According to this study, which is based on a very limited sample, the NFI would seem to miss more SPs than they find, when the company registers is considered as the ”truth”. In a future examination buffer zones could be added on to the stump plot-coordinates in order to allow for differences in digitalization between the different data sources to be accounted for.

The supposition made that the buds open on the first of May could be responsible for rather big parts of the differences observed between companies’ registered seasons and the seasons determined by the NFI. Most of the felling sites that were noted by the companies and were not noted by the NFI were cleanings or thinnings. In those cases the reason might be that the cleanings might be registered in a clump for spring and another clump for fall, or even once a year. Also they can be registered for a whole stand even though only parts of it needed cleaning. In addition a lot of cleanings are performed on trees that have not yet attained the 50 mm diameter bar for stump-calliperation. For final felling sites the areas are sometimes adjusted after the cut when next new aerial-photos are purchased. This study has not taken these factors into count.

The division line between the seasons should be better studied, perharps through interviewing the companies’ staff responsible for their data registration. In addition the importance in securing the data quality in the stand registers should be stressed. Perharps the stump plot was actually situated to the side of the actual felling but inside the department with a registered felling.

Recapitulation of the limitations of the present study:

- Small sample size. These results are based on a small number of plots. With such small numbers the individual NFI team can influence the results.
- Differences in map data. Errors in GPS waypoints, the inventory plot was in a neighbouring stand.
- SPs fall on parts of stand left for nature conservation or even outside cut area.
- The assumption that the buds open on the first of May every year. The parameter changes within the country and between the years.
- Errors in interpretation of the data from the forest companies registers – the register and its maps might not be updated often enough to work as a true reference without additional investigations.

6.5 Recommendations for future evaluations of season determination in the NFI

Finally, here are some points that might be considered when performing future evaluations of season determination in the NFI:

- A broader database/sample; it might be possible to have similar information from other large forest owners as well (SCA, Sveaskog, Swedish church, etc).
- Contacting a sample of their districts and ask about their routines regarding registration in the stand registers (frequency, accuracy).
- Taking in information on the quality of digitalization of maps from the forest owners.
- Buffer zones for the SP coordinates (facilitates comparison and insurance that the SP's are included, that it is possible to verify the stand described by NFI and the stand described in company registers etc.).
- Look closer at stands with registered felling during the critical period in spring that divide the seasons – differentiate the delineation between different regions and maybe even with additional data of the actual year.
- Field visits to a sub-sample of plots with differences in season or treatment type.

7 Conclusions

Forests are at the heart of Sweden, especially when facing a transition from oil dependency. We will increasingly turn towards the forests for providing construction wood, paper, furniture, fuel, heating and other goods. This development might place additional demands on government control systems in order to ensure and communicate a sustainable use of the forest.

In this light the fact that Sweden has two ways of estimating the national gross felling is probably a good thing as the two figures can be compared in order to assess their accuracy. This study has shed light on possible improvements to the gross felling estimates for those two methods.

Improvements suggested for the SFA's data:

Increased co-operation with VMR

Bio-fuel survey

Imports and exports within the EU (the SCB-questionnaire (INTRASTAT) does not cover trade with an annual value below 1 500 000 SEK)

"Other wood"-survey (the last was performed as a part of AVB92)

Measure of level of uncertainty

Improvements suggested for the NFI:

Volume estimates (study placement of measurement vs cut, bark thickness study, stump shrinkage study)

Remote sensing technology (combining satellite data with field data)

Organisational (additional trainings on test sites, GPS-waypoints for all SP, stressing importance of SP's and felling statistics)

Additional studies (questionnaires to landowners, another study of this type)

Additional improvements and open reports of possible errors would increase credibility, but also in addition the two can be compared and thereby work as an extra control system. In the future there would be good possibilities of increased accuracy in the data through remote sensing and new technologies.

In a comparative study on NFI data between 1973 and 1977, Daamen (1980) found that there were differences in what SPs were inventoried between the NFI field team and the Control field team (making the same inventory in the same SP without the first teams knowledge and with more time).

Table 7.1. Differences in season determination between NFI normal teams and control team from Daamen (1980).

	Ordinary field team	
	Season 1	**Other**
Control field team		
Season 1	729 (68.3 %)	189 (17.7 %)
Other	149 (14.4 %)	NA

Table 7.1 could be interpreted as indicating an insecurity in season determination on (189+149) 338 of the SPs, i.e. indicating insecurity in season determination for approximately

30% of the SPs with noted fellings. Daamen's (1980) study does not show that any particular treatment should be more difficult to determine the time of other than fellings performed on non-forest lands and other fellings.

SFA gross felling statistics depend on a figure from the NFI regarding felled wood left in the forests. The relative share of the gross felling left in the forest as estimated by the NFI, is used by the SFA in the calculation of their gross felling estimate. This figure could be included in NFI sample by measuring and determining the season of cut on those trees that are found within the current sample plots. However, there would be nothing to weigh that figure by as is done today were the NFI to stop producing a gross felling estimate. In addition, the season determination of a single tree is even more difficult than a management unit. A volume of felled trees left in the forest would be difficult to estimate in any other way than in a sample (as NFI are doing). Changing the NFI, i.e. taking away the stump calliperation as it is performed today would probably lead to less emphasis on season determination and eventually the current know-how would probably dissipate, as well as the felt importance of the stump calliperation and season determination would decrease with time. The data for felled wood left in the forest would then potentially have bigger errors than what the NFI produces today and with nothing to weigh it by it would also have an effect in the SFA's gross felling data, all be it rather small.

Yet another consequence of halting NFI stump inventories would be to statistics on regional distribution, species harvested and extraction of other assortments related to areas and land ownership types. (For example figure 7.9 and table 7.12 in 2006 SSÅ (Anon., 2006) containing forest land area subject to final felling, thinning and cleaning, by ownership category and region, and for entire country as well as area subject to final felling, by ownership category).
Data on extraction of tops and branches, as well as data on areas of stump extraction will probably have increasing demand. These parameters are estimated today using NFI-data. However, extracted stumps would leave the NFI teams with less stumps to measure in order to estimate a volume.

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