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Wood resource dynamics in the Scandinavian forestry sector

Virkesbalansens dynamik i den skandinaviska skogsnäringen

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Abstract

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The Scandinavian forestry sector is facing a major challenge. After a century of rapid growth—both in forestry and the forest products industry—the sector is approaching a situation where rapid growth will no longer be possible simply because most of the annual forest growth is already being utilized. One may choose to let the forces of the free market shape the transition from rapid growth to moderate growth. *Or one may choose to pursue policies that are intended to improve the transition in one way or another.*

Wood Resource Dynamics *(i.e. this volume) describes the historical background for the current situation, both concerning the supply of and demand for wood and concerning existing legislation and management practises. The volume further describes the problems caused by slow growth in the forestry sector, and a discussion of the various policies that can be conceived to soften these problems.*

A system dynamics simulation model was developed to elucidate the likely future effects of the various policies. The volume proceeds to illustrate how this computer simulation model of the Scandinavian forestry sector can be used in discussions of long term policy for the forestry sector. The general applicability of the simulation model is being demonstrated by adapting the model to the case of Finland.

Finally, Wood Resource Dynamics *gives a short introduction to the system dynamics method for model building by presenting two applications to concrete, short term problems in the forestry sector—pulp inventory control and forest stand management.*

In this publication "forestry sector" refers to both forestry and the forest products industry.

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Contents

Preface 5

1 Forestry in Sweden during the industrial age 7
by Leif Mattsson and Einar Stridsberg
1.1 The purpose, theme and arrangement of the paper 7
1.2 The latter half of the 19th century: a period of accessibility and exploitation 8
1.3 The first half of the 20th century: forest production for industrial conversion 10
1.4 The last few decades: harvesting problems 13
1.5 The balance between supply and demand in wood resources in Scandinavia 16

2 Transition strategies for the Scandinavian forestry sector 19
by Jørgen Randers and Lars Lönnstedt
2.1 The challenge of a transition to a period of modest growth 19
2.2 Model simulations illustrate the policy options 20
2.3 Two transition paths 21
2.4 Policies to facilitate the transition . . 25
2.5 Future tasks of the forestry sector 26

3 "The transition from ample to scarce wood resources" A play in four acts . . 28
by Jan-Evert Nilsson and Carsten Tank-Nielsen
3.1 Prologue 28
3.2 Act one: Development determined by free market forces 28
3.3 Act two: Government price control 30
3.4 Act three: Regulated industrial expansion 32
3.5 Act four: Active industrial collaboration 34
3.6 Epilogue 35

4 The SOS model and the Finnish forestry sector 37
by Jari Kuuluvainen
4.1 Developments in the Finnish forestry sector between 1945 and 1975 . . . 37
4.2 Reparameterization of the SOS model 39
4.3 Some structural elements of the model and their relevance to Finland . . 43
4.4 Conclusions 45

5 Stock fluctuations in the pulp industry 46
by John E. Høsteland
5.1 Introduction 46
5.2 Theories explaining economic fluctuations 46
5.3 Sulphite pulp 47
5.4 A system dynamics model for stock fluctuations 49
5.5 Simulations with the model . . . 53

6 The dynamics of a simple stand . . . 55
by Kjell Kalgraf
6.1 Introduction 55
6.2 The state of a stand 55
6.3 Increment as expressed in the model 57
6.4 Other mechanisms in the model . . 61
6.5 Model runs 61
6.6 The model stand with four thinnings 62
6.7 Model stands developing into natural forest 63
6.8 Comments 64

Summary 65

Sammanfattning 66

Preface

Since the 1960's there has been an increasing awareness of the fact that the world's natural resources are finite. Consequently, alternative strategies to a continued materialistic expansion have attracted increasing attention. In some countries and in some industrial sectors, low growth policies have already become a reality. The Scandinavian forestry sector represents an upcoming example: after a rapid increase in the consumption of wood by the forest products industry in the 1950's and 1960's, the annual harvest has now reached the same level as the forest increment. Thus, a transition from a period of rapid growth to one of modest growth has become necessary.

This situation formed the point of departure for a research project carried out between 1974 and 1978 by the Resource Policy Group in Oslo. The project, entitled "Society and Forestry" (termed SOS after the initials of the Norwegian project title), was financed by the Technical Research Councils in Norway and Sweden and was given the following terms of reference:

- To identify the problems arising from the constraints made by the limited wood resources on continued growth in the forest products industry.
- To elucidate the consequences of policies that were proposed in order to facilitate the transition from a period of rapid growth to one of modest growth in the industrial use of wood.
- To design a model for the simulation of conceivable development patterns in the Scandinavian forestry sector during the next 30—50 years, for a number of different assumptions.

Two comprehensive accounts of the project are available.

- Randers, J., Stenberg, L. og Kalgraf, K.: *Skognæringen i overgangsalderen,* J. W. Cappelens Forlag, Oslo, 1978. An English translation entitled *The Forest Sector in Transition* is available from the Resource Policy Group, P.O. Box 324 — Blindern, Oslo 3, Norway.
- "Samfunn og Skog-prosjektet — en teknisk rapport" (Society and Forestry—a technical report), Resource Policy Group, Oslo, 1979.

The first publication is a popular account of the project while the second describes the construction of the simulation model. *Wood Resource Dynamics* serves as a complement to the two publications in that it makes more of the results of the project available in English. In addition, this publication includes a number of papers dealing with some of the special aspects of the project.

Wood Resource Dynamics is directed at researchers and other persons active in the sector, who are interested in the wood resource problem and in the type of policy analysis of which the SOS-project is an example. We have endeavoured to make the publication readable and have therefore avoided detailed accounts and mathematical expressions. Six papers are included. They have been written and arranged in such a way that they may be read together or individually.

All of the authors of the papers are, or have been, associated with the Resource Policy Group in one way or another. Jørgen Randers directs the group; Kjell Kalgraf, Jan-Evert Nilsson, and Carsten Tank-Nielsen are researchers in the group; John E. Høsteland, Jari Kuuluvainen, and Lars Lönnstedt have been associated with the group as guest researchers; Einar Stridsberg participated in the reference group that formed the basis for the SOS model. Leif Mattsson and Einar Stridsberg further have worked together on a historical project within the scope of the Society and Forestry project.

The guest researchers of the group were financed through grants from The Swedish University of Agricultural Sciences, The Agricultural Research Council of Norway, The Finnish Academy and The Finnish Forest Research Institute.

The authors are themselves responsible for the content of their papers, although they have had to tolerate the advice and directives of the editors, as well as extensive re-drafting.

Lars Lönnstedt *Jørgen Randers*

1 Forestry in Sweden during the industrial age[1]

by Leif Mattsson and Einar Stridsberg

1.1 The purpose, theme and arrangement of the paper

The industrial revolution is generally accepted to have been an era of great change, which also applied to forestry. At around the end of the first half of the nineteenth century, the conversion of wood at sawmills on an industrial scale began to assert itself to an increasing extent. During the next 150 years, the new industrial conditions would give rise to a strongly dynamic development in forestry, which represented a sharp departure from the direction followed by earlier development and which applied not only to the overall picture but also to the other forms of forest utilization. The "new" activities made possible by industrialization would undergo a changing process of development, as would the "old" activities associated with the agrarian community, some of which were to disappear rapidly while some were to continue pertinaciously.

The purpose of this first paper is to provide a picture of this dynamic turn of events that has led to the situation in which we find ourselves today, in order to make it possible for the reader to assess the following, more forward-looking papers against the background of historical fact. In this context we would like to emphasize the importance of keeping the overall picture in mind; for instance, when concentrating on the problem of the imbalance in the supply and demand of wood, one must also consider other factors that, at first glance, would not appear to have any bearing on the matter. Thus, it is our hope that an historical review, which underlines the multifarious interests that were involved in the exploitation of the natural resources of the forest in the past, will help to encourage an understanding of the need for a comprehensive and multilateral view in respect of future events as well.

We have elected to make the description of the management of the forest resources in an historical perspective, together with the wood-consumption particulars presented in figures 1 and 2, the central theme of this paper. Indeed, wood consumption is the one phenomenon since the 1850s that it has been possible to estimate quantitatively over such a long period of time and for the country as a whole.

With the institution during the 1920s of the National Forest Survey in Sweden, it became possible to replace the previous estimates of increment, which were very much a matter of guesswork, with more reliable calculations of increment and standing volume, with the result that meaningful studies on the balance of wood resources in quantitative terms became possible (see also figure 3).

To distinguish between the "new" and "old" uses of wood, we have divided the total consumption of wood, as shown in figure 1, into the two industrial assortments of sawlogs and pulpwood (ind) and into a category known as other consumption (oth), mainly consisting of household wood, firewood and charcoal wood. In figure 2 the consumption of industrial wood is similarly divided into the two assortments of sawlogs (sl) and pulpwood (pw). As can be seen from the trend lines, three quite clear phases of development may be discerned

[1] This paper is a much condensed synopsis of certain parts of the research project, "The role of the forest in Swedish land use—a development study". A more comprehensive account, with fuller documentation, will be found in Swedish in the book, "Skogen genom tiderna" (published by LT Förlag, Stockholm, 1980).

during the 125 years between 1850 and 1975. Consumption during the latter half of the 19th century (phase one) is characterized by a sharply increasing trend, which is clearly dominated by the increasing consumption of sawlogs, but which also gains impetus from a slight increase in the consumption of other assortments. In respect of the first half of the 20th century (phase two), the consumption of sawlogs remains at roughly the same level (figure 2) but, owing to the emergence of the new pulpwood assortment, the consumption of industrial wood continues to increase at about the same rate as before. However, because of a decrease in the consumption of other wood, which is of the same order as the increase in the consumption of pulpwood, the trend is broken as regards the total consumption of wood. Although this trend was steady between 1905 and 1955, the averages over the interim five-year periods show wide deviations. Finally, the trend towards increased wood consumption reappears between 1955 and 1975 (phase three), although this time the trend is stronger and applies to both pulpwood and sawlogs, with the consumption of other wood falling to a rather insignificant level.

The presentation of the rest of this paper will be based on these clearly discernible phases. In a final section we will then compare the development in Sweden with that in Norway and Finland and conclude that the future situation facing the forestry sector is the same in all three countries; viz. the consumption of domestic wood can only be increased modestly because of the constraints imposed by the domestic supply of wood resources.

1.2 The latter half of the 19th century: a period of accessibility and exploitation

In addition to the extraction of wood referred to above, in former times the forest resources were also affected by an *agrarian form of forest use* that focused on grazing and shifting cultivation, as well as on other diverse forest activities such as the distillation of tar and potash. It is evident that shifting cultivation also implied an extraction of wood from the forest, in as much as the wood was converted to the requisite ashes. But even in the case of grazing it is obvious that felling work carried out by the farmer involved a conscious thinning-out in order to produce fewer trees but better grazing (compare, for example, the 1899 forestry committee report, page 67). During the 18th century and early 19th century, the "shortage" of forests was a much talked about subject, with the shortage of wood looked upon as a problem over an extensive area. A severe limitation on the utilization of wood and far-reaching improvements in silvicultural activities were recommended as the means of getting to grips with the problems. Yet instead of a decrease in the consumption of wood, the latter half of the 19th century witnessed an enormous increase in consumption, as is shown in figure 1.

One cannot refrain from asking how a development that was so diametrically opposed to that which was recommended could possibly have taken place. The answer is mainly to be found in the fact that industrial growth in the forestry sector for the most part implied that previously inaccessible wood resources were now becoming available (dominated in Norrland by the clearing of waterways and the construction of driving courses), and in the fact that industry was now taking over many of the harvests formerly under the auspices of agrarian forest uses. The abolition of shifting cultivation, which the authorities had been advocating for centuries, quickly became a reality when the felling of wood for industrial conversion provided the crofter with a higher income and the farmer a better yield. Similarly, the extent of potash distillation, and, somewhat later, also of tar production, fell to an insignificant level.

Another feature of this expansive development was the way in which the involvement of the conversion industry also concerned the "land" business. In view of the capital resources that the timber trade had at its disposal, it probably seems natural that the trade should primarily have been

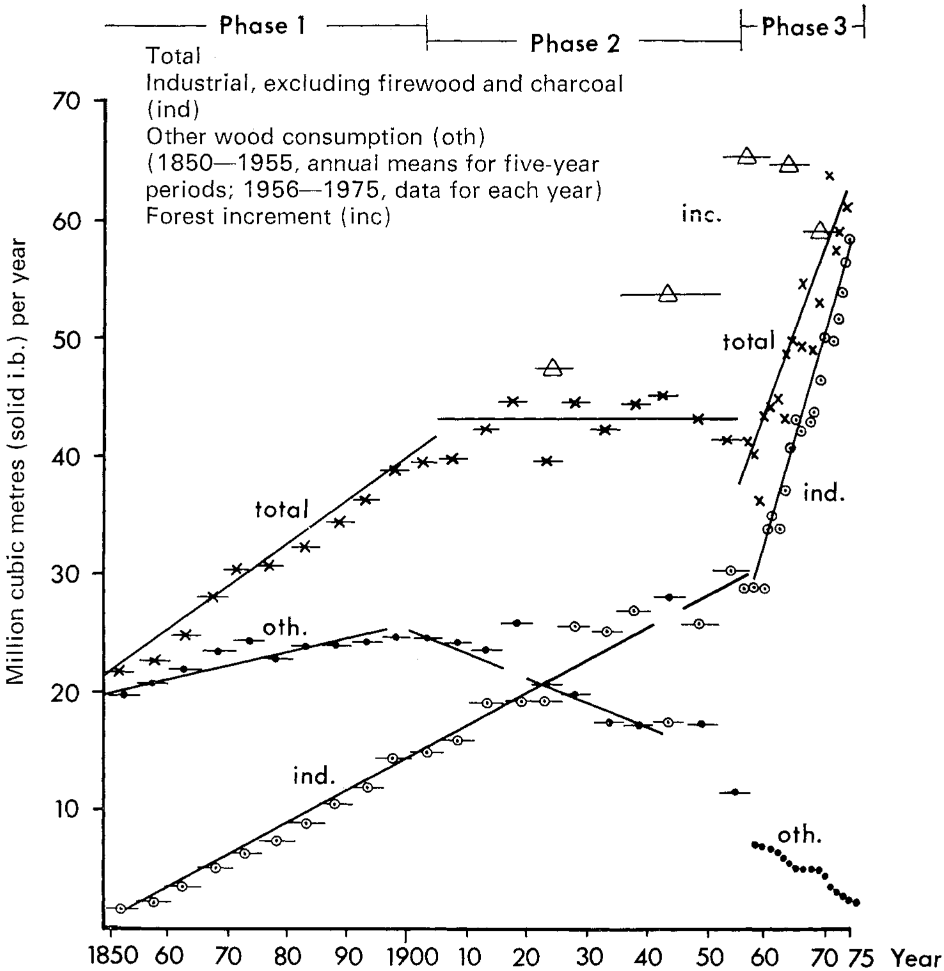


Figure 1. Wood consumption and forest increment, 1850—1975.
Sources: Arpi, 1959, "Sveriges skogar under 100 år", part 1.
"Statistical Year Book of Forestry", 1955—1975. The National Forest Survey (unpublished information provided by Klaus Janz)

responsible for the river-driving activities and no more, with the sawmill company receiving the logs at the lower landing after they had been felled and horse-drawn to the river by the woodlot owner. But as far as the enormous areas of state forest acquired in Norrland since 1865 were concerned, the state forest enterprise was content to sell standing timber, and the involvement of farmer forest owners became even more passive. For these forests, the logging rights acquired by the sawmill company were not confined to individual trees that had been assessed and marked but were generally in the form of wide exploitation rights, which often covered periods of as long as 50 years. In view of the availability of both forest and manpower during the winter logging season, it would appear that the timber trade succeeded, thanks to a deliberate strategy, in putting itself in a negotiating position where supply exceeded demand. With such an ample supply of wood resources in relation to demand, the timber trade had little interest in silviculture or in the concept of the forest as a renewable natural resource. This applied to the farmers to an even greater extent, because they were just as critical as before of the silvicultural proposals that forest grazing should be abandoned.

1.3 The first half of the 20th century: forest production for industrial conversion

Towards the end of the 19th century most forest land had become accessible and the resources from large-dimension stands started to dwindle (cf. the sawlog curve in figure 2). In contrast, production rose considerably in a pulp industry that had grown up in southern Sweden in the late 1860s in the form of small-scale operations at groundwood mills. But after the change to chemical pulp, the industrial activities developed into very large-scale operations requiring considerable capital investment. By this time even the forest enterprises in Norrland decided it was wise to invest in these mills as a valuable complement to the sawmills. This use of smallwood enabled the thinnings that were conducive to growth to be implemented and the inert remains of small-dimension forests to be removed.

However, during the 1890s the forest enterprises had already shown a preference for purchasing entire estates instead of just the exploitation rights; this was partly because of the terms of such agreements being reduced from 50 to 20 years in 1889. Since the acquisition of such estates embraced the standing crop as well as the forest land, there was a greater readiness to regard the forest as a renewable natural resource, in consequence of which there was a greater awareness of the importance of silviculture. But the acquisition of the estates by the enterprises meant that the land-owning farmers faced the threat of "being reduced to tenants, lodgers and proletarians". The final solution to the problem came in the form of the land acquisition act of 1906, which made it illegal for companies to acquire land. In spite of the efforts of strong forces within industry to have the law rescinded, instead the provisions of the act were not only widened but extended to apply to the whole country—not just to the provinces of Norrland and Dalarna. Since the sharp increase in the area of crown land also started to decline at this time, the land acquisition act of 1906 remains a distinct dividing line between the highly dynamic, land-acquisition activities of the 19th century and the rigid land-ownership structure that is characteristic of the 20th century.

But the question as to who should *own* the land also raised the question as to who should *use* the land and, consequently, also *how* the land should be used. In this way the very much socially oriented land acquisition act came to have important consequences in respect of those interested in maintaining proper silvicultural activities. In the conflict between the interests of the two forestry groups, namely, the small firms with their roots in farming on the one hand, and the large enterprises concentrating on industrial wood conversion on the other, the community at large had taken the side of the weaker party—the farmers. But, for this sympathetic attitude towards the farmers to persist, society required the farmers to respond with a sympathetic attitude towards the silvicultural demands that were now being asserted with steadily increasing pressure. At a faster rate than the long drawn-out and highly emotional debate of 1892—1906 about land acquisition, the national silvicultural act had found its way onto the statute books between 1895 and 1903. However, the most important aspect of the act was not its rather obtuse wording but the institution of the regional authorities—the forestry boards—who were to administer the law; but rather than functioning as legal watch-bodies, they came to act more as advisory bodies to the forest-owning farmers.

The situation described mainly concerned northern Sweden, where a great deal of land was acquired by the forest enterprises. In contrast, specific conditions applied to the mining districts of central Sweden, with their long-standing tradition of forest management that was geared to the production of charcoal. In southern Sweden, farmer-

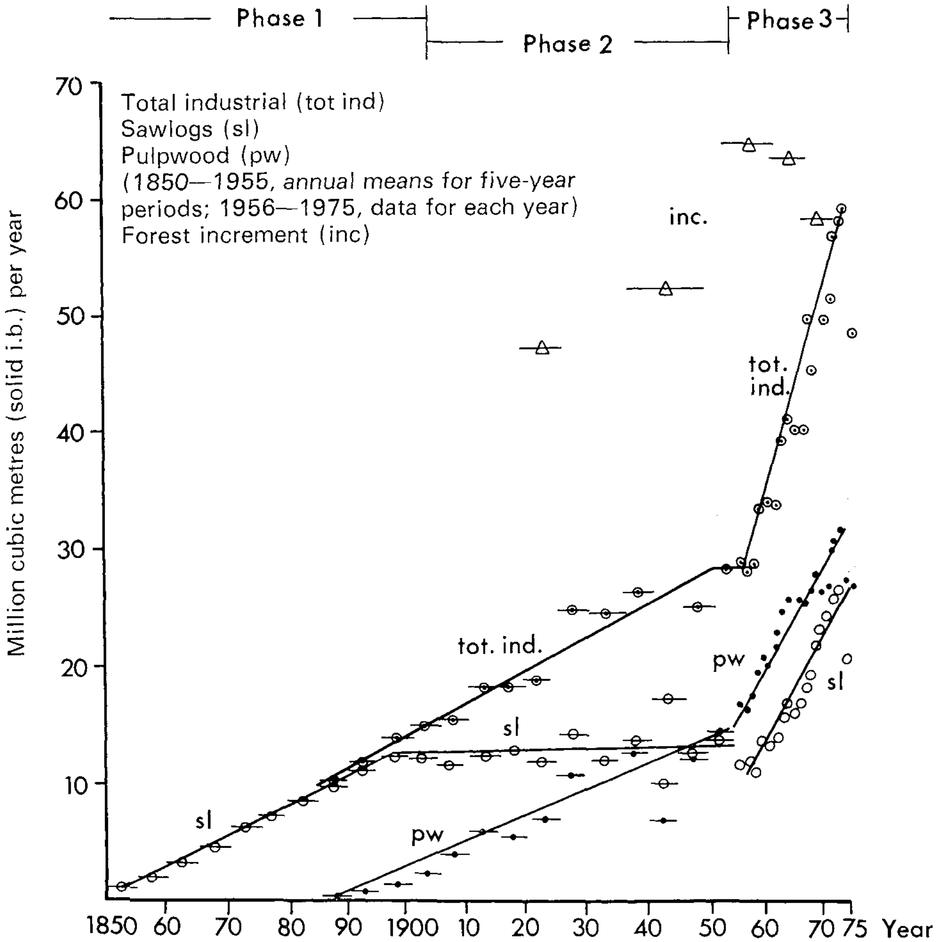


Figure 2. A breakdown of the industrial consumption of wood by assortment, and forest increment, 1850—1975.
Sources: Arpi, 1959, "Sveriges skogar under 100 år", part 1.
"Statistical Year Book of Forestry", 1955—1975. The National Forest Survey (unpublished information provided by Klaus Janz)

owned forests predominated and forest produce was more diversified, with greater emphasis on the home market and on wood conversion at the joineries and furniture factories. But in addition to this there were also forestry operations that concentrated on specific products for export and which fluctuated to a high degree with fluctuations in international trading conditions. Thus, such activities were of a distinctive short-term nature and it was against these "opportunist exploiters" that the silvicultural advocates directed themselves. Since the responsibility for ensuring observance of the law was removed to some extent from the shoulders of the forest owners and placed more on those holding the logging concessions, the resistance against the "profiteering wood speculators" grew, with the result that the regulation of forestry by the community, both in the south and in the north, acquired the nature of a form of protection for the farmers against illicit and ruthless exploitation. The greatest friction at this time centred on forest-land grazing but, thanks largely to the efforts of the forestry boards, in close collaboration with agricultural expertise, this ancient activity declined considerably. Consequently, the forestry pursued by the farmers also concentrated on the production of wood, and pulpwood, in particular, became known as "a farmer's assortment". Because of the income that could now be made from these small-dimensioned forests, wood for household use became the subject of limitations and austerity measures (cf. figures 1 and 2).

Accordingly, the break in the trend in wood consumption that occurred at around the turn of the century found parallels in other fields, although most particularly in respect of the land-acquisition and silvicultural legislation described above. The general trend from a relatively free to a more restricted production climate that came to characterize the 20th century, together with the exercise of greater control by the community at large and the emergence of influential pressure groups, strongly manifested itself in the forestry sector at a very early juncture.

The greater influence exerted by society in the form of the silvicultural act made itself apparent through a successive tightening of legislation through the acts of 1903, 1923 and 1948. First to form a trade association were the forest enterprises, doubtlessly spurred on by the additional pressure arising from the agitation around the land-acquisition legislation. The individual forest enterprise found that the Association of Swedish Forest Owners represented a means of consolidating the unity of the enterprises and of promoting the social responsibility and silvicultural interests of the enterprises. In 1918 the employees formed the Swedish Union of Forest Workers. It was really not until the 1920s that the farmers or private woodlot owners formed an association, which was mainly to be responsible for silvicultural matters. However, largely as a result of the depression of the 1930s, the association was reorganized to become an economic association, whose chief aim was to create a powerful counterpart on the suppliers' side to the purchasing organizations set up in 1920 by the forest products industry. But after the forest owners' movement had widened its field of activity in 1950 to include the forest products industry, and after similar moves towards integration in the public sector had taken place since the 1930s, the three main categories of forest owner, namely, the state, the forest enterprises and the private woodlot owners, had all adopted very similar policies, which were also consistent with the wishes of the community. Thus, compared with the shifting, dynamic and liberal period of the 19th century, the first half of the 20th century was a period of much greater unification, which in time could be distinguished by the increasing concensus in respect of the general principles governing the use of the natural resources of the forest. *The forestry sector therefore developed towards a common goal: the production of wood for industrial conversion.*

As was true for industry in general, the main feature of the development in production was the increase in knowledge that had been gained from scientific research. In the case of the forestry sector, this applied above all to the biological production techniques. Here again, the trend can largely be traced back to the turn of the century. Even towards the end of the 19th century, it was generally possible throughout Europe to discern a trend towards a critical view of the excessively rigid framework within which forest management plans were drawn up, and during the 20th century, therefore, greater emphasis was put on silviculture based on biological techniques. However, one would have to wait until the 1940s until a fundamental principle of silviculture became widely accepted throughout the country.

The main direction in which society's guidance of silviculture had been aimed right from the beginning of the century was to break the exploitation of the forests which, at the end of the 19th century to a much greater extent than in the middle of the century, had resulted in forest production having become run down over a wide area. But with the introduction of constructive forestry, in which only a proportion of the annual increment was cut, with the remainder being left to increase the forest assets, the production capacity of the forests was increased. With the completion of the second national forest survey, it was possible to quantify the success that these efforts had achieved; from figures 1, 2 and 3 we can see that there had been an increase in both increment and the volume of wood in the stands.

1.4 **The last few decades: harvesting problems**

From figure 1 we can see that there was a renewed strong trend towards an increase in wood consumption during the two decades covered by phase 3, i.e. 1955—1975. Generally speaking, this can be seen as the result of adaptation to the considerable increase in the volume of wood resources that had been built up over the past 50 years. Because of the way in which annual increment was steadily outpacing the annual cut, as had been established by the national forest survey (see figure 1), fears were being voiced in around 1960 that instead of an "understocking" of wood resources, there was now a danger that the forests were becoming "overstocked", and, because of insufficient clear-cutting, were becoming too "elderly", with excessively large-dimensioned trees. Even the 1973 report of the committee appointed in 1965 to examine forestry policy strongly recommended that the policy of restricting annual cuts should be abandoned in favour of encouraging felling.

Yet, as can be seen from figure 1, in the meantime the forest products industry had expanded and wood consumption had increased at a much faster rate than during the similar period of expansion in the 19th century. But a new forest committee appointed in 1973 was soon able to ascertain that the consumption of wood by the rapidly expanding forest products industry had now attained the same proportions as increment. Thus, Sweden now found itself in that situation which forms the theme of

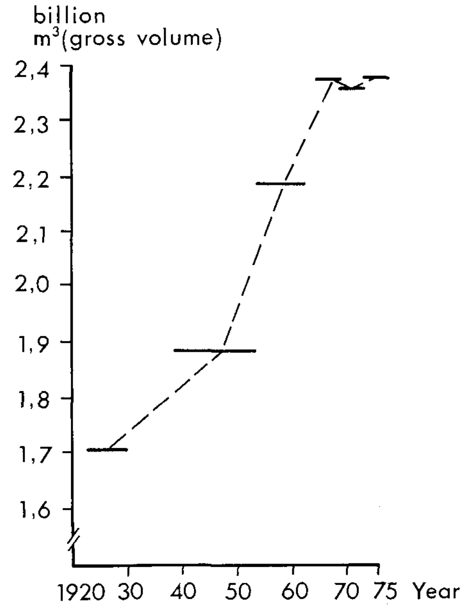


Figure 3. Development in the volume of the standing crop.
Source: "The Statistical Year Book of Forestry", 1955—1975.

the papers in this publication: the constraint imposed on the forest products industry to break away from rapid growth owing to the limited supply of resources. Perhaps the conflict has been heightened in Sweden by the most recent phase of development, with the demand predicted by the buyers on the one hand (that the consumption of wood will continue to increase at the same rate as during the last 20 years), and, on the other, the supply considered practicable by the supporters of sustained-yield forestry, in the light of a number of different, alternative forestry policies. To illustrate just how completely irreconcilable the demand and available supply are, in figure 4 the former has been represented by an extrapolation of the curve of the trend during phase 3, and lines have been inserted to represent the supplies that would be available from three different forestry policies, as proposed by the 1973 committee in its report of 1978 entitled, "Skog för framtid" ("Forests for the future"). In spite of the fact that these alternatives represent widely differing views

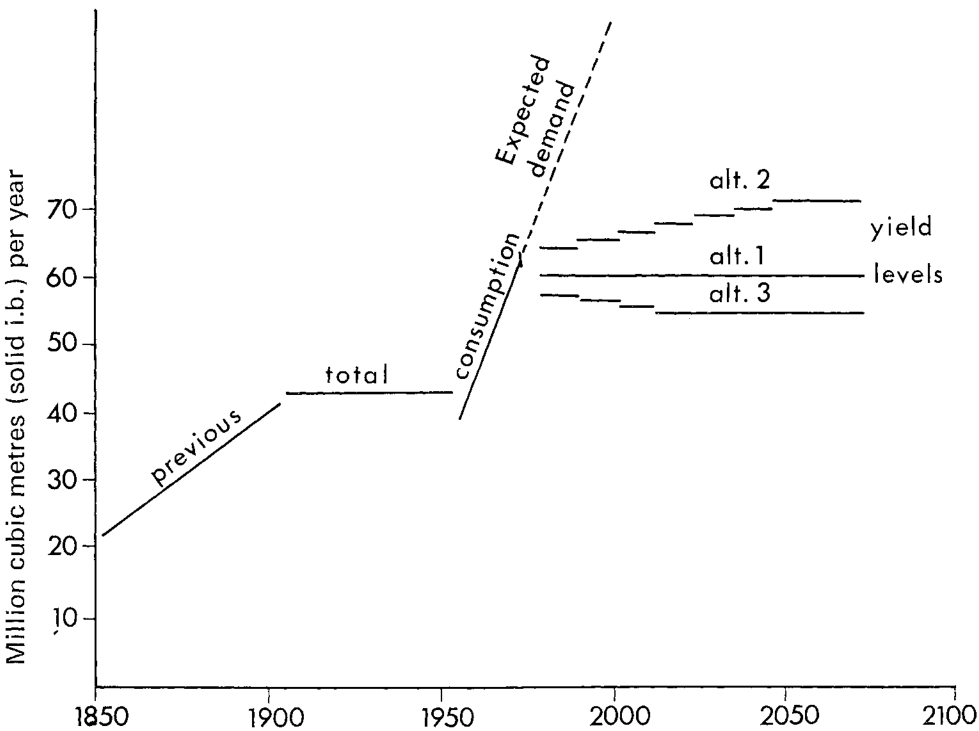


Figure 4. Expected demand and potential yield—two irreconcilable concepts.
The expected demand (dashed line) is derived from an extrapolation of the main trend in wood consumption during the period 1955—1975. The yield levels represent the three alternatives in respect of potential yield and annual cut as presented by the 1973 committee on forestry in the appendix to its publication, "Skog för framtid", SOU 1978: 7 (addenda).

on the type of logging policy to be adopted, the differences in the volumes of wood available become almost insignificant when viewed in the light of the expected demand.

To return to our purpose in this historical analysis of relating what actually did happen, we find that, with respect to the share of the consumption of wood in phase 3 accounted for by the two main categories of industrial wood and other wood (figure 1), there has been a slight increase in the rate of decline in the importance of the latter. From a share of 60 % at the turn of the century, and of 25 % in 1950, the share of other wood is now less than 10 %, and therefore no longer serves as a "reserve" of any importance so far as the supply of industrial wood is concerned. As regards the sawmill industry we find that, after the period of stagnation that occurred during the first half of the 20th century, it has now entered a period of growth, with an increase in the consumption of wood that is commensurate with that of the pulp industry. However, to a great degree this is related to the larger tree dimensions in the now more-mature forests in southern Sweden and to a greater concentration of industry in this area.

In common with phase 2, we find that in addition to the increase in wood consumption phase 3 also represents a new era in other important respects. In contrast to the first 50 years of the 20th century, when the main feature was the emphasis given to production, interest during the last few decades clearly came to be focused on the problems of harvesting, in consequence of which mechanized methods of logging were introduced. This was a development that could reasonably be expected in a situation where wood prices had been falling since the "Korean boom" of 1951 until the general boom of 1973/1974 and, at the same time, labour costs had been rising faster than machine costs.

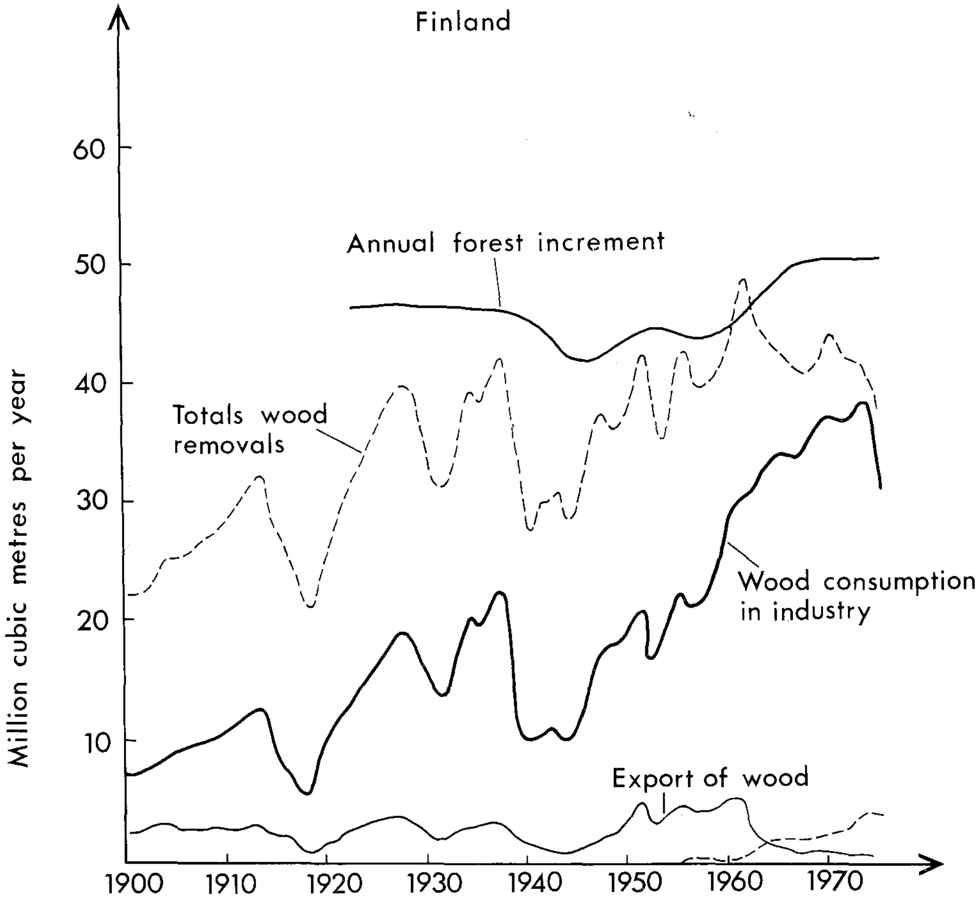
Yet mechanization has also had great implications in respect of the primary production in the forests. In previously unknown ways and apart from the aim of encouraging a high yield, silviculture became directed at satisfying the common requirements of loggers and the conversion industry for more homogeneous stands with a limited number of tree species and greater uniformity as regards the age and diameter composition of the stands. The extent of clear-cutting increased at the expense of thinnings and encompassed logging units many times greater in area than before. The introduction of year-round logging brought about an increase in insect damage, as well as in purely mechanical damage to the stand and the ground. The adverse effect that clear-cutting of vigorous stands, the reduction in thinnings, etc., had on the silvicultural result also gave rise to an unexpected—but in retrospect hardly surprising—development that was detected in the national forest survey; namely, a reduction in increment (see figures 1 and 2) and stagnation in respect of the volume of stands (see figure 3).

However, mechanized forestry does counteract this situation to some extent since it also enhances increment, largely as a result of fertilization. But this activity, together with other artificial operations, such as chemical treatment, has also brought environmental considerations more to the fore. Combined with the effects of large-scale operations on stand structure in the form of poorer adaptation to changes in the site, a deterioration in the microclimate and homogeneous monocultures, with the dismal landscapes and the danger of ecological calamity to which they give rise, these developments have created a demand for a more environment-conscious forestry that takes into account the desires of conservationists and recreational interests to preserve the forests as nature areas.

But the social effects of modern methods of forestry have also been conspicuous and far-reaching. The jobs previously made available by large-scale forestry to the farming population during the winter season have now disappeared and, in the private forestry sector too, the forest owner associations are operating as logging contractors, employing the same methods as large-scale forestry and characterized by the high level of mechanization and permanent year-round work forces. The benefits to the employees have been higher wages and, above all, secure, year-round employment, although a great deal still remains to be done to reduce accidents and occupational injuries.

But although greater productivity has been achieved through a drastic reduction in the man-day requirement per cubic metre, there is another side to the coin: the sparsely populated areas have become even more sparsely populated, and even large-scale forestry has been unable to escape the serious adverse effects of the movement of people away from the rural areas. As regards the prospects of using forestry to supplement and improve the agricultural situation in areas where farming was not sufficiently extensive, the early years of mechanization encouraged a pessimistic approach to the combination of farming and forestry, and the concept of forestry as a supporting industry for agriculture was as good as given a death certificate by the 1973 committee report.

However, the idea has been revived in more recent years, largely because of the development of less-destructive machines that are capable of performing more-selective and more-refined operations, with greater yields and less environmental damage as a result. Thus, there are now much brighter prospects of gradually increasing mechanization on the farmer-owned estate by means of more-diversified and small-scale, motor-manual operations, especially as far as thinning and silvicultural operations are concerned. The government guide-



Figures 5a, b and c. Forest increment, annual cut and industrial consumption of wood in Finland, Norway and Sweden, 1900—1976.

lines for policy in the agricultural sector that were presented in 1977 clearly demonstrated that attitudes have now become favourably disposed towards joint farming and forestry ventures.

In this historical account of forestry in Sweden we have chosen wood consumption as the central theme; partly because this is probably the clearest way of describing the development of the forestry sector and the problems facing the sector at the present time (and which are discussed in the following papers), and equally because wood consumption has played a central role in the development of forest management policies: from the multifarious land use of the agrarian society, through the period of "single-minded" wood production for industrial conversion, up to today's demand for a new kind of "multiple use forestry", where new nature and environmental considerations have superseded those which dominated in the old, agrarian society. But we have also tried to reveal, against the background of the break in the trend in respect of wood consumption and the different phases that clearly emerge therefrom, the way in which a new period of transition is evolving in many essential respects.

1.5 The balance between supply and demand in wood resources in Scandinavia

Figure 5 illustrates the trends since the turn of the century in Finland, Norway and Sweden in respect of annual cuts, the in-

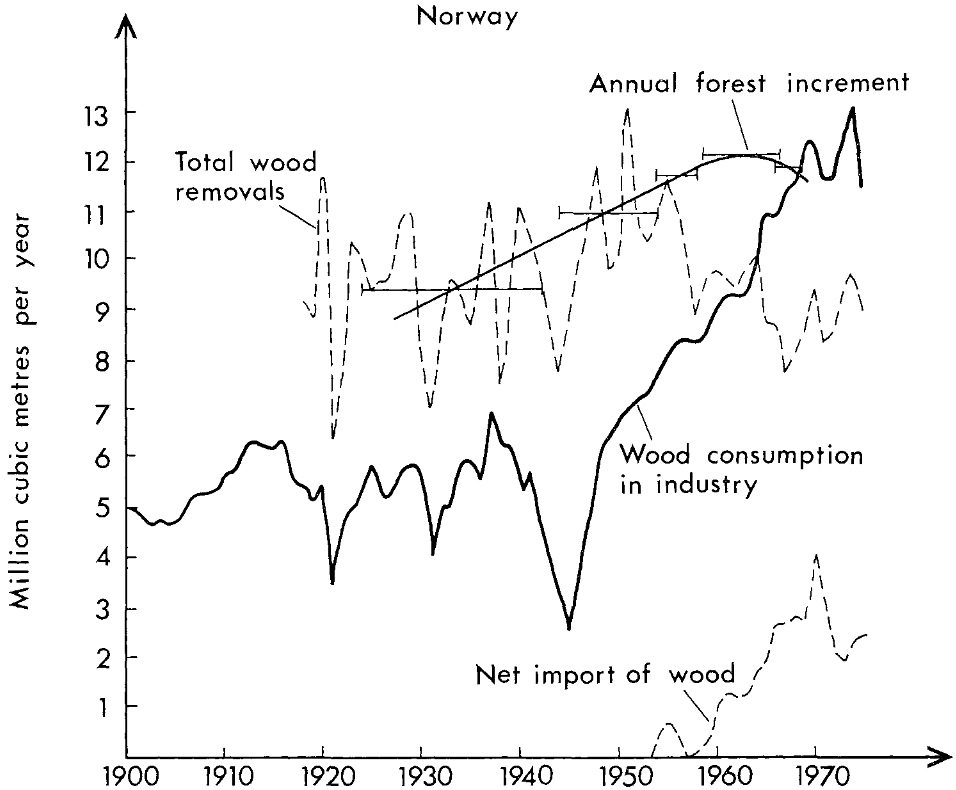


Figure 5b.

dustrial consumption of wood, increment, and roundwood imports and exports. The graphs presented in figure 5 show that the main features of the development during the present century are similar in a number of important respects:

- In all three countries, the industrial consumption of wood has been increasing, both in absolute terms and in terms of its share of total wood consumption.
- In all three countries, the two world wars caused sharp falls in the industrial consumption of wood.
- In the case of increment, the trend of an earlier rise becoming a fall in more recent times is discernible for Norway and Sweden.

Some important differences, which even applied during the 19th century, are also in evidence. In the early 19th century, Norway was clearly the dominating, timber-trade country, with exports around ten times greater than Sweden's. Consequently, the exploitation of large-dimension forests hit Norway much harder than it did Sweden, with the result that the pulp industry later became the main export industry in Norway. Another characteristic difference between Sweden and Norway is that the widely fluctuating annual cut in Norway was of the same magnitude as increment from the 1920s up to the 1950s, when a sharp fall in the potential cut of the forest owners took place and persisted during the last two decades. The continued increase in the industrial consumption of wood in Norway has only been possible through considerable imports of wood and a reduction in the consumption of wood outside the industry.

Initially the development in Finland presented a totally different picture, since the isolated nature of the market meant that industrial production at around the turn of the century was relatively low and exports of roundwood were relatively high. Sub-

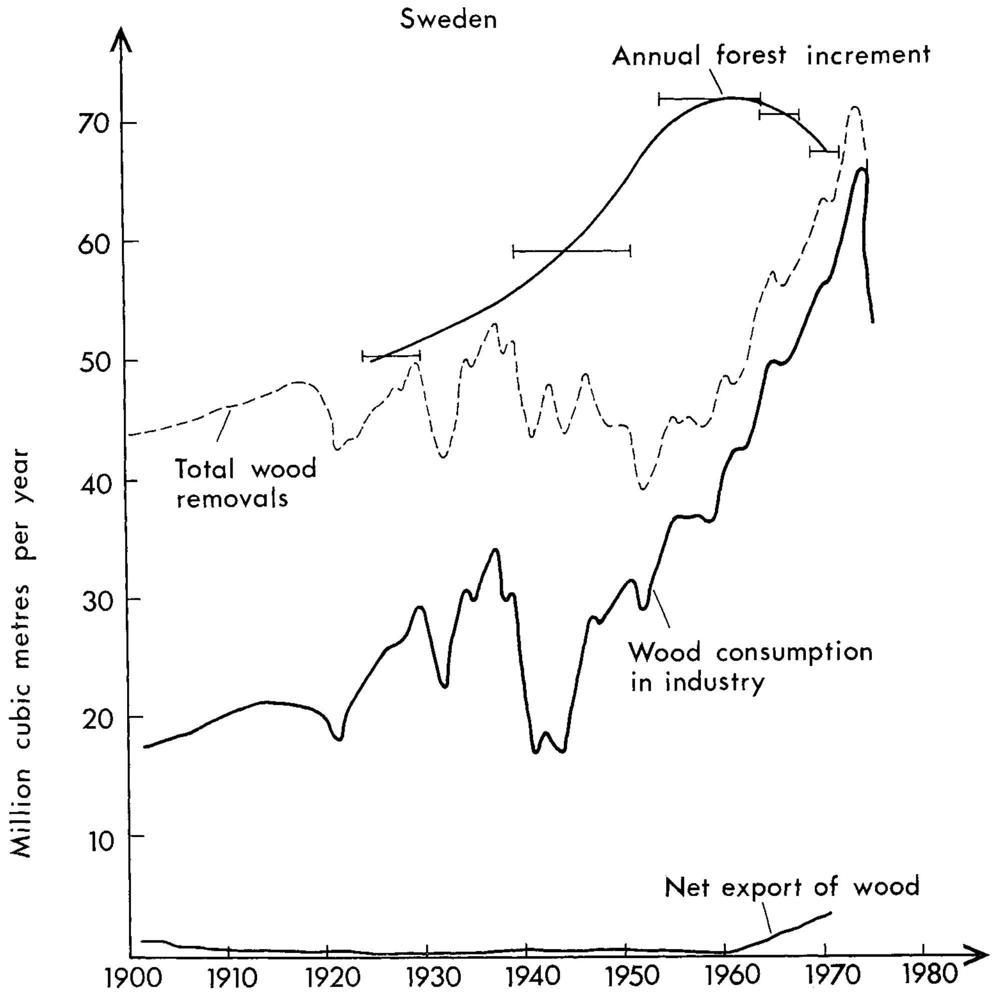


Figure 5c.

sequently, however, and particularly after the second world war, the forest products industry went through a period of rapid development. Finland emerged as a country in which the forestry sector became a key industry, and the consequent awareness of the necessity of maintaining a secure supply of wood to the industry has had a strong bearing. We can see from figure 5 that this has been revealed in three different ways since 1960: through increased increment; through a reduction in the share accounted for by non-industrial consumption of wood; and through timber exports giving way to imported wood.

More recently, the boom of 1973/1974 and the subsequent, prolonged period of recession have had a striking effect on the development of the forestry sector. The industrial consumption of wood in all three countries also rose rapidly to a peak during the boom, only to fall back sharply with the subsequent recession. Thus, the pressure on domestic forest resources was relieved after the boom. But after the period of peak consumption, the forest products industry has expanded its capacity, with the result that a future upswing in the market will see production at a level that the domestic supply of wood will not be able to sustain. The Scandinavian forestry sector is therefore subject to the constraints imposed on it by the limited, domestic supply of wood raw materials.

2 Transition strategies for the Scandinavian forestry sector

by Jørgen Randers and Lars Lönnstedt

2.1 The challenge of a transition to a period of modest growth

Although, as outlined in the preceding paper, the total annual cut in Scandinavia is now verging on what is sustainable there are ways of diminishing the effect of this constraint: the annual regeneration per unit area could be increased through intensified silvicultural activity, the introduction of new species or by means of higher stand densities; the forest area could be extended; a greater utilization of bark, branches, tops and roots could increase the yield of wood fibre from a given roundwood cut, as could a reduction in natural losses in the forest. A reduction in the amount of waste at the mill could increase the potential yield from a given volume of wood, thereby increasing the potential share of the annual cut available to the mills; and, as a last resort, wood could be imported.

But all these options present difficulties, since for them to be effective a considerable amount of time and money must be injected. In spite of the considerable potential offered by these options in theory, in our view it would amount to no mean feat if industrial production were to be increased by 50 % during the next 30 years. This represents an average annual growth rate of 1.4 %—which is considerably lower than the 5 % annual growth achieved between 1950 and the early 1970s. Thus, it seems to us that even if forestry were given all the reasonable support that it would like, customary growth rates would still prove impossible; even the achievement of a growth rate of 1.4 % would only be possible after successful reorganization of economic and institutional factors aimed at enhancing wood production. Moreover, ecological considerations would also be a limiting factor.

Because the annual cuts in Canada, the USA and the USSR—Scandinavia's main competitors on the international market—are still below the potential yield in those countries (although the situation is likely to change in about 20 years time), the Scandinavian forestry sector will be severely handicapped in comparison, owing to its inability to expand at the same rate as its competitors.

Low growth rates will create a number of problems in the forestry sector:

- *Employment* will be threatened, since modest growth will accelerate the reduction in job opportunities. If the production volume remains constant, the number of jobs in forestry and the forest products industry will fall at a rate commensurate with the rise in productivity. It is conceivable that the reduction will be of the order of 50 % every 10 years. However, the trend could be counteracted by the successful development of new products and by increases in the value added to the raw materials.

- *Rural communities* will be threatened because a slow rate of growth encourages the centralization of production. If the production volume remains constant, the number of production units will decline at a rate commensurate with the increase in the scale of production units. Again, a 50 % reduction every 10 years is conceivable. The successful development of small-scale production units would work against greater centralization.

- *The community at large* will be threatened, since measures to conserve energy, reduce pollution and improve working conditions are more difficult and more costly during periods of decline.

- *The forest products industry* will be threatened because a slower rate of growth will mean that the production costs will be higher than those of its competitors with access to an ample supply of wood. No matter what measures industry takes, the situation in which production volume remains constant will result in an increase in costs:

  a) If the rate of closure of production units is increased to make room for continued traditional expansion of the production capacity, the average life of plant would be diminished, resulting in increased capital costs per produced unit.
  b) If customary rates of closure are maintained, the addition of new capacity would be reduced, thus increasing the average age of plant. One result would be an increase in the variable costs per ton in relation to those of competitors with up-to-date production capacity. An attempt to offset these increased costs through greater modernization of existing plant would be difficult, bearing in mind that the investment cost per unit capacity is higher when not coupled with expansion. Costs increases of the order of 30 % are conceivable.

In view of the difficulties they are facing, the above mentioned four interest groups in the forestry sector are bringing considerable pressure to bear on those seeking to limit exploitation of the forest, with a view to preserving its long-term production capacity, its ecological diversity and the opportunities for recreation provided by it. Thus, the Scandinavian forestry sector is faced with a major challenge: after a century of rapid growth, in just a few years it will have to learn to live with a situation in which production volume will remain at an approximately stable level. Although little can be done about the problems in a state of equilibrium, the transition from a period of rapid growth to one of modest growth, on the other hand, will largely be shaped by the strategy followed by the forestry sector. But before a strategic decision is taken, a greater understanding is needed of a) the new situation, b) the policy options open to the sector and c) the likely consequences of the alternative policies in a given set of conditions. The forestry sector should therefore review the various dangers and opportunities before making any decisions by means of which it will partly be shaping its own future. The purpose of this paper is to contribute to this preparatory work.

2.2 Model simulations illustrate the policy options

Our knowledge of the way in which the forestry sector actually will develop is as limited as everyone else's. However, our conceptual framework and formal model system represent an instrument by means of which a variety of possible transition paths can quickly be generated. Each transition path (model simulation) provides a picture of one possible line of development in a transition from a period of rapid growth to one in which production volume will remain by and large constant. In an attempt to identify the likely effects of proposed policies, a knowledge about the set of cause-and-effect relationships embedded in the model—and therefore responsible for the model simulation—is useful.

One's use of the model simulations will depend on one's task: for the national policy maker, the different transition paths will describe the consequences of his own policy decisions; for corporate decision-makers, the transition paths will illustrate possible future business environments. In both cases the transition paths should serve as a basis for policy talks and decisions.

Each model simulation is no more than the logical consequence of a number of assumptions in respect of trends and causal relationships. The principal causal relationships are shown in figure 6. Some of the

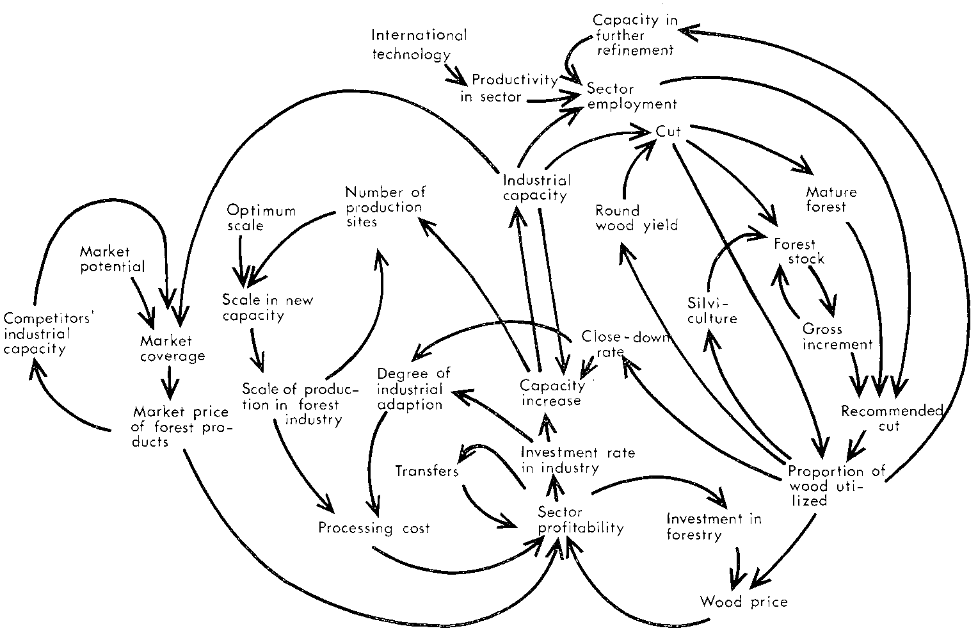


Figure 6. Major cause-and-effect relationships in the SOS simulation model for the transition from a period of rapid growth to one of modest growth in the Scandinavian forestry sector.

main assumptions are as follows:[1]

- The forest products market is global and growing at an annual rate of 4 %.
- The forest products industry outside the Scandinavian countries has unlimited supplies of wood and will grow at an optimum rate.
- Advancements in technology will result in 5 % annual growth in the optimum scale of production.
- The Scandinavian forestry sector will rely solely on domestic supplies of wood.
- The Scandinavian forest products industry does not collaborate perfectly in investment planning and to some extent has to compete in the market for wood and end-products.
- The forestry sector can greatly increase the wood yield in the long run, provided it gets the necessary stimulus.
- The average value added for the total Scandinavian production volume of around 100 million cubic metres per year will not extend beyond planed wood, a medium-grade paper and impregnated board.

Even if the above assumption seems plausible—at least as far as the next 30 years are concerned—it would not be right to draw any conclusions from the model simulations without a study first having been made of the stability of these conclusions vis-à-vis alternative assumptions. If other, equally plausible, assumptions were to lead to different conclusions, *no* conclusion should be drawn unless it can be based on information and insights gained from sources other than our analysis.

2.3 **Two transition paths**

The two model simulations described below reflect two different ways in which the forest products industry may adjust to the

[1] It is extremely simple to change assumptions in the model system. It generally takes around 15 minutes, at a cost of around US $ 3.00 in respect of computer time, to obtain the consequences of an alternative set of assumptions.

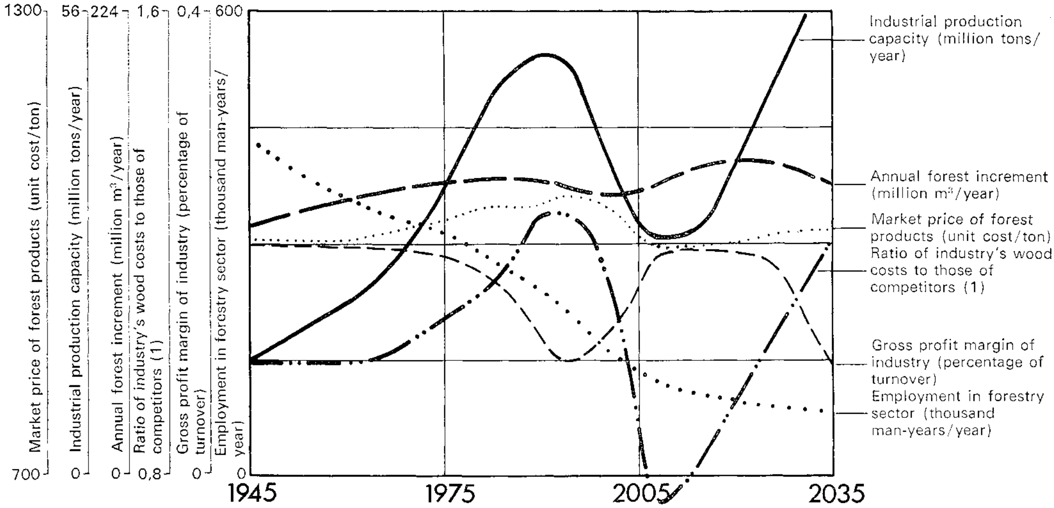


Figure 7. No regulation, Scandinavia, 1945—2035. The transition from rapid to slow growth when governed by market forces, causing over-expansion and decline.

limited domestic supply of resources. The first simulation assumes *no regulation,* either governmental or in the form of a voluntary industrial agreement, of industrial expansion; this will occur to the extent to which it is profitable and practicable. Plant will be closed down when business considerations say so. Conversely, the second simulation assumes *strict regulation* of investment in the industry. It is assumed that an undefined but powerful authority will endeavour to adapt industrial capacity to the sustainable wood supply by controlling the creation of new production capacity. It is our belief that the future development will actually lie somewhere between the two.

The descriptions pertain to the Scandinavian countries (Finland, Norway and Sweden) during the period 1945—2035. The computations are initialized to resemble the situation immediately after the second world war, i.e. in which a) there is a low industrial capacity in relation to the forest increment; b) Scandinavia is an important producer in a rapidly expanding world market; and c) rapid technological advancement is creating rapid growth in the optimum scale of production. Since the perspective is a long-term one, any short-term variations around the long-term trend, e.g. business cycles in inventory levels, prices and sales, are disregarded.

No regulation—over-expansion

Figure 7 shows the development in the model system (illustrated by the time variation of six important variables) when the *transition* is *governed by market forces.* Industrial production capacity expands rapidly until 1985, when the growth rate falls and eventually turns negative. Capacity declines steadily over a 20-year period, to be followed by a second period of growth after the turn of the century. Employment in the forestry sector falls throughout the period but most rapidly during the period of industrial decline. The same is true of the number of industrial production plants, as a result of the increasing centralization of production facilities towards the year 2000. The annual cut develops in pace with development in industrial capacity and the associated industrial consumption of wood. Consequently, the annual cut ultimately exceeds the gross increment in the forests, with reductions in the cut and a decline in the standing volume occurring during the last quarter of the century. Only when production capacity has fallen way below the level of the annual forest regrowth, when wood is again in ample supply and cheap, does the second period of growth occur.

Briefly, then, figure 7 shows a transition path where the industrial expansion is curbed by rising wood prices caused by increasing utilization of domestic wood resources. Market forces finally constrain industrial expansion. An interesting fact, however, is that industrial capacity does not remain static once the higher wood prices are able to offset the pressure for industrial growth. Instead of a state of equilibrium, in which profits are just sufficient to maintain production capacity, the industry slides into a lasting decline, with production capacity (and the consumption of wood) falling year after year, until it is down to 60 % of its former maximum. The forest products industry only expands to an unsustainable level in the first place, because counteractive forces do not become strong enough until it is too late.

The spectacular *over-expansion* is possible in the model system for two reasons: a) because excessive harvest can continue for long periods thanks to accumulated stocks of mature forest; and b) because no regulation of industrial investment or the annual cut was assumed. In spite of its undesirability, the overrun can occur because: a) the forestry sector includes several independent decision-makers, each of whom is interested in further expansion; and b) a history of growth (1945—1985) results in a modern industry with ample funds to pay for the expensive wood. A deterioration in the financial condition only starts when wood prices start to go up and, even later, gains impetus when the reduction in investment becomes apparent in the form of older production equipment. The period of decline is entered at the time when the least efficient production units are no longer able to pay for the raw materials. Companies, typically the small ones, go bankrupt and closures take place. The period is a surprisingly long one: one reason is that the early closures do not lead to relieved pressures on the wood market and thus falling wood prices. In the model system, the remaining companies tend to snap up the newly released wood resources and expand plants that are still operating, thereby making them competitive and capable of paying high wood prices for an additional number of years. In consequence, the excessive utilization of the resources tends to continue for decades. In the model system, the over-expansion is accentuated, and the period of decline prolonged, because of another process, namely, a temporary increase in the international market prices of forest products. The increase occurs when the Scandinavian countries, which were formerly a major supplier, find themselves unable to expand in pace with international demand. A gap then develops in the market and is only filled by foreign competitors after a period of some five to ten years—the time needed by competitors to identify the situation, to plan their operations and to expand their production capacity. Market prices during the intervening period are artificially high.

Wood prices increase a) because harvesting costs rise when the wood has to be transported from sites further away from the processing industries (possibly also sites with smaller-dimension trees), and b) because the shortage of wood affords the forest owners greater strength at the negotiating table and also bigger profits. The latter effect is the most noticeable one and the one most likely to trigger proposals for imposing restraints on the "windfall" profits of the forest owners. Another model simulation (not shown) investigates the effects of an *assumed limit on forest owner profits*, which significantly reduces the price of wood when wood is in short supply. The simulation reveals that not only is there a decline even in this case but that it is much stronger and more prolonged—which may be surprising at first glance, since the object was to avoid a decline. However, the (obvious) explanation for this is that improved profitability in the forest products industry results in greater expansion; and in this case the

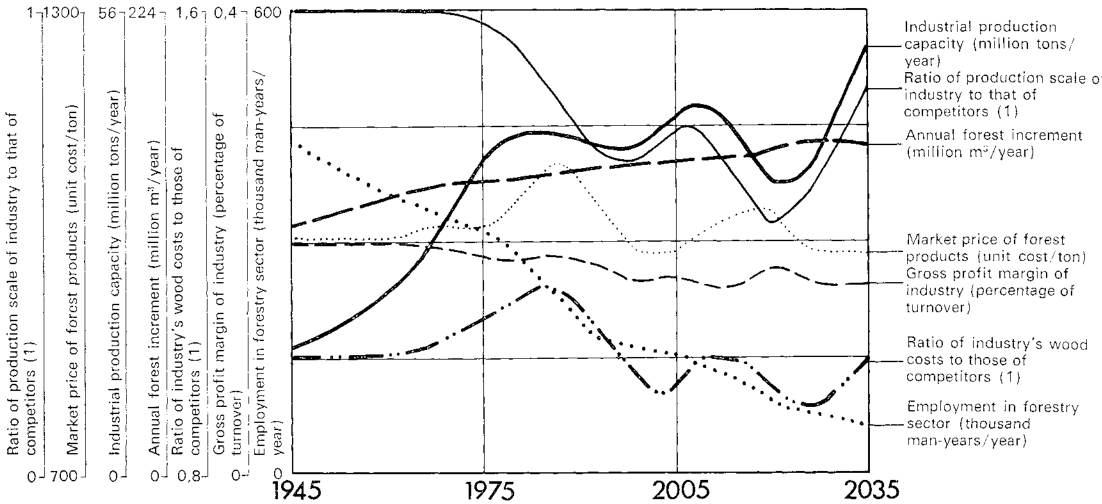


Figure 8. Strict regulation, Scandinavia, 1945—2035. Effects of an assumed strict regulation of industrial expansion to avert growth beyond the sustainable level, causing a smoother development.

expansion is not curbed by rising wood prices but is only restricted by the increasing shortage of wood. Once the physical shortage is a fact (manifested through a lack of mature forests), the period of decline will persist until the natural biological processes have been able to restore the supply of mature forests. Since the biological processes are much slower than the economic processes in figure 7 the period of decline is correspondingly longer.[2]

An attempt to provide *financial assistance* to the forest products industry during the period of decline will also accentuate the over-expansion. The increased financial muscle enables the industry to expand further and survive longer, even when raw materials are expensive.

Strict regulation—no over-expansion

One proposed way in which over-expansion, excessive cuts and price increases can be averted is to limit industrial capacity to a sustainable level. Figure 8 shows the result of introducing into the model system a regulatory authority with sufficient power to *limit industrial investment plans* to ensure that the total consumption of wood does not exceed the gross increment in the forest. In the model system, regulation takes the form of companies being permitted to realize only part of their plans for increasing capacity. Yet although this procedure succeeds in limiting the growth of industrial capacity, the central problem in the sector changes from one of high wood costs to one of high processing costs attributable to the use of outdated production plant. Since the increased processing costs are offset by the lower cost of wood, the industry survives. The forestry sector still experiences a period of decline but it is less acute and also is interrupted by boom periods.

The following is revealed from a more detailed investigation of the simulation:

The fuller utilization of wood resources in the early 1970s leads to an increase in logging costs and to considerable expendi-

[2] It is possible to describe the model system development in much richer detail through detailed study of the other model variables that are not plotted. Detailed investigations of the developments in, for instance, the financial sector of the forest products industry, the age structure of the forestry sector, the cost structure in respect of wood, etc., can constitute valuable input data for talks on strategy and policy.

ture by the forest products industry aimed at achieving a similar increase in the utilization of wood fibre at the mill (see figure 8). Consequently, the price of wood goes up. But in around 1975 industrial capacity has reached a high enough level to warrant regulation of investment plans. The rate of expansion is checked and because the industrial capacity no longer reaches levels which place excessive pressures on the wood markets, wood prices remain at reasonable levels. The assumed regulatory authority limits investment. Since the assumption is that companies do not collaborate perfectly (e.g. by pooling building permission), a number of plants of below optimum size are built. The processing costs rise relative to those of foreign competitors and profitability tends to decline. After some years of constrained investment activity, the industrial plant becomes so out-dated that closures become increasingly frequent, going beyond what is necessary to stabilize capacity, and a slight decline occurs. The decline is halted when the international product prices increase and there is a fall in the domestic price of wood, owing to reduced pressure on the respective markets.

A policy of strict regulation leads to an accelerated accumulation of mature forest, which makes possible lower wood prices and an earlier recovery in the forest products industry. As shown in figure 8, there is very little tendency towards excessive cuts.

If strict investment regulation is supplemented by an agreement on the part of industry to ensure that the few plants that are actually built during this time will be of optimum size, this will have a desirable effect on development from the point of view of the industry (not shown here). Such *collaboration* is conducive to greater competitiveness since plants are bigger and production costs lower. The cost of this advantage is an accelerated reduction in employment and increased centralization of the industry.

In order to reduce the rapid structural change in the industry, the government could conceivably decide to provide *subsidies* (e.g. such as cuts in taxes and other levies for small, decentralized plants). The aim would be to reduce the number of closures, especially in regions with few alternative job opportunities. Such subsidies would tend to make the industry more profitable and, consequently, better able to survive. In turn, this would result in greater ability to expand and a greater need for regulation. For if regulation is ineffective, the subsidies will result in greater decline later on. Conversely, where regulation is effective, a carefully balanced subsidy would make it possible to save production units that would otherwise have been eliminated through competition.

2.4 Policies to facilitate the transition

The transition from a period of rapid growth to one of modest growth in the forestry sector will be accompanied by one or more of the following problems:

- A tendency towards increased wood prices.
- A tendency towards excessive cuts.
- A tendency towards lower employment in the sector.
- A tendency towards accelerated centralization.
- A tendency towards intensified conflict between the wood producers and the environmental and recreational interests.
- A tendency towards over-expansion and decline.
- A tendency towards reduced competitiveness owing to static production volume.

This is not the first time in history that the forestry sector has been faced with a serious shortage in the supply of wood. What is different today is the rapid growth to which the sector has become accustomed and the accuracy in estimates of forest resources. This time, it is unlikely that the shortage of wood is fallacious or that the transition will be much delayed. A multitude of policies have been proposed to facilitate the transition and these can be categorized in a few main groups, according to their aims.

Attempts to continue historical growth

The ways in which the production volume in the forest products industry could be increased were outlined above. In our view there is little scope for expansion in the industry. Even a significant break-through would only postpone the transition, not alter its fundamental character. The policies tend to be costly and are accompanied by social, ecological and technological problems that will grow in intensity when the policies are pursued to the extreme.

Attempts to increase competitiveness through planned allocation of limited wood supplies

The forestry sector can survive longer if the limited wood resources are distributed between the mills with this end in mind. In the long term, resources can be allocated to those processes returning the highest profits. In the short term and with a given industrial structure, the wood can be allocated to mills with the lowest marginal costs. However, these policies would tend to conflict with policies on employment and decentralization.

Attempts to maintain employment through planned allocation of wood

This strategy is based on the construction of new plants, the expansion of existing plants and closures being organized in such a way that a reduction in costs is achieved with a minimum rise in regional unemployment. In the long term, research and development work aimed at increasing the competitiveness of small and medium-sized mills or at facilitating modernization without simultaneous expansion could prove valuable.

Attempts to increase the value added

There are two ways in which this can be achieved: processing of the raw material right through to the production of conventional consumer products (e.g. planed wood, paper and treated board); or development of new products (e.g. prefabricated houses or products for the graphical industry). Both alternatives can mollify the negative effects on employment. A regular introduction of new products paves the way for higher profitability and a greater degree of internal financing because the industry can fix prices at cost plus mark-up. However, success is dependent on the industry keeping ahead of its competitors in the development and marketing of new products.

The traditional way of increasing the number of jobs created through processing of the wood raw materials, namely, through conversion to paper, and planing and pre-cutting of all sawnwood, could do no more than postpone by ten years the time at which new products would be needed to maintain employment levels. The development of new products is a time-consuming process and must therefore be initiated long before new products are urgently needed. The strategy is further hampered by the need for large volumes, by the distance of the industry from the consumer, and by trade barriers.

Attempts to initiate new economic activity

The problems created for the community through the closure of production units could conceivably be lightened if the forest products industry were to make full use of its analytical, financial and management resources in establishing new economic activities at the places concerned. Apart from benefiting the community, such diversification also makes sound business sense. The main stumbling block is the way in which companies tend to confine themselves to operations with which they are familiar. This institutional inertia often results in such activities being put off until it is too late.

2.5 Future tasks of the forestry sector

The main challenge facing the Scandinavian forestry sector is to achieve a smooth transition into a period of modest growth and then to become accustomed to a period during which production volume will remain stable. A major decision that will have to be made is whether or not resources should continue to be directed towards sustaining the traditional strategy of growth, or in other words, to continue to strive for a steadily increasing production of the traditional bulk products. We believe that this course would be futile. The forestry sector would be better advised to invest its time and money in attempts to solve the serious problems presented by a constant level of wood consumption.

Another major decision that has to be made is whether some form of regulation of the industry should be introduced or whether the shaping of the transition should be left to the free market forces. In our opinion regulation of industrial growth could solve the serious problem of overexpansion and that restrictions in respect of the annual cut could avert the grave consequences of excessive, local exploitation of the forest.

Finally, one should not be fooled by the current (1978) sombre market conditions into thinking that warnings in respect of the shortage of wood are merely a fallacy. The current crisis should rather be seen as a fortuitous breathing space that grants us time in which to discuss, develop and implement an effective, regulatory framework before the next boom comes.

To do this, the following questions must be answered:

- How can the aggregate size of the sector best be regulated to preserve the wood resources?
- How can the revenue earned in the sector be split between forestry and the forest products industry in such a way that both parties will be able to attain their objectives (improved silviculture and increased value added)?
- How can new ideas and new technology be introduced when expansion is out of the question?
- How can the economy of communities dependent on one local industry be consolidated to mollify the effects of closures?
- How can a situation be averted in which economic pressures in the sector have a detrimental influence on the forest ecosystem?

It is vital that the forestry sector evolves a strategy and implements it while profitability is still relatively high, as this will not be the case in a declining industry. Equally, new investment must be split between forestry and the forest products industry in such a way that assures both parties of the resolution of their problems. If the world market for forest products does not continue to grow at the rate assumed above, the financial constraints may well be imposed sooner than would otherwise have been the case.

The longer a serious and open-minded debate on these matters is put off, the more limited will be the resources and the shorter will be the time available for solving the problems. Action must be taken before the forestry sector finds itself in the middle of the transition.

3 "The transition from ample to scarce wood resources" A play in four acts

by Jan-Evert Nilsson and Carsten Tank-Nielsen

3.1 Prologue

This paper, which is in the form of a play, demonstrates the way in which the model can be employed in strategic talks to increase knowledge and enhance understanding of the problems facing the forestry sector during a transition from rapid to modest growth. The play is based on a dialogue that took place when the SOS project was presented to panel members at a symposium in Stockholm.

The play, which is in four acts, is based on future situations as simulated by the model. Each act or simulation represents a given transition strategy:

Act one: Development determined by free market forces.
Act two: Government price control.
Act three: Regulated industrial expansion.
Act four: Active industrial collaboration.

The cast includes:

- a member of parliament
- a director of a forest products company
- an "ombudsman" or spokesman for the employees
- a private woodlot owner (forest owner)
- a policy analyst.

The role of the policy analyst is not to intervene in the dialogue but merely to outline the content of the simulated future situations.

The scene being set, let the play begin!

3.2 Act one: Development determined by free market forces

The curtain rises with the panel faced with the transition path that has been generated by the model, subject to the proviso that activities in the forestry sector will be of a consistent nature. The simulated future situation reflects the outcome of development determined by free market forces, with the nature of the transition determined by prices and economic resources.

Policy analyst:

The consequence will be a period of transition during which industrial capacity will expand rapidly until 1990 (as we can see from figure 9). During this time, production capacity will rise above the level of the sustainable yield, as a result of which a prolonged period of decline will be inevitable. Excessive growth or over-expansion is a consequence of short-term thinking. Profitability is good, the wood prices reasonable and the market buoyant; indeed, the future is bright. But the expansion leads to rising wood prices, which in turn reduce the profitability since the production capacity is now higher than the sustainable yield from the forests. Industrial decline is therefore an unavoidable reality.

Increasing unemployment is the most readily apparent consequence of the industrial decline. While the industry was expanding, the growth was able, to a certain extent, to counteract the reduction in employment brought about by increased productivity.

The subsequent decrease in production capacity will merely serve to accelerate unemployment.

The sharp decline in the industry manifests itself in that a large number of mills are forced to close down, thereby aggravating regional problems.

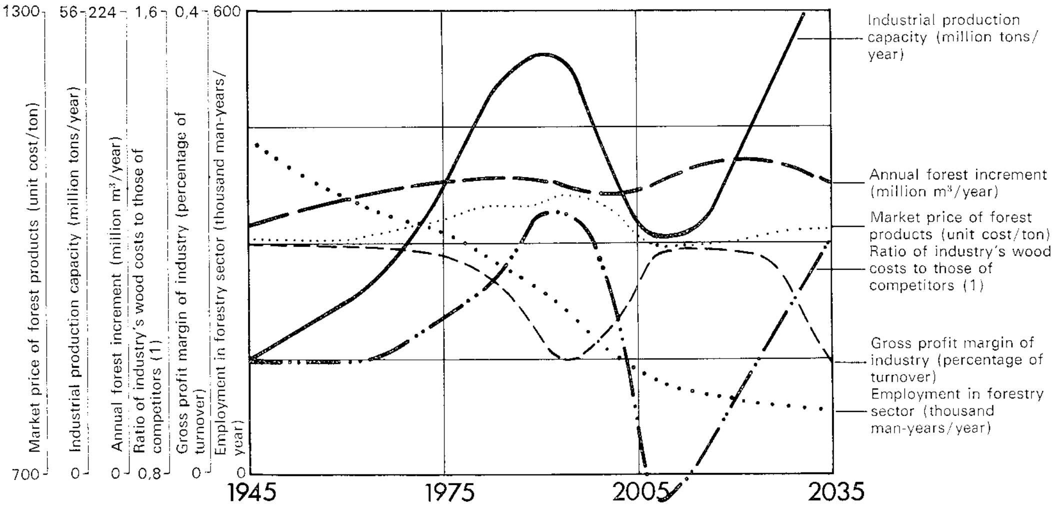


Figure 9. Development determined by free market forces.

Member of parliament:

In the interests of the community we have three main objectives in the forestry sector; namely, we want to maintain:

a) an internationally competitive forest products industry;
b) sustained-yield forestry; and
c) employment and a regional balance.

During the period when the supply of raw materials made the continued expansion of industrial capacity possible, there was really no conflict between the three objectives. But, as we can see in the scenario before us, these conflicts are now accentuated. Consequently, those of us who are concerned about all of the aspects of the problem are confronted with a further constraint on measures that we can take.

Company director:

The scenario presents us with a picture of the future that, from our point of view, is as undesirable as it is unexpected. A sharp decline in industrial capacity creates considerable problems for our competitiveness as well as for employment. This decline is therefore totally unacceptable.

If we compare the conditions in the Scandinavian forest products industry with those of our competitors abroad, the problem becomes as clear as daylight. We find that the production technology is identical, as are the products and, with one important exception, the nature of costs as well. It is in this exception that the problem lies—the cost of raw materials. For the Scandinavian industry to be able to defend its position on the world market, the raw material costs must be kept under control and on the same level as those of our competitors. Clearly, then, we must regulate the raw material costs as a matter of necessity. If this were followed by a decrease in logging costs, it shouldn't create any serious difficulties for forest owners.

Forest owner:

You know, there is a complex relationship between the price of wood and the supply. To adjust the price of wood is therefore to over-simplify the problem. What we should be concentrating on is the creation of a properly functioning market. The invisible hand of the market in itself is an assurance of an efficient allocation of the resources.

Ombudsman:

But this invisible hand is not only an instrument for allocating resources. It is also a means of redistributing wealth. We can never accept as reasonable a situation in which the forest owners just grow richer on the profits of their monopoly, while, at the same time, the forest products industry is being forced to close down more and more mills; and often in places where the mill provides all the jobs in the area. If it's a choice between increasing unemployment among the workers in the industry or the rapid accumulation of additional wealth on the part of the forest owners, it is obvious where our priorities lie. The present pricing mechanism must be abolished and wood prices controlled. After all, this is the cause of the problems facing the industry.

Forest owner:

To claim that the forest owners are growing rich at the cost of the workers suggests to me that there is a misunderstanding in respect of the way in which the pricing mechanism actually works. The question of the distribution of wealth must be dealt with separately, for example through taxation. In this context it is of little interest into whose pockets the money actually falls.

The price merely provides an indicator on which the various parties can base their respective courses of action. A rise in the price of wood reflects that the volume of the annual cut is broaching on the volume increment of the forests. In this way a curb is put on a trend which conflicts with the policy of sustained-yield forestry. If we allow the price to be fixed by bureaucratic decree at a low level, we throw the road open to an unrestrained and ruthless exploitation of our forest resources. And neither case does anything for employment, since the rise in unemployment is the result of advancements in technology and has nothing to do with the price of wood.

Ombudsman:

It must be a very strange sort of technology if it only makes the forest owners richer.

Member of parliament:

I think the whole thing is a question of balance. On one side we have the forestry interests and, on the other, we have to consider the question of employment in the industry and the areas in which the effects are being felt. In view of the current situation, a ceiling on the price of wood is a conceivable solution to the problem. However, it must be sufficiently high for the forest owners yet, at the same time, must serve to increase the competitiveness of the Scandinavian forest products industry. But it must be said that a government price control would not necessarily be a definitive solution; we must therefore reserve the right to adopt any additional measures that may be required to supplement this policy in the future.

3.3 **Act two: Government price control**

Following on from the dialogue of Act one, this simulation concerns government price controls. Basically, the policy ensures that the net operating surplus of forest owners is not permitted to exceed 50 % of the wood price. The model is changed and a few minutes later the new transition path appears, with an appearance that is illustrated in figure 10.

Policy analyst:

The simulation shows that the decline in the industry is still a reality. Admittedly, it now occurs at a later date, but the decline is generally stronger and persists for a longer period.

With the lower cost of wood afforded by the pricing policy, the forest products industry is able to maintain profitability for a longer period than would otherwise have been the case. Thus, the situation allows the industry to continue to grow above the previous level. The inevitable result of this is an excessive overcut. Forest increment is drastically reduced and there is a conspicuous physical shortage of wood. In spite of the favourable economic situation, several mills must therefore be closed down.

Notwithstanding the limit imposed on the

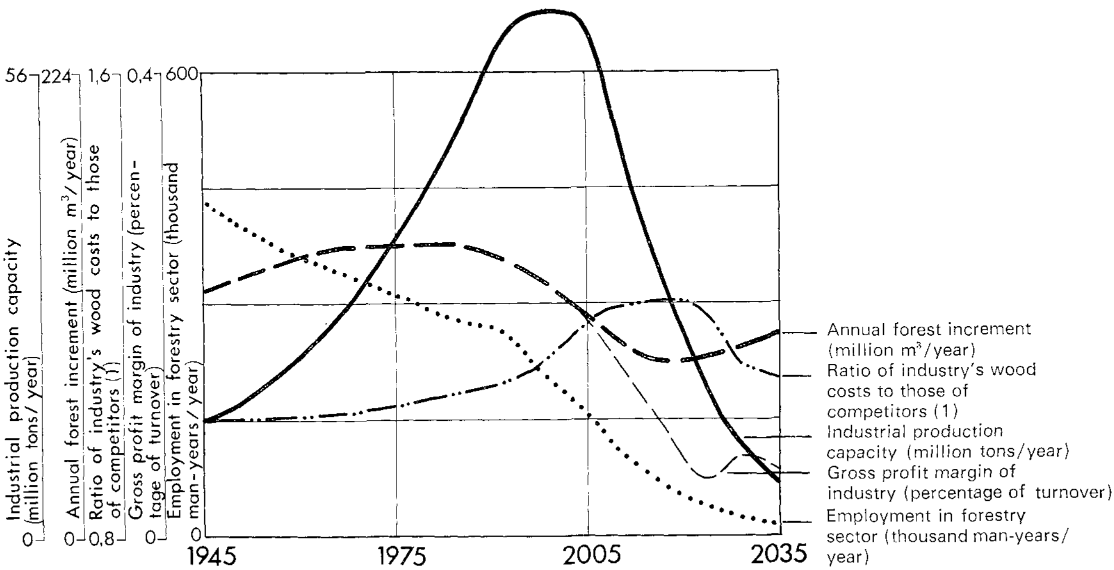


Figure 10. Government price controls.

net operating surplus, the price of wood rises somewhat. This is explained by the fact that the intensive exploitation of the forests has made it more expensive to extract the wood, the standing crop is less dense in the stands, transport distances have increased, etc. The cost of wood, which in the control or reference development shown in figure 9 fell rapidly in conjunction with the decline in the industry, now falls at a much slower rate, as is apparent in figure 10. This contributes to prolonging the crisis facing the industry. The reason that the response to fluctuations in demand is slow in coming is that in this case the shortage is due to physical reasons. Thus, the change in the price of wood at this stage is determined by the regeneration of the forest, which can only occur after considerable time. Only when the forest has become reestablished will the cost of wood have reached its original level.

Forest owner:

Clearly the scene shows that the imposition of government restraints on forestry may be compared to crossing the stream to fetch water. The problem does not lie in forestry itself but stems from the expansion in industrial capacity. The natural thing to do would therefore be to control this expansion. A policy restricting the creation of additional capacity might be one way of achieving this.

Ombudsman:

Even the unions wouldn't wish to see a future like the one described in this scene. We want to prevent powerful fluctuations. It seems obvious, then, that steps must also be taken to control the increase in production capacity.

But at the same time we have to remember that unilateral restraints on growth involve the risk of accelerating structural changes. So we must be certain that such changes will not manifest themselves in unemployment. To this end the forest products industry must start thinking along different lines. Further conversion is a precondition for employment levels being maintained.

Company director:

I must admit that government price controls do not seem such a good idea as I had reason to believe earlier. This is especially true in the light of the long-term consequences. Nonetheless, this does not mean that the regulation of industrial expansion is a better solution.

The consequences of regulating expansion in this way will be that the forests are preserved at the cost of the industry becoming outdated. Obviously we are aware of the advantages in terms of production technology that are inherent in the construction of new mills. But by imposing constraints on the capacity of the industry, we prolong the life of the present production lines. Thus, in time the mills will become steadily outmoded and the Scandinavian industry will gradually lose its competitiveness.

Member of parliament:

The scene underlines the necessity of finding overall solutions that take into account both the present situation and that of the future. A policy of government price controls obviously only serves the short-term interest. In the longer term, such measures lead to a worsening of the situation for all concerned. The solution is also unacceptable for the community at large, since we will lose a considerable amount of our forest land, which not only serves as an economically important source of raw materials but also provides opportunities for recreation. At best this policy could only be used as a temporary solution and only on the condition that it were possible between now and the time when the industrial decline sets in to drastically improve the forest increment. One possibility would be to make use of fast-growing tree species and to intensify silvicultural activities. But I remain doubtful about the potential effectiveness of these measures. If industrial capacity should grow faster than the forests, this alternative would be almost utopian.

Our point of departure must be to curb excessive increases in industrial expansion. We have to accept the fact that the forestry sector is faced with a biological limit in addition to the economic and marketing limits. Future growth must therefore be at a lower level than that to which the industry has been accustomed in the past. A realistic alternative would therefore be to regulate expansion in production capacity by imposing limits on the establishment of new plant—starting now. The industry itself should welcome such a measure since this will avert a sharp decline at around the turn of the century.

3.4 **Act three: Regulated industrial expansion**

Regulated industrial expansion is imposed through limits on the establishment of new plant, and a new transition path is generated (figure 11).

Policy analyst:

The process of decline changes drastically. Instead of considerable over-expansion, followed by an equally marked decline, the industry goes through a much steadier phase of development. What happens is that growth in the industry is arrested at the end of the 1970s in conjunction with the demand for wood attaining the same level as the potential supply. A consequence of this is that the price of wood does not go up. Thus, profitability in the industry can be maintained, which implies that there is still a powerful stimulus to expand. Since the regulatory mechanism is not perfect, a certain amount of excessive growth does take place. This over-expansion then causes a sharpening of the controls, whereupon the industry's expansion plans are cut back to such an extent that the establishment of new capacity is not as great as the capacity lost through closures. In this way, the industry is steered into a situation of moderate decline.

Once industrial capacity has fallen to a level that is acceptably below the prescribed ceiling, the demands for regulation are relaxed and the industry enters a new period of growth. However, this is only of short duration and the industry once again enters a period of stagnation. The reason for this is that the capacity increases that foreign

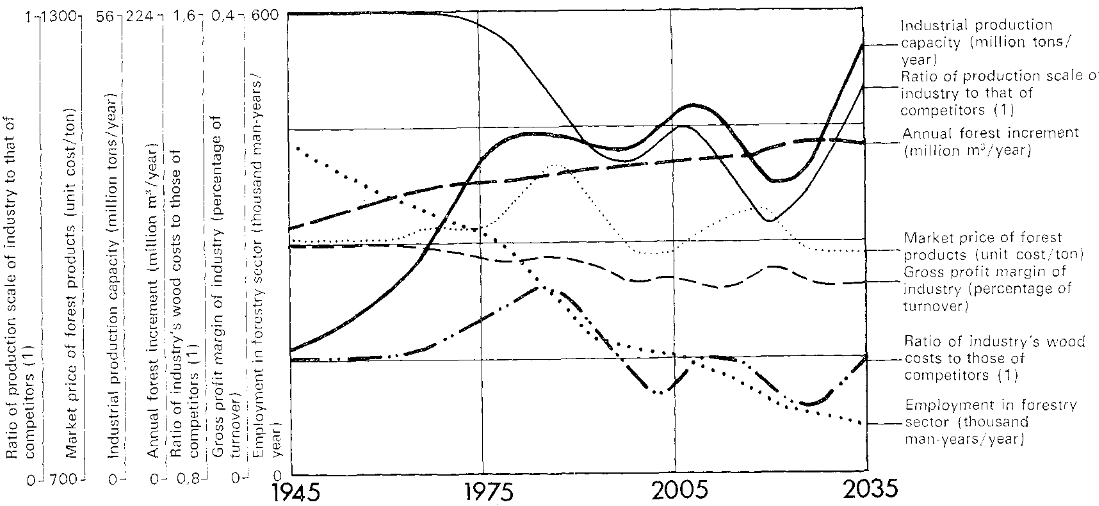


Figure 11. Regulated industrial expansion.

competitors decided were necessary during the earlier period of decline are now coming on line. As a result, world market prices are kept down. Profitability in the Scandinavian forest products industry falls and the economic base that was decisive for new growth disappears. Instead, the industry faces a further period of decline, although on this occasion it can be attributed to economic factors.

Forest owner:

Now we are getting close to a form of development that is acceptable. Admittedly many may hold the view that wood prices are rising too sharply but what we must remember is that this makes it possible for high prices to be charged on the European wood products market.

Company director:

I wish it were true that a high cost of wood enabled us to charge higher prices on the market—if so our troubles would be over. The limited supply of raw materials would then influence neither profitability in the industry nor employment. Only the forest owners would make greater profits.

Member of parliament:

If we compare our experience of government price controls and of a policy of restricted expansion, then the latter policy is clearly the most advantageous. Whereas the policy of price control has considerable drawbacks for all concerned, a policy of regulated industrial expansion spreads the disadvantages relatively evenly.

Company director:

What we are dealing with is a highly export-oriented industry operating in an atmosphere of stiff international competition. The unfavourable development in the price of wood is therefore a central issue. The forest products industry will end up in an impossible situation. The forest owners must make a concerted effort to reduce their costs instead of extracting the maximum benefit from their monopoly of the market.

Forest owner:

I think it would be much nearer to the truth if we were to talk about a sellers' market rather than a monopoly.

Company director:

Another serious effect of imposing con-

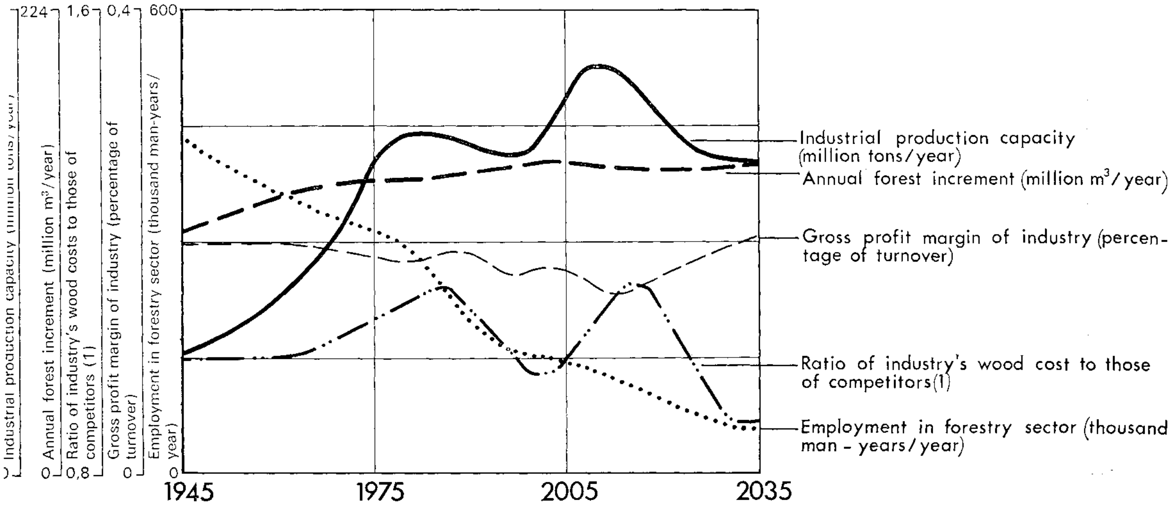


Figure 12. Active industrial collaboration (and regulated expansion).

straints on industrial expansion—which the simulation only gives an indirect hint of—is that the structure of the industry will become obsolete and the other variable costs (apart from the cost of wood) will also increase in consequence.

Member of parliament:

Unfortunately it is true that this policy will exacerbate the problems associated with the structure of the industry. But the problem is not confined to the fact that old mills are being closed down. The lower level of profitability also limits the prospects of the industry investing in further conversion.

Ombudsman:

We have already established that a policy that restricts industrial expansion inevitably gives rise to serious problems in respect of the structure of the industry. And experience just lends weight to our view. There will be a rapid rise in unemployment.

Company director:

It might be possible to offset the negative effects on costs if the companies were to collaborate in new investments. In that way, we could create modern production facilities and a development that would not be far from the optimum.

Ombudsman:

Optimum, maybe, but not for us. I guarantee that a merger between some of the major industrial companies would cause the unemployment curve to shoot off the top of the chart.

3.5 Act four: Active industrial collaboration

By means of simple modification of the model parameters, the pattern of investment in the industry is changed. Through collaboration with each other, the companies construct a limited number of optimum production units instead of a larger number of smaller ones. Thus, in spite of the shortage of wood, the industry is much better equipped to maintain its international competitiveness.

Policy analyst:

If we focus our interest on the gross profit margin of the industry, we find in figure 12 that this improves. Thanks to the collaboration between the companies, the industry is able to construct optimum production units as expected, in spite of the policy of regulating industrial expansion. Productivity rises faster and, in consequence of the controlled expansion, this tends to sharpen the increase in unemployment. The improvement in profitability enhances the ability of the industry to grow, which tends to increase the volume of the overcut in the forest. However, this is not of such a magnitude that it constitutes a threat to the policy of sustained-yield forestry during the period in question.

Company director:

I am surprised by the fact that the effect of active collaboration in the industry is to widen the gap between production capacity and forest increment. Nonetheless, the gap never becomes so wide that it poses a threat to sustained-yield forestry. From the profitability curve it is apparent that the forest products industry manages tolerably to maintain its international competitiveness.

So the indications are that this is the gospel to be preached. Of course there are practical difficulties but these should not prove insurmountable.

Forest owner:

The simulation also demonstrates quite clearly that the question of employment cannot be solved by the forestry sector: the solution is to be found in other branches of industry.

Member of parliament:

You know, to claim that we must look outside the forestry sector in order to solve the employment problem is analogous to throwing out the baby with the bath water. I am convinced that the solution to the problem is essentially a matter of increasing the degree of conversion. We must find more sophisticated ways to convert the valuable raw materials provided by the forest.

Ombudsman:

Of the three objectives mentioned by the member of parliament by way of introduction, it is certainly difficult, given that there is a limited supply of raw materials, to realize all of these aims. Apparently, the task of maintaining employment levels is going to be difficult to achieve. But if the companies feel any responsibility towards the community, the forest products industry must endeavour, to a much greater extent than before, to diversify away from the traditional forestry sector. It is obvious that if employment levels are to be maintained, there must be continued growth in production.

Yet I fear that we cannot rely on the social responsibility of the companies. The government and parliament must seriously attack the problem and take measures to safeguard the jobs of the workers.

3.6 Epilogue

One vital aspect emerging from the model experiments is the necessity of the subject being approached with an overall view. It is essential in attempts to deal with the problems arising during the transition period that a detailed knowledge be combined with insight into how the various components interact and thus form a whole. Failure to look at the whole picture often results in over-simplified definitions of the problem being arrived at far too quickly.

When confronted with a symptom of a problem, we are inclined to seek the solution in the proximity of the symptom. But, at best, this procedure can only achieve the elimination of the symptom, without coming any closer to solving the real problem. The policy of imposing constraints on wood prices serves as an excellent example of this. In this case, the rising wood prices are the symptom, the problem being how to reduce the cost of wood to the forest products industry. This policy will merely succeed in eliminating the symptom while the fundamental problem associated with the period of transition will persist and, quite likely, also be exacerbated. This policy also demonstrates clearly how a solution that is successful in the short term can make the long-term problem even more difficult.

If one accepts the need for an all-round perspective on the subject, one must also accept the fact that there is no optimum solution. The solutions/strategies can only be assessed on the basis of their consequences for the various interests. The conflict between the different interests can never be formulated totally impartially as a function of the objectives. Thus, our aim should be to achieve a consensus rather than an optimum solution. The model represents a means for increasing understanding of complex processes and is not an instrument that produces solutions.

Three conditions must be satisfied if a model is to serve the purpose outlined above. First, the model must be made up of concepts that have a base in reality. These concepts must then be integrated in a structure that is straight-forward enough to enable the users, on the basis of the simulation results, to understand the mechanisms in the model system that create the results. Understanding is not gained from the results but through the light thrown on the underlying mechanisms. Secondly, the model must be constructed so that it can be modified easily and quickly to enable new results to be obtained. Thirdly, the use of the model should not involve any great costs. If we consider the dialogue of the play and remember that the model in question only requires five minutes work and three dollars of computer time to modify a given strategy and generate the results of the new strategy, then clearly system dynamics more than satisfies these demands.

4 The SOS model[1] and the Finnish forestry sector

by Jari Kuuluvainen

4.1 Developments in the Finnish forestry sector between 1945 and 1975

The Finnish forestry sector has been faced with constraints imposed on it by the physical shortage of wood raw materials since the early 1950s. The decision was therefore taken to compare developments in the sector with alternative developments produced by the SOS model.

The relationship between the annual cut and the allowable annual cut for the period 1950—1977 is presented in figure 13. As can be seen, in the early 1960s the annual cut was far greater than the allowable cut, although since then it has steadily fallen, in spite of which the earlier annual growth rate in the forest products industry (including paper manufacture) of about 4 % has been maintained (figure 14). It has been possible to maintain this growth rate for two main reasons:

1. Between 1960 and 1975 the consumption of wood for non-industrial purposes fell from 15 million m^3 per annum to 7 million m^3 per annum.
2. The trade balance in respect of wood exports and imports had moved from a surplus of 5 million m^3 in 1960 to a deficit of 5 million m^3 in 1975.

Another important factor has been the increase in the utilization of industrial wood residues from about 2 million m^3 per annum in 1960 to some 5 million m^3 per annum in 1975. At the present time, it is not possible for the forest products industry in Finland to significantly increase its utilization of raw materials from the traditional sources. Thus, the constraint imposed on the industry by the shortage of domestic roundwood is only just starting to make itself felt.

The gap between the annual forest increment and the annual cut in Finland has developed differently from that in other Scandinavian countries. Up to the mid-1970's, the annual cut in other Scandinavian countries was well below the annual forest increment; now, however, Scandinavia is faced with the dilemma whereby the annual cut cannot be increased further if the principle of sustained-yield forestry is to be maintained.

By the late 1960's it had become clear that if Finland wished to pursue a policy of sustained-yield forestry, then the expansion of the forest products industry would have to be controlled. Accordingly, 1969 saw the introduction of voluntary controls over the industry's investment plans. This voluntary restraint has been effected by the industry itself in cooperation with the Bank of Finland. This type of regulatory system does not exist in Norway or Sweden. The fall in the industrial growth rate in the early 1970s can probably be attributed partly to this voluntary regulation policy. However, many of the investment plans that were rejected between 1969 and 1972 were to be approved in 1973 and 1974. Consequently, the production capacity of the industry is still expanding, although at a slower rate than before. According to studies carried out by the Central Association of Finnish Forest Industries, a growth rate of about 3 % in the sawmill, pulp and paper sectors could be maintained during the 1970's, in spite of the restraint imposed by the allowable annual cut.[2]

Since exact figures of the total capacity of the forest products industry are not available, production figures only are pre-

[1] The Society and Forestry model.
[2] Kirves, Lauri, 1973: Taloudellinen katsaus. KOP 1973/74.

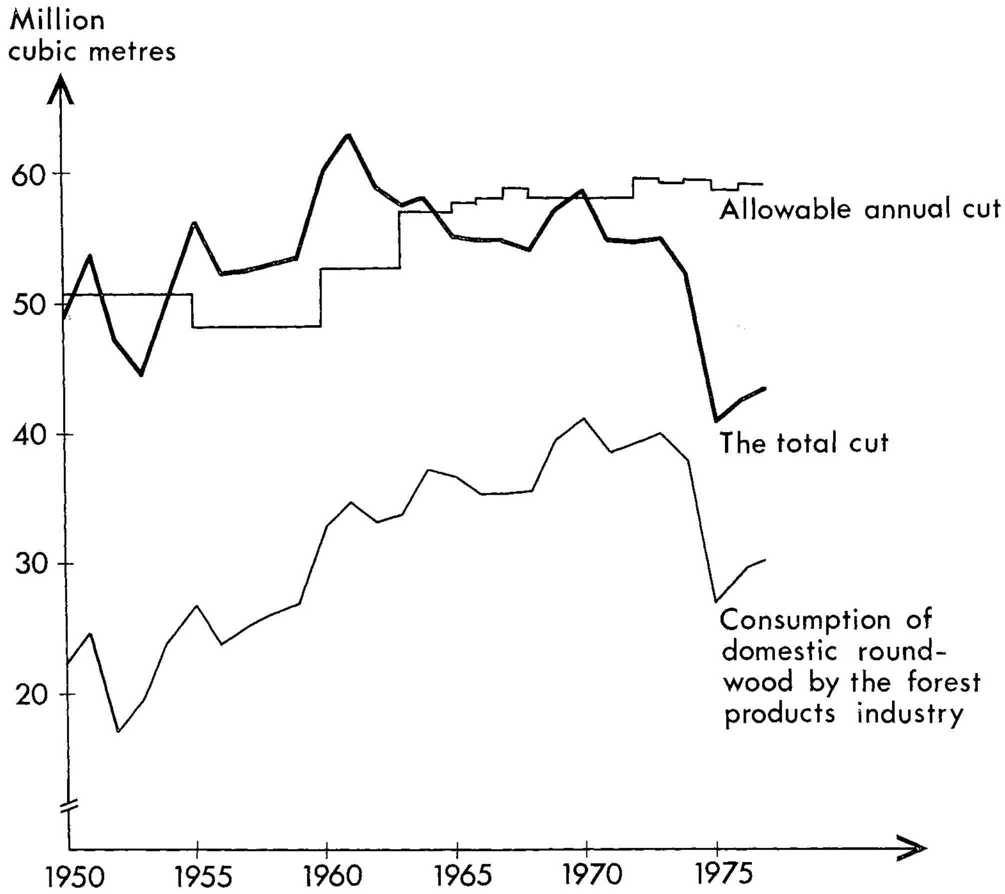


Figure 13. The total cut, the allowable annual cut and the consumption of domestic roundwood by the forest products industry in Finland, 1950—1977.

Annual forest increment adjusted according to age structure.

The difference between the total cut and the consumption of domestic roundwood by the forest products industry is accounted for by the consumption of fuelwood, roundwood exports and wood residue left in the forest. Wood residue left in the forest amounts to about 10 % of the total cut.

Sources: Pöntynen, V., 1962, Suomen Puunkäyttö ja Metsätase vuosina 1947—1961.
Kunnas, Heikki, 1973, Metsätaloustuotanto Suomessa 1860—1965. Kasvututkimuksia. Helsinki.

sented in figure 14. The sharp fall in production between 1975 and 1976, the result of a decline in demand on the market, has meant that utilization of the industry's capacity has been very low.

In spite of rapid expansion in the industry, the gross profit margin of the industry has been decreasing since the early 1960s (figure 15). The main reason for this is probably the adverse trend in pulp and paper prices: while in real terms the prices have remained fairly stable since the early 1960s, the cost of wood to the mill has been rising. In addition, labour costs have also been increasing, especially in respect of "fringe" benefits, and productivity has not risen sufficiently to compensate for this increase. Nonetheless, this does not entirely explain the low gross profit margin.

Since the downward trend in the gross profit margin has been in evidence since the early 1960s, it cannot be attributed to the

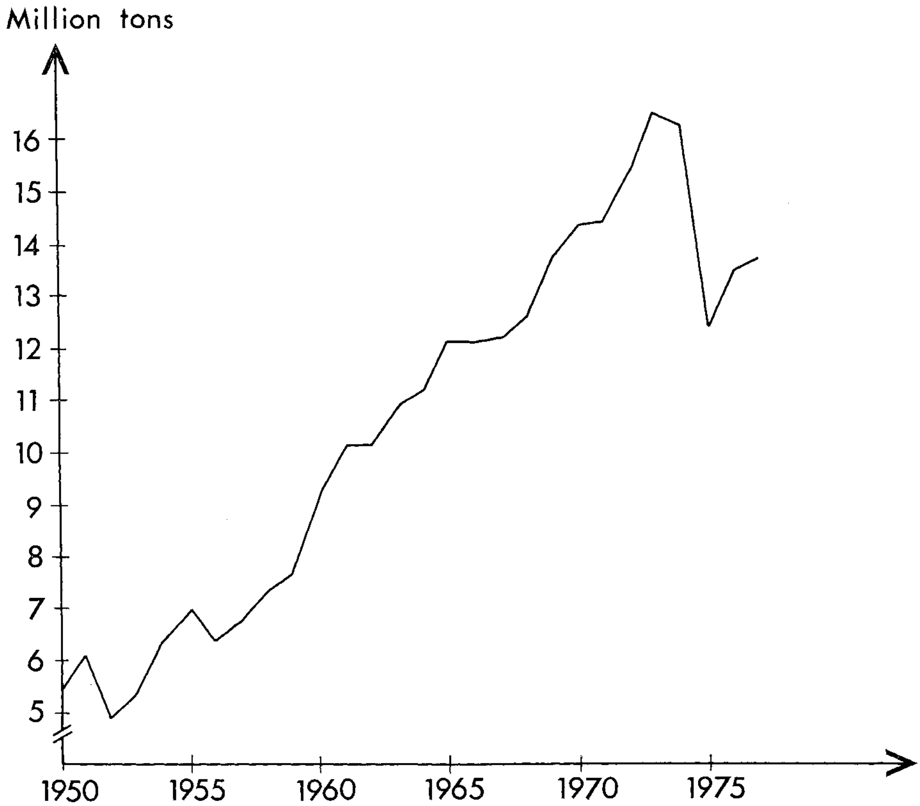


Figure 14. Total production of the Finnish forest products industry, 1950—1975 (including sawmilling, panel and pulp and paper industries, million tons per annum).

recent decline in the market. Unfortunately, there is not enough information available for a comparison to be made of the development in the gross profit margin in the Finnish forest products industry with that of the industry in Norway and Sweden.

4.2 Reparameterization of the SOS model

In order to adapt the SOS model to Finnish conditions, new parameters were introduced into the model in the spring of 1977, although structural changes to the model were avoided. Some of the aspects of the reparameterization process are worth mentioning. The process is not very difficult when the necessary data are available. However, the researcher must be fully familiar with the model before he can make changes to the parameters, yet the acquisition of such knowledge is not only time consuming but almost impossible without the aid of the model designers. This is particularly true when there is no technical documentation available.

The actual reparameterization of a system dynamics model—even one of the size of the SOS model—involves a few months' work at the most. In the present case, 14 initial values, 23 constants and 17 tables were changed. Most of these changes were in respect of figures that had to be altered to correspond to new initial conditions.

Although an in-depth description of the reparameterization process is not possible here, a few examples may be in order to give the reader an idea of the nature of the changes. The SOS model breaks down into 5 segments, according to the different functions in the forestry sector: forestry itself,

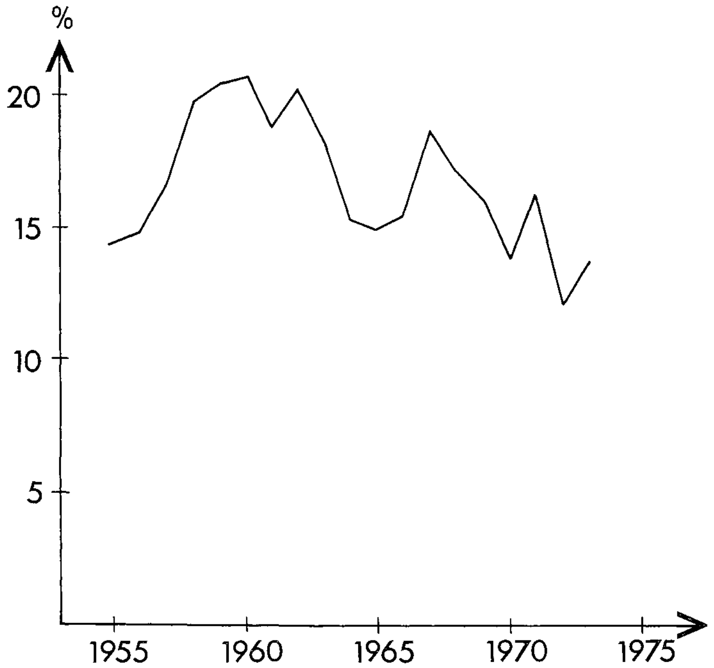


Figure 15. The gross profit margin of the twelve major enterprises in the forest products in Finland, 1955—1973.
Sources: Palo, Aki, 1977, Pohjois ja Etelä-Suome metsäteollisuuden kannattavuus ja kantohinnat. Ihminen ja Metsä. Helsinki.

the forest products industry, the end-product markets, the competitors of the Scandinavian forest products industry and, finally, society, in the interests of which it is desirable to keep the annual cut at a sustainable level (society as a regulator).[3]

The initial values in each segment of the model had to be changed to represent the situation in Finland. The changes do not affect the functioning of the model but merely adjust the scale of the model to the correct level. Since structural changes were avoided, it was considered sufficient to modify the scale in the model segments end-product markets, competitors and society as a regulator.

Most of the differences in the constants and table values in respect of the parameters for Scandinavia in general and Finland in particular concern forestry itself and the forest products industry. The differences in the forestry segment are attributable to the fact that the age structure of the Finnish forests deviates from that assumed in the model in respect of Scandinavia as a whole. In addition the logging policies in Finland differ somewhat from those in the original SOS model: thinnings in Finland account for a much larger proportion of the annual cut, whereas in the original model emphasis was given to final felling. These differences do not seriously affect the structure of the system but imply that certain parameters must be given different values.

As regards the forest products industry, sawnwood, wood-based panel and pulp are dealt with in the model,[4] with paper manufacture being classified as further refinement of the products. Further refinement, however, only has a bearing on employment in the industry and does not influence the cost structure. In Finland, on the other hand, the further refinement of pulp is an important factor, determining the total industrial capacity and the cost structure of the industry. Moreover, greater utilization of branches and roots is less significant in Finland than has been assumed in the SOS

[3] Randers, Jørgen; Stenberg, Lennart; Kalgraf, Kjell, 1978: Skognæringen i overgangsalderen. Oslo.
[4] Ibid.

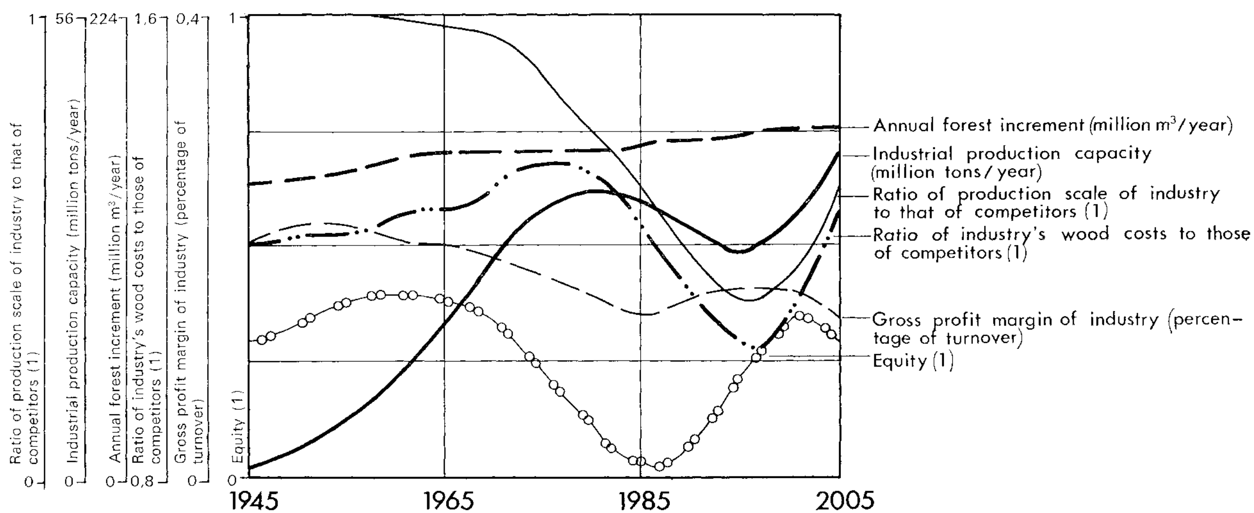


Figure 16. Development of the Finnish forestry sector given by the SOS-model (regulation of industrial growth starts in 1969).

model. Thus, in respect of Finland, the table of roundwood yield concerns the relationship between industrial roundwood consumption and industrial capacity. Consequently, roundwood yield is increased by an increase in the use of industrial wood residue and with further refinement of pulp. As a result, the cost structure of the industry must also be changed. Although these parameter changes conflict with the basic assumptions made in the original model, they were considered necessary in order that a better picture could be obtained of developments in industrial capacity and of the effect of relative changes in different cost items.

Other values that were changed were those in respect of the non-industrial consumption of wood and the volume of imported wood (figure 13). In the original SOS model, pertaining to Scandinavia as a whole, the assumption is that there will be no imported wood. However, had Finland not imported wood, the development in the sector during the historical period might have been quite different (for import figures, please refer to page 37). Thus, changes in the parameters brought the historical period in line with the actual development of the forestry sector in Finland between 1945 and 1975.

The trends in the main variables in the example run come fairly close to the historical reality (figure 16). The exponential growth in industrial capacity starts to slow down towards the end of the 1960s (figure 14). The gross profit margin starts to deteriorate in the early 1960s (figure 15) owing to high variable production costs and high wood prices.

The high variable production costs appearing in the re-run are explained by the low level of the average scale of production compared with that of the industry's foreign competitors. As mentioned earlier, variable production costs have been increasing in Finland, although whether the reason for this is that given by the model is difficult to say. Of course it may be argued that productivity increases have not been high enough to compensate for the increase in labour costs.

Another reason for the fall in profitability is the increase in wood costs, largely attributable to higher stumpage prices. In real terms, the stumpage price in Finland has been increasing, especially during the 1970s. This is reflected in the fact that in spite of an increase in the value-added in industrial production, the share of the average sales value of the products accounted for by the stumpage price has fallen only slightly.

Another important aspect is the development that has taken place in logging costs; however, additional research is necessary before this aspect can be clarified.

The relationship between the total consumption of wood and the annual forest increment, as presented in the re-run of the model, agrees fairly well with the situation in reality. The annual cut and industrial consumption of domestic roundwood are not directly comparable owing to the existence of non-industrial wood consumption and wood imports, and because of the difference in the structure of production in the Finnish industry compared with that of Scandinavia as a whole, as described in the SOS model. Nevertheless, if we assume a capacity utilization of 100 % and that no wood was imported, the industrial demand for domestic raw materials together with the wood consumed in non-industrial uses would probably have come very close to the allowable annual cut in 1975.

The latest computer run shows equity in the forest products industry to be in decline after the beginning of the 1960s. Although this variable cannot be measured directly, a good pointer to it is the relationship between total revenue from sales and the total of borrowed capital. In reality, the amount of borrowed capital in the industry up to the mid-1970s was growing in relation to sales revenue, which suggests the decrease in equity shown in the model.

The low rate of growth in industrial capacity during the 1970s, shown in the re-run, can partly be explained by the self-regulation started by the industry in 1969, and partly by the fall in profitability. This could well be true in reality as well. One might even ask whether or not the true development would have been different if no regulation had been introduced.

Because of the low level of profitability, the capacity of the forest products industry starts to decrease after the 1980s. In spite of the low cost of wood, the increase in variable production costs is enough to cause a fall in production capacity. The industry finds itself unable to secure sufficient loans to finance both required net investments and the modernization of existing capacity. Once equity in the industry has increased, after 1990, an increase in production capacity will again be possible.

This run is based on the assumptions included in the SOS model but much more work is necessary to determine the relevance of the assumptions to the Finnish forestry sector. Nonetheless, the run does raise some interesting questions. For example, if the predicted development in equity becomes a reality, what would have to be done to guarantee sufficient investment in this field? Again, how can a satisfactory level of profitability be attained in a situation of limited growth? The results of this run are not a forecast of future development in the Finnish forestry sector but, together with the work done on the model, they do raise many questions and some probably very important problems deserving of further analysis.

4.3 Some structural elements of the model and their relevance to Finland

Although the SOS model contains many interesting structures and assumptions worthy of study, here we are limited to a discussion of just some of the elements and their relevance to the Finnish situation.

Non-industrial wood consumption and imported wood

A continuing decrease in the non-industrial consumption of wood together with the importation of wood provided the Finnish forest products industry with an opportunity to become aware of the pending shortage in the supply of wood. Moreover, it was probably this decrease in non-industrial consumption that averted a situation during the 1960s where the consumption of wood could have considerably exceeded the allowable annual cut. It is difficult to say whether or not the present system of self-regulation in Finland will be able to prevent industrial capacity from rising above the present limit in the domestic supply of wood resources, once the additional supplies of wood from other domestic sources have been exhausted.

Costs

There are two important mechanisms in the SOS structure that reduce profitability in the forest products industry when a physical constraint is imposed on the supply of raw materials: the increase in the costs of raw materials compared with those of competitors, and either an increase in processing costs or in capital costs. During a period of only modest growth, commodity producers can either maintain their traditional rate of establishing new capacity and increase closures of existing plant, or maintain the traditional rate of closures and cut back on the establishment of new plant. The former strategy entails higher capital costs per unit of production, whereas the latter entails corresponding higher variable costs. The situation most likely to occur in reality will lie somewhere between these two extremes. The SOS model assumes that raw material costs account for 50 % of the total production costs. This is because the manufacture of paper and paperboard have been excluded from the cost structure of the model. On the whole, the raw material costs in the Finnish industry account for only about 30 % of the total costs, mainly because of further-refinement pulp (converted products being excluded). At the present time, paper and board products account for some 70 % of the value of Finnish exports of pulp and paper.

The availability of wood

The SOS model assumes that the woodworking industry will be able to obtain all the wood it requires, provided that it is willing to pay the market price. When wood becomes scarce, forest owners tend to press up the stumpage prices. In addition, logging and haulage costs increase, with a resulting decrease in profitability in the industry. In the model, the stumpage price is a function of roundwood consumption relative to the allowable annual cut.

But according to recent studies in Finland, rises in the stumpage prices may not be enough to guarantee an adequate supply of roundwood to the industry within the limits imposed by the allowable annual cut. During the last 10 years, there has been a decrease in the total consumption of wood and an increase in stumpage prices. This means that the overall supply curve is shifting to the left. One possible explanation for this is the continuing change in the structure of forest ownership—to which the supply of wood is closely related. In addition, the demand curve may be shifting, owing to the decrease in non-industrial consumption of wood for example. The dynamics behind these shifts is at least as important to the development on the roundwood market as are movements along the supply and demand curves. This is because, from the point of view of the forest products industry, stumpage is a residual value, the level of which might not rise sufficiently for it to influence the long-term supply of wood. Even in the short term, during 1974 and 1975, when stumpage prices more than doubled, there was no increase in the commercial cut in Finland.

Investment regulation

In the SOS model, the regulation of growth is separated from the financing system. In Finland, regulation is carried out by the forest products industry itself in cooperation with the Bank of Finland; thus, only investment plans with a borrowing requirement are affected, as a result of which good profitability tends to diminish the effectiveness of the regulatory policy.

Increased value-added and scale of production

In the SOS model for Scandinavia as a whole, the forest products industry is restricted, by definition, to the production of commodities. Economies of scale are therefore of great importance in determining the cost of production. It is assumed that a lower rate of growth in the commodity-producing industry will necessarily involve either higher processing costs than those of foreign competitors (low weighted-average scale) or higher capital costs when the scale of production is kept at the optimum level. In both cases, then, the total production costs will be higher than those of competitors who are able to maintain their earlier growth rates and have ample wood resources.

The validity of the assumption concerning the effects of the production scale is debatable. Jaakko Pöyry and Co. and the Central Association of the Finnish Forest Industries have studied the effects of the economies of scale. For example, in respect of the pulp industry they found that an increase in plant size from 200 000 to 400 000 tons per annum produced an increase in profitability of about 2 or 3 % (measured from the level of the gross margin). They also found that successful integration can increase profitability from 10 to 18 %, depending on the field of production.[5] However, considerable caution should be applied to this type of short-term study, when it is the long-term relationships that are of interest. Wohlin concludes that a large proportion of the benefit attributable to "economies of scale" stem more from modern techniques than from the actual scale itself.[6] Apart from this, the maximum size of mills is likely to grow much more slowly in the future, than was the case during the 1950s and 1960s.[7]

[5] Pärnänen, Heikki, 1974: Lopputuotteen merkitys raakapuun hinnointteluun. Raakapuun hinnoittelupoliittinen seminaari Seinäjoella 14—15.02.1974.
[6] Wohlin, Lars, 1970: Strukturomvandling i skogsindustrien. Stockholm.
[7] Eklund, Risto and Alonen, Pekka, 1978: Investment in the forestry and wood-processing sector. FAO. Geneva.

Even if the effects of scale are less significant than has been assumed in the SOS model, the model does draw attention to a vital question: How, when faced with constraints on growth, can a branch of industry maintain its competitiveness when its competitors can enjoy growth at the same rate as before?

A lower growth rate consumes less capital for expansion, thus leaving more capital for the modernization of old plant. But will the decision-makers in the capital markets feel inclined to allocate capital to a field of production in which zero growth is to be expected?

4.4 Conclusions

The forestry sectors in Finland, Norway and Sweden are all faced with a pending physical fibre constraint. Apart from the higher refinement rate in the Finnish paper industry, the production structure in the forest products industries has been similar in all three countries during the post-war years. Thus, Scandinavia as a whole has been taken as a single unit in a model designed to study a transition from a period of rapid growth to one of modest growth, necessitated by a shortage in the supply of wood raw materials. The reparameterization of the SOS model provided an excellent opportunity to study the structure of the forestry sector. Since the reparameterization work requires in-depth study of the model, a researcher obtains a good picture of the relationship existing in the production field, especially if he is granted the opportunity of discussing the problems with the model builders. Important in a model like the SOS model is how a certain variable develops during the course of time. But even more important is why it does so. When reparameterization of a model is carried out to adapt it to a new area, its structure must be consistent with the structure of the production field in the area concerned. It follows, therefore, that when studying the model the researcher must take into account the structure of the sector in question in the new area. During this process, the model indicates the most important factors affecting the development of the relevant sector.

The differences between the structure of the SOS model and the structure of the Finnish forestry sector (examples of which were presented in the previous section) do not seriously affect the applicability of the model to the Finnish forestry sector. The structure of the model is sufficiently flexible for the necessary corrections to be made. Thus, it is possible to use the SOS model to study the development of the Finnish forestry sector under the conditions imposed by a physical fibre constraint. A simulation model has also been built in Finland in order to study the long-term strategies of the forestry sector (the Finnish forestry sector planning model). For the most part this model is a simplification of the SOS model. The Finnish model was deemed necessary because the Finnish forestry sector would be faced with other limits before the pending shortage of wood became a fact. These limits also concern the domestic supply of raw materials but are human in nature. A discussion concerning these constraints is beyond the scope of this paper. However, the SOS model is relevant if the physical fibre constraint alone is to be studied. The structure of the SOS model is such that the model can apparently be employed to study the physical fibre constraint in respect of Scandinavia as a whole as well as in respect of an individual country. Problems of a more national nature, on the other hand, require other specialized models.

5 Stock fluctuations in the pulp industry

by John E. Høsteland

5.1 Introduction

In recent years, the situation facing the Scandinavian forestry sector has been quite dismal—or even catastrophic in the case of a number of enterprises. All those who believed that the encouraging trend of 1973 and 1974 would continue have now had to admit that the clouds did not have a silver lining. From 1975 onwards the stocks of various products began to grow as a result of the fall in sales and efforts to maintain production levels. Everyone seemed to be awaiting a new upturn in the market; however, it proved to be some three years before sales began to rise again.

If we look at the historical background the turn-about will not seem quite so dramatic. Indeed, cycles with a 4—7-year duration would appear to be normal in the sector. Figure 17 shows the development between 1957 and the present time in respect of the production levels, sales and stocks of sulphite pulp; similar fluctuations to those presented in the figure were previously in evidence during a period reaching way back into the past. The stocks of pulp that were regarded as being extremely high in 1977/1978 were equally large after the "Korea boom" of 1951 and during the late 1930s. In fact, when related to sales, the stocks at that time were greater than during the "record" year of 1977.

So what caused these fluctuations? To most people these fluctuations in economic activity remain both mystical and incomprehensible, occurring as they do at various times for apparently unknown reasons. One commonly held view is that the fluctuations are caused by circumstances outside the forestry sector, which really have little or nothing to do with it. Thus, it is up to individuals to adapt themselves to developments as best they can. Such adaptations will be made on the basis of certain expectations concerning developments during the near future. These may be expectations concerning increases or decreases in prices, or the increased scarcity of a commodity or the like. The expectations stem from information of developments in the immediate future up until the time at which decisions must be taken. The view, both forwards and backwards in time, is a short-term one. If developments have shown an upswing in prices and sales during the last couple of years, most people expect the trend to persist. It is for this reason, then, that it takes a certain time before everyone will accept and believe information that signals departures from the expected pattern.

The purpose of this paper is to show, with the aid of a system dynamics model, that the short-term (4—7 years) fluctuations in production, sales, prices and stocks can largely be explained by the decision-making process within the sector, particularly with regard to the inherent reluctance in the sector to change course. Because of the correlation between stocks, production, sales and products, the system is rarely or never in equilibrium. The structure is such that it gives rise to comparatively regular fluctuations, which in this case occur as cycles of 4—7 years. The main problem is apparently the difficulty of changing the degree of capacity utilization in the industry in order to balance production and sales.

5.2 Theories explaining economic fluctuations

A wide variety of theories to explain variations in economic activity have been developed throughout time. One of the older theories is the "sunspot theory", which attributes the fluctuations to procreative changes in farming caused by climatic variations. The biblical example of seven years of famine and seven years of plenty may be a variant of this theory, which would suggest that the theory is of ancient origin. Others maintain that the variations are purely stochastic: Slutzky (1937),[1] for example, refers to economic fluctuations as statistical illusions.

Another explanation is that the USA dominates the world economy, with the result that every 4 years the American electorate causes 4-year business cycles.

The more widely acknowledged theories for fluctuations in the macroeconomy are based on the accelerator-multiplier principle (Samuelson, 1973).[2] However, the evidence would suggest that the forces on which these theories are based give rise to fluctuations of greater duration than the 4—7-year waves (Low, 1977).[3] A 4—7-year wave is attributable more to variations in capacity utilization than to changes in capacity (Randers, 1978).[4]

As regards analyses of variations in production and prices of individual commodities—or possibly groups of commodities—the Cobweb theorem is best known. The "hog-cycle" phenomenon is the typical example. The point of departure of the theorem is that the production planning is based on the price at a given time. However, a period of time will elapse before the commodity will be put on the market. If, however, at that time the demand for the commodity is higher than it was previously, the supply will not be sufficient to meet the demand at the old price. Thus, the price will rise. Because prices are now high, production (supply) will be increased during the next period. As a result, the supply will be greater than is necessary to satisfy the demand at the old price, causing the price to fall again. During the next period production will therefore be decreased. And so on.

5.3 **Sulphite pulp**

As a background to the simulation model described in the final section of this paper, I have taken the production of sulphite pulp for sale as an example.[5] Let us take a closer look at figure 17 in an attempt to explain the development of the different variables presented on the graph. To eliminate seasonal and fortuitous variations, the calculations are in respect of 12-month averages. The export prices are quarterly averages.

It is clear from the figure that there are a number of quite regular fluctuations in this field, which is particularly true in respect of the movement in stock levels. Since the stock of finished products is the accumulated difference between production and sales, the regular fluctuation in the stock level can be referred to the regular imbalance between these variables.

The evidence suggests that it is a relatively stable, underlying pattern of events that causes these regular fluctuations. Let us take a closer look at these "waves". In around 1967 production was lower than sales. At the same time stocks were at a relatively high level and, consequently, when sales started to rise again it did not matter that production lagged behind sales for a comparatively long period, as the stocks of finished products made up the difference. Production was stepped up but it was some time before it could catch up with sales. Prices had also risen quite sharply during the period. In 1970/1971, the sales curve turned and once again it took time before a reduction occurred in capacity utilization, with the result that stockpiling took place.

[1] Slutzky, E. 1937: The Simulation of Random Causes as the Source of The Cyclic Process. Econometrica. April.

[2] Samuelson, P. 1973: Economics. Ninth Edition. McGraw Hill. New York.

[3] Low, G. W. 1977: The Principle of Conservation and the Multiplier-Accelerator Theory of Business cycles. I: "The System Dynamics Method". Ed.: J. Randers and L. Ervik. Oslo.

[4] Randers, J. 1978: Om den økonomiske utvikling pa 10—15 års sikt. Bergen Bank. Kvartalstidsskrift 1978: 4.

[5] Some of the sulphite pulp produced is used in the internal production of paper and is therefore not included here.

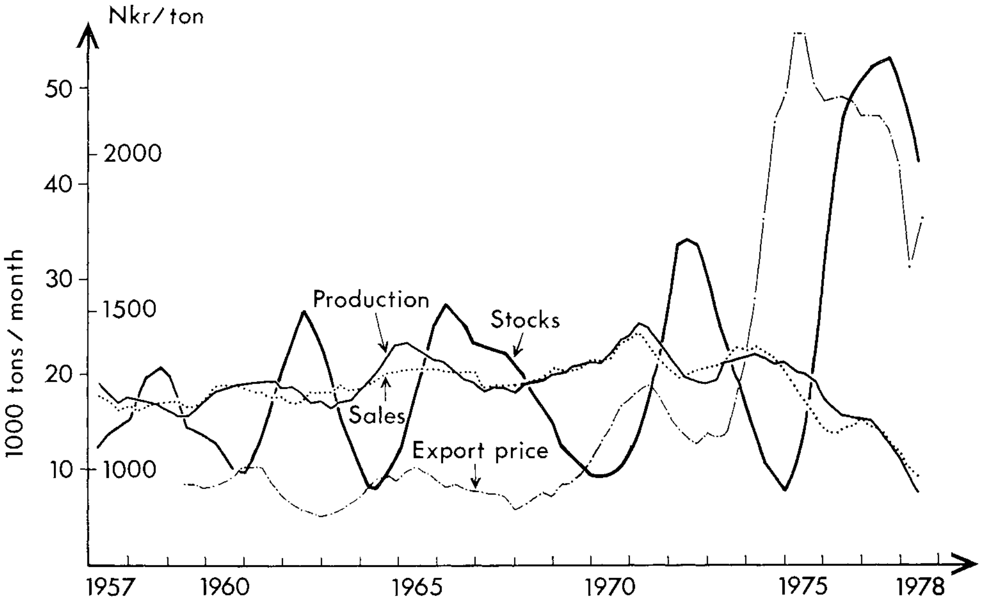


Figure 17. Monthly figures for production, sales and stocks of bleached sulphite pulp, averaged over 12 months, and quarterly export prices of bleached sulphite pulp in Norway.
Source: Papirindustriens Sentralforbund, 1978. Høsteland, J. E., 1978, Produksjons- og lagersvingninger i celluloseindustrien. En systemdynamisk analyse. Rapport 1/1978. Institutt for skogøkonomi, Norges landbrukshøgskole, Ås-NLH.

Two questions can be asked here: Was the fall in sales the result of rising prices? Was the rise in prices the result of the low level of stocks, which gave the impression of a growing shortage of the commodity on the market? It is impossible to say for certain which factors were the causes and which were the effects; however, there are a number of theories that can be advanced.

The market for sulphite pulp may be characterized as a "free competition" market. Pulp is a bulk product and the prospects are therefore slim of a firm producing special grades or qualities that would enable it to find a market segment in which the firm could operate more or less as a monopoly. There are three possible reasons for a decrease in exports of pulp from Norway:

- A fall in the production of paper will result in the buyer requiring smaller quantities of pulp.
- As a result of increased prices, the buyer will reduce its stocks of pulp.
- After a given supplier increases its prices, the buyer will turn to other suppliers who will therefore increase their market share at the expense of the former supplier.

Now we will find that the consumption of paper in Western Europe has been rising quite steadily throughout the period. Consequently, the indications are that the decline in the exports of pulp from Norway in 1971 can largely be explained by a combination of the last two factors.

That there was also a turnabout in prices can hardly be explained by anything other than the fact that the supply (production + stocks) was greater than the demand. The storage costs gradually forced the industry to lower its prices in an attempt to create an increase in demand. At the same time, it was a while before the industry accepted the fact that there had been a turn in the sales trend. It attempted to maintain the levels of production and prices in the hope that the fall in sales would only be short term. However, as the stocks built up the industry was forced to cut down on capacity utilization. Growing stocks once again coincided with falling export prices, and it seems reasonable to conclude that there is a cause-and-effect relationship between prices and stock levels.

When there was an upswing in sales again in 1972, once again a period of grace was required before production was stepped up. Stocks were rapidly exhausted and prices were pressed up again.

There were probably special circumstances surrounding the development that took place in 1973 and 1974. It seems that many were led to believe that there would be a general shortage in world resources, not least in respect of paper, pulp and timber. This resulted in abnormally high demand, high prices and, naturally enough, a sharp increase in production in the pulp industry.

The industry was generally optimistic and when sales fell back again, it was a long time before the industry was prepared to cut back on production. However, in the meantime stocks had risen so high that a reduction in output was unavoidable. In this situation, a variety of measures were taken to avoid a recession. In Sweden stockpiling subsidies were introduced in grand style in the hope that this low in the business cycle could be weathered. The effect of this was probably that the trough between the waves became deeper and longer.[6] It was not until the stockpiling subsidies had been discontinued and the Swedes also became willing to cut back on their output that an upswing began to manifest itself. Now (1979), stocks have been rapidly falling for about a year and prices have started to rise. The signs are that we are entering a new upswing in respect of demand and production. The question to be asked here is whether or not this trend will follow the traditional pattern.

5.4 A system dynamics model for stock fluctuations

We have now discussed the development in respect of production levels, prices, sales and stocks in the Norwegian pulp industry. Let us now deal with a more formal model that can be used to describe a corresponding development.

Let me straight away emphasize that there are two main elements in the model, namely, *stocks* and *delays*. While the level of stocks is significant both to production levels and pricing, delays or sluggishness in the system give rise to fluctuations.

A traditional market model, in algebraic form, in which supply and demand are a function of the price, will have the following appearance:

$s = f(p)$
$d = h(p)$
$s = d$
where,
s = supply
d = demand
p = price

These three equations are generally adequate for calculations of the magnitude of the variables. However, observe the units that are used: both supply and demand refer to units per time period, whereas the price is expressed in kronor per unit. This is a flow model, in which no consideration is given to developments in stock levels.

In reality, the supply in respect of a commodity embraces not only that which is produced but also that which is available in stock at a given time; similarly, demand includes not only that which is required to maintain production, but may also involve purchases for stockpiling purposes. Thus, a model that does not include a variable in respect of the stock situation is not sufficient for an analysis of production and price adjustments in a market. Banks (1976)[7] states the following concerning the necessity of incorporating stock levels in the analysis:

"... inventories—or, more specifically,

[6] Swedish exports of bleached sulphite pulp account for some 50 % of Europe's imports of this pulp.
[7] Banks, F. E. 1976: The Economics of Natural Resources. Plenum Press. New York.

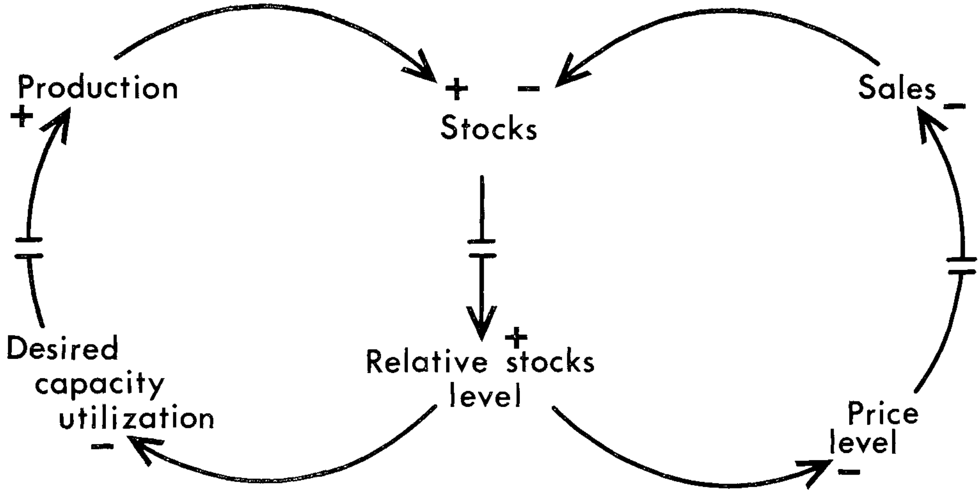


Figure 18. Cause-and-effect diagram for the dynamic stock-fluctuation model. = indicates delays. The arrows indicate the direction in which the effect works and the prefixes (+ or −) at the arrow ends indicate the type of effect: a minus sign signifies that a change in the initial variable produces a converse effect in the affected variables; a plus sign signifies that the change in both variables is in the same direction.

> the relation of inventories to demand—play a key role in determining the market price of a commodity. It seems to be a statistical fact that the price of most industrial raw materials is a function of the ratio of inventories to demand, and, since this concept cannot be conveniently fitted into a flow model, this type of model cannot be regarded as completely suitable for the investigation of the markets for raw materials until it is augmented."

In every stock-oriented industry (as opposed to order-oriented industries such as the engineering industry), one of the policy requirements will be to possess a given stock of saleable commodities to act as a buffer against fortuitous variations in both output and sales. The movement in respect of stock levels will constitute the physical evidence of the extent to which output and sales are in equilibrium over a given period of time (Praski, 1978).[8] If sales exceed output during a given period, the stocks will fall and when they have fallen below the specified, desired level, two things may happen.

Firstly, the firm will endeavour to increase production. The output will have to be increased above the level of sales for a time since the production will have to be sufficient to cover both sales and the building-up of stocks to the desired level. Only when this has been achieved can the production be cut back to the level that corresponds to sales.

Secondly, prices will probably go up. Since sales are greater than the volume of production, demand will exceed production. Again it will be the stock level that will most accurately reflect how real the "scarcity" is.

If stocks are high, it will not matter if production lags behind sales for a while. In such a situation, nobody would claim that the commodity is in short supply. Not until stocks are at a low level will prices rise. The reaction of the market to higher prices may initially be an increase in demand, since it is reasonable to assume that further

[8] Praski, S. 1978: Industrilagrens roll i konjunkturen. Särtryck ur Industrikonjunkturen. Våren 1978. Stockholm.

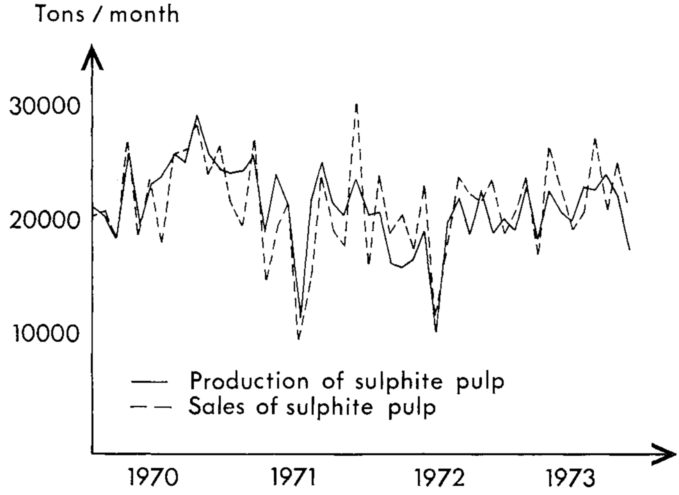


Figure 19. Monthly figures for the production and sales of bleached sulphite pulp, 1970—1973.
Source: Papirindustriens Sentralforbund. 1978.

price rises are in the pipeline. Taking a longer-term view, however, one may assume that the effect will be a fall in consumption and a decline in sales. Assuming that output remains constant, the fall in sales will result in increased stocks.

A cause-and-effect diagram illustrates in a simplified manner the interaction between the variables, whereby a change in one variable will influence another. The diagram in figure 18 illustrates the interaction between the variables included in the "stock-fluctuation model".

Let us briefly consider how we should read a diagram like this. One proceeds from one variable to another, at the same time assuming that all other variables are constant. Obviously, with the model simulations all of the variables can vary simultaneously. One can start anywhere in the diagram. Let us start with "Stocks" and suppose that these increase. This will affect the relative stock level (the ratio of stocks to sales). The plus sign signifies that an increase in stocks will result in an increase in the relative stock level. The increase in the relative stock level will then influence both the "desired capacity utilization" and the "price level". The minus sign signifies that an increase in the relative stock level will result in a fall in both the price level and capacity utilization. Lower capacity utilization will give lower production which will gradually diminish the stocks. A fall in prices will result in increased sales, which will diminish the stocks more rapidly. As we can see, there are two feedback loops, which are continually working towards the desirable stock level.

If the described mechanism had acted instantaneously, the market would have been in equilibrium every time and there would have been no fluctuations. However, a number of delays are inherent in the system. It takes time before the decision-makers are in receipt of information about changes in the situation, and before they accept that there has actually been a departure from the expected development on which they had based their current policies. Many may find it strange that changes in sales, for example, cannot be identified relatively quickly. However, it may be easier to understand it if we consider the disturbances, fortuitous and seasonal variations, that occur in the system. Figure 19 presents monthly figures in respect of production and sales. It is not easy to discern a trend in these curves and every method for calculating trends can only provide conclusive figures in respect of changes in trends several months after there has actually been a

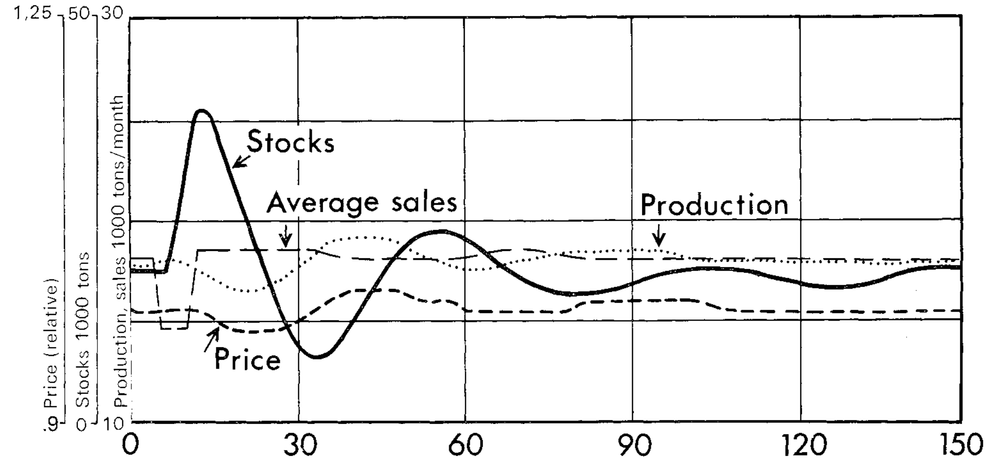


Figure 20. Simulation showing how the model system responds when exogenous forces cause sales to fall by 20 % over a six-month period. Explanations: The scale on the left refers to the different variables. The price, expressed in relative terms, ranges from 0.9 to 1.25. Stocks, sales and production are expressed in tons. The time scale, below the figure, ranges from 0 to 150 months.

turn-about. This is added to the time it takes to collect information and to the fact that each individual firm regards the fluctuations in a slightly different light, because sales contracts are of varying length. Another delay lies in changing the production: increases or decreases in capacity utilization cannot be effected in a day. Production planning takes time. Moreover, there is apparently a certain reluctance to cut back production, since this often requires reductions to be made in the labour force, with workers being laid off, etc. A certain sluggishness is also present in the market: sales contracts are often long term and include guarantees in respect of prices. Furthermore, such cut-backs often mean that long-standing relations in the trade must be broken. Yet, if a buyer can benefit from purchasing goods from a competing supplier, it is unlikely that he will refrain from doing so.

A number of such delays are incorporated in the model, including the time taken:

- to detect and accept changes in the level of sales and stocks.
- to effect changes in capacity utilization.
- before there is a willingness to change prices.
- for the market to respond to new prices.

The model in question is constructed of a number of differential equations, which are solved successively during the simulation. The model is programmed in DYNAMO, which is a highly suitable programming language for dynamic simulation problems (Pugh, 1976).[9] I would refer anyone interested in studying the model in more detail to Høsteland (1978). The following equations provide a broad illustration of the most important function relationships in the model:

$P_t = f(L_{t-i}/S_{t-i})$ $\quad P'_L < 0 \quad P'_S > 0$
$S_t = g(p_{t-j}, X_t)$ $\quad S' < 0$
$p_t = h(L_{t-g}/S_{t-g})$ $\quad p'_L < 0 \quad p'_S > 0$
$L_t = L_{t-1} + P_t - S_t$

P = production (tons/month)
S = sales (tons/month)
p = relative price (1)
L = stocks (tons)
X = exogenous variable

[9] Pugh, A. L. 1976: DYNAMO User's manual. Fifth Edition. MIT Press. Cambridge. Mass. USA.

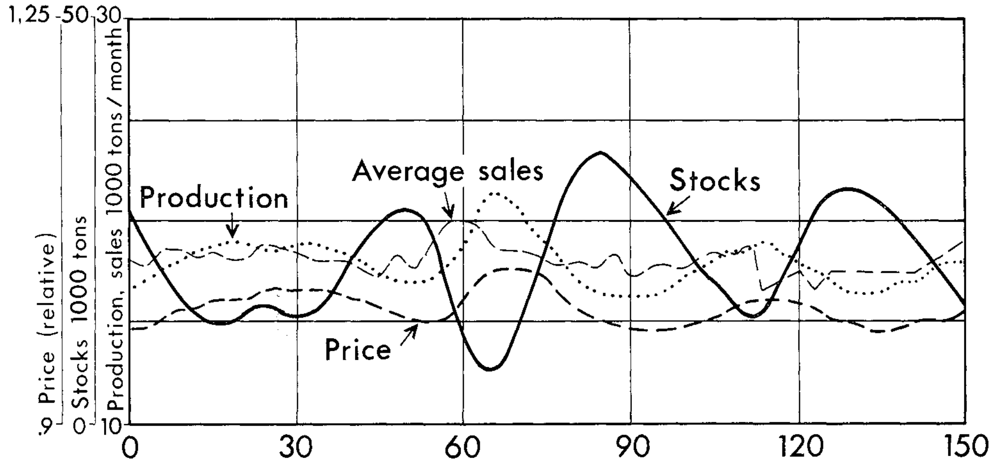


Figure 21. Simulation showing how the model system responds to fortuitous variations in sales. (For an explanation of the figure please refer to figure 20.)

The various delays are denoted by (t – i), (t – j) and (t – g). It is possible to experiment with delays of varying magnitude in the simulation model, although these will normally all be less than six months. It is the interactions between them that create fluctuations with very high amplitudes. X_t is an expression for the exogenous variables. X could conceivably be a vector and is not necessarily one simple variable.

5.5 Simulations with the model

The intention with this model has not primarily been to create an instrument for making predictions, but to demonstrate the way in which the dynamic interaction between a number of variables can generate a pattern that can be observed in reality. An understanding of why the various events occur is the first step along the road to guiding development in the desired direction.

In a model such as this calculations are performed successively; in other words, the initial situation or point of departure must be defined. In the case of this model, the initial situation is usually one of equilibrium, i.e. production is at the same level as sales and stocks are at the *desired level.*

To test the way in which the model reacts when this balance is disturbed, we introduce a 20 % drop in sales over a six-month period. The result of this simulation is shown in figure 20. This external shock triggers a number of oscillations in the system, which only steady down after a period approaching 10 years. We find that the system functions in the way described earlier. The wave length that is generated is of the order of four years and the reciprocal proportional magnitude of the variables appears to be acceptable. The response to the fall in sales is delayed, but gradually, as the stocks grow, production is forced down and prices also fall somewhat. Nor is the adjustment fast enough when sales rise again, and in the attempt to adjust stocks to the desired level we find that the fluctuations persist for a while by themselves, even if they are subsequently dampened considerably.

By changing the parameters and the relations between the variables it is possible to determine those factors that have a decisive influence on the magnitude and duration of the fluctuations and on the speed at which the fluctuations are dampened. Quite naturally the length of the delays is critical: the longer the delays, the longer the wave length and the greater the amplitude. It has also been established that rather extreme conditions are required before there can be any drastic dampening of the fluctuations. The nature of the programming language makes it an easy task to change parameters and institute new simulations.

A common assumption is that fluctuations in prices and production are caused by regular fluctuations in demand. Yet, the fact is that fortuitous variations from one month to another are sufficient to generate fluctuations. This is demonstrated by the experiment in figure 21, in which the sales vary fortuitously around an average.

The reason that there are also fluctuations now is attributable to the dominance of the sluggishness in the system over the fortuitous variations that occur when the system first is out of balance. This is often referred to as the "rocking-horse theorem". Owing to the inertia in a rocking horse when it is first set in motion, it will continue to rock fairly regularly, provided only that it receives slight encouragement in both directions.

Fortuitous variations will always be present in both production and sales, making each wave individual, even if the underlying structure is comparatively stable. This makes the job of forecasting in this field a difficult one. However, clearly the use of leading indicators and the identification of turning points are important to industrial planners, in their attempt to shorten delays and react more promptly to changes in the market.

Apart from these fortuitous variations, periodic variations also occur, for instance, variations in the sales of a commodity in pace with the general trend in the business cycle. Regular variations in demand will enhance stock fluctuations.

In this paper I have endeavoured to demonstrate, using a relatively simple model, the way in which fluctuations can occur in a simple business. The main conclusions to be drawn from this analysis may be summarized as follows:

- The sluggishness in the adjustment of production to sales may explain the short-term fluctuations in the pulp industry.
- Since it is difficult to dampen these fluctuations, the pulp industry will probably have to live with these fluctuations in the future as well. This fact must be taken into account in production planning.
- By prolonging (increasing the delay in) the response to changes in the market, for example, by introducing stockpiling subsidies, one makes the troughs in the business cycle deeper and wider.
- In theory, it is possible for an individual firm to weather a recession by stockpiling its output, but this is not possible for a branch of industry as a whole.
- The level of stocks constitutes an important indicator of where one stands in the business cycle.

6 The dynamics of a simple stand

by Kjell Kalgraf

6.1 Introduction

This paper contains a description of a simulation model, which can reproduce the development over a period of time of certain main parameters in a forest stand, namely, volumetric density (m^3/ha) in respect of the standing volume, tree density (number of trees per hectare), the annual natural regeneration (number of trees per hectare per year), the annual natural thinning in respect of trees (number of trees per hectare per year) and of volume (m^3/ha per year). The model has been conceived to test the dynamic effects on volumetric density and the mean tree dimension (m^3/tree) of activities such as thinning, fertilization, spraying and ditching.

The cause-and-effect relationships in a stand have been captured in a system-dynamics model in which the forest is seen as a feedback-loop system. Increment is seen as a cumulative process that is determined by the state of the stand and governed by the volumetric density and tree density. As in a real stand the model generates the development over a period of time in an untreated stand by internal mechanisms in the system. When the stand is subjected to activities emanating from outside the stand, the development will be different. The relationship between such activities and development in the stand is studied in simulation experiments, whereby a computer is used to solve the set of simultaneous differential equations that determine the development of the system. When presented in graphical form, the simple cause-and-effect structure is able to serve as an aid to communication between professionals and laymen in matters pertaining to forestry.

System-dynamics symbols

The variable for the state or stocking of a stand, e.g. the standing volume of wood per unit area, is denoted by means of rectangular symbols ▭. Flows that produce a change in the state of the stand, e.g. increment, are denoted by arrows ⟶. The mechanism that regulates the flow is denoted by the symbol ▭⋈. Flows to or from the surroundings are denoted by arrows that terminate in a cloud-like symbol ☁⟵ where the cloud represents a source or a termination. A flow of information is denoted by a broken arrow ⇢. Auxiliary variables are denoted by means of circles ○, and constants by means of small circles bisected by a short, straight line –⊖–.

6.2 The state of a stand

The state of a stand can be described comparatively well by means of two variables: the commonest used are volumetric density and age, with age being related to the tree dimension. When the volumetric density and age are known, increment and natural thinning can be determined. Regeneration depends on the supply of seed, which may come from the stand itself or from neighbouring stands, and on the germinability of seed which depends mainly on volumetric density.

The processes of growth, natural thinning and regeneration change the state of a stand in such a way that during the next rotation these processes will be of a different magnitude. Thus, the system is a self-regulating one, in which the state of the forest determines a number of processes which, in turn, affect the state of the forest.

The basic concepts used in the model are as follows:

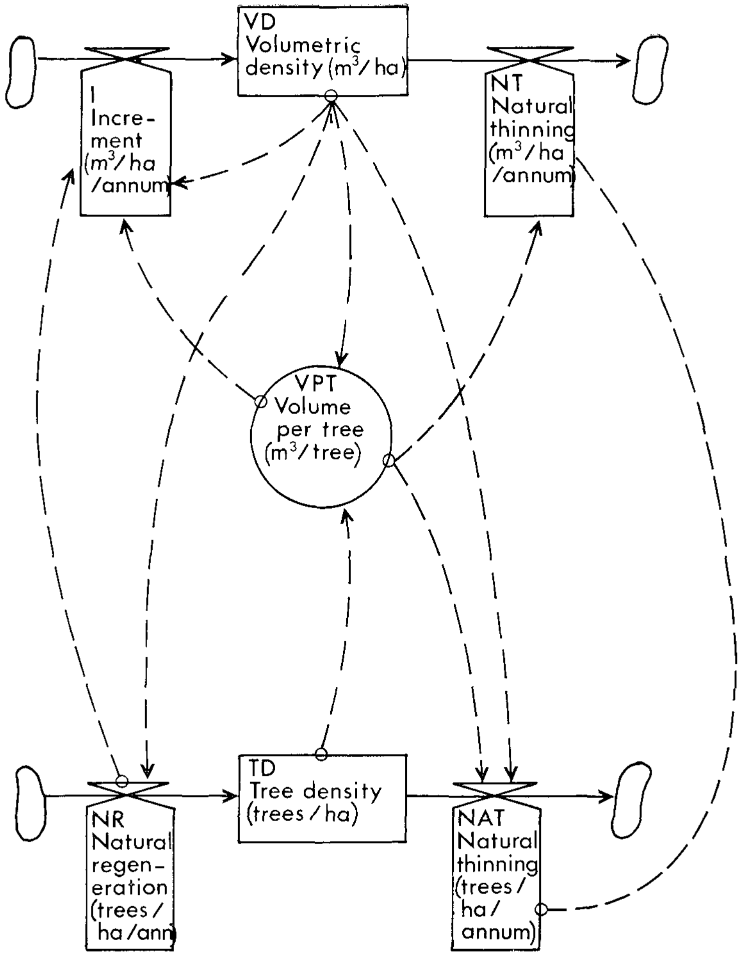


Figure 22. A schematic presentation of the interaction between volumetric density, tree density, natural regeneration, increment and natural thinning.

Volumetric density—which refers to the volume of all stemwood inside bark per unit area, expressed in m^3/ha.

Tree density—which refers to the number of trees per unit area, expressed in trees/ha.

Increment—which is the annual increase in volume inside bark of stemwood per unit area, expressed in m^3/ha per year.

Natural thinning—which is equivalent to the number of trees that die per unit area during a year, expressed in trees/ha per year.

Natural regeneration—which refers to the number of new trees per unit area appearing in a given year, having sprouted from seeds released in the stand itself or in neighbouring stands, expressed in trees/ha per year.

Thinning—which is the human activity involving the removal during a year of a given number of trees per unit area, expressed in (extracted) trees/ha per year.

Final felling—which refers to the felling of all remaining trees in a given area, with the possible exception of a number of seed trees, expressed in (extracted) trees/ha per year.

Of the above, volumetric density and tree density are variables describing the state of the stand. A broad outline of the relationships between the variables is presented in figure 22. As may be seen in the figure, volumetric density increases as a result of growth and decreases as a result of natural thinning. The tree density increases as a result of natural regeneration and decreases as a result of natural thinning. The extent to which increment, natural thinning and natural regeneration are in turn dependent on the state of the stand is indicated by the dashed information lines. Increment is dependent on regeneration (the additional volume contained in new seedlings each year), on volumetric density and on the volume per tree[1] (growth in respect of trees already established in the area). The effect of volume per tree reflects the effect of age on increment. Natural thinning is also dependent on volume density and volume per tree.[2] In the case of trees dying as a result of natural thinning, these create a loss of volume in the stand, which is dependent on the number of such trees and the volume per tree (which volume has a certain correlation with the average volume per tree in the stand). Natural regeneration is primarily dependent on the volumetric density of the stand, i.e. the germinability of new seed depends mainly on density, in so far as we assume that there is an abundant supply of seed that is largely determined by conditions outside the stand itself. The volume in the form of new shoots is small and only significant during the actual regeneration cycle, since it represents the initial volume in the cumulative process that builds up the standing volume.

In figure 22 several closed cause-and-effect chains can be distinguished:

- Volumetric density influences growth, which, in turn, influences volumetric density.
- Volumetric density influences volume per tree (age), which influences growth, which, in turn, influences volumetric density.
- Volumetric density influences natural thinning of trees, which influences the natural thinning volume, which, in turn, influences volumetric density.
- Volumetric density influences volume per tree (age), which influences natural thinning of trees, which influences the natural thinning volume, which, in turn, influences volumetric density.
- Tree density influences volume per tree (age), which influences natural thinning of trees, which, in turn, influences tree density.
- Tree density influences volume per tree (age), which influences growth, which influences volumetric density, which influences natural thinning of trees, which, in turn, influences tree density.
- Tree density influences volume per tree (age), which influences growth, which influences volumetric density, which influences natural regeneration, which, in turn, influences tree density.

A more detailed description of the way in which these feedback loops function in the model is presented in figure 23.

6.3 **Increment as expressed in the model**

Figure 23 will not be dealt with in depth,[3] but let us consider the concrete expression of increment. In the model increment (I) is the aggregate value of the number of trees (TD) multiplied by the increment per tree (IPT), plus the natural regeneration (NR) multiplied by the volume per seed (VS), plus the newly planted seedlings multiplied by the volume per seedling; thus

$$I = TD \times IPT + NR \times VS + P \times VP$$

Natural regeneration and planting are only relevant during the regeneration cycle. The increment per tree (IPT) is equivalent to the volume per tree (VPT) multiplied by the increment percentage (PI), i.e. $IPT = VPT \times PI$. The volume per tree is the relationship between volumetric density (VD)

[1] Delbeck, K. 1965: Metoder for tilvekstberegninger i glissen skog. Melding fra Institutt for skogtaksasjon nr. 2—4, s. 5—47, Ås—NLH.
[2] Brantseg, A. 1961: Skogbestandets pleie. Skogbruksboka bind II, s. 355—384, Oslo.
[3] Readers interested in greater detail are referred to: Dynamikk i et Skogbestand, GRS 23, Gruppen for Ressursstudier, Oslo, 1975.

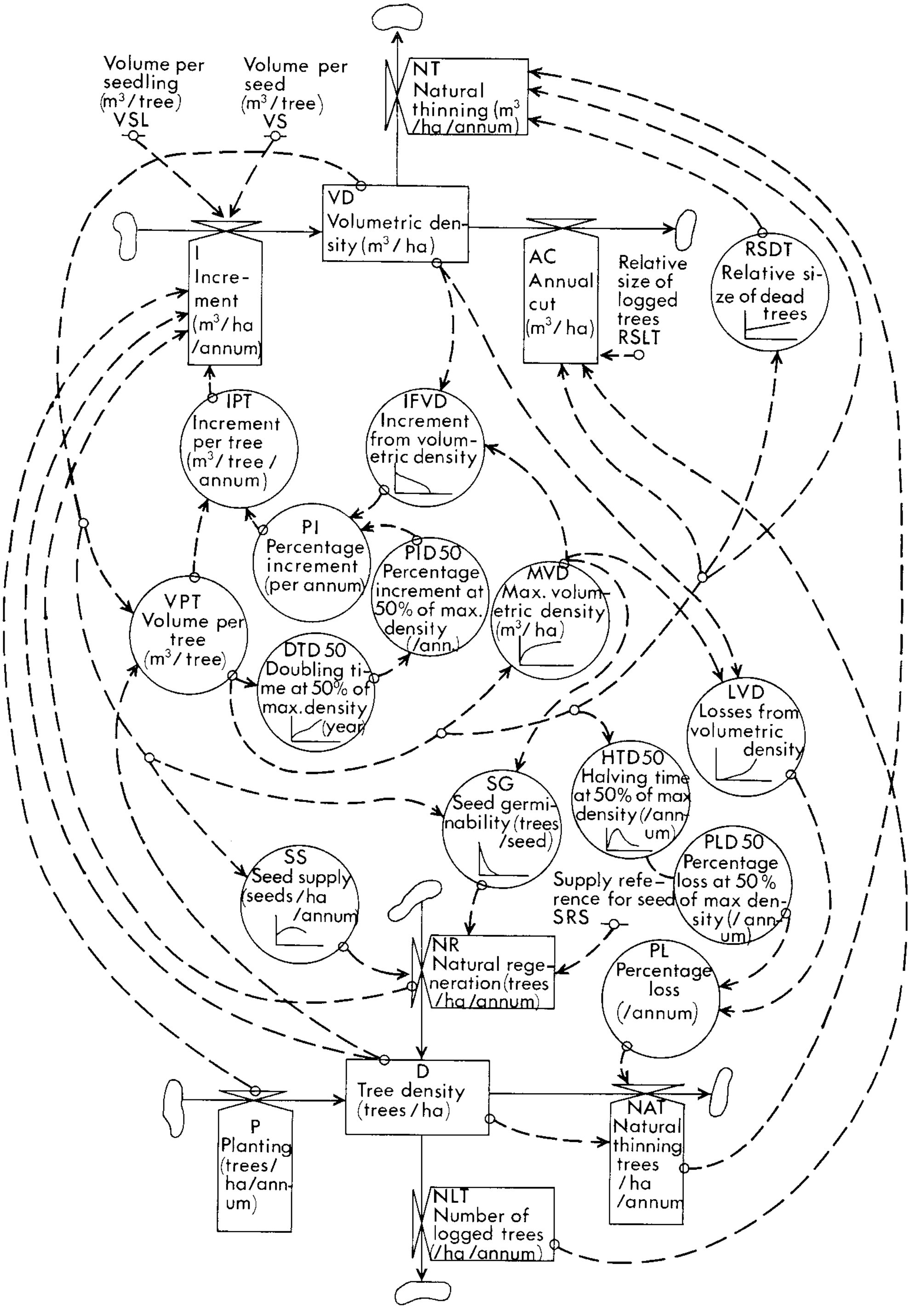
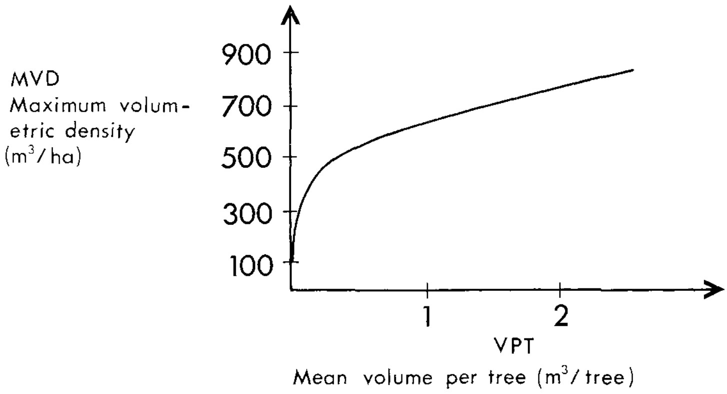


Figure 23. The DYNAMO flow chart for the forest increment model.

Figure 24. Assumed relationship between mean volume per tree and maximum volumetric density. (The figure is based on the graph published by A. Jørgensen Hope, Taksering av Sølvverks-skogene 1931, together with the assumption that each tree requires an area equivalent to ten times that of its diameter in order to survive.)



and tree density (TD), i.e. VPT = VD/TD. The increment percentage is dependent on the volumetric density and the volume per tree (age). This relationship is roughly equivalent to a multiplicative expression of the interdependence of the effects of volumetric density and volume per tree, i.e. PI = PID50 × IFVD. The age effect is derived from the increment percentage at 50 % of the maximum volumetric density (PID50), which decreases monotonically as age increases. The effect of volumetric density is derived from the increment percentage from volumetric density (IFVD), which also decreases monotonically as the volumetric density increases in relation to the maximum volumetric density in respect of the mean tree dimension that applies at a given time. The maximum volumetric density is equivalent to the density when increment is nil and which, characteristically, is greater in the case of large trees than in the case of small trees. Small shoots, for instance, will never be able to attain a volumetric density of 100 m^3/ha, regardless of how tight the seedling spacing is, although this volumetric density is easily reached naturally in sparse stands containing more-mature trees. The existence of a maximum volumetric density can be proved theoretically, although the density will be dependent on the height curve for the stand in question (the correlation between mean diameter and mean height). The curve in figure 24 is based on a special height curve and should therefore only be regarded as an approximation.

The increment percentage at maximum volumetric density will be nil. In reality stands can never achieve this particular density, since natural thinning increases sharply as the density approaches the maximum limit, with growth and natural thinning becoming balanced a good way below maximum volumetric density, as a result of which the density ceases to increase. Thus, to obtain a reference curve for increment percentage, we take one half of the maximum volumetric density as our point of departure. Thus, in practice the increment percentage can be determined by means of measurement in a stand with a density equivalent to half the maximum volumetric density. In the case of small trees, the increment percentage is considerable (100 % or more per annum) but falls sharply as the volume per tree increases. It seemed expedient, therefore, to work with a doubling time at 50 % of the maximum volumetric density, rather than with the increment percentage. The correlation between the two is:

Doubling time = (ln 2)/increment percentage, or

^{e}(Doubling time × increment percentage) = 2
(e = 2.71828 . . .)

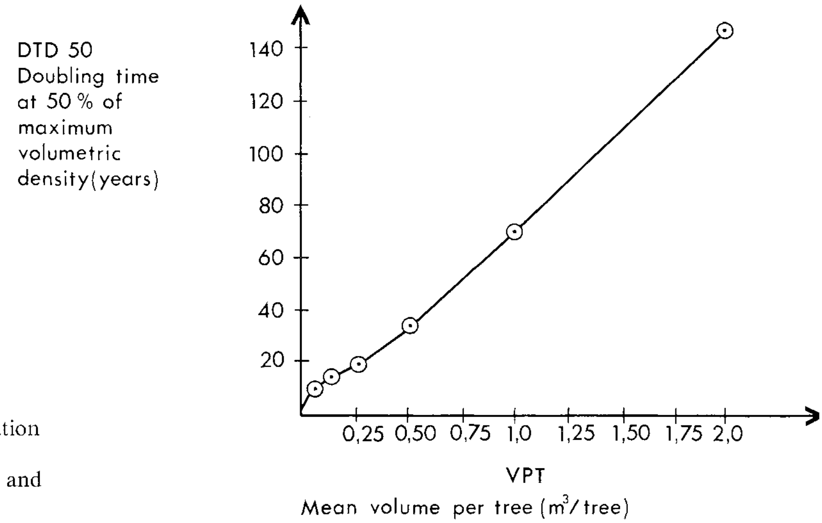


Figure 25. The assumed correlation between mean volume per tree and doubling time.

The doubling time is the time required for the volume per tree to double itself at a constant increment percentage. The course described by the doubling time is shown in figure 25.

The doubling time is extremely short in the case of small trees (high increment percentage) and increases rapidly (the increment percentage decreases rapidly). In the case of larger trees, the doubling time increases relatively evenly, i.e. the increment percentage decreases evenly. In an average, well-treated stand the volume per tree lies between nil and 0.5 m^3/tree, whereas in natural stands the volume per tree may be greater. The curve in figure 25 is partially based on data from real stands (in the normal area) and partially on estimates. The other effect of increment percentage stems from volumetric density. It is not the absolute value of volumetric density that is of importance but whether or not the volumetric density is large or small in relation to the maximum volumetric density for a given average tree dimension. As the volumetric density approaches the maximum, competition will become great and the increment percentage will fall towards nil. Conversely, when the volumetric density is low, competition will be less intensive and the increment percentage will increase. Generally speaking, the volumetric density in a stand will be around 50 % of the maximum value. The curve in figure 26 should be regarded as an approximation of the relationship between increment percentage and volumetric density. Measurements made in stands indicate that the curve in respect of normal values in the stands will be such that a 10 % reduction in the volumetric density will create an 8 % increase in the increment percentage.[4]

The dynamic effect of the correlation in figure 26 is that the system tends to keep the volumetric density at the reasonable level in comparison with the maximum density of the tree dimension concerned. Since the trees are growing, the maximum volumetric density will also increase and variations in volumetric density/maximum volumetric density will be small. In actuality it is the age effect that manifests itself and determines the increment percentage, unless of course drastic changes in the volumetric density/maximum volumetric density are effected by silvicultural operations such as thinning.

[4] Eide og Langsaeter, 1941: Produksjonsundersøkelser i østnorsk granskog. Meddelelser fra det norske skogforsøksvesen 7, s. 355—500, Ås—NLH.

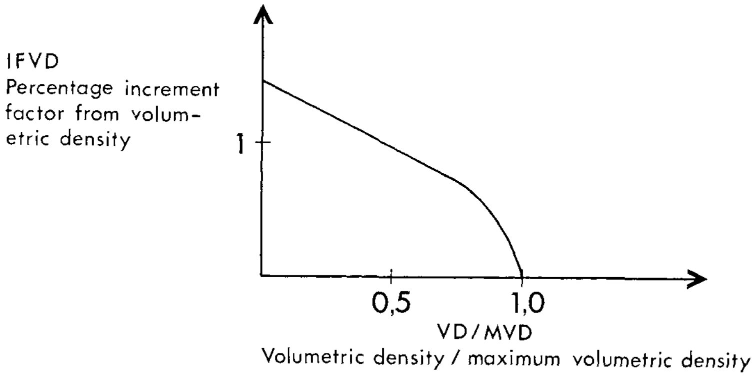


Figure 26. Assumed correlation between volumetric density and increment percentage.

6.4 **Other mechanisms in the model**

Variables influencing increment also influence *natural thinning*. As far as natural regeneration is concerned, the supply of seed is governed to a large extent by neighbouring stands, whereas the viability of seeds will depend on the volumetric density/maximum volumetric density.[5] This means that regeneration will cease at comparatively low volumetric densities in new stands, since the maximum volumetric density will be low; on the other hand, regeneration in older stands may occur when the volumetric density is much greater, because the volume will then be concentrated to fewer and larger trees, with the result that new trees will have more room to grow between the old ones.

Checking of the dynamic development in the model is achieved by comparing the increment from the model with that determined by an increment formula.[6] The formula is based on data derived from stands of between 20 and 100 years old and may be written as follows:

$$I = \sqrt{TD} * 10^{-0{,}915 - 0{,}00113 * TD + (60{,}8)/(A+50) * e^{-60/VD}}$$

where

I = increment (m^3/ha per annum)
TD = tree density (trees/ha)
A = age (years)
VD = volumetric density (m^3/ha) and
e = 2.71828.

When the model is run in the computer values will be obtained for TD and VD. If, at the start of the run, the trees are very young, the value of A can be selected to correspond to the time elapsing during the simulation, enabling current values of I to be calculated and then compared with the increment produced by the model. In the runs described in the following pages, the value of I and the increment produced by the model are shown. The two runs described were selected at random in order to illustrate the properties of the model.

Since there is a wide variety of increment formulae, it is difficult to find objective criteria for choosing between them. Nonetheless, we decided that it would be expedient to conduct the comparison using one of these increment formulae. An alternative method would have been to compare the results from the model with measurements made in a stand.

6.5 **Model runs**

The results of system dynamics runs are usually presented in the form of graphs, with time being plotted along one axis and the dimensions that are of interest plotted

[5] Haugberg, M. 1962: Grunnlaget for skogens naturlig foryngelse. Skogbruksboka bind II, s. 143—157, Oslo.

[6] Andersson, S.-O. och Stålhandske, S.-I. 1974: Volymtillväxtfunktionen för tall i norra Sverige. Stencil Institutionen för skogsskötsel, Skogshögskolan.

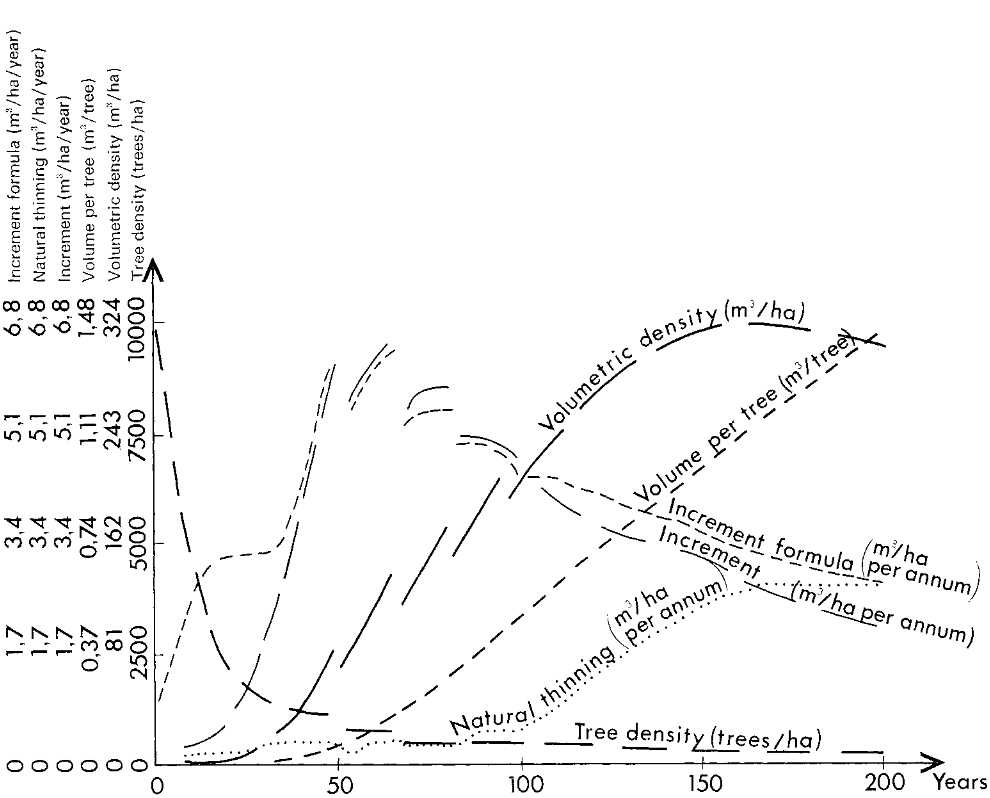


Figure 27. Thinning experiment.

along the other. One can choose which model dimensions should be plotted and can easily change them between runs. We have elected to plot volumetric density, tree density, volume per tree, increment and natural thinning, and also an auxiliary magnitude of increment derived from the increment formula in order to provide a gauge of the feasibility of the model development. We will deal with two model runs, one in which four thinnings are carried out and one in which we allow the stand to develop without the occurrence of events like windthrows and fires, until the stand matures into what may be called a forest in natural equilibrium.

6.6 The model stand with four thinnings

We start with a young stand with a volumetric density of 1 m³/ha and with 10,000 trees/ha. Thinnings are carried out at age 50, 65, 80 and 95 years, with 300, 200, 100 and 50 trees/ha, respectively, being removed in a short period of time, and where the volume of the thinned trees corresponds to the average volume per tree in the stand. The results are presented in figure 27.

At age 50, the tree density falls rapidly towards 1250 trees/ha, whereas the volumetric density increases to 90 m³/ha. Numerous weak trees (below the average size for the stand) will therefore be suppressed while the remaining trees will grow vigorously. Increment will increase sharply from an insignificant level to a level of about 6 m³/ha per annum at about age 50.

The outcome of the first thinning will be a reduction in standing volume and tree density. Since the trees removed will be average-sized (although other assumptions can be tested), the volume per tree will not be affected. Increment, on the other hand,

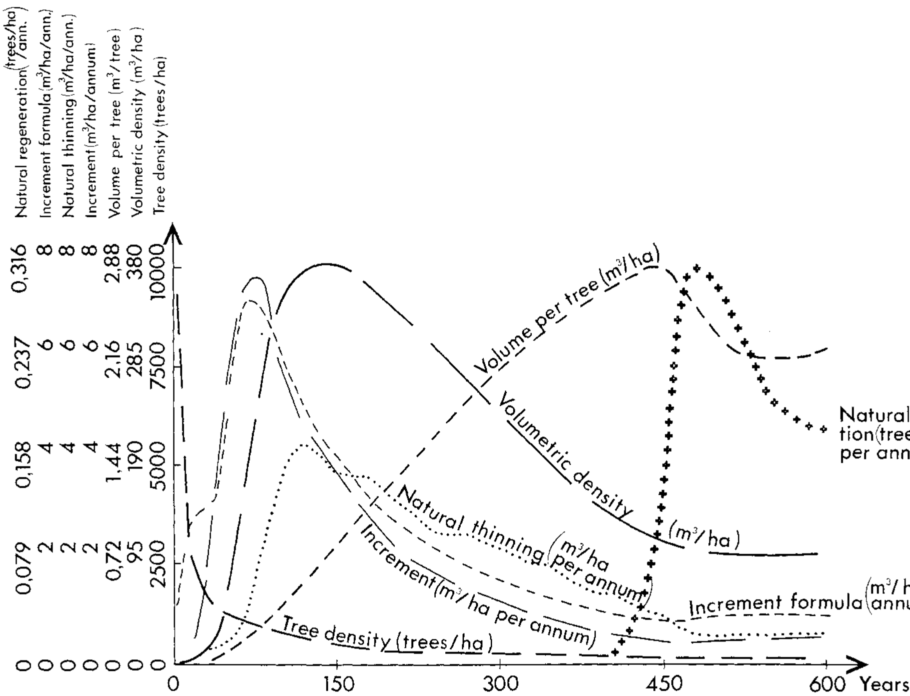


Figure 28. Development into natural forest.

will fall, even if the increment percentage rises owing to the reduction in volumetric density. This effect is normal. An increase in volumetric density implies an increase in increment within the normal range of variation in respect of volumetric density, even if the increase is of a slightly lower magnitude because of the fall in the increment percentage. Only when the volumetric density reaches considerable proportions will this relationship be reversed.

Subsequent thinnings will produce a corresponding effect: the volume will become concentrated to fewer and larger trees. After thinning, the increment percentage will rise, although, in time, when the trees have grown, the increment percentage will fall because of the age factor, while the mean volume per tree will increase slightly as if no thinning had been carried out. Thus, the standing volume in thinned stands will never obtain the same maximum value compared with that in unthinned stands.

There is relatively good agreement between the increment computed in the model and that derived from the increment formula; this is partly attributable to the fact that a deliberate effort was made to maintain consistency in the parameterization of the model. This is especially true of areas for which there are no known data. Consequently, the observed consistency merely demonstrates that paramaterization of the model is possible such that the model and increment formula will follow approximately the same development over a period of time. It is quite possible that the parameters used are not entirely reasonable in some areas compared with the situation in reality, but this can only be determined if the parameters are compared with data collected in an existing stand.

6.7 Model stands developing into natural forest

In this case we assume that no silvicultural activities will be carried out and that there will be no exogenous occurrences such as fires, windthrow, etc. The model commences with a volumetric density of 1 m^3/ha and 10,000 trees per hectare. The results are presented in figure 28.

Volumetric density will culminate after 130 years. By this time the trees will have grown so large that natural thinning will outstrip increment. The volumetric density will continue to fall because the trees will grow even larger. Finally, the forest will become so sparse that natural regeneration will start to occur, leading to a reduction in the mean volume per tree because of the small volume of the new trees. In time the forest will attain a balance in respect of increment, characterized by a relatively low volumetric density, and relatively few, albeit large, trees—a seemingly reasonable situation.[7]

6.8 **Comments**

A model of the type shown here is ideally suited as an instrument of communication. For example, the model could well be employed in training, in order to illustrate the important relationships existing in a stand. Moreover, the model should be suitable for use in talks between forestry experts on the one hand and laymen on the other.

It is possible to achieve quantitative accuracy with this type of model. However, if the numerical values are to be reliable, a considerable amount of work must be laid down on the determination of the model parameters in respect of given tree species and site quality indices. The model could then also be used to estimate quantitative changes resulting from given activities.

A clear limitation of the model is its ability to deal with simple stands only. Consequently, the evaluation of consequences in respect of larger forest estates is beyond the scope of the field of application of the model. Thus, the model is not suitable for determining the economic consequences in respect of larger forest estates, although obviously it could be coupled with a structure designed to calculate the economic consequences for a stand.

[7] Huse, S. 1965: Strukturformer hos urskogsbestand i Øver Pasvik. Meddelelser fra Norges landbrukshøgskole, Vol. 44, nr 31.

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Summary

"Forestry in Sweden during the industrial age" outlines the historical background to the situation facing the Swedish forestry sector at the beginning of the 1970s, namely, an imbalance between the supply of forest resources and the expansion of the forest products industry. A similar situation is also to be found in Finland and Norway.

"Transition strategies for the Scandinavian forestry sector" provides an account of the problems facing the forestry sectors in Finland, Norway and Sweden in the transition from a period of rapid growth to one of modest growth. With reference to a simulation model that has been constructed according to the method of system dynamics, the paper also describes some conceivable alternative courses of action for the sector and presents a synopsis of some tendencies that should be taken into account by the strategic planners.

"The transition from ample to scarce wood resources" demonstrates how the ability of the simulation model can be used in practice in a policy discussion. The paper describes a hypothetical discussion between representatives of the main groups affected by the transition. Accordingly, the parts include a director of a forest enterprise, an "ombudsman" or spokesman for the employees, a private woodlot owner and a member of parliament. The views put forward by the representatives help to promote knowledge and understanding of the transition problems.

"The SOS (Society and Forestry) model and the Finnish forestry sector" discusses the possibilities of using the SOS model to study the consequences for the Finnish forestry sector of constraints imposed by the supply of wood resources. To provide the necessary background, an account of the development of the Finnish forestry sector since 1945 is also included. There is an account of the reparameterization work and of the subsequent simulation run. Finally, a number of conditions that might be peculiar to the Finnish forestry sector when compared with the structure of the SOS model are discussed. The conclusion to be drawn is that the model structure is apparently of a sufficiently general nature for the model to be used in studies on the consequences of constraints on the supply of forest resources in the forestry sector of any individual Scandinavian country.

The last two papers provide examples of the system dynamics method. In addition, *"Stock fluctuations in the pulp industry"* serves as a complement to the long-term-oriented SOS model in that the article presents a system dynamics model of the production in Norway of bleached sulphite pulp and short term fluctuations in stock levels.

"The dynamics of a simple stand" describes the way in which i forest stand can be represented by means of system dynamics. The purpose is to show how a system dynamics model is constructed and how it functions.

Sammanfattning

"Skogshushållningen i Sverige under industrins tidevarv" (Forestry in Sweden during the industrial age) ger ett historiskt perspektiv på den situation som den svenska skogsnäringen stod inför i början av 1970-talet — en bristande balans mellan skogsproduktion och skogsindustriell utbyggnad. Denna situation återfinns även i Finland och Norge.

"Övergångsstrategier för den skandinaviska skogsnäringen" (Transition strategies for the Scandinavian forestry sector) innehåller en redogörelse för de problem som uppstår för skogsnäringen i Finland, Norge och Sverige vid en övergång från snabb till långsam tillväxt, en beskrivning — med hjälp av en systemdynamisk simuleringsmodell — av möjliga handlingsalternativ för näringen samt slutligen en sammanställning av några tendenser som bör beaktas vid valet av strategi.

I artikeln *"Övergången från goda till knappa virkestillgångar. Ett skådespel i fyra akter"* (The transition from ample to scarce wood resources. A play in four acts) illustreras hur simuleringsmodellen i interaktivt syfte kan utnyttjas vid en diskussion mellan människor resp. mellan människor och dator för att välja en strategi inför skogsnäringens övergångsproblem. I rollistan återfinns representanter för de viktigaste intressegrupperna i skogsnäringen: en direktör från ett skogsbolag, en ombudsman från arbetstagarna, en skogsägare och en riksdagsman. Inläggen från de olika intresserepresentanterna bidrar till att öka kunskapen om och förståelsen för skogsnäringens övergångsproblem.

I *"Samfunn og Skog-modellen och den finska skogsnäringen"* (The SOS model and the Finnish forestry sector) redogörs för möjligheterna att använda SOS-modellen för att studera virkesbegränsningens konsekvenser för enbart den finska skogsnäringen. Som bakgrund redogörs för den finska skogsnäringens utveckling sedan 1945. Arbetet med reparameteriseringen presenteras liksom resultatet — en simuleringskörning. Möjliga specifika särdrag hos den finska skogssektorn jämfört med SOS-modellens struktur diskuteras. Slutsatsen blir att modellstrukturen bedöms vara tillräckligt generell för att studera virkesbegränsningens konsekvenser för skogsnäringen i ett enskilt skandinaviskt land.

I de två följande artiklarna ges exempel på systemdynamiken som metod. *"Lagersvängningar i cellulosaindustrin"* (Stock fluctuations in the pulp industry) kompletterar dessutom den långsiktigt inriktade Samfunn og Skog-modellen genom att artikeln presenterar en systemdynamisk modell över produktion och lagerfluktuationer för blekt sulfatcellulosa i Norge.

I *"Dynamiken för ett förenklat skogsbestånd"* (The dynamics of a simple stand) visas hur en modell över skogens produktionsförlopp kan representeras med hjälp av systemdynamik. Avsikten är att visa hur en systemdynamisk modell byggs upp och fungerar.