The Forest Resources of the Former European USSR

Sten Nilsson, Ola Sallnäs, Mårten Hugosson, and Anatoly Shvidenko

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Preface

The IIASA Forest Study started in 1986 with the overall objective of analyzing the future development of European forest resources. The results for Western and Eastern Europe have recently been presented by Nilsson, Sallnäs, and Duinker (1992). The cooperative work between former Soviet organizations and the IIASA Forest Study to analyze the forest resources of the European part of the former USSR started in 1987. At that time, perestroika and glasnost had just begun, although the centrally planned state called the USSR still existed. Since then this state has gone through tremendous social, economic, and political transitions. First, central planning and the Communist party were dissolved and later the USSR was dissolved. The study has worked throughout this process and has both gained and suffered from the transition. The data collection was carried out in the framework of the centrally planned state of the USSR. At the time of final preparation of this book, the USSR no longer existed; instead it was replaced by 15 individual countries.

The coup in August 1991 in Moscow not only symbolized the end of an empire which used to cover one-sixth of the globe's land area, but was an event which dramatically influenced society. This development resulted in a new political structure – the Commonwealth of Independent States (CIS). This new structure is not yet stabilized and the features of its future political functions are still uncertain. The disintegration process of the former USSR can, for the moment, be said to be characterized by the struggles of individual states to establish sovereignty prior to finding new links for any kind of unification. In addition, a number of former republics of the USSR do not plan to participate in any political or economic establishment of new interstate structures of the former USSR territory.

Interstate documents signed, so far, by the CIS lack agreements on a common policy concerning the natural resources and the environment. In the former republics, where natural resources were declared people's property, the attitude toward natural resources and legal and economic conditions for forest policy making will change. However, changes in the forest resources and structures are expected to take a rather long time.

For the moment, most attention will probably be paid to the overall economic problems facing the society of the former USSR. However, the economic transition following the current economic strains may rather quickly influence the existing management of the forest resources.

The forests of the former USSR contain some of the most valuable resources in the region. In addition, the forest resources are important components for sustainable development of the biosphere. This can be illustrated by the assumed climate-change process; the forests' biomass (above ground) of the former USSR sequesters about 5 billion tons of CO_2 and generates about 4 billion tons of oxygen. Restoration of overmature and declining forests in the European north, Siberia, and the Far East is estimated to increase the rate of fixation of CO_2 by about 20 percent in the former USSR. If the low-quality and low-density deciduous forests grown after mining the forest resources of the former European USSR were to be restored, the fixation rate of CO_2 would increase by another 10 percent. In addition, the Forest Fund (see Appendix B for definition) of the former USSR contains more than 440 million hectares of non-forested land. About 30 percent of this area is suitable for afforestation. Such afforestation would sequester another 20 percent of CO_2 (Isaev, 1991).

The existing State Forest Account and the uniform data from the state enterprises of the former USSR made it possible to assess the actual state and possible future development in a consistent manner. These data from the former USSR may be the last opportunity for a long time for analyzing the huge forest assets of the former European USSR based on a common and consistent set of data.

Thus, a consistent analysis of the forest resources of the former European USSR is not only important to policy makers within the region, but also important to the international community dealing with a sustainable development of the natural resources and the environment of the globe. Therefore, we have decided to use the former names of the regions and republics in the presentation of the results of the analyses.

The IIASA Forest Study concentrates on the future development of forest resources in Europe but also addresses social, economic, and ecological consequences of future trends. As noted in the beginning, the potential for the development of the forest resources in Western and Eastern Europe has been analyzed and presented by the Forest Study (Nilsson *et al.*, 1992). This book has as an overall objective of completing the analyses on the possible development of the total European forest resources by presenting detailed results for the European USSR.

Remedial actions against air pollution in saving the European forest resources have also been presented by the Forest Study (Nilsson, 1991b). Economic impacts on the European forest resources from air pollutants have been estimated by Nilsson (1991b) and are also discussed by de Steiguer *et al.* (1991).

The specific objectives of this book are:

- To gain an impartial view of potential developments of the forest resources in the European USSR.
- To build alternative and consistent scenarios of the future developments.
- To illustrate the effects of forest decline from air pollutants.
- To identify meaningful policy options concerning the forest resources of the European USSR.
- To support future policy decisions concerning the forest resources of the European USSR.

It is important to point out that in this book we report a lot of information classified as official statistics. Readers familiar with former USSR statistics may, in a number of cases, find discrepancies between what we report as official figures and what is presented in official reports. This is a result of the fact that information in the official reports may be reported as valid for a specific year, although, in reality, the information given in the documents is, for different reasons, the average for several years. Consequently, we have in such cases used information valid for the specific year indicated in this book, instead of the average information presented in official documents, which we have corrected. In addition, in some cases, new areas have been included in or deducted from the forest resources, but have not yet shown up in the official statistics, although we have taken those changes into account. Thus, our objective has been to use these updated statistics on the forest resources.

Acknowledgments

In 1986 the IIASA Forest Study began to address the question of long-term development of European forest resources. The current study on the former European USSR forest resources has been carried out by the Forest Study in close collaboration with the Swedish University of Agricultural Sciences, Garpenberg, where most of the basic calculations were done.

This study would not have been possible without the liberal changes in the former USSR society, which began in the mid-1980s. In spite of this liberalization, the study would never have been implemented without Academician Alexander Isaev, former head of the USSR Forest State Committee. His assistance and support made it possible to initiate and conduct the study, even during difficult conditions. We express our sincere gratitude to Academician Isaev for all his help.

We also would like to thank many researchers from the Russian Research Center for Forest Resources (VNIIZ Lesresurs) who helped us with the basic data collection and data preparation. We would especially like to thank Yuri A. Kukuev and Valentina V. Sdobnova for their significant contribution. We are deeply indebted to Dr. Charles Backman, CINTRAFOR, University of Washington, USA, for cross-checking the manuscript against his databases on the forest sector of the former USSR.

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Chapter 1

Background

The total standing volume of the world's forests is 360 billion cubic meters. The total volume of mature and overmature stands in the Forest Fund in the total USSR is estimated at 48.3 billion cubic meters, of which 40.3 billion cubic meters are coniferous species (IMF, 1990; Goskomles, 1990–1991). About 25 percent of the forested area and of the total standing volume of the USSR is located in the European part. Forest products yield the second highest, after oil, amount of foreign currency in the USSR. FAO (1990) estimates that the USSR in 1988 had 18.3 percent of the world's industrial wood production. Sedjo (1990) estimates the same share for the mid-1980s. Petrov (1989) has presented an estimate of the impact of the total forest sector on the national economy in the USSR for 1988 in the following way: 2.8 percent of GNP; 4.5 percent of industrial output; 7.2 percent of industrial workers; 3.3 percent of industrial capital investments; 3.2 percent of exported value; 3.6 percent of industries' energy consumption; and 7.0 percent of railway freight turnover. Forestry workers constitute 0.3 percent of the total labor force in the USSR (Ellman, 1989).

The trade of forest products is mostly the export of low value-added products such as logs and lumber. However, a recent trend shows an increasing share of higher value-added forest products of the exported volume (Backman and Waggener, 1990; Waggener and Backman, 1990). The USSR has been an important supplier of lumber to Europe and of logs to Japan (Waggener and Backman, 1991).

The harvests in 1989 and 1990 are presented in *Table 1.1.* The total harvest in the USSR is about 400 million cubic meters of which 250 million cubic meters are harvested in the European USSR. The harvests are primarily coniferous species. In 1988, the total territory of the USSR was reported to be 2,240 million hectares and the Forest Fund Area was said to

Table 1.1. Harvests of commercial wood in the USSR.

	Year	Total harvest	State forests: Final felling (mill. m^3): Total	Conif-erous	Decid-uous	Other fellings	Thin-nings	Harvest in agri-cultural collectives	Area harvested (1,000 ha): Total	In final fellings
Total USSR	1989	411.4	331.2	235.7	95.5	22.6	43.4	14.2	2,132.6	1,905.1
	1990	379.2	301.8	213.9	87.9	21.2	42.9	13.3	1,957.2	1,743.0
Europe/Ural	1989	248.4	191.9	117.1	74.8	8.4	36.2	11.9	1,060.2	991.8
	1990	226.3	174.4	104.9	69.5	7.2	35.5	9.2	891.7	827.5

Source: Goskomles, 1990, 1991.

Table 1.2. Comparison between annual allowable cut (AAC) and actual harvest (AH) in final felling of commercial wood, in million cubic meters.

				Coniferous					Deciduous				
									Hard deciduous			Soft deciduous	
	Year	Form[a]	Total	Total	Pine	Spruce/fir	Cedar	Larch	Total	Oak	Beech	Total	Birch
Total USSR	1989	AAC	625.3	392.6	122.8	150.7	16.8	102.3	15.3	7.3	1.4	217.4	139.7
		AH	331.2	235.7	87.1	112.2	3.3	33.2	7.4	3.8	1.3	88.1	48.8
	1990	AAC	623.6	391.7	122.5	150.5	16.5	102.3	14.8	7.0	1.3	217.0	139.9
		AH	301.8	213.9	80.1	101.2	2.1	30.6	6.6	3.4	1.2	81.3	44.8
Europe/Ural	1989	AAC	239.9	130.0	47.3	82.6	–	0.1	9.0	5.1	1.4	100.9	59.4
		AH	191.9	117.1	38.2	78.9	–	0.0	5.9	3.5	1.3	68.9	38.2
	1990	AAC	238.5	129.9	47.2	82.6	–	0.1	8.5	4.8	1.3	100.1	52.3
		AH	174.4	104.9	36.0	68.9	–	0.0	5.4	3.2	1.2	64.1	35.3

[a]AAC = annual allowable cut; AH = actual harvest.

Source: Goskomles, 1990, 1991.

Table 1.3. Annual allowable cut (AAC) and its degree of utilization in 1982.

Region	AAC (mill. m^3) Total	Coniferous	Deciduous	AAC (% final fellings) Total	Coniferous	Deciduous	Thinnings (mill. m^3)
European North and Urals	169.2	107.6	61.6	75.8	89.1	54.8	5.4
Western Siberia	103.5	49.3	54.1	27.7	37.9	18.5	2.1
Eastern Siberia	174.2	125.6	48.6	35.1	44.0	12.0	2.3
Far East	97.7	85.9	11.8	32.6	36.7	9.9	1.3
Regions rich in forest (total)	645.5	469.4	176.1	41.8	48.1	31.3	11.1
Total USSR	591.8	396.9	221.9	50.1	56.7	38.2	47.8

Source: Petrov, 1989.

be 1,254.2 million hectares, with 941.5 million hectares classified as forest land and 814.3 million hectares as forested land with a total standing volume of 85.9 billion cubic meters (IMF, 1990; Goskomles, 1990–1991). The forest terms are defined in Appendix B. A comparison between the annual allowable cut (AAC) and the actual fellings in final fellings is presented in *Table 1.2*. The AAC is only calculated on the final fellings in the USSR. The AAC for total USSR is about 625 million cubic meters and for the European part approximately 235 million cubic meters per year. Petrov (1989) has presented a different disaggregation of the AAC and its utilization for 1982 (*Table 1.3*). The information in *Table 1.3* differs somewhat from official statistics on AAC. This can be explained by the fact that the AACs are changed continuously within a year and in many cases the scientific literature does not reflect the final AAC for a given year. From the tables, it can be seen that the degree of utilization of AACs is low in the USSR. This is a result of limited economic accessibility of the AACs. Petrov (1989) points out that by taking all the restrictions on the physical potential into account, the accessible standing volume may be as low as 30 to 35 billion cubic meters (to be compared with 85.9 billion cubic meters of total standing volume). Backman and Waggener (1991) report that in 1988 the USSR contained 406.2 million hectares of exploitable stocked forest land which corresponds to an exploitable volume of 50 billion cubic meters.

The mean annual increment (MAI) in 1988 for forests managed by the State Forest Service was 894 million cubic meters, and the total increment was estimated at 980 million cubic meters (IMF, 1990; Goskomles, 1990–1991). Fedorov *et al.* (1987) state that in 1983 the net MAI was 850 million cubic meters for total USSR, but economically exploitable MAI was only 640 million cubic meters. It should be underlined that the MAI and increment reported in official statistics (see above) are calculated as changes in growing stock of individual stands over a specific time period divided by the average age of the stands. This gives an underestimate of the real annual increment. The real annual increment is estimated by experts to be some 1.5 billion cubic meters per year. But this real increment is not presented or discussed in any of the official statistics.

The exploitable increment in the European part of the USSR is estimated at 360 million cubic meters, of which 195 million cubic meters is coniferous wood (Anon, 1990, 1991).

1.1 Reasons for the Low Harvest Level

The harvest level is low in relation to both standing volume and annual increment. This can be further illustrated by a comparison with Swedish conditions. The USSR has nearly 35 times as much forested area as Sweden but the total harvest is only about 5 times higher. One explanation for this big difference can be found in the difference in growth rates. The USSR is the world's richest country with regard to forest resources, but repeatedly pronounced problems of inefficient wood supply to the existing forest industry (UN, 1989a) and acute deficit of lumber and paper for the domestic demand (Libert, 1989) have been reported. Petrov (1989) stresses that only 60 to 70 percent of the domestic demand for mechanical wood products is, at the 1988 rate of harvesting, satisfied. The corresponding figure for paper products is 30 to 40 percent.

Many researchers have tried to explain the reasons for this situation. The factors identified include the following: too many authorities involved in the decision process; defective administration and planning systems; overharvesting and deforestation; mismanagement and lack of silviculture; waste of raw material; forest fires; lack of skilled labor; and inefficient forest industry.

1.1.1 Too many authorities in the decision process

According to Libert (1989) too many ministries and institutions are involved in the decisions about management of the forest resources and the forest industries. The responsibility of different ministries is unclear, which results in paralysis in decisions and actions required. Eberhardt (1990) has identified 25 ministries, state committees, and other organizations involved in environmental management of the natural resources. Barr (1988) confirms that "the damage to the forest resource can partly be sought by the activities of 10,000 enterprises under the jurisdiction of 34 institutions." According to statistics from Goskomles (1990), the harvesting in 1990 was managed by 32 All-Union ministries and committees. These conditions result in confusion. According to Barr (1988), in many cases different organizations find that areas allocated for harvests have been harvested earlier by competing organizations. However, Soviet officials have argued that these problems were exceptions.

1.1.2 Defective administration

Pryde (1983) demonstrates that the major problems in Soviet forestry are similar to the problems in other sectors in the Soviet economy, namely, defective administration and poor management. According to Soviet inventory data both forest area and growing stock increased from 1961 to 1978. Official releases and assessments of inventory data claim that the improvements stem from improved effectiveness of forestry measures and improved management of the resource (Nikolayuk, 1975). However, Holowacz (1975, 1985) says that this result is not from improved measures but from new areas being included in the inventories. Barr (1988) argues that many shortcomings in the forest management can be masked by the existing administration by clever adjustments of inventory information. He also stresses that "the practices followed by managers and producers in a strongly centralized economy and society in which financial rewards and reduction bonuses often occur from behavior that is contrary to the long-term interests of the society at large or the nation as an economic system" are the driving forces for mismanagement of the forest resources.

Pryde (1972) argues that no manager objects to fines for overharvesting or for not following cutting standards if the timber gained generates extra bonuses for overfulfillment of set production quotas. Goldman (1972a) underlines that the administration is a bottleneck for sound development of the natural resources. Ziegler (1979) argues that an administrative reorganization is the key issue for improvement of management of the natural resources and the environment.

Barr and Braden (1988) state that the planning system (that is, the economic system) itself is increasing the shortages in Soviet forestry. As an example they mention the freight-rate structure. The rates convey economic messages to individual enterprises which lead to the planning of suboptimal alternatives.

Much harm to forest resources was caused by numerous reconstructions of the forest management by the state and by transferring parts of the forest resources to different organizations. Before 1988 the state forest management

Table 1.4. The development of the forested area in the USSR as a percentage of total land area in some European regions.

Region	1696	1796	1888	1914	1988
European Russia	53	50	42	35	35
North and Northwest	70	71	66	64	52
Central	56	46	36	30	42
Volgo-Vyatsky	80	71	48	39	51
Central Chernozyomny	24	17	12	10	9
Povolzhsky	38	29	18	18	9
Ural	73	67	56	59	43
Ukraine	–	15	10	9	15
Byelorussia	–	39	34	27	34

Sources: Tsvetkov, 1957; Isaev, 1991.

in the USSR was managed by ministries of the forest industry and agriculture. The USSR State Forestry Committee was established in 1988 and later became the USSR State Forest Committee (Goskomles). It was assigned to manage 94 percent of the country's forest. The overall task was formulating scientifically based policies to manage the forest resources and controlling the fulfillment of the USSR forest legislation. During 1986–1988, about 230 million hectares were transferred from the responsibility of Goskomles to the Ministry of Forest Industry. However, to date, this transfer has not been reflected in the official statistics. The management of these areas worsened after the transfer. Soviet officials underline that the authoritarian system in the USSR before 1988 was a drawback for solid development of the forest resources.

Goskomles was dissolved in late 1991, and in 1992 the Department of Forests of the Russian Federation within the Ministry of Ecology and Natural Resources was established.

1.1.3 Deforestation and overharvesting

Deforestation is normally a resultant of society's development. From 1696 to 1914 the area of forests of European Russia (except Caucasia) decreased by 62 million hectares (Tsvetkov, 1957; Isaev, 1991). The development of forested area (for definition see Appendix B) as a percentage of the total land area between 1696 and 1988 in European regions is presented in *Table 1.4*.

The major reason for the reduced forested area was the cultivation of agricultural land. Agricultural land increased by 127 million hectares in European Russia from 1696 to 1914. After 1914 the forested area, as a percentage of total land area, did not change much in the European USSR as a whole. However, some subregions had rather dramatic changes, in both positive and negative effects. These changes can by explained by two factors. The first one being agricultural collectivization which led to a strong movement of peasants from the countryside to cities. As a result, abundant agricultural land was naturally overtaken by forests. The second process was excessive exploitation by nonsustainable management of the forest resources which led to a decrease of the forested area (for example, in the northern part). Contributing to the negative development of the forested area also was the construction of new infrastructure. The increased forested area after 1914 in Ukraine and Byelorussia is a result of large-scale afforestation.

From 1983 to 1988, the forested area increased in the European part of the USSR by 1.1 million hectares and the non-forested area decreased by 0.4 million hectares, with the total standing volume increasing by 0.8 billion cubic meters (Goskomles, 1989). As can be seen in *Table 1.4*, the most noticeable decrease occurred in the Northern and Ural regions.

At the national level, an underharvesting in relation to the allowable annual cut (AAC) has taken place (*Table 1.3*). But at the regional level overharvesting is reported. According to Libert (1989) a serious overharvest was carried out from 1966 to 1986 in European Russia. He reports an overharvest of about 665 million cubic meters in total USSR of coniferous forests during this period. According to data from Goskomles, the regional overharvest totaled 700 million cubic meters in state forest enterprises, during the last 20 years. This overharvesting is a result of "high grading" the harvests, which means taking out the high-valued stands, highly productive stands, coniferous stands, and easily exploitable stands. The AAC is set according to species in the USSR and then totaled. Thus, even if the actual harvest were kept within the limits of the total AAC, the individual species could be overharvested. For example, in the Arkhangelsk region, the total utilization of the entire AAC in 1987 was 84 percent, although 12 enterprises out of 26 overharvested the coniferous AACs. Regions with extreme overharvest in the European part are Arkhangelsk, Komi, and Karelia. Libert (1989) predicts that the harvesting possibilities will be finished within 10 to 30 years in these regions. Similar reports are presented for different subregions of Siberia. Barr and Braden (1988) state that many forests are still being "mined" or "high-graded"; others are undergoing depredation through the uncontrolled intervention of nomadic loggers, who are destroying the resource base allocated for major mills. They conclude that a major problem in utilization of Soviet forests seems to rest with the formulation of programs and policies of sustained yield.

Table 1.5. Comparison between actual harvest and mean annual increment in 1988.

Region and districts	Actual harvest (mill. m^3) Timber	Total volume	Total mean annual increment	% utilization of mean annual increment
Northern region total	74.8	82.3	74.9	110
Arkhangelsk	23.4	25.7	20.0	129
Vologda	13.6	15.0	14.7	102
Murmansk	1.3	1.4	2.0	70
Karelia	10.0	11.0	11.9	92
Komi	25.3	27.8	26.4	105
Ural region total	51.7	56.9	72.7	78
European USSR	230.1	253.1	332.2	76

Source: State Forest Account, Goskomstat, 1990.

Kautaissoff (1987) says that USSR is rapidly loosing its forest resource base by overharvesting and deforestation. Komarov (1980) suggests that deforestation is only one element in a widespread despoliation of natural resources in the USSR. Sutton (1975) argues that future timber supply is likely to be most critical for coniferous timber due to past exploitation. North and Solecki (1977) have a similar pessimistic viewpoint on the future wood supply due to overexploitation. Barr (1988) estimates that overexploitation during the 1950s resulted in extensive areas of forests characterized by stands with poor quality poplar, birch, and alder trees and irregular stands of coniferous species. He also illustrates that the overutilization is reducing the area of European spruce forests. The overexploitation has also generated significant opportunity costs in the European part. In another source, Barr (1987) stresses that in the European part of the USSR the operations of existing industry are jeopardized since the forests have been "ruthlessly exploited in the past." Considerable local overharvesting of the European north can be illustrated by data on actual harvest and the total mean annual increment (*Table 1.5*). As shown in *Table 1.5* most of the Northern region has an overharvest. However, this is not the case in the other regions, which can be concluded from the figures concerning total European USSR.

Barr (1987) also stresses that the reserves of commercial forests have a life expectancy of 13 years in Kostroma, 20 years in Kirov and Vologda, 30 years in Karelia, and 50 years in Arkhangelsk and Komi (all in the European USSR). Barr estimates that the commercial forests will be exhausted within four years in Byelorussia, within nine years in the Ukraine, within eight to ten years in the Baltic republics, and within ten years in the Central Black Earth region. He argues that this is a result of fulfilling the excessive plans for commercial roundwood harvests by cutting the high-yielding stands first. Pryde (1972) makes a similar conclusion by saying that in Soviet forestry it is common to extract the most convenient timber instead of the most biologically sustainable timber.

Barr (1983) concludes,

> European forests have been overcut in general and are dominated by juvenile and immature stands, but contain important reserves of deciduous timber, and offer the best possibilities for rapid regeneration and improvement given good management.

Deforestation and overutilization of the forest resources are not extensively discussed in the Soviet literature according to Barr (1988), although currently this problem is widely discussed in different media.

1.1.4 Waste of raw material

Complete statistics on wood losses through the course of logging and wood processing do not exist. Investigations by the Research Institute of Forest Industry (Burdin, forthcoming) indicate that wastes from logging, transportation, and industrial processing add up to 110 million cubic meters at a harvested volume of 330 million cubic meters. This waste corresponds to 33 percent of the harvested volume. With current technology, about 50 percent of the total waste is estimated to be usable in some form of production, but only 30 percent is utilized in reality. Another study estimates that in the Northern region the annual loss in logging is about 10 million cubic meters per year. A UN report estimates a waste volume of 79 million cubic meters of which 68 million cubic meters were reported to be utilized for 1988 (UN, 1989a).

Thus, considerable losses take place in the logging, transportation, and industrial processes. Regional studies on waste have been presented by the State Association Lesproject and by Manakov and Mochalova (1990). These results are discussed in Chapter 6. But, from these studies it can be concluded that about 50 percent of the waste is utilized in some form of production.

According to Libert (1989) only one-third of the harvested wood reaches the final consumer (the industry or market). Barr (1988) has calculated the losses and concluded that of the 400 million cubic meters harvested in total USSR, about 160 million cubic meters are lost in various stages of production. According to Barr (1988), only 50 percent reaches the industry and only 8 percent of the scrap is utilized in some form. Petrov (1989) finds that the waste of wood raw material is about 30 to 35 million cubic meters per year in the European USSR. This corresponds to 12 to 14 percent of the yearly harvested volume in this part of the USSR. Petrov (1984) states that about 50 percent of residual wood is without utilization in the USSR. Kautaissoff (1987) blames the wastefulness on transportation difficulties like long hauls, lack of roads, and shortage of vehicles.

Isaev *et al.* (1991) state that the efficiency in the utilization of the standing solid wood (stemwood) is about 25 percent. The authors illustrate that at a harvest of 380 million cubic meters of wood biomass in the European USSR in 1989 there was a total loss of 182 million cubic meters. This can be compared with the total felling of commercial wood in Siberia in 1989 of 140 million cubic meters. The losses of the 182 million cubic meters wood biomass was constituted according to the following: stumps and tops, 20 to 26 million cubic meters; brush wood acceptable for use, 18 to 20 million cubic meters; branches, 20 to 25 million cubic meters; and dead trees, 7 to 8 million cubic meters.

Timber losses also occur from timber rafting. The current extent of timber rafting is about 77 million cubic meters per year in the USSR, whereby the official losses are reported to be 4 percent, although realistically seemingly higher.

1.1.5 Mismanagement and lack of silviculture

Libert (1989) characterizes the management of the USSR forest resources as a mining process. He underlines that the general opinion in the USSR has been that the forests are an inexhaustible resource. This has led to lack of interest in silviculture measures like regeneration, cleanings, and thinnings. Barr (1987) agrees and says that the major problem with the management "seems to lie in the very size and visibility of the forest resource."

Ziegler (1987) argues that many people do not believe that natural resources in the USSR could be seriously depleted at any time in the near future. The author concludes, "Thus, there is a problem with the size of the country."

Libert (1989) underlines that if any reforestation takes place after harvesting the result is poor due to low-quality work. He estimates that successful coniferous reforestation only takes place on from 30 to 40 percent of the reforested land. On about 50 percent of the reforested areas coniferous species are replaced by deciduous species. On from 10 to 20 percent of the harvested area there is no regeneration at all. This results in tremendous areas of backlog land. Libert (1989) reports that 100 million hectares in the total USSR are classified as "forest land without forest." Barr (1987) estimates the total USSR regeneration backlog at 130 million hectares. According to the most recent inventory data, the extent of this kind of land was reported to be 139.8 million hectares. In 1966, it was estimated at 360 million hectares. Libert (1989) argues that the basic problem is allocation of funds for regeneration. While 5.8 billion rubles were allocated for the harvest of about 400 million cubic meters only 150 million rubles were allocated for regeneration of 2.2 million hectares in 1988. As discussed in the Soviet press, the regeneration work required was impossible to carry out with the funds available for operations.

Barr (1987) estimates that final harvests occur on about 3.5 to 4 million hectares per year in the USSR but reforestation takes place only on 1 to 1.5 million hectares. Libert (1989), Petrov (1989), and UN (1989a) report a forest regeneration of 2.2 million hectares of which about 1 million hectare are carried out in the form of planting or sowing. The rest is reforested by natural regeneration. Barr (1987) underlines that areas reported as reforested do not always have a satisfactory stocking density. Kautaissoff (1987) says that on paper much reforestation is taking place in the European USSR but in reality something else is happening. Barr (1987) fears "the large discrepancy between rates of harvesting and actual regeneration will lead to extensive fluctuations in logging and exhaustion of the resource." Based on analysis of 1983 inventory data Barr (1987) strongly recommends that measures should be taken to solve the problem with the big discrepancies between harvests and regeneration in the European USSR and Ural region. Barr (1988) also argues that the relation between harvesting rate and reforestation rate is nearly three to one in the European USSR.

The survival rate of coniferous plantations is only about 20 to 40 percent, and in several regions more than 50 percent of final harvested areas are not accessible during the plantation season due to inefficiencies in the infrastructure. It should be pointed out that heavy machinery is used for logging, especially in the final cut. As a result, the soil degrades, erosion starts, and reforestation is hampered.

The major harvesting method is final felling which accounts for about 90 percent of the harvested volume, with individual cutting areas the size of 100 to 400 hectares; the annual area of traditional thinning is about 2.5 million hectares (UN, 1989a). Statistics from Goskomles show that in 1990 thinning was carried out on 3.36 million hectares in total USSR, of which 2.82 million were done in the European part. In addition to this, sanitation harvests are carried out on an area of 1.5 million hectares. This kind of harvest very often has the characteristics of thinnings. Libert (1989) estimates the total area thinned to be 3.6 million hectares per year with a yield of from 40 to 50 million cubic meters. He underlines that it should be possible to harvest some 160 million cubic meters per year in thinnings in the total USSR. Barr (1988) says the thinning yields from 18 to 20 million cubic meters per year in the

Table 1.6. Distribution of forest groups in the state forest lands in the USSR.

	Total USSR		European Ural	
	Mill. ha	%	Mill. ha	%
Group I	261.2	22.0	67.1	33.0
Group II	70.8	6.0	52.4	26.0
Group III	847.2	72.0	81.7	41.0
Total	1,179.2	100.0	201.2	100.0

European USSR but could easily sustain 27 million cubic meters. Barr (1987) underlines that 19 million hectares in the European USSR need increased felling and an additional 24 million hectares require sanitary fellings. In the European part vast areas were cut during the Second World War and were never replanted. These vast areas are made up of birch and aspen stands, which require urgent thinnings. The problem with deciduous species is that they have limited value in Soviet forestry because there are few technological possibilities of using the deciduous wood in the current structure of the pulp industry. For 1980 it is reported that 6 million cubic meters of 45.2 million cubic meters harvested deciduous species were used to make pulp. About 40 million cubic meters per year of deciduous wood are not cultivated in the European USSR (Libert, 1989). Barr (1988) concludes that about 23 million hectares (19 percent) of the forests in the European USSR is not managed at all. The final harvesting or cutting is restricted in many regions of the European USSR due to lack of mature forests. To compensate for the wood deficit from this restriction a satisfactory total harvested volume was achieved by increasing heavy commercial thinnings, resulting in a reduction of future mature forests by 30 to 40 percent. This way of management is called "profit cutting" (Shvidenko, 1986). Thus, it can be concluded that basic silviculture, including required thinnings, has to a large extent been neglected in the Soviet forestry so far.

The Soviet forest resources are roughly grouped into three major groups: protected forests (Group I); restricted industrial forests (Group II); and general industrial forests (Group III). Complete definitions are given in Appendix B. The overall distribution of the different forest groups is presented in *Table 1.6*.

These groups are discussed in more details in Chapter 2. The harvest in Group I (protected forests, approximately 22 percent of total forest land) is heavily restricted; the harvest is mainly carried out as light thinnings. Libert (1989) estimates that more realistic management of the protected forests could yield another 20 million cubic meters per year in the total

Table 1.7. Extent of forest fires in the USSR.

Year	Number of fires (1,000)	Burned area (1,000 ha) Forest land	Non-forest land
1988	24.4	792.4	225.4
1989	28.1	1,646.3	424.4
1990	25.3	1,384.0	310.5

USSR. Petrov (1989) estimates that selective harvest of the forests in Group I, in the European USSR, could increase the harvests in this part of the USSR by 10 to 20 million cubic meters. However, it should be underlined that discussions on restructuring the management of the protected forests in the future are under way.

1.1.6 Lack of skilled labor

In 1989 the number of employees in forestry was 393,000, of which 83,000 were specialists with higher and secondary education. More than 20 percent of the work force could be characterized as administrative. There are big difficulties in recruiting skilled labor force for forestry operations. Only about 4 percent of the labor force has any form of forest training (Libert, 1989). The difficulties in recruitment is strongly connected to the social conditions for the workers. Very often they have to stay in remote camps for long periods away from families and with no access to supplies.

1.1.7 Forest fires and forest diseases

Vast areas are burned each year by forest fires of which over 90 percent are induced by man (Libert, 1989). The statistics on the extent of forest fires are incomplete. However, Barr (1988) reports that 4 percent of the forest land constitute burned and destroyed stands. Pryde (1972) estimates the total annual losses in the USSR by forest fires at 1 million hectares per year.

About 780 million of the total 1,252 million hectares of the Forest Fund in the USSR is protected in some form against fires. Goskomles has information on the extent of forest fires (1988–1990), which is regarded as reliable and is presented in *Table 1.7*. Forest fires are estimated to generate an annual loss of from 90 to 205 million cubic meters of wood in the USSR.

The forests of the USSR are also attacked and damaged by other factors such as diseases. The extent of dead forest area caused by these factors for the USSR is presented in *Table 1.8*. The total decline by these factors is estimated at affecting 5 to 8 million hectares per year with about 2.5 million in the European part.

Table 1.8. Area of dead forests and their causes in total USSR, in thousands of hectares.

Cause	1980	1986	1989
Insects	2	6	26
Animals	19	8	14
Fungi	2	2	4
Air pollutants	92	86	70
Climate	61	37	95
Total	175	139	208

1.1.8 Inefficient forest industry

Forest industries have never received any high priority in the allocation of funds by central authorities (Barr, 1988; North and Solecki, 1977). This has resulted in an inefficient industry according to international standards. This means, among other things, an extremely high wood consumption per output unit in the industry (Libert, 1989). In an international comparison the manpower requirements seem to be two to five times higher in the Soviet industry than in the industry in North America and Western Europe (Suhonen, 1990). Similar results have been achieved in an analysis of production in the woodworking industry by UNIDO (1983). The IMF (1990b) illustrates that the annual labor productivity change in the industry decreased from 3.6 in the period 1951–1973 to 1.0 during the period 1974–1984. All of this results in a low-paying capability for the wood by the industry. These problems were identified at an early stage in the ongoing economic reform process in the USSR. For example, Aganbegyan (1987) stresses that the labor productivity must increase by from 1.5 to 2 times and the input–output ratio in the industry must be improved.

Investments in the industry have been very rare during the last decades. The situation can be illustrated by the conditions in the Krasnoyarsk region in Siberia. There are 60 forestry enterprises in the region with the average being in operation for 52 years. The establishment of the forest industry was limited by the establishment of proper logging capacities. The industry also had no accessible technology to deal with small-sized wood, low-quality wood, deciduous species, and larch. As a result the wood supply is already exhausted in six of the enterprises in the Krasnoyarsk region; in 26 enterprises the wood supply will be exhausted within five years.

There are 157 pulp and paper mills in the USSR. During the last 15 years, not a single new plant has been built. The equipment is obsolete. Between 1987 and 1990, some 430,000 tons for pulp production had to be taken out of production due to obsolete machinery. At the same time, it

Table 1.9. Forest industry production in the USSR.

Products	1970	1975	1980	1985	1989
Industrial wood removal with bark, mill. m^3	335.00	395.10	356.60	368.00	369.50
Lumber, mill. m^3	116.40	116.20	98.20	98.20	101.10
Veneer, mill. m^3	2.05	2.20	2.02	2.19	2.30
Particle boards, mill. m^3	1.99	3.99	5.45	6.90	8.34
Fiber boards, mill. m^2	208.30	486.00	4,706.70	566.00	646.90
Chemical pulp, mill. tons	5.11	6.81	7.12	8.37	8.51
Mechanical pulp, mill. tons	1.67	1.90	1.95	2.13	n.a.
Paper, mill. tons	4.18	5.21	5.29	5.99	6.31
Board, mill. tons	2.52	3.70	3.44	4.03	4.33
Furniture, bill. rubles	3.00	4.50	6.00	7.90	10.03

Table 1.10. Paper production in several European republics, in thousands of tons.

Republic	1970	1980	1986	1987
Russia	4,476	4,462	5,205	5,479
Ukraine	187	209	309	313
Byelorussia	103	189	190	202
Latvia	148	131	160	153
Lithuania	102	108	120	121
Estonia	105	93	95	99
Georgia	36	39	35	28
Uzbekistan	23	25	26	25
Armenia	5	14	15	15
Total	5,185	5,270	6,155	6,435

Source: Magnusson, 1990.

was identified that another 500,000 tons of pulp capacity do not meet the environmental requirements and must be taken out of production in the near future (Forest Industry, 1990).

Magnusson (1990) concludes, "Soviet pulp and paper industry is beset by numerous, and difficult problems such as shortage of fiber, environmental problems, product quality, production capacity, and organization."

The locations of the Soviet pulp and paper industry are illustrated in *Figure 1.1*. Forest industry production in the USSR is presented in *Table 1.9*. The production of paper in several European republics is presented in *Table 1.10*.

Logging operations are regarded as part of the forest industry in the USSR. The mechanization of the logging and silvicultural operations is low. About 40 percent of the harvesting operations and some 70 percent of the

Figure 1.1. Locations of the Soviet pulp and paper industry. Source: Magnusson, 1990.

silvicultural operations are carried out by human energy. The harvesting machines have been destructive; they are heavy and have damaged the forest soil. Productivity in the harvesting operations is low. The average productivity is about 1,000 cubic meters per 400 workdays.

1.1.9 Other factors

The deforestation in the USSR also is a product of other processes. Barr (1988) cites the central planning system (which is discussed in Section 1.3), alienation of forest land for industrial development, and various wars as reasons for the deforestation.

It is hoped that the transition to a market economy will in the long run improve the conditions for sustainable forestry development. But the destruction of the economy in the USSR in recent years has resulted in less resources available for forestry and the forest industry, which has caused a considerable decrease of the harvest levels in 1990 and 1991.

1.2 The State and Development of Forestry According to Officials in the USSR

The USSR State Forest Committee was responsible for the forest resources in the USSR. The committee supplied the Forest Study with information on the development of the forest resources in the USSR, based on the State Forest Accounts (*Table 1.11*).

The committee has acknowledged that the state of the forests in the European USSR is not satisfactory. The current species composition, productivity, and the actual land use do not secure sustainable wood supply or ecological and social functions of the forests in the long term. Regionally, the development has been very unsatisfactory in Siberia (*Table 1.12*).

The committee has stressed that the forests have been deteriorating because of irrational use. The ecological conditions are unfavorable in several subregions in the European USSR due to emissions of air pollutants. The committee has been concerned about expected serious effects of assumed climatic change. The ecological conditions were a driving force for the adoption of the resolution on "Urgent Measures on the Improvement of the Country's Ecological State" in November 1989. Goskomles (1990) developed – based on this resolution – a new concept for the development of the USSR forests with two goals: large-scale forestry regeneration and filling the gap between fellings and reforestation.

Table 1.11. Development of the forest resources of the European/Ural region and total USSR. For definitions, see Appendix B.

	1966	1973	1983	1988
Forested land (mill. ha)				
USSR	625.6	637.4	655.6	654.1
European	147.1	146.3	149.9	150.9
Coniferous forested land (mill. ha)				
USSR	489.6	504.1	518.3	518.3
European	92.6	92.5	94.9	96.0
Total growing stock (mill. m^3)				
USSR	74,010	74,243	75,329	74,886
European	16,921	16,979	18,341	19,139
Growing stock: mature and overmature forests (mill. m^3)				
USSR	52,834	51,111	47,654	44,948
European	9,951	8,944	8,384	8,419
Non-forested area (mill. ha)				
USSR	131.4	115.2	96.2	98.9
European	10.1	7.4	4.7	4.3
Forest plantations (mill. ha)				
USSR	10.8	15.7	21.5	23.8
European	9.3	13.1	17.4	19.2
AAC (mill. m^3)				
USSR	630.7	620.3	634.7	636.2
European	264.8	253.1	250.2	247.1
Actual final felling (commercial volume, mill. m^3)				
USSR	355	351	318	339
European	242	225	192	199
Thinning (commercial volume, mill. m^3)				
USSR	26	39	43	43
European	23	33	36	36

Table 1.12. Development of the forest resources (forested areas) in some regions of Siberia.

	1983		1988	
Region	Area (mill. ha)	Growing stock (bill. m^3)	Area (mill. ha)	Growing stock (bill. m^3)
Yakutsk	128,178	9,761	125,627	8,848
Tyumensk	43,094	5,096	41,769	4,749
Irkutsk	54,533	8,641	51,839	8,568
Krasnoyarsk	111,962	13,937	111,261	13,806

Guidelines for the forest reproduction have been developed for three zones:

- In the first zone (including regions with scarce forest resources – Volgograd, Arkhangelsk, Povolzksky region, and North Caucasia) the reforestation is directed toward establishment of protected forests.
- In the second zone (including regions with moderate forest resources – the Baltic republics, Caucasia, Ukraine, Byelorussia, and Moldavia) the allowable cut is normally fully utilized and the reforestation should equal or exceed the harvested area.
- In the third zone, which for many years has been regarded as containing an unlimited wood supply, there is a strong imbalance between harvested and reforested areas. The level of silvicultural activities is very low in this zone which includes Northern and Northwestern regions and the Perm and Sverdlovsk districts of the Ural region. Thinning intensity is not adequate and there is an unacceptable replacement of coniferous species by deciduous species.

The program proposed suggests strongly increased reforestation and intensified silvicultural activities for these regions. The resolution has also set a goal of about 4.5 million hectares of reforestation for each five-year period in the European USSR up to the year 2005.

1.3 Central Planning, Natural Resources, and the Environment

Many scientists have stressed that the centrally planned system has had strong negative effects on the development of the natural resources and the environment in the USSR. The links between the centrally planned system and the depletion of natural resources and destruction of the environment are discussed in this section.

In Parsons (1977) it is argued that Marx and Engels had a disastrous point of departure concerning the natural resources and nature: "Marx and Engels expected a Communist society to achieve 'social mastery' over nature through technology – to resolve the dialectical process of using nature to eliminate the threat posed to mankind by the natural environment."

Ziegler (1987) points out that Lenin agreed with this viewpoint. Ziegler illustrates this by quoting a famous statement made by Lenin in 1920: "Communism is Soviet power plus the electrification of the whole country." Ziegler explains that the early Communist commitment was to support a strong modernization of society without concerns about nature. The author goes on to say that Stalin continued this development by launching the first five-year plan in 1928. This plan was a massive effort to industrialize the USSR regardless of the resources lost or the sacrifices. Ziegler points out that there have been major changes over time in official Soviet attention to natural resources and environmental protection since Stalin's death but some fundamental perceptions remained until the late 1980s.

In 1987 Jancar (1987) stated that in the USSR policies were ruled by the ideologic man: "Man rules nature by compelling it to serve his aims by changes brought by him." Pryde (1972), Goldman (1972b), and Fullenbach (1981) have also used ideology and a very strong confidence in technical solutions to explain earlier failures in natural resource and environmental management in the USSR.

Ziegler (1987) writes that the Communist party "claims to be the sole organization equipped to discover the objective laws of nature." He argues that the party line has generated a popular attitude toward natural resources and environment which can be described as a "combination of indifference and ignorance." Scarlet (1987) does not agree and argues that nature and environment is one of two fundamental issues getting strong support from the public.

Jancar (1987) stresses that the most important function of the Communist ideology was the following: "Policy making in USSR is to limit the area of discussion by setting bounds to policy alternatives." Linked to the ideology was the assignment of a value to natural resources, which was a very controversial issue (Jancar, 1980). Jancar (1987) notes that since "resources cost nothing, the demand made upon them exceeds in many areas their capacity to deliver."

Jancar (1987) points out that until the late 1960s exploitation of natural resources and environmental problems were dismissed as problems belonging to capitalism. In the 1970s, Soviet scientists and journalists started to stress these kind of problems. At the same time an interest concerning the exploitation of natural resources and environmental problems in the USSR was starting to be developed in the West.

The State Planning Committee (Gosplan) was responsible for the development of the national social and economic plan. According to Jancar (1987) natural resources and the environment were not taken into account in this plan up to the year 1974. She argues that even in the late 1980s, these plans were not sensitive to the problem "of accommodating long-term economic development to the carrying capacity of individual regions." Furthermore, she underlines that the overall planning process during the Communist era can be characterized by limited attempts to assess externalities, shortcomings in cost-benefit analysis, emphasis on growth in GNP instead of sustainable development.

According to Ziegler (1987) the planning process was steered by departmentalism which supports "narrow, segmental interests pursued by the various ministries and institutes in the USSR, at the expense of the general welfare." Jancar finds that a characteristic feature of the planning and administrative systems was the separation of the administration of natural resources from their exploitation. She emphasizes that there was a lack of public access to policy making under the Communist regime. The juncture of interests between government and industry in the planning process has often been cited as being responsible for making decisions that resulted in the inefficient use of natural resources and destroying the environment. Goldman (1972a) supports this opinion by stressing that the power of one party as both the regulator and the manufacturer poses a great danger.

Industry also represented a major element in state power. The more autonomous an industrial organization, the more it bypasses party directions and governs the policy directions (Jancar, 1987). A characteristic of the system was that the ministry in charge of using natural resources was also in charge of protecting natural resources. Jancar (1987) writes, "Territorial administrations become the victims of the branch decision making taking place at the top of the hierarchy where the special relationship between the party leadership and industry assigns a setback."

Lowenhardt (1981) finds that there were difficulties in assigning responsibilities in the centrally planned system and it was difficult to identify the dynamics of individual decisions. Kelly *et al.* (1976) explain that the Communist party elite failed in accepting the political costs for sustainable development of natural resources and the environment.

Experts have had an influence in strengthening and improving the planning process over time in the centrally planned system. But Jancar (1987) underlines that their influences had the following limitations:

- The mechanisms for changes of the plan by experts were only slight modifications of proposals by the party. Scarlet (1987) finds that experts only urged a fine-tuning of the structure and did not challenge the basic values of the existing system.
- The problems of information censorship made it nearly impossible for an expert in one ministry to generate a global picture of a problem.
- Experts' advice was most likely to be accepted if it did not threaten the existing power structures. The experts followed the don't-rock-the-boat strategy.

Jancar (1987) argues that, in principle, the same can be said about scientists. They were very sensitive to the dangers of violating the rules. There was a clear separation between scientific work and the real power. Very often scientists had no access to real data. Therefore, they had to focus on theory building with limited implications or applications.

Western analyses of the science sector in the Communist USSR have not been very favorable (see Gustafson, 1980; Popovskii, 1980; Kueen, 1989; Balzer, 1989). Fortescue (1990) illustrates an internal violation of science in Communist USSR. This violation was driven by "the prevalence of schools and monopolies, the reliance of institutes on one or two universities for all their recruitment, low job mobility, highly specialized institutes, an obsession with national security and secrecy, long publication delays, etc."

Gorbachev tried, through the processes of glasnost and perestroika, to reconstruct the science sector. As a result of this Soviet scientists started to examine the science sector and stated, "Soviet science is now too weak to be able to make any serious contribution to solving the Soviet Union's host of technical, economic, and social problems" (see Fortescue, 1990).

Powell (1977) argues that a big failure in the central-planning process was the absence of influences from autonomous groups and the public. Jancar (1987) points out that local governments and nongovernmental organizations had limited influence on the policy process and very few of the regulations following the policy decisions were made public and accessible to researchers.

All of this resulted in a strongly limited pluralism in the decisions on the natural resources and the environment in the centrally planned system.

Bush (1972) points out that many organizations were involved in the management of the natural resources and the environment. Therefore, even if the political power was centralized, party leaders and planners were not able to impose decisions on the actors of the system's subsystems. Jancar (1987) illustrates that interbranch rivalry delayed implementation of policies for a decade.

These opinions and conclusions, made mainly by Western scientists, provide a rather negative picture of the relations between central planning and the management of natural resources and the environment. However, it must be remembered that the centrally planned USSR had a rather long tradition concerning forest regulations. A basic law on forests was implemented at a meeting in May 1918 by the Council of People's Commissars chaired by Lenin (Weiner, 1988). Downing (1984) notes that there is an extraordinary similarity in the failures in environmental management between the centrally planned USSR and the US administration; Eberhardt (1990) expands this conclusion to be valid for a comparison with all environmental protection administrations in Western European countries. He writes "Soviet environmental law expresses the firmest commitment to environmental protection and establishes the highest environmental goals of any country in the world." But the implementation did not keep up with the plans. Pryde (1987) is of the opinion that the overall trend concerning policies for natural resources and environment started to move in the right direction during the late 1980s. Scarlet (1987) underlines that the Soviet leaders realized during the 1980s that the natural resources and the environment required protection but they were unsure about the proper allocation of funds. Eberhardt (1990) points out that the Central Committee of the Communist party of the Soviet Union and the Council of Ministers of the USSR in 1988 made a resolution based on shortcomings of the current policies concerning required future management of the natural resources and the environment.

Thus, there was a green movement under way in the USSR in the late 1980s, but this movement seems to have disappeared with the disintegration of the USSR (Nikolsky, 1991). For the moment, the former USSR is in a turbulent stage of transition. Therefore, the establishment and implementation of future policies concerning the natural resources and environment are more or less unpredictable.

1.4 Future Development of the Forest Sector

Several analyses have been carried out on development of the forest sector of the USSR. Most of the Western analysts have a rather gloomy picture of long-term development mainly due to mismanagement and overutilization of forest resources. Barr (1987, 1988) is one of the authors following this direction. Nevertheless as recently as 1983 he concluded that the USSR has the capacity to increase its wood supply by 1990 (Barr, 1983). He estimated an increase from 332 million cubic meters in 1975 to 411 million cubic meters in 1990, a rather substantial increase of about 5 million cubic meters per year. Based on this development he also concluded that the USSR will be able to play a significant role on the international markets for the rest of the century.

In 1983 UNIDO presented a study on the USSR forest and woodworking industry. The study reports:

> The availability of considerable stocks of mature stands provides for stable and systematic development of all branches of the forest complex, aimed at meeting the ever-growing requirements of the national economy for timber and its products.

No quantitative estimate of the future wood supply is made in the UNIDO study.

Volkov (1988) expects decreased availability of and increased demand for coniferous wood in the future, but concludes that the increased demand can be met by the unused forest resources in the USSR together with other supplies. Dykstra and Kallio (1987) estimate a rather unchanged industrial roundwood production from 1985 to 2030. WRA (1988) estimates the roundwood supply to be from 380 to 400 million cubic meters by 2000. The report also suggests that the increased wood supply between 1985 and 2000 will be consumed domestically.

Libert (1989) has a very pessimistic view on the development of the forest sector in the USSR. He concludes that even if the existing problems of mismanagement, labor supply, and overharvests are solved soon it will take about a century for the USSR forest sector to play an important role in both national and international economies.

A UN study produced by Soviet specialists suggests an increase of the wood supply from 368 million in 1985 to 413–430 million in 2000 (UN, 1989b). Arnold (1990) does not estimate any changes in the wood supply up to 2000 and concludes that the major supply will come from the European and Ural regions. Petrov (1989) points out that the forest resources in the European region may be able to supply the future increased domestic demand in this region in several ways:

- Full utilization of the allowable cut (an additional 30–40 million cubic meters per year).
- An increase in thinnings (25–30 million cubic meters per year).
- Better utilization of the resources in Forest Group I (10–12 million cubic meters per year).
- Full utilization of wasted wood (30–35 million cubic meters per year).

Backman and Waggener (1990, 1991) have made a "near-term outlook" on the USSR forest sector, which includes the following:

- The forest sector will be segregated into the European region and the Asian region. Development of the Asian region will be driven by the export potentials in the Pacific Rim, while the European region will be driven by increased domestic consumption and restricted availability of wood.
- Emphasis will be on improving development of the forest resources in the European region. "The forest resources of the European USSR are being exploited at or beyond the current ability of the resource to sustain itself."

- The harvest of industrial wood will not increase at the same rate as the growth rate of the industrial capacity. "The overall increase in harvest can be expected to be muted."
- The forest sector is assumed to shift away from the exporting of logs and lumber toward higher value-added products.

A master plan for the forest sector of the Northern European region of USSR has recently been prepared by the Finnish consultant company Jaakko Pöyry for Gosplan. So far, the results from this exercise have been treated confidentially by the Soviet authorities.

Other analyses have been carried out on strategies for the whole forest sector development. Barr (1987) and Barr and Braden (1988) illustrate that different opinions exist in the USSR about where to concentrate future activities in the forest sector – the European part or Siberia and the Far East. They estimate the development costs to be from two to three times higher in Siberia than in the European part and the forest increment to be much lower in Siberia. The authors suggest a strategy with continued less intensive forestry in Siberia and an organization of an efficient sustained yield system in Europe–Uralia during the next 20 to 30 years. In the long run such a strategy should offset the need for further exploitation of peripheral forests in Siberia, although some eastern forests obviously will be utilized to fulfill regional demand for unprocessed roundwood and some export obligations of roundwood, chips, and lumber to the Pacific market.

Eronen (1984) analyzed the location strategies for the USSR pulp and paper industry using the Strategy theory developed and presented by Ansoff (1965, 1989). In this theory investment decisions are subordinate to long-term business strategy and the time horizon involved in the decisions are too long for exact economic cost and return calculations. Eronen found excesses in industrial capacities in the following regions of the European USSR: Karelia, St. Petersburg, Arkhangelsk, Volgo-Vyatsky, the Baltic republics, and the Western Urals.

Eronen (1982) concluded that raw material supply and markets are inadequate factors for prediction of industrial location in the USSR and that other factors determine the location.

Barr (1970) found that the wood-processing industry in the USSR is not completely oriented toward the location of the raw material. Other unidentified and unquantified factors also have major influences on the location.

Already in 1955, Rodgers (1955) identified regional pulpwood supply problems for the pulp industry in the USSR. The supply problem was caused by rapid harvest of the best pulpwood stands and long transportation distances between the best forestry sources and the industrial locations.

Sedjo and Lyon (1990) have used control theory to analyze the effects on the world market by different future regional wood supply. They found that market-driven regions react to changes in forces operating outside the true market system. Therefore, from a world market point of view there was already a need to have a reliable view on the wood supply in the centrally planned USSR. This demand is further expressed in the USSR by transforming completely to a market economy.

Barr and Braden (1988) stress that multifaceted pressures on the forest resources, particularly in accessible regions, means that the overall usage of forests will be intensified in the future and that attempts will be made to gain the greatest possible yield from all aspects of the forest in the USSR.

1.5 Conclusions

It is obvious that a degradation of the natural resources and the environment is taking place in the USSR. Mathews (1991) reports that current costs for pollution and resource degradation amounts to at least 15 percent of the GNP. Many factors – historical, geographical, cultural, legal, administrative, political, and ideological – have formed the current state of the European forest resources. The same factors will to a large extent form the future of these resources in this region. Based on the literature review some major trends in the opinions about the future development of the European forest resources can be identified:

- Western resource analysts have expressed the opinion that the forest resources have been mismanaged during a long time and that this will generate severe drawbacks on development possibilities.
- Western quantitative analyses of the future wood supply in the USSR are cautious and suggest a future supply similar to current supply. This is probably a result of lack of accessibility to basic data for accurate analysis and uncertainties about the existing forest resources.
- Reports from international governmental organizations (produced by Soviet experts) and Soviet experts under the centrally planned system foresee a rather strong growth possibility of the wood supply.

Petrov (1989) has presented the means to increase the future harvest level in the European part of the USSR. He stresses that this part of the USSR has some productive advantages over other regions of the USSR. These advantages are lower wage rates (20 to 60 percent lower), lower investment costs, easier availability of labor, and better physical and social infrastructure.

Chapter 2

Overview of Forest Resources of the European USSR

2.1 Area and Vegetational Zones

The European USSR is an area of enormous size. It extends over 25 degrees of latitude, from 45° to 70°, and nearly 2,500 kilometers from east to west. The area forms a low-lying plain between the Polar basin in the north and the Caucasian Mountains and the Caspian and Black seas in the south. In the east the Ural Mountains and the Ural River form the boundary of the area which extends to Central Europe and the Baltic Sea in the west. The area constitutes a major part of Europe since it encompasses about 51 percent, or 507 million hectares, of the total area of Europe, which is about 1,003 million hectares (Encyclopaedia Brittanica, 1982).

Nowhere in the world is the relationship between climate and the character of the vegetation so marked as in the European USSR since the vast area has no elevations high enough to affect the distribution of the vegetation (see, for example, Haden-Guest *et al.*, 1956). Mountains are situated only on the rims, and the distribution of the vegetation results from the climate prevailing in the different parts of the plain. The succession proceeds according to latitude. From the north to the south, the European territory is divided into 10 vegetation zones (see *Figure 2.1*) of which there are four major forest zones: coniferous forests (61 percent of the forest area), mixed forests (17 percent), deciduous forests (11.5 percent), and forest steppe (2.4 percent).

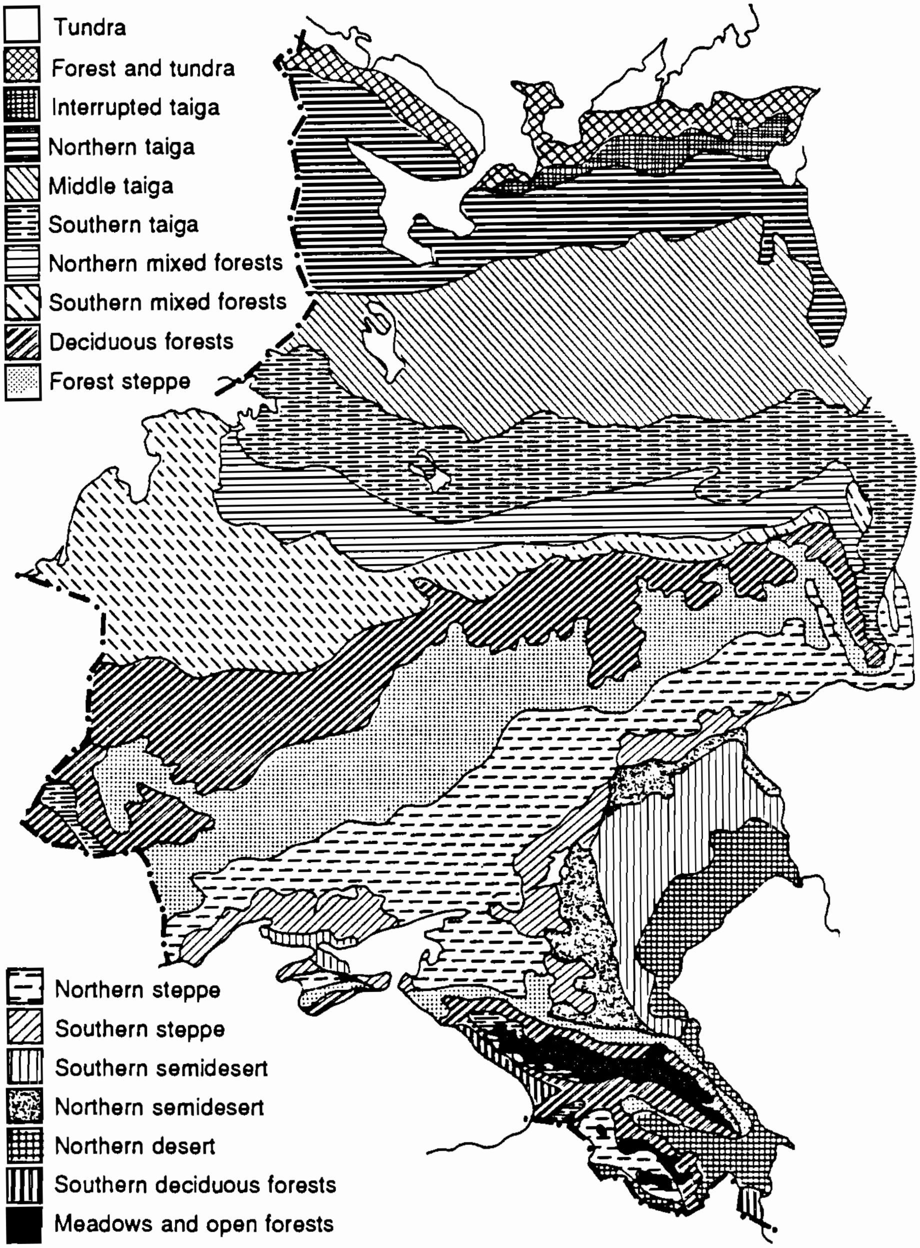

Figure 2.1. Vegetation zones of the European USSR. Source: Kurnaev, 1973.

Table 2.1. Characteristics of the vegetation zones of the European USSR.

Zones and subzone	Distribution of forested area in %[a]	K	Average site index
Tundra	0.1	0.4	–
Forest tundra	1.5	0.5	–
Coniferous forests (taiga)	61.0		IV.0
Sparse taiga	2.8	0.8	V.0
Northern taiga	13.7	1.2	IV.6
Middle taiga	28.9	1.5	IV.2
Southern taiga	15.6	1.8	III.0
Mixed forests	17.0	1.9	II.2
Broad-leaved deciduous forests	11.5	2.3	II.4
Forest steppe	5.9	2.4	II.0
Steppe	2.4	2.1	II.8
Semidesert	0.3	0.8	III.0
Desert	0.1	<0	–
Grassland and grassland sparse forests	0.2	1.7	–
Total/average	100.0	1.7	III.5

[a]For definition, see Appendix B.

Suitability for forest production in the 10 vegetational zones has been analyzed by Gorev (1968, 1974). He used the following criteria for analyzing growing conditions:

$$K = 0.01[R_T - (0.1T - 0.1T_R)] ,$$

where K is the index of climatic conditions for forest growth; T is the sum of temperatures greater than 10° C per day; R_T is the amount of precipitation evaporated at the temperature sum T; and T_R is the part of the temperature sum employed in evaporation.

The coefficient K is well correlated with the forest growth in the 10 vegetation zones and is presented in *Table 2.1*. In *Table 2.2*, the intensity in forest utilization of the vegetation zones is presented.

The major part of the forest resources of the European USSR is found in the northern part of the forest zone in the so-called taiga. This is an approximately 1,000-kilometer-wide belt of mainly spruce and pine forests in the tundra along the Arctic shoreline (*Figures 2.1* and *2.2*). This belt is followed by a belt of mixed forests in the central part of the East European plain. The latter belt, in which pine, birch, oak, and beech are the main stand species, is rather narrow in the east widens in the west, reaching a maximum distance of about 1,200 kilometers from the Gulf of Finland to the Black Sea. Farther south the forest gradually thins out; this area forms

Table 2.2. Intensity in forest utilization of vegetation zones in the European USSR, in cubic meters of commercial wood per hectare of forested area.

Vegetation zone	1960	1980	Estimated possible utilization
Forest tundra and sparse taiga	0.02	0.02	0.19
Northern taiga	0.82	0.96	1.63
Middle taiga	1.54	1.53	1.70
Southern taiga	2.33	1.86	2.11
Northern mixed forests	2.74	1.86	2.44
Southern mixed forests	2.11	1.91	2.32
Deciduous forests	1.92	1.66	1.99
Forest steppe	2.00	1.56	1.71
Northern steppe	1.12	1.36	1.78
Southern steppe	0.26	0.17	0.27
Northern semidesert	–	–	–
Southern semidesert	1.33	0.50	1.15
Meadows and sparse forests	0.65	0.34	0.36

the flat grass steppes. These become more arid as one proceeds to the south, changing into semideserts toward the southeast and the Caspian shoreline, followed by grass, and finally fir forests climbing up the Caucasus Mountains.

2.2 Administrative Regions

The European USSR is divided into 18 administrative or economic regions (see *Figure 2.3*); 17 of these regions are included in this analysis of the forest resources. The Russian republic is represented by nine regions, the Ukraine by three regions (based on the forest classification in the State Forestry Account for Ukraine and not on the industrial activities, which is the case for the rest of the territory), and the remaining five economic regions are independent Soviet republics (Estonia, Latvia, Lithuania, Byelorussia, and Moldavia).

The only region that is not included in this work is the fourth subregion of Ukraine which includes the southern part of the republic and among other areas the Crimean peninsula at the Black Sea. The exclusion of this region does not affect the results of the analyses since few industrial forests are located there. Thus, the three Caucasian republics (Georgia, Armenia, and Azerbaijan) are not included in the analyses. It should also be pointed out that several Soviet economics publications divide the Ukraine into different subregions.

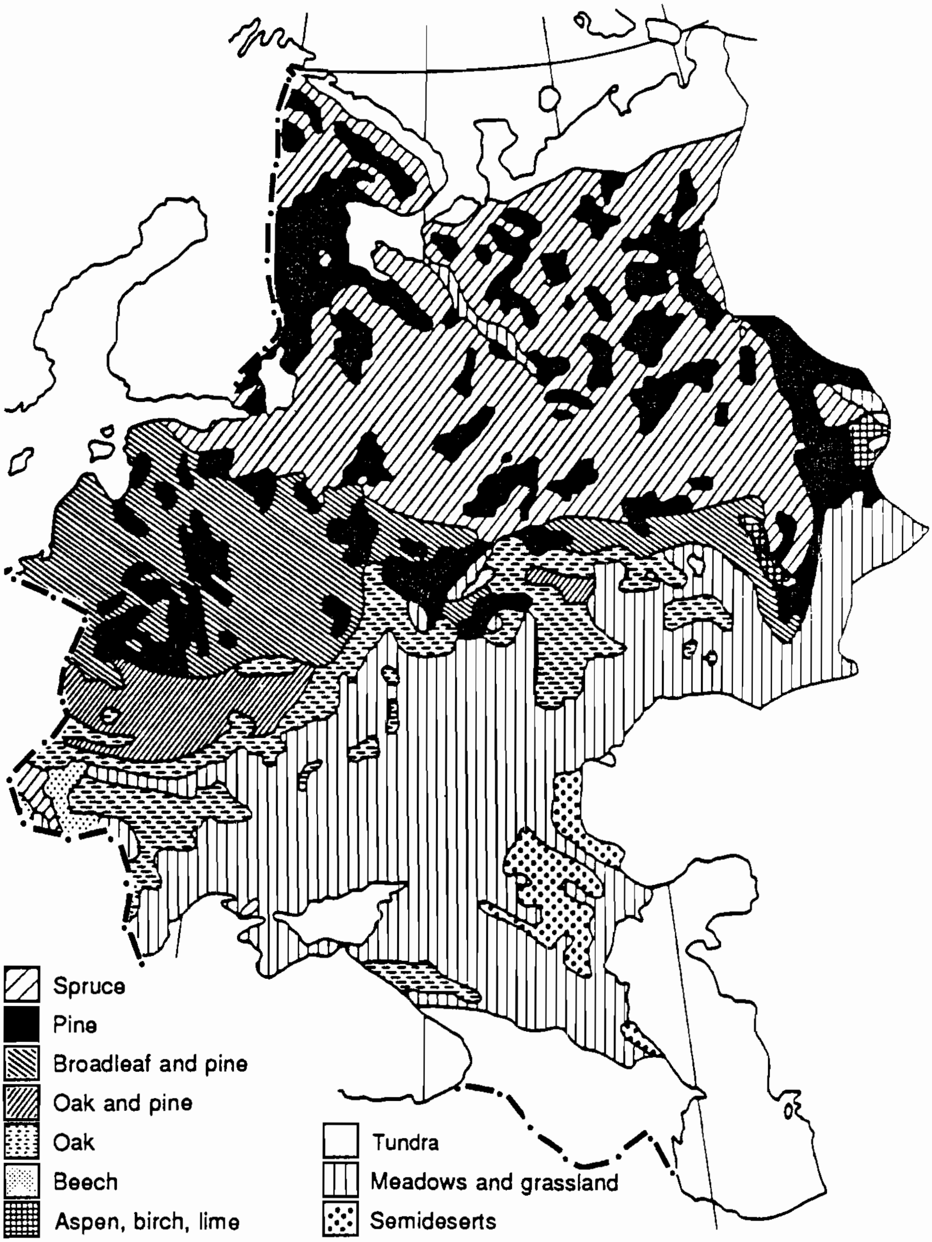

Figure 2.2. Major vegetation zones and types of forests of the European USSR. Source: Haden-Guest *et al.*, 1956.

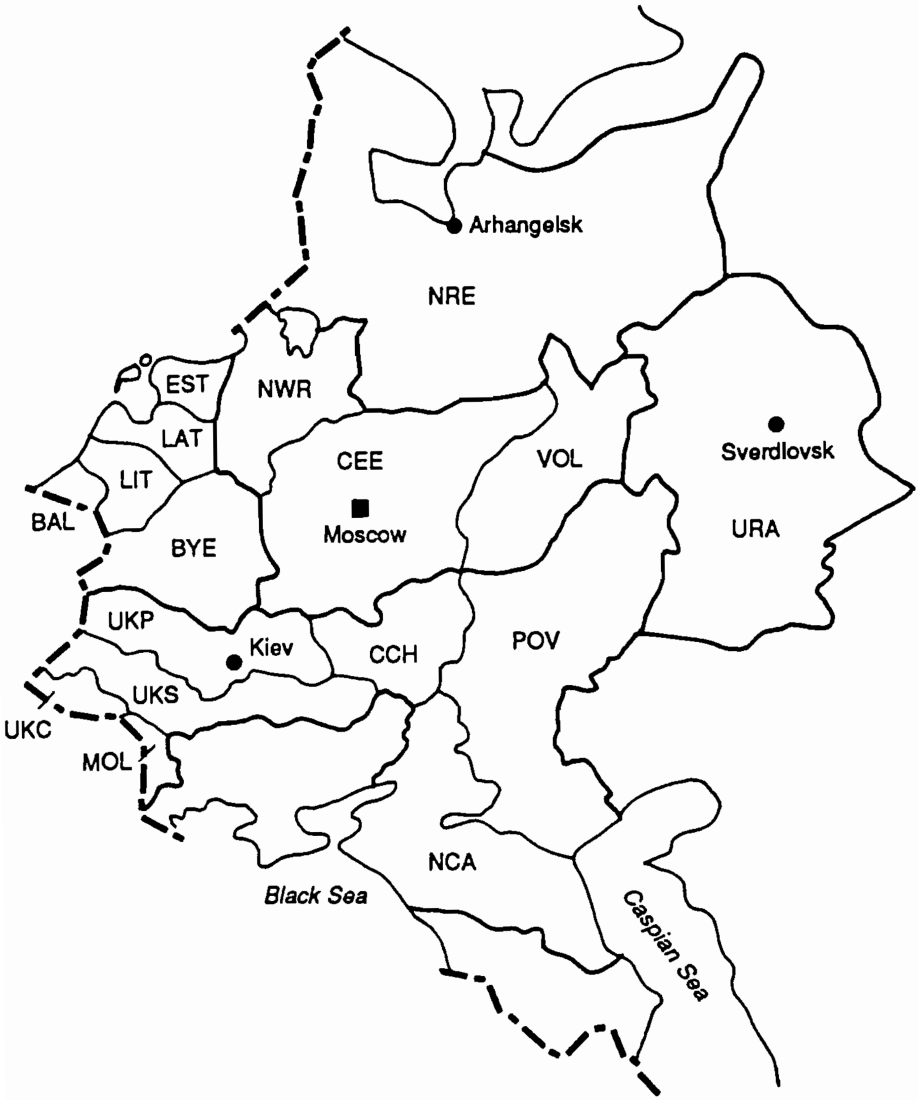

Figure 2.3. The economic regions of the European USSR.

Table 2.3. Data on forest areas of the economic regions of the European USSR, in millions of hectares.

Region	Abbreviation	Territorial area	Forest Fund area	Area classified as forest land	Forested area	Commercial forest area
Russia						
North	NRE	146.6	98.0	72.1	69.2	60.8
Northwest	NWR	19.7	8.2	6.4	6.2	5.7
Central	CEE	48.5	14.5	13.5	12.9	10.9
Pre-Baltic	BAL	1.5	0.3	0.2	0.2	0.2
Volgo-Vyatsky	VOL	26.3	11.6	11.0	10.5	9.6
Central Chernozyomny	CCH	16.8	1.3	1.3	1.1	0.9
Povolzhsky	POV	53.6	4.8	4.4	4.0	2.8
Ural	URA	82.4	35.5	31.3	29.7	25.1
North Caucasia	NCA	35.5	3.6	3.1	3.0	1.4
Ukraine						
Carpathians	UKC	4.0	1.8	1.2	1.2	0.6
Polesye	UKP	12.0	2.7	2.5	2.5	2.0
Forest Steppe	UKS	18.4	3.2	2.5	2.5	1.3
Independent States						
Moldavia	MOL	3.4	0.3	0.3	0.3	0.1
Byelorussia	BYE	20.8	6.8	6.3	6.0	5.3
Estonia	EST	4.5	1.6	1.1	1.0	0.8
Latvia	LAT	6.4	2.1	1.7	1.7	1.3
Lithuania	LIT	6.5	1.5	1.3	1.2	1.1
All regions		506.9	197.8	160.2	153.2	129.9

Forest data from the whole Ural region are used as input, in spite of the fact that the eastern and southern parts of the region, about 40 percent or 33 million hectares of the total area (see *Table 2.3*), are part of Asia. The area including all of the 18 economic regions is referred to as "European-Uralia USSR" (see, for instance, Barr and Braden, 1988). In this work though, we use the expression "European USSR" since the main subject of the book is forest resources, not the geography of the European USSR.

It should also be noted that the the Pre-Baltic, Central Chernozyomny, and Povolzksky regions are also called the Kaliningrad, Black Earth, and Volga Littoral regions in Western literature.

2.3 Forest Areas

The data in this chapter are from a specific data collection made for the Forest Study. The principal methods of this collection is described in Chapter 4.

Data on the total territory, Forest Fund, forest land, forested area, and commercial forests are presented in *Table 2.3*. (For definition of the different areas see Appendix B.) Detailed data on the forest resources are only available for forests managed by state forest organizations. The relation between forests managed by state forest organizations and total forests for all of the former USSR is the following: Forest Fund, 94 percent; forest land, 93 percent; and forested area, 92 percent. The remaining forests are administered by other ministries. The data in this chapter deal only with the forest resources managed by state forest organizations. Thus, we are missing detailed data on nearly 10 percent of the forest resources of the former European USSR in our analysis. The commercial forests category includes areas designated for economic timber production; the forested area category also encompasses forest lands that are strictly protected or are not compatible with normal timber production. Destroyed forests and so-called shrub land can also be included in the latter category. The areas with production roles, as well as the rest of the forests, can be separated into three groups – I, II, and III – according to the level of restrictions on forestry operations, implemented for promoting protection. The structure and functions of the noncommercial forests are shown in *Table 2.4*. The reserve forests in Group III (see above) are not included in *Table 2.4*. The forested area is divided into commercial and noncommercial forests.

From *Table 2.3* and *Figure 2.4* it can be seen that approximately two-thirds of the commercial forests, or about 76 million hectares, of the European USSR are found in the Northern and Ural regions, while the regions in the south and west have comparatively small commercial forest areas. The total area in the category classified as forest land is also small in these regions.

Table 2.5 and *Figure 2.5* show the distribution of commercial forest areas of three major species groups. From the table and figure it can be seen that nearly three-fourths of the coniferous-dominated areas are found in the Northern and Ural regions and that most of the remaining species group is located in a central belt of the European USSR: the Northwestern, Central, Volgo-Vyatsky, Pre-Baltic, and Byelorussian regions.

The pattern of areal distribution of the hard deciduous species (see *Table 2.5* for specific types) differs, as one would expect, quite considerably from that of the coniferous group although the total area of the latter group are substantially larger. Forests where hard deciduous species are the main

Table 2.4. Functions of noncommercial forests of the European USSR.

Function	Area (mill. ha)	Growing stock (mill. m^3)
Reserves	0.63	106
National parks	0.50	118
Forests of scientific importance and "monuments of nature"	0.18	30
Forests for fruit production	0.36	75
City parks	0.16	24
Green belts (parks)	3.84	685
Green belts (protected)	0.09	4
Sanitation forests	1.21	213
Erosion protective forests	1.14	157
Forests of special value	0.33	55
Highly protected forests and nonexploitable forests	11.85	1,503
Total	20.30	2,970

Table 2.5. Commercial forest areas in the economic regions of the European USSR.

Region	Coniferous (mill. ha)	Deciduous (mill. ha)		Total (mill. ha)
		Soft[a]	Hard[b]	
North	49.140	11.676	0	60.8
Northwest	3.457	2.204	0	5.7
Central	5.407	5.280	0.257	10.9
Pre-Baltic	0.062	0.072	0.024	0.2
Volgo-Vyatsky	4.887	4.467	0.223	9.6
Central Chernozyomny	0.269	0.168	0.448	0.9
Povolzhsky	0.740	1.205	0.852	2.8
Ural	13.876	10.628	0.505	25.1
North Caucasia	0.082	0.309	1.001	1.4
Carpathians (Ukraine)	0.236	0.012	0.341	0.6
Polesye (Ukraine)	1.271	0.399	0.306	2.0
Forest Steppe (Ukraine)	0.486	0.195	0.604	1.3
Moldavia	0.003	0	0.148	0.1
Byelorussia	3.633	1.489	0.219	5.3
Estonia	0.549	0.285	0.003	0.8
Latvia	0.878	0.419	0	1.3
Lithuania	0.698	0.344	0.036	1.1
All regions	85.674	39.152	4.967	129.9

[a]Birch, aspen, alder, willow, poplar, etc.
[b]Beech, oak, ash, locust, hornbeam, etc.

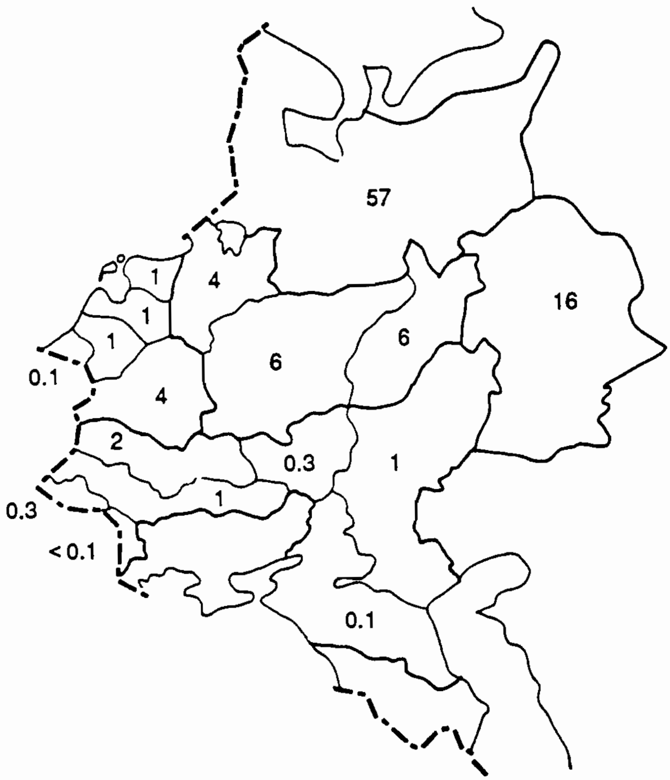

Figure 2.4. The distribution of total commercial forests in the economic regions of the European USSR, in percent.

stand-composing species is mainly found in a belt from the mid-east (southern Ural) to the southwest (Ukraine), and the single region in which these species are most common is in the North Caucasian region where 20 percent of the total area is situated.

The area distributions of both coniferous and hard deciduous commercial forests are well in line with the extension of the principal vegetation and forest zones (shown in *Figure 2.2*), while the distribution of the soft deciduous group [*Figure 2.5(b)*] differs from that pattern since most of this species type is located in the Northern and Ural regions. The reasons for this deviation are that the main areas of the soft deciduous species (primarily birch and aspen) are scattered in the coniferous zone of the taiga and in regions where one would expect to find other soft deciduous species, mainly

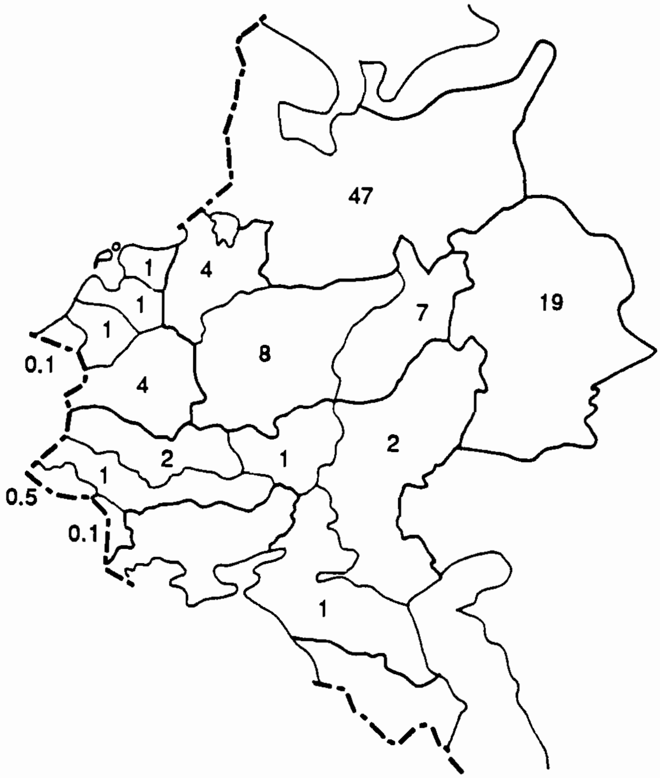

Figure 2.5(a). The distribution of coniferous commercial forests in the economic regions of the European USSR, in percent.

in the mixed forest belt, and the potential forest areas are occupied by other means of land use.

In conclusion, the coniferous species group is the major species in the forests of the northern and western parts of the European USSR. In the central, eastern, and southern regions the deciduous species are as important as, or more important than, coniferous species as the stand-composing species.

2.4 Forest Groups

As mentioned in Section 2.3 the forests can be divided into three forest groups according to their function and the level of restrictions implemented for protection purposes.

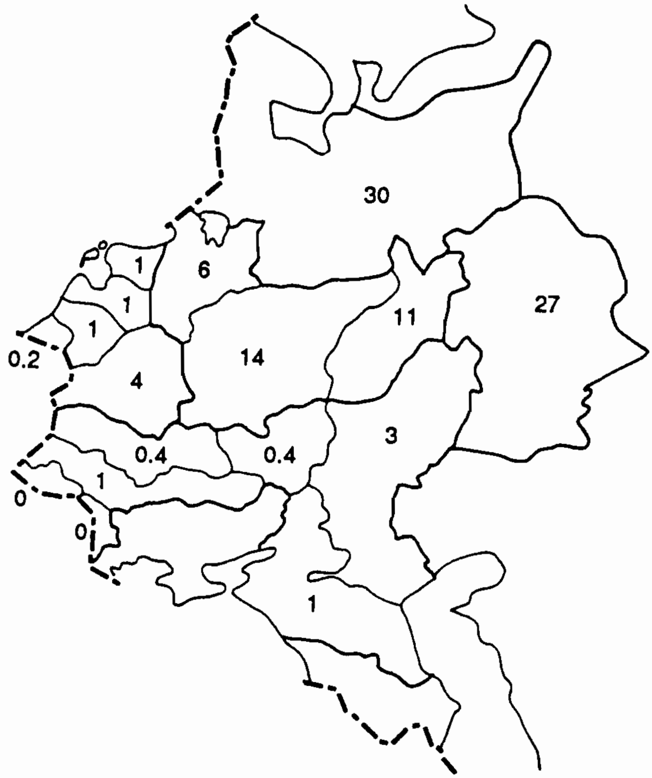

Figure 2.5(b). The distribution of soft deciduous commercial forests in the economic regions of the European USSR, in percent.

- *Group I – Forests protected for ecological reasons.* This group is divided into two subgroups: IA, representing forests with pure protective purposes, only sanitary and selective cutting is allowed on forest land of this subgroup; and IB, representing forests that are protected for commercial (industrial) purposes.
- *Group II – Forests protected for industrial and recreational reasons.* These forests are located in densely populated areas. In areas of this group normal logging is carried out to maintain the ecological sustainability, primarily by keeping the forest at a level equal to or under the mean annual increment.
- *Group III – Forests protected for industrial reasons.* The cuttings in these forests may exceed mean annual increment in a certain location. The forest management is directed toward industrial wood production.

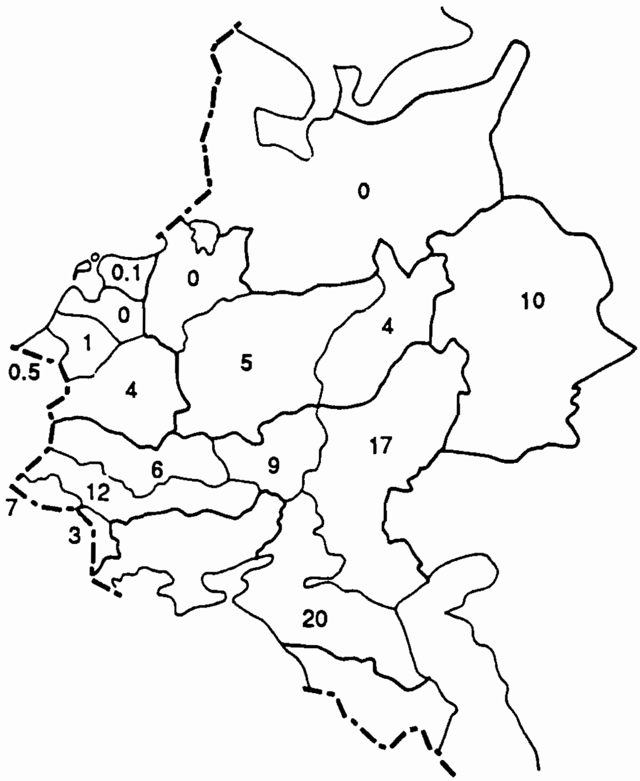

Figure 2.5(c). The distribution of hard deciduous commercial forests in the economic regions of the European USSR, in percent.

The distribution of commercial forest areas in the forest groups is shown in *Table 2.6.* From the table, it can be seen that the forests with few restrictions (those which belong to Group III) are found in only four regions: the Northern, Volgo-Vyatsky, Central, and Ural regions. These economic regions cover the coniferous belt of the taiga which is the most important area as far as harvests in the European USSR are concerned; about 75 percent of the annual harvested volume originate from these regions (see Chapter 5).

2.5 Age-Class Distribution

The distribution of commercial forest areas according to age classes clearly indicates differences in historical utilization of forest resources in different parts of the European USSR. These are mainly due to geographic,

Table 2.6. The distribution of commercial forest areas in the forest groups in the economic regions of the European USSR, in percent.

Region	Total area (mill. ha)	Forest Group I (% of total)	Forest Group II (% of total)	Forest Group III (% of total)
North	60.8	15.5	7.1	77.4
Northwest	5.7	30.4	69.6	–
Central	10.9	29.9	58.9	11.8
Pre-Baltic	0.2	49.9	50.1	–
Volgo-Vyatsky	9.6	17.8	45.6	36.6
Central Chernozyomny	0.9	75.7	24.3	–
Povolzhsky	2.8	48.0	52.0	–
Ural	25.1	17.1	41.0	41.9
North Caucasia	1.4	59.3	40.7	–
Carpathians (Ukraine)	0.6	13.0	87.0	–
Polesye (Ukraine)	2.0	18.6	81.4	–
Forest Steppe (Ukraine)	1.3	54.4	45.6	–
Moldavia	0.1	93.0	7.0	–
Byelorussia	5.3	35.5	64.5	–
Estonia	0.8	15.1	84.9	–
Latvia	1.3	43.8	56.1	–
Lithuania	1.1	33.8	66.2	–
All regions	129.9	21.3	30.8	47.9

demographic, political, and biological reasons. In *Figure 2.6* the structures are summarized in a schematic way to illustrate the structural differences from the southwest, where there is a concentration of young and middle-aged stands, to the northeast where mature and overmature stands are widespread.

In the populated economic regions of the southwest, especially in the Ukraine, a certain overutilization of forest resources in the beginning of this century, combined with losses from World War II, has created significant deficits in supply to the local forest industry. Although the age-class structure of the Northern and Ural regions shows a different pattern, with substantial surpluses of mature and overmature forests, the industries in these regions do not automatically face a better situation since the availability of the forest resources is limited due to an underdeveloped infrastructure.

The age-class characteristics are thus of great importance to both present and future forestry operations of the European USSR; they affect the spatial and temporal aspects of the timber supply, regarding availability of volume as well as specific assortments, and must therefore be kept in mind when addressing the issue of the future structure of the forest industry and the

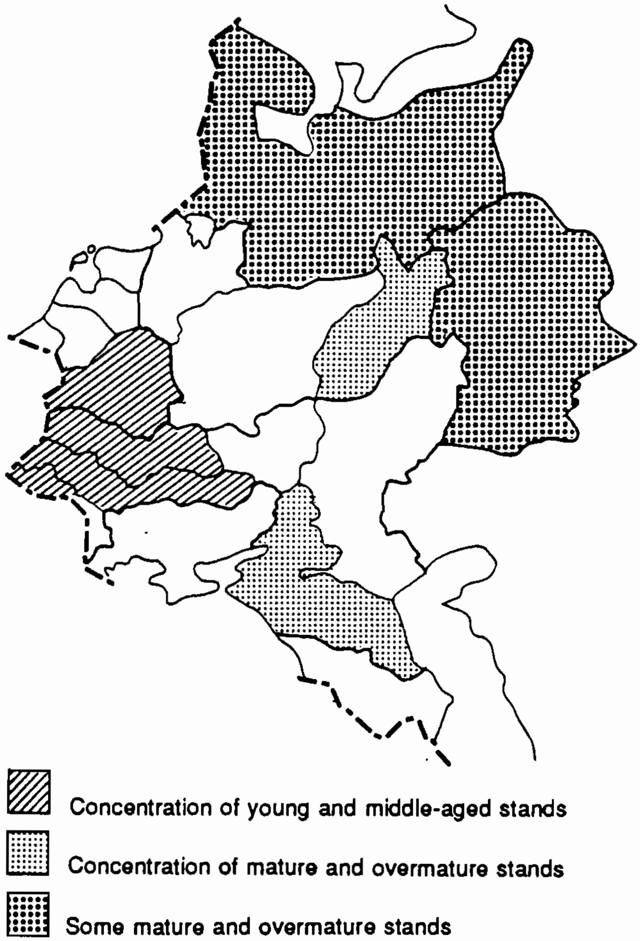

Figure 2.6. The principal forest age-class structure of commercial forests in the economic regions of the European USSR.

infrastructure of the European USSR. For more detailed descriptions of age-class distributions for aggregates and individual regions see Chapter 5 and Appendix A.

2.6 Standing Volume

The data on mean growing stock are given in *Table 2.7.* The data do not significantly deviate from data on standing volume in other European countries

Table 2.7. Volume data on commercial forests in the regions of the European USSR.

	Mean growing stock (m^3 ha^{-1})				Total growing stock (mill. m^3)	
		Deciduous				
Region	Coniferous	Soft	Hard	Average	Coniferous	Deciduous
North	129	63	0	63	6,339	736
Northwest	132	132	0	132	456	291
Central	166	126	196	129	898	716
Pre-Baltic	117	132	164	140	7	13
Volgo-Vratsky	144	126	123	126	704	590
Central Chernozyomny	166	104	141	131	45	81
Povolzhsky	139	129	106	119	103	246
Ural	141	114	120	114	1,957	1,272
North Caucasia	363	135	245	219	30	287
Carpathians (Ukraine)	276	155	247	244	65	86
Polesye (Ukraine)	166	111	147	127	211	89
Forest Steppe (Ukraine)	189	202	175	182	92	145
Moldavia	23	0	118	118	0.07	17
Byelorussia	147	134	126	133	534	227
Estonia	106	108	139	108	58	31
Latvia	168	155	0	155	148	65
Lithuania	194	163	130	160	135	61
All regions	138	105	166	112	11,781	4,953

and regions (see also Nilsson *et al.*, 1992). For example, in the Nordic countries the mean growing stock is 93 cubic meters per hectare while it is 116 and 132 cubic meters per hectare, respectively, for the Northern and Northwestern regions of the USSR. A comparison of Poland and Byelorussia gives similar results: 163 and 142 cubic meters per hectare. Finally the total figures for the European USSR and the rest of Europe are strikingly similar: 122 and 129 cubic meters per hectare, respectively. One might conclude that the forest state of these areas are fairly similar.

The age-class characteristics give another picture of the conditions. Differences in the distributions of relative density of age class between the different regions within the European USSR are evident. These differences basically indicate a forest state in which the old forests of the Northern and Ural regions are understocked (have a relatively low density) while the majority of the young forests in the southwest (especially in the Ukraine) has a rather high relative density, which means that the stands are well stocked or even overstocked in relation to proper silviculture and management.

Table 2.8. Mean growth and the distribution of commercial forest area over site class in the regions of the European USSR.

Region	Mean growth (m^3 ha^{-1} yr^{-1})	Areal distribution of site classes (% of commercial forest area) Site class IA and better	Site class I	Site class II	Site class III	Site class IV	Site class V and worse
North	1.20	0.2	0.8	1.0	3.4	18.9	75.7
Northwest	2.75	0.3	9.0	42.4	28.7	10.4	9.2
Central	4.17	4.3	47.7	34.6	8.3	2.4	2.7
Pre-Baltic	4.48	2.8	33.0	44.2	15.7	2.6	1.7
Volgo-Vyatsky	3.58	1.4	19.2	37.1	28.7	10.2	3.5
Central Chernozyomny	4.75	8.9	31.6	37.4	19.2	2.8	0.0
Povolzhsky	4.21	3.1	21.2	32.9	28.2	12.8	1.8
Ural	2.55	0.0	2.0	19.8	34.0	24.0	20.2
North Caucasia	3.31	0.8	6.5	27.8	35.3	19.0	10.5
Carpathians (Ukraine)	7.86	16.1	59.9	20.4	3.4	0.1	0.0
Polesye (Ukraine)	3.91	9.2	32.7	38.6	12.6	3.5	3.4
Forest Steppe (Ukraine)	4.08	12.7	43.7	33.6	8.5	1.3	0.2
Moldavia	4.22	3.9	8.9	13.9	16.7	5.5	51.4
Byelorussia	4.21	5.6	35.3	42.4	11.9	3.1	1.7
Estonia	2.66	0.9	12.0	26.2	29.9	21.3	9.7
Latvia	4.05	11.4	29.6	31.9	16.5	8.5	2.1
Lithuania	3.16	6.9	24.5	37.8	23.5	5.8	1.5
All regions	2.36	1.5	10.6	16.8	14.7	15.9	40.6

Some exceptions to these age-class distributions exist. The first exception is the North Caucasian region which shows an extremely high figure for mean growing stock of coniferous. This is mainly due to the fact that a major part of the stands of this species group are very old. The very low figure for conifers in Moldavia, 23 cubic meters, is due to the young ages of these forests.

2.7 Growth and Site Classes

The mean growth of the forests of the European USSR (*Table 2.8*) is generally low in comparison with the forest in the rest of Europe. The figure for all USSR regions under study is 2.4 cubic meters per hectare per year while about 3.8 cubic meters per hectare per year (UN-ECE, 1986) is the mean forest growth for Europe excluding the USSR.

The foresters of the USSR are using a system with seven site classes, from class "IA and better" (the best site class) to class "VB and worse" (the worst site class), to describe the growth potentials at the single stand level. In this book the data for the original site classes have been aggregated into six classes in the analyses and simulations. The distribution of the forest area over the slightly aggregated classes are shown in *Table 2.8*.

From the table it is easy to conclude that a major reason for the relatively low overall growth figure for the European USSR is that over 40 percent of the forest land belongs to site class 6, which is due to the very large areas with poor growth conditions found in the Northern region. Good growth conditions, with potential annual growth exceeding five cubic meters per hectare per year, is found only in one region, the Carpathians, where spruce and beech forests grow at the rate of 7.9 cubic meters per hectare per year – a rate that is expected in similar Central European forests.

Chapter 3

Methods of Analysis

3.1 Conceptual Framework

The objective of this study is to describe the forest resources of the European USSR and to analyze possible futures for these resources. To present a dynamic description of the forests an assessment of future harvest potential is desirable. Through a simulation of possible development of the forests under different assumptions the potential can be determined. It should be pointed out that the concept of potential is in this context rather vague and undefined. We are seeking not a totally optimal cutting level, but rather a realistic high sustainable level of harvest which can be pursued under specific assumptions. These assumptions include harvesting strategies, silvicultural measures, and regeneration intensity. However, at the center of the analyses is the basic biological dynamics of the forest, expressed as growth level and the forests' response to silvicultural measures. Changes in the biological production process can of course be impelled by external factors like air pollution or climatic change.

3.2 Models

To carry out simulations of the development of forest resources under the different assumptions we need a model that can depict the forest's basic biological dynamics in a proper way, respond to different activities, and take into account changes in the environment.

Naturally the model must be estimated from available data, which implies that the model concept must correspond to the way the forests are described. The data available are described in Chapter 4. It can be concluded that all the forests are represented by data based on area characteristics.

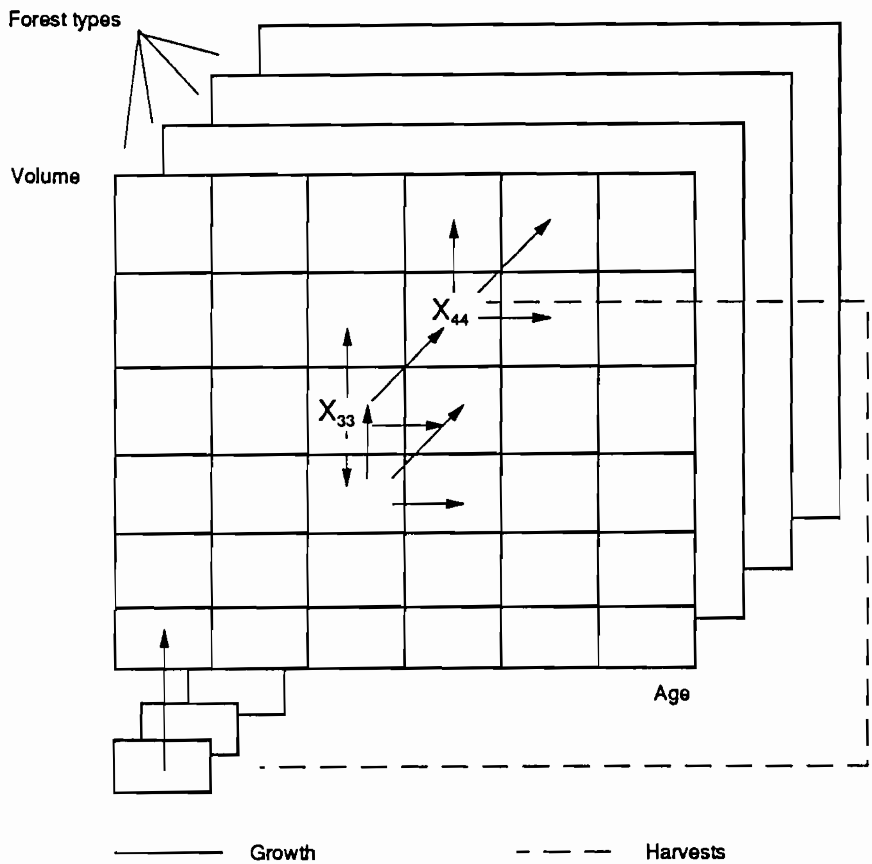

Figure 3.1. Transitions in the matrix model.

In other words, the description is based on data for specific areas and their features like standing volume, species composition, and growth.

Specific forest types are described by age and standing volume. A matrix defined by 10 intervals for the volume dimension and 14 intervals for the age dimension is defined for every forest type. The forest state is then depicted by area distributions over these matrices. The dynamics of volume increment are expressed as transitions of areas between the fixed states in the matrices (*Figure 3.1*).

Harvest and regeneration activities are introduced through controlled transitions. Thinnings are expressed as the fraction of the area residing in a cell of the age-volume matrix that is thinned. This area is moved one step down in the volume dimension, thus simulating the harvest of the difference in volume between the cells, whereupon the area grows in a normal way. An area unit that is clear-cut is moved to a bare class, the transitions out of which are controlled by a *young forest* coefficient. This coefficient then expresses the intensity and quality of regeneration efforts. A more extensive discussion of the area-matrix model and its characteristics is found in Sallnäs (1990).

3.3 Forest Description

As indicated in Section 3.2, an age-volume matrix is established for every forest type. The concept of forest type is used for a stratum that is defined by region, forest group (for definition see Chapter 2), site class, and species. The level of aggregation into forest types is dependent on available data. In Chapter 4 the data available for the European USSR are described in detail. The overall structure of the database linked to the model is illustrated in *Figure 3.2*.

To get a reasonable size of the model for the simulations, six site classes for every region were used. The other variables vary from region to region. In total 1,242 forest types were used to describe the forests of the European USSR.

3.4 Estimation of the Growth Model

Three sets of parameters must be given for the model:

- Parameters describing the forest state, such as area and standing volume, including data about the external changes to the initial conditions, such as changes in the forest land base.
- Parameters describing the biological dynamics, such as growth and site quality.
- Parameters describing activities and external factors influencing the dynamics.

3.5 State Description

In the database only figures for area and standing volume are available at the age-class level. This means that to use the model, a procedure has to be applied to produce a distribution of area over volume for each age class. When elaborating this procedure two assumptions are made:

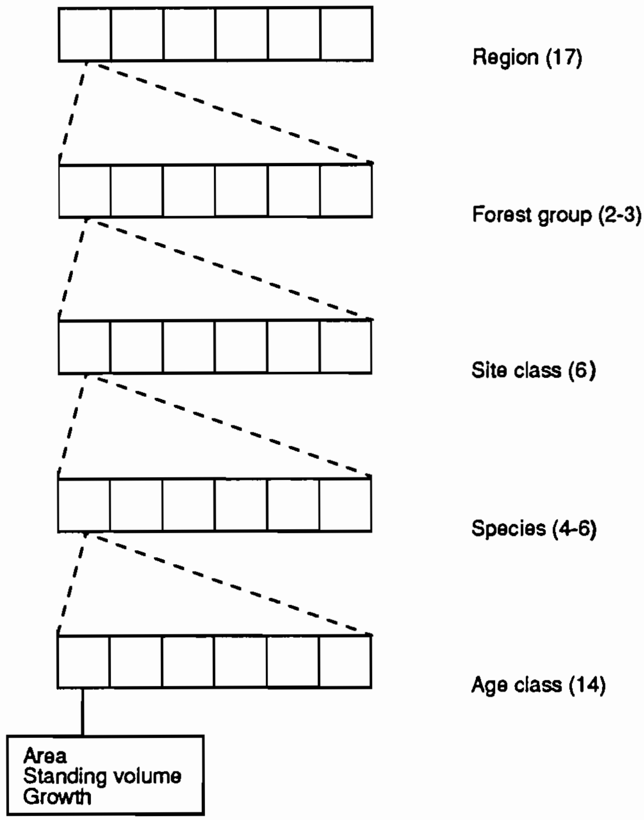

Figure 3.2. The structure of the database linked to the simulation model. Numbers in brackets indicate the number of classes used for the variable.

1. The standard deviation in relation to the mean volume per hectare is approximately the same for different areas with similar types of forest. Values for the coefficient of variation that were available for some regions were extrapolated to other regions.
2. The variance in volume per hectare increases with age. The relation between the variance and age must be established.

When the area distribution over volume classes is calculated, three variables are used: the mean volume per hectare, the coefficient of variation in volume per hectare, and the correlation between volume per hectare and age or transformations of age. The calculation is performed in four steps.

1. Calculate the variance in volume per hectare, using mean volume per hectare and the coefficient of variation:

   $$s^2 = (mv \times cv)^2 \ ,$$

   where cv is the coefficient of variation, mv is the mean volume per hectare, and s^2 is the variance in volume per hectare.
2. Calculate the conditional variance mean age:

   $$s^2_{ma} = (1 - r^2) \times s^2 \ ,$$

   where s^2_{ma} is the variance in volume per hectare mean age and r is the coefficient of correlation between age and volume per hectare.
3. Calculate the ratio of variance to age and use this ratio to calculate the variance in each age class:

   $$k = s^2_{ma}/ma \ .$$

   The variance in age class i is then

   $$s^2_i = k \times ma_i \ .$$

4. The class limits for the volume classes are calculated using the largest volume per hectare plus three times the largest standard deviation as the upper limit for the largest volume class. This span is then divided into a sequence of volume classes of increasing width. The distribution of area over the volume classes is calculated using the mean and the standard deviation of volume in each age class and a modified normal distribution. After analyses of available data it was decided to use ln (age) as a transformation of age in the calculations.

3.6 Biological Dynamics

The percent volume increment is estimated with functions of the following type:

$$I_v = a_0 + \frac{a_1}{T} + \frac{a_2}{T^2} \ ,$$

where I_v is the five-year volume increment in percent of the standing volume; T is the total stand age in years; and a_0, a_1, a_2 are coefficients.

The functions are estimated from data on age and percent volume increment. The percent volume increment is calculated on volume increment and standing volume (cubic meters per hectare). This means that each function is associated with a series of standing volume over age. As described in Section 3.2, a distribution over volume classes is created in the matrix. Consequently, the mean volume in an age-volume cell will deviate from the mean volume series. Accordingly, the percent volume increment will also deviate from the value given by the function, which means that some correction must be made. The correction is made according to:

$$I_{va} = I_{vf} \times \left(\frac{V_m}{V_a}\right)^{\beta} ,$$

where I_{va} is the five-year percent volume increment for actual standing volume; I_{vf} is the five-year percent volume increment given by the function; V_a is the actual standing volume (cubic meters per hectare); V_m is the standing volume (cubic meters per hectare) from the mean volume series; and β is the parameter that describes the relation between relative standing volume and relative volume increment. From studies of this relation in yield tables and data available for this study, the value of the parameter ranges from 0.25 to 0.45, depending on species and site classification.

3.7 Management Activities

Management is controlled in two levels in the model. First, a basic management program is defined for each forest type. In this program the thinning, final felling, and regeneration are included.

Thinnings are expressed as a percent of growth in each forecast period. This percentage of growth is then converted in the forecasting model to percentage of the area in a matrix cell to be thinned. The thinning percentages are extracted mainly from yield tables and depend on age, species, and site.

Thinning prognoses can be modified in the model by the algorithm

$$A_t = a + b \times \left(\frac{L}{c}\right)^{d} ,$$

where A_t is the proportion of the volume increment that is thinned; L is the number of the age class; and a, b, c, d are parameters that can be changed.

The final felling in forests with even-aged stands is performed using stand age as a criterion for harvest. First, an age is set when final felling can occur. Then, the felling profile of the age classes above this age limit is defined. The amount of final felling in each forecast period (usually five years) is expressed as a proportion of the area in each cell. The following algorithm is used:

$$L \succeq c; \quad A_t = a + b \times (L - c) ,$$

where A_t is the portion of area that will be felled in one forecast period; L is the age-class number; c is the first age class where final felling is performed; and a, b are coefficients that depend on species, site class, and other information about silviculture regimes.

The regeneration intensity is expressed by a coefficient controlling the transition rate from the barren class to the ordinary matrix. The values range between 0.4 and 0.9 depending on region and species.

These expressions are supposed to correspond to an ideal management program. If these programs are applied at an aggregated level, the resulting cutting profiles over time will be quite uncontrolled, since in many cases the present forest state does not correspond to ideal management. Therefore, a second management programs is introduced. Here, a total harvest level, differentiated among species groups and type of harvests (e.g., thinning, final felling), can be prescribed. In each period, the activity structure defined by the handbook program is shifted upward or downward to meet the cutting levels prescribed.

3.8 Line of Analysis

A handbook program is formulated for every forest type. The programs are based on the recommendations issued by Soviet foresters, although it is well known that these recommendations are not always converted into action.

Final fellings in the handbook programs are strictly carried out according to an age-dependent harvest intensity. No discrimination is made between different forest groups.

Thinnings are carried out according to recommendations, in the sense that they are focused on well-stocked stands. The main discrimination is thus over the volume dimension, so that stands with a density below 0.5 are not thinned at all, while above this limit the thinning intensity is increased with increased stocking level. In all cases full regeneration is assumed to take place.

The general objective of this work is to illustrate possible future developments of the forest resources under specific assumptions. Using the defined management programs as a base, different scenarios have been formulated, aimed at illustrating different possible developments of the forest resources. By simulating the development of the forest resources under different management programs, with or without further restrictions, it is possible to analyze the possible outcome of the forest management. The simulations and scenarios used in the study are further discussed in Chapter 5 and in Appendix A.

Chapter 4

Basic Data Collection and Regional Aggregation

The structure of the analytical tool used for the analyses has been described in the Chapter 3. Linked to this tool is the tailor-made database also described in Chapter 3. The basic data collection for generation of the database has been carried out by the All-Union Scientific Research Information Center for Forest Resources of the USSR State Forest Committee (today known as the Russian Research Center for Forest Resources, VNIIZ Lesresurs).

To create the structure of the database the basic data were collected from two different methods: (1) sample plot information used in the forest management plans at the enterprise level and (2) data from the State Forest Account (SFA) supplemented with information from sample plots collected for forest management plans at the enterprise level.

The first method was employed for Byelorussia, Lithuania, Polesye, and the Forest Steppe region (Ukraine). The second method was used for the rest of the regions.

The first method implies that areas (A_i) and volumes (V_i) for all sample plots in homogeneous strata defined by species groups, site classes, and specific age classes were totaled. The mean standing volume ($\overline{v}$) per strata was then determined by dividing the total volume by the total area according to

$$\overline{v} = \frac{\sum V_i}{\sum A_i} , \tag{4.1}$$

where i is the number of the sample in the strata. The increment for each strata was calculated on the following formulas:

$$Z_D = Z_N(2.0 - 1.0 \times d)d \tag{4.2}$$

for stands with shade tolerant species and

$$Z_D = Z_N(1.7 - 0.7 \times d)d \tag{4.3}$$

for stands with shade intolerant species. In these equations Z_D is the increment for the actual strata; Z_N is the increment for stands with a volume density of 1; and d is the mean volume density.

For the regions where basic data were collected and calculated according to the second method, complete detailed field data for all individual strata were missing for the detailed age-class distribution used. The age-class distribution available in existing data (SFA) only deals with the classification of young, middle-aged, premature, mature, and overmature stands. Hence, field information was lacking for a 10-year age-class distribution. In this case the information from the State Forest Account was basically employed for the rough age-class distribution. To achieve a distribution over the 10-year age classes all sample plots from 15 to 20 of the most representative forest enterprises for each region were used. The forest enterprises selected had established new management plans within the last five years. The information attained from these sample plots was used to generate a percentage distribution over 10-year age classes.

The current increment and mean volume per strata were evaluated according to equations (4.1) to (4.3). But for regions and species with no field information on the increment data, the increment was taken from yield tables adjusted for the density monitored in the field. The data collected for the database reflect the conditions from January 1988, and encompass the forest resources registered by the Soviet Forest Legislation at that time. Thus, forests belonging to collective farms are not included in the databases. Areas registered by the legislation may have changed in individual republics due to the ongoing transition of the USSR. *Table 4.1* illustrates the disaggregation of the database employed by this study.

The basic analyses have been carried out for each of the 17 regions based on the specific regional data collected. To get an overview of future development possibilities of forest resources we have chosen to present first the results for aggregates of the economic regions (Chapter 5). We present the results for individual regions in Appendix A. However, it should be stressed that the forest resources in the USSR are very heterogeneous. Therefore, to get a complete picture of the resources, the aggregated results have to be studied in combination with the regional analyses presented in Appendix A.

It should be underlined that before this study a consistent database at this level had never been produced in the USSR. This is the first time detailed information of this kind has been made available both inside and outside the USSR.

Table 4.1. Disaggregation of the database.

Region	Number of forest groups	Number of site classes	Number of species groups	Number of age classes
North	3	6	4	14
Northwest	2	6	4	14
Central	3	6	6	14
Pre-Baltic	2	6	5	14
Volgo-Vyatsky	3	6	6	14
Central Chernozyomny	2	6	5	14
Povolzhsky	2	6	6	14
Ural	3	6	5	14
North Caucasia	2	6	8	14
Carpathians (Ukraine)	2	6	4	14
Polesye (Ukraine)	2	6	5	14
Forest Steppe (Ukraine)	2	6	7	14
Moldavia	2	6	6	14
Byelorussia	2	6	6	14
Estonia	2	6	5	14
Latvia	2	6	5	14
Lithuania	2	6	6	14

4.1 Aggregation of Economic Regions

The aggregation of the economic regions (see *Figure 2.3*) can be based on many different factors. Important parameters for the aggregation are the following:

- Total direct demand for forest industrial products and indirect demand for forest resources.
- Density of population per area unit, illustrating the pressure on the forest resources.
- General-purpose road, logging road, and railroad densities.
- Forest industrial capacities.
- Availability of forest resources.
- Ecological status.
- Administrative borders.
- Status of trade and economy.
- Status of the socioeconomic factors.

The current population and infrastructure in the different economic regions of the European USSR are presented in *Table 4.2*. The general-purpose road density in *Table 4.2* is calculated on the basis of total land area of the

Table 4.2. Population and infrastructure of regions in the European USSR.

Region	Population (1,000)	Density of population (persons km^{-2})	Road length (km): General-purpose roads: Roads	Road length (km): General-purpose roads: Railroads	Road length (km): Logging roads: Roads	Road length (km): Logging roads: Railroads	Road density (m ha^{-1}): General-purpose roads: Roads	Road density (m ha^{-1}): General-purpose roads: Railroads	Road density (m ha^{-1}): Logging roads: Roads	Road density (m ha^{-1}): Logging roads: Railroads	Total density of roads
North	6,069	4	27,706	6,668	55,602	5,555	0.19	0.05	0.73	0.070	1.04
Northwest	8,200	42	22,775	971	16,179	1,301	1.16	0.05	1.56	0.130	2.90
Central	29,964	62	46,281	5,915	59,816	1,684	0.95	0.12	2.94	0.080	4.09
Pre-Baltic	857	57	1,589	191	1,708		1.05	0.13	6.33		7.51
Volgo-Vyatsky	8,396	32	26,742	2,831	36,968	2,510	1.02	0.11	2.78	0.190	4.10
Central Chernozyomny	7,661	46	14,586	1,161	8,030	110	0.87	0.07	5.46	0.070	6.47
Povolzhsky	16,212	30	24,129	1,135	28,278	15	0.45	0.02	5.93	0.003	6.40
Ural	20,116	24	83,590	6,933	85,431	4,981	1.01	0.08	2.42	0.140	3.65
North Caucasia	16,473	46	12,365	704	12,857	80	0.63	0.02	3.51	0.020	4.18
Ukraine[a]	51,201	149	34,072	3,642	64,646	586	1.91	0.02	8.67	0.080	10.68
Moldavia	4,185	124	3,703	137	1,358		0.21	0.01	4.24		4.46
Byelorussia	10,078	49	25,633	2,168	100,093	31	1.24	0.10	14.24	0.004	15.58
Estonia	1,556	35	3,231	441	9,495		0.72	0.09	5.25		6.06
Latvia	2,647	42	3,116		9,997		0.69		3.77		4.46
Lithuania	3,641	56	3,702	862	26,776		0.57	0.13	14.71		15.41

[a]Total Ukraine including the regions UKC, UKP, and UKS.
Sources: Goskomles, 1988; Goskomstat, 1988.

Table 4.3. Aggregation of economic regions based on total population, in millions of inhabitants.

Region	Population
Pre-Baltic	0.9
Estonia	1.6
Latvia	2.7
Lithuania	3.6
Moldavia	4.2
North	6.1
Central Chernozyomny	7.7
Northwest	8.2
Volgo-Vyatsky	8.4
Byelorussia	10.1
Povolzhsky	16.1
North Caucasia	16.5
Ural	20.1
Central	30.0
Ukraine	51.2

regions. The logging road density is calculated on the basis of the Forest Fund areas of the regions (for definition see Appendix B).

4.2 Population

The population is concentrated in the southern and central parts of the European USSR. There also is a rather large population in the Ural region. Based on the total population figures (*Table 4.2*) five different groups of regions are identified (*Table 4.3*).

The Northern region is scarcely populated. The highest density is found in the southern part of the region. A rather high density of population is found in the central parts of the European USSR and in the Baltic republics. By studying the population density (*Table 4.2*) four groups can be identified (*Table 4.4*).

4.3 Infrastructure

The definition of infrastructure in this study is limited to the density of railroads, general-purpose roads, and logging roads. Normally, several parameters are included in the conception of infrastructure, such as vehicle density, intensity of infrastructure usage, intensity of goods transport, time

Table 4.4. Aggregation of economic regions based on population density, in persons per square kilometers.

Region	Population density
North	4
Ural	24
Povolzhsky	30
Volgo-Vyatsky	32
Estonia	35
Latvia	42
Northwest	42
Central Chernozyomny	46
North Caucasia	46
Byelorussia	49
Lithuania	56
Pre-Baltic	57
Central	62
Moldavia	124
Ukraine	149

span for transportation of difficult products, flows of information and goods, in-migration and out-migration, energy production and consumption, and spatial interaction with other regions.

However, it has not been possible to access regional information on these parameters in this study. The USSR has the largest inland waterway transportation system in the world. Blaha and Kahn (1991) estimate the total network at 146,000 kilometers. They point out that a unique system of canals has recently been completed in the European USSR. However, this waterway network is not included in the current density of the transportation network (*Table 4.5*).

Blaha and Kahn (1991) point out that the highway network in the USSR is small and the railway shipments encounter big problems. The problems are caused by a lack of capital investments, aging rolling stock, a shortage of 800,000 freight cars, out-of-date locomotives, and substandard railroad tracks. Only 60 to 70 percent of the requirements for new railroads have been satisfied. Loading and unloading equipment is far from sufficient, and labor turnover is high. To update the railway system about 150 billion rubles (1989 ruble value) must be invested during the next 10 years.

In the USSR, the average one-way transport distance by truck from the forests to a reloading point or directly to the industry is estimated at 55.1 kilometers; the same distance by narrow-ranged railway is 53.6 kilometers.

Table 4.5. Current density of the transportation network, in meters per hectare.

Region	Total road density (general-purpose roads, logging roads, railroads)
North	1.04
Northwest	2.90
Ural	3.65
Central	4.09
Volgo-Vyatsky	4.10
North Caucasia	4.18
Moldavia	4.46
Latvia	4.46
Estonia	6.06
Povolzhsky	6.40
Central Chernozyomny	6.47
Pre-Baltic	7.51
Ukraine	10.68
Lithuania	15.41
Byelorussia	15.58

About 65 percent of the roundwood is transported via reloading points at railroads and 29 percent via reloading points at waterways. It means that only 6 percent of the harvested volume in the USSR is transported directly from forests to industry. These average distances are estimated to increase by one kilometer per year. The average total one-way roundwood transport distance from the forests to industry is estimated at between 1,200 and 1,700 kilometers in the USSR. This estimate also includes transports from the Ural to the Baltic republics.

At present, the average forest road density in the USSR (all types of forest roads) is estimated at 3.58 kilometers per 1,000 harvested cubic meters of wood (0.58 kilometers on a firm surface). For sufficiently structured transportation, a density of 5.25 kilometers (1.52 kilometers on a firm surface) per 1,000 cubic meters of harvested wood is required. To meet future demands, about 30,000 kilometers of forest roads per year must be built during the next 20 years (16,000 kilometers of roads on a firm surface).

Taking road and railway density into account, less-developed infrastructure is found in the Northern, Northwestern, and Ural regions (see *Table 4.5*). The best-developed infrastructure is found in the Central and Baltic republics and in the southern parts of the European USSR. The information about infrastructure (expressed as total road density) indicates an aggregation into five groups (*Table 4.5*).

4.4 Forest Industrial Capacity

The industrial capacities of the regional forest in 1988, expressed as roundwood consumption equivalents and in million cubic meters, are presented in *Table 4.6*. The big forest industrial centers are in the Northern and the Ural regions. The central parts of Ukraine also have a fairly well-developed industrial capacity. The major part of the total industrial capacity is within the mechanical wood industry (44 percent). The capacity of the pulp industry is surprisingly low; it constitutes only 8.5 percent of the total capacity. This is a strong indication that the industry is mainly directed toward bulk production and not directed to higher value-added production. High proportions of the industrial capacity are allocated within the energy (17 percent) and other industrial (25 percent) sectors. These figures are very high in comparison with the rest of Europe.

From *Table 4.6* it can be seen that about 90 percent of the capacity of the pulp industry is located in the Northern, Ural, and Pre-Baltic regions, with capacities of other industrial branches following the actual distribution of the regional forest resources more closely. The major wood consumer is the mechanical wood industry (almost 45 percent). The consumption in the pulp industry is about 9 percent of the total industrial capacity. The capacities for energy production constitutes about 17 percent of the total capacity. The consumption capacity of wood in the chemical industry and other industries is high, about 31 percent of the total forest industrial capacities. Based on the statistics on the regional industrial capacities five groups can be identified (*Table 4.7*).

4.5 Commercial Forests and the Status of Trade and the Economy

If the commercial forest areas in *Table 2.5* are studied a grouping of six aggregates can be identified (*Table 4.8*).

Trade and economic factors are difficult to quantify, and there are difficulties in obtaining relevant statistics for the regions discussed and analyzed in this book. Wolf (1991) has presented some data on some of the regions concerning trade. This information is presented in *Table 4.9*.

One of the major problems with trade in the USSR is that many products come from factories dedicated to making only one specific product, which

Table 4.6. Industrial capacities, in million cubic meters of roundwood equivalents in 1988.

Region	Mechanical wood industry	Pulp industry	Chemical industry	Other industries	Wood for energy	Total
North	24.98	14.01	1.52	11.02	10.39	61.92
Northwest	5.32	0.31	0.30	3.15	2.00	11.08
Central	14.14	–	1.82	8.34	5.30	29.60
Pre-Baltic	4.80	2.93	1.12	3.89	3.16	15.90
Volgo-Vyatsky	10.94	0.18	1.31	8.13	5.44	26.00
Central Chernozyomny	1.64	–	0.06	1.08	0.52	3.30
Povolzhsky	5.12	0.09	0.68	4.52	3.08	13.49
Ural	23.38	3.69	2.12	12.10	9.30	50.59
North Caucasia	3.50	–	0.78	2.53	1.14	7.95
Ukraine[a]	12.85	0.52	1.93	8.21	1.78	25.29
Moldavia	0.60	–	0.12	0.30	0.02	1.04
Byelorussia	5.88	0.18	0.84	1.45	0.84	9.19
Estonia	1.59	0.48	0.35	0.67	0.57	3.66
Latvia	1.58	–	0.32	2.02	1.84	5.76
Lithuania	1.59	0.38	0.44	0.86	0.67	3.94
Total	117.91	22.77	13.71	68.27	46.05	268.71
Percentage	44.00%	8.50%	5.10%	25.20%	17.20%	

[a]Total Ukraine including the regions UKC, UKP, and UKS.

Source: All-Union Scientific Research Information Center for Forest Resources of the USSR, the USSR State Forest Committee.

Table 4.7. Aggregation of economic regions based on industrial capacities, in million roundwood equivalents per year.

Region	Total industrial capacity (mill. m^3)	Primary forest industry (mill. m^3 yr^{-1})
Moldavia	1.04	0.60
Central Chernozyomny	3.30	1.64
Estonia	3.66	2.07
Lithuania	3.94	1.97
Latvia	5.76	1.58
North Caucasia	7.95	3.50
Byelorussia	9.19	6.06
Northwest	11.08	5.63
Povolzhsky	13.49	5.21
Pre-Baltic	15.10	7.73
Ukraine	25.29	13.37
Volgo-Vyatsky	26.00	11.12
Central	29.60	14.14
Ural	50.59	27.07
North	61.92	38.99

results in complicated distribution under conditions with an inefficient infrastructure (IMF, 1990a; CIA, 1991). Another problem with analyses of trade is that the USSR is so large that it is difficult to obtain trade statistics for the subregions. Also there are large variations in the trade in the subregions. However, most of the trade is internal trade.

European banks have developed specific checklists of the socioeconomic status of different regions of the USSR to be used in investment analysis of these regions (see Deutsche Bank, 1991 and Hoorn, 1991). A sample checklist is presented in *Table 4.10*. Again, it must be kept in mind that it has only been possible to carry out a ranking for total Russia and large differences exist between subregions of the USSR. Based on this ranking, it can be seen that the Ukraine, the Baltic republics, and Russia have the best socioeconomic status of the regions under study.

4.6 Final Aggregation

We have combined the factors discussed in this chapter with the vegetation zones presented in *Figure 2.2* and the administrative borders of the economic regions presented in *Figure 2.3* and have arrived at the five aggregates in

Table 4.8. Aggregation of economic regions based on commercial forest area, in millions of hectares.

Region	Commercial forest area
Moldavia	0.15
Pre-Baltic	0.16
Carpathians	0.69
Estonia	0.84
Central Chernozyomny	0.90
Lithuania	1.10
Latvia	1.30
Forest Steppe	1.30
North Caucasia	1.40
Polesye	2.00
Povolzhsky	2.80
Byelorussia	5.30
Northwest	5.70
Volgo-Vyatsky	9.60
Central	10.90
Ural	25.10
North	60.80

Table 4.9. Data on Soviet trade in some regions in 1989.

	Export as a percentage of NMP[a]		Internal trade balances (billion rubles at
Region	Internal	External	world market prices)
Russia	18.0	8.6	28.5
Ukraine	39.1	6.7	−3.9
Byelorussia	69.6	6.5	−2.2
Estonia	66.5	7.4	−1.1
Latvia	64.1	5.7	−1.4
Lithuania	60.9	5.9	−3.3
Moldavia	62.1	3.4	−1.5
Georgia	53.7	3.9	−1.5
Armenia	63.7	1.4	−0.3

[a]NMP = Net Material Product excluding nonmaterial services.
Source: Wolf, 1991.

Table 4.10. Ranking of socioeconomic factors of individual regions in the USSR.

Factor	Strong socioeconomic status				Moderate socioeconomic status			
	Ukraine	Estonia, Latvia, Lithuania	Russia	Georgia	Byelorussia	Moldavia	Armenia	Azerbaijan
Degree of industrialization	9	10	8	6	8	2	3	3
Profit potential of industry	6	5	6	3	4	2	1	2
Agriculture production	10	8	6	7	5	9	3	3
Profit potential of agriculture	6	3	3	6	3	7	1	2
Degree of self-sufficiency of industrial goods	7	6	8	3	5	2	1	2
Availability of minerals	8	0	10	4	1	0	4	7
Profit potential of minerals	8	0	10	4	0	0	4	8
Market-orientated outlook	3	10	2	9	3	5	8	2
Proximity to Western Europe	6	10	4	6	7	7	6	4
Educational level of population	6	9	5	5	7	5	4	4
Homogeneous population	6	6	5	2	6	2	6	6
Infrastructure	8	10	5	6	6	8	6	4
Total ranking	83	77	72	61	55	49	47	47

10 points = good potential; 5 points = moderate potential; 0 points = no potential.
Source: Deutsche Bank, 1991; Hoorn, 1991.

Table 4.11. Final aggregation of economic regions.

Northern aggregate	=	Northern region
Central aggregate	=	Northwestern, Central, and Volgo-Vyatsky regions
Baltic aggregate	=	Pre-Baltic, Estonia, Latvia, Lithuania, and Byelorussia regions
Ural aggregate	=	Ural region
Southern aggregate	=	Central Chernozyomny, Povolzhsky, North Caucasian, Carpathians, Polesye, Forest Steppe, and Moldavia regions

Table 4.12. Commercial forest areas of aggregates of the European USSR, in thousands of hectares.

		Deciduous		
Region	Coniferous	Hard[a]	Soft[b]	Total
Northern aggregate	49,140	0	11,676	60,816
Central aggregate	13,751	480	11,951	26,182
Baltic aggregate	5,820	282	2,609	8,711
Ural aggregate	13,876	505	10,628	25,009
Southern aggregate	3,087	3,700	2,288	9,075
Total	85,674	4,967	39,152	129,793

[a]Beech, oak, ash, locust, hornbeam, etc.
[b]Birch, aspen, alder, willow, poplar, etc.

Table 4.11. These aggregates will be used for the overall presentation of our analyses.

The commercial forest areas (industrial forests) for the five aggregates are presented in *Table 4.12*. The Northern aggregate is too large. As illustrated earlier this aggregate consists of only the Northern economic region. It would have been desirable to break down this region into several suitable subregions. However, this was not compatible with the aim of generating a consistent database for all of the European USSR. A map of the final aggregates is presented in *Figure 4.1*.

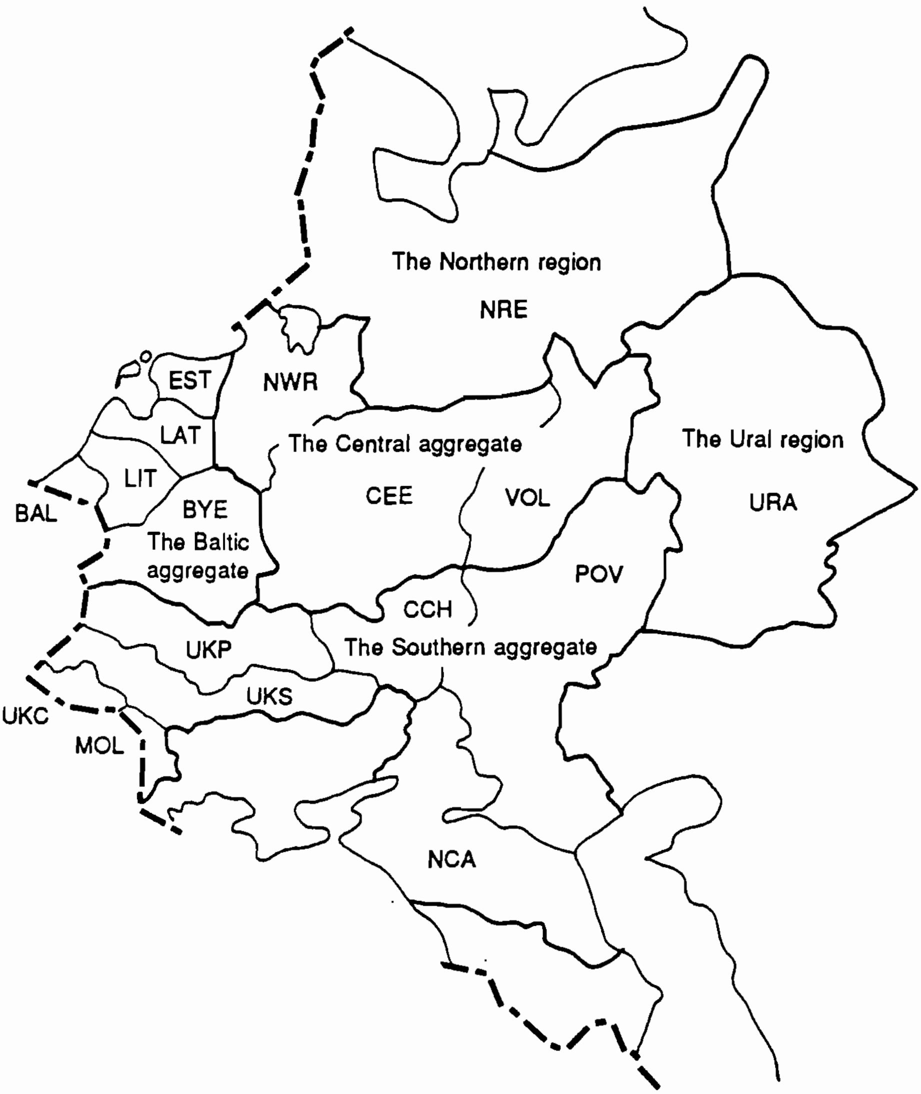

Figure 4.1. The basic regions of the European USSR and the aggregates employed in the study.

Chapter 5

Basic Results for Aggregates

The basic analyses of the future development of the forest resources, expressed as biological potential wood supply, consists of two scenarios: (1) handbook silviculture and (2) Forest Study estimates of reasonable future silviculture and harvest levels. In contrast to the study for Western and Eastern Europe (Nilsson *et al.*, 1992) no scenario according to the European Timber Trend Study (ETTS-IV) harvesting level is carried out in the analyses for the European USSR. The reason for this is that the ETTS-IV study did not present any estimates of the future harvest level for the USSR (UN, 1986). A later study (UN, 1989a) did present an analysis on the future harvesting possibilities, but it only dealt with the total USSR; information on the European USSR could not be identified or separated from the total aggregate.

For both scenarios and for each species or aggregate of species in each economic region (defined in Chapter 2), specific silviculture and management programs are defined. These programs are based on existing practices and possible future changes. The basic information about the management practices has been collected by the All-Union Scientific Research Information Center for Forest Resources of the USSR. This basic information has been used by the IIASA Forest Study team to calculate and design the management programs into the form required by the Timber Assessment Model (Chapter 3). The major components of a silviculture program in a scenario are reforestation and harvests; the latter component is disaggregated into thinnings and final fellings.

In the simulations it is assumed that stipulated reforestation in the different management programs in the future will be carried out. As illustrated

Table 5.1. Recommended management program for spruce stands on poor site.

Region	Final felling age	Number of thinnings per rotation period	Thinning intensity (%)
Northern region of USSR	121–160	4–7	10–25
Northern Sweden	110–120	1–2	30–35

in Chapter 1 doubts remain on whether stipulated reforestation has been carried out in the USSR.

The recommended silvicultural management in the European USSR differs from that in the rest of Europe. This is a result of the ecological conditions and traditions in forest management (Chapters 1 and 2). The number of thinnings during a rotation period is higher in the European USSR, but the harvested volume is much lower than in the rest of Europe. In many cases, the rotation periods are longer in the European USSR. To identify these differences, the recommended management program for spruce stands on a poor site in the Northern region of the USSR and northern Sweden is given in *Table 5.1*. It should be noted that the programs carried out in the USSR are less intensive than those presented in *Table 5.1*.

The two basic scenarios, with the assumption of no forest decline from air pollutants, are intended to show how growing stock and potential wood supply can evolve under different silvicultural programs. It is very important to underline that the scenarios present biological potential wood supplies. Many factors can restrict the actual harvest or limit the possibilities of the harvested wood reaching the market or the final consumers (Chapter 1). These factors have not been taken into account in the two scenarios. Thus, the scenarios illustrate the biological, sustainable cutting level.

The simulations have a time horizon of 100 years, beginning in 1988. The forest areas presented in *Table 2.3* are used throughout the basic analyses with no changes in the land base over time. Soviet researchers have reviewed and contributed to the simulations (scenarios). Based on these reviews, all scenarios were rerun. We present the final results of the simulation in this chapter.

5.1 Basic Scenarios

In the Basic Handbook Scenario the forests in each economic region are treated at the stand level strictly in accordance with the silviculture programs that have been defined as ideal by Soviet researchers. Handbook silviculture means the ideal silvicultural programs that should be practiced under normal conditions in the forests of the various economic regions. In this scenario, the handbook silviculture rules have been applied, beginning in the first five-year period over the entire 100 years, regardless of the degree to which they were actually applied. The results from this scenario are the starting point and the framework for the formulation of alternative scenarios. The results from this approach show the degree to which the actual forest structure in each economic region matches an *ideal* structure (that is, if ideal silviculture had been applied) which in turn indicates the degree to which forest policies incorporating ideal silviculture have been implemented in the various economic regions.

The objective of the Basic Forest Study Scenario is to strive for consistently high sustainable levels of both growing stock and harvests over the total simulation horizon of 100 years. Handbook silviculture is implemented, to the extent possible, under these two constraints (high and even levels of harvests and growing stock).

In Chapter 2 two regions that feature a forest state that differs from the other regions were identified. A large proportion of *old growth* forests is evident. In an area like this, two crucial question are relevant to forest management: Should the old forest be eradicated? If so, inside which time horizon should this be done? The Basic Forest Study Scenario, characterized by a nondecreasing stock and an even harvest path, is in these cases not very appropriate. Hence, for these regions the question of the liquidation of the old forests has been explicitly addressed in alternative scenarios. They are further described in the context of results for individual regions in Appendix A.

5.2 Guide to the Results

In this chapter, we focus on the basic simulation results for the aggregates. The five aggregates (Northern, Central, Baltic, Ural, and Southern) have been defined in Chapter 4 and mapped in *Figure 4.1*. For each aggregate, and for the European USSR as a whole, we present two tables and three sets of diagrams. The tables and diagrams convey information from the two scenarios. *Tables 5.2* to *5.7* present selected scenario data on growing stock and annual harvest volumes at the beginning of the simulation and at specific points during the simulations. These data are also contained in the diagrams, but are provided in tabular form for convenient numerical comparison. The growing stock and potential harvest level is expressed in cubic meters over bark. Bar charts on projected development of annual growing stock and annual harvest levels for each five-year period are given for all forests (*Figures 5.1, 5.4, 5.8, 5.12, 5.16, 5.20*), coniferous forests (*Figures 5.2, 5.5, 5.9, 5.13, 5.17, 5.21*), soft deciduous forests (*Figures 5.3, 5.6, 5.10, 5.14, 5.18, 5.22*), and hard deciduous forests (*Figures 5.7, 5.11, 5.15, 5.19, 5.23*). The results for the individual economic regions are presented in Appendix A.

5.2.1 Northern aggregate (Table 5.2 and Figures 5.1 to 5.3)

The Northern region is the only economic region in the Northern aggregate. There are big variations in the forest conditions between subregions of the Northern region, but there were no possibilities of getting consistent data for the subregions of the Northern region. Subregional problems with the wood supply may be hidden behind the aggregated information for the total Northern aggregate. Due to the age structure in the Northern aggregate there are many alternative ways of achieving a sustainable development of growing stock and future harvest. The conditions used in the Basic Forest Study Scenario are in line with the future forest policy developed by the USSR authorities. Alternative ways of achieving sustainable development of growing stock and harvests are presented in Appendix A.

The results for total forests using the Basic Handbook Scenario clearly illustrate that the forests of the Northern aggregate do not have a structure corresponding to an implementation of ideal silviculture programs. Many overmature forests are located in this aggregate. This is evident from the extremely high harvest pulse in the beginning of the simulation period (*Figures 5.1* to *5.3*). The principal pattern is the same for both coniferous and deciduous species but most pronounced for coniferous species, which constitutes 90 percent of the growing stock in the Northern aggregate.

Thus, the crucial point in formulating a realistic management policy (the Basic Forest Study Scenario) is to liquidate the overmature forests. The Basic Forest Study Scenario gives a slight increase of the harvest level over time. Both basic scenarios generate a decrease in the growing stock over the simulation period, but this is not an indication that the long-term sustainability of the growing stock is threatened. It is an effect of the existing age-class distribution, which will result in a fluctuating growing stock over a period of time longer than 100 years (which is the simulation horizon) under sustainable management. The effects of the reconstruction on the growing stock will be visible later due to slow growth and long rotation periods in the Northern aggregate. The average total growth rate is only 1.2 cubic meters over bark (o.b.) per hectare per year (the Basic Forest Study Scenario) in this aggregate.

Table 5.2. Northern aggregate.

	Basic Handbook	Basic Forest Study
Selected data on harvests and growing stock		
Total		
Growing stock[a]	116–80	116–82
Fellings[b]		
Year 1	889.4	88.2
Year 40	53.6	95.9
Year 80	88.8	97.2
Coniferous		
Growing stock[a]	129–87	129–86
Fellings[b]		
Year 1	835.2	76.0
Year 40	38.2	81.4
Year 80	72.6	82.0
Soft deciduous		
Growing stock[a]	63–51	63–64
Fellings[b]		
Year 1	54.2	12.2
Year 40	15.4	14.5
Year 80	16.2	15.2
Hard deciduous		
Growing stock[a]	0–0	0–0
Fellings[b]		
Year 1	0.0	0.0
Year 40	0.0	0.0
Year 80	0.0	0.0
Summary of results		
Potential harvest (mill. m^3 o.b. yr^{-1})[c]		
Total	116.3	95.2
Coniferous	98.5	80.8
Soft deciduous	17.8	14.4
Hard deciduous	0.0	0.0
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]		
Total	1.6	1.2
Coniferous	1.6	1.2
Soft deciduous	1.4	1.2
Hard deciduous	0.0	0.0
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)		
Total	116–80	116–82
Coniferous	129–87	129–86
Soft deciduous	63–51	63–64
Hard deciduous	0–0	0–0

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

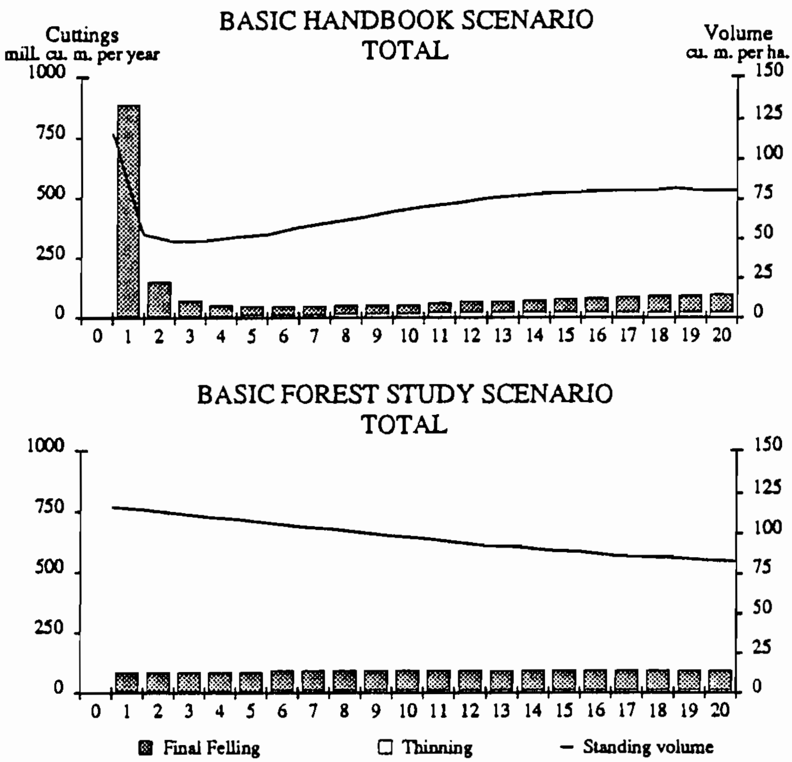

Figure 5.1. Projections of total potential harvest and growing stock in the Northern aggregate under the basic scenarios. Current fellings are 82.5 million cubic meters o.b.

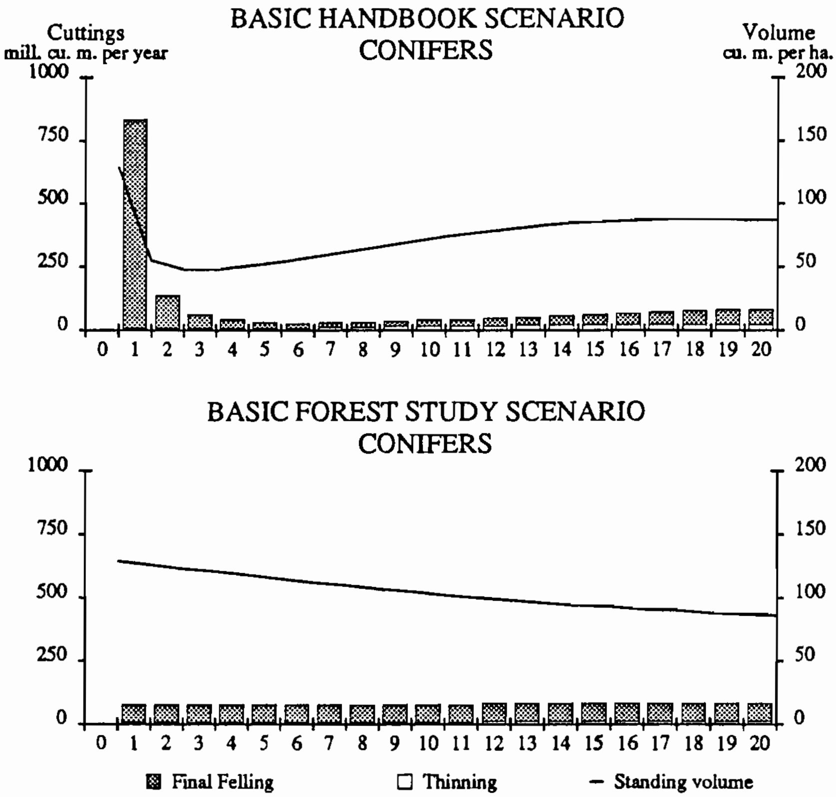

Figure 5.2. Projections of potential harvest and growing stock of coniferous species in the Northern aggregate under the basic scenarios. Current fellings are 70.4 million cubic meters o.b.

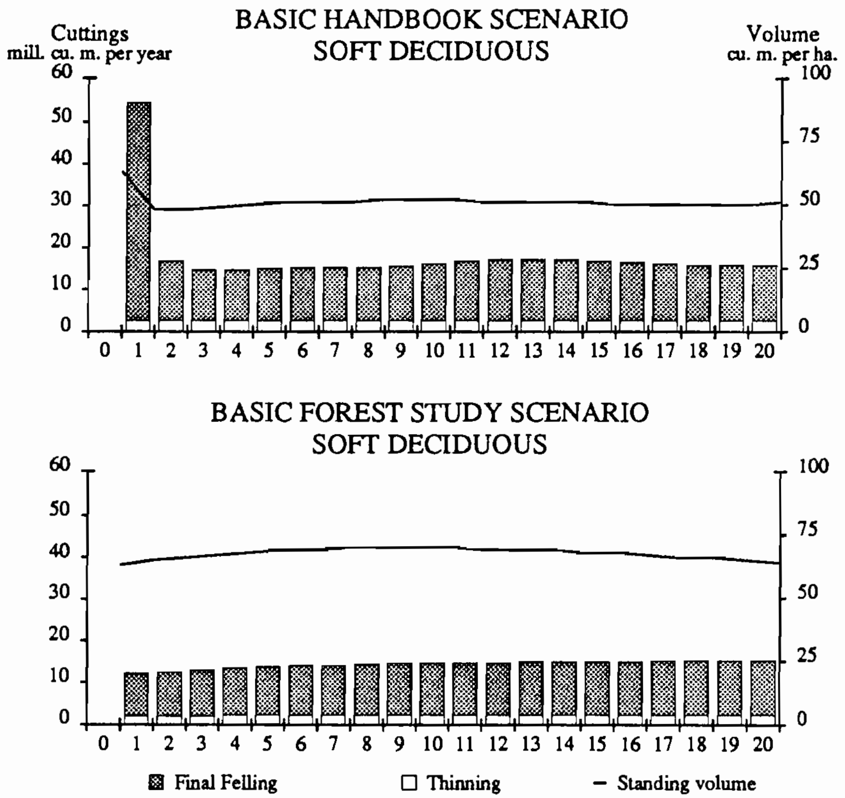

Figure 5.3. Projections of potential harvest and growing stock of soft deciduous species in the Northern aggregate under the basic scenarios. Current fellings are 12.1 million cubic meters o.b.

The Basic Handbook Scenario gives a higher average total potential harvest (some 20 million cubic meters per year) than the Basic Forest Study Scenario. The average total growth rate during the simulation period is also higher in the Basic Handbook Scenario (1.6 cubic meters per hectare for the Handbook Scenario and 1.2 cubic meters per hectare for the Forest Study Scenario). The average growing stock is similar at the end of the two simulations, but the time paths are quite different.

Thus, we estimate that the Northern aggregate can sustain an average total harvest of 95 million cubic meters o.b. per hectare for each year over 100 years. The corresponding figures for coniferous and deciduous (only soft deciduous such as birch, aspen, alder, willow, poplar) species are 81 and 14 million cubic meters o.b. per hectare per year respectively. With a more intensive harvest of overmature forest in the beginning of the simulation period, the sustainable total potential harvest could be further increased, which is illustrated in Appendix A.

5.2.2 Central aggregate (Table 5.3 and Figures 5.4 to 5.7)

In the Central aggregate there is an overall discord between the initial structure of the forest resources and the structure that would develop if handbook silviculture were implemented. In the Basic Handbook Scenario a harvest pulse in the beginning of the simulation period is obtained which is not possible to carry out due to physical limitations. The pattern is the same for coniferous and deciduous species. The pulses, however, are not very pronounced, so the initial structure differs quite substantially from that of the Northern aggregate. The Basic Forest Study Scenario generates a slight increase over time in the harvests but at a much more stable level than under handbook conditions throughout the simulation. In the Basic Handbook Scenario the growing-stock level is about the same at the end of the simulation period as in the beginning. The exception is the development of the growing stock for hard deciduous species for which a decrease is observed over the simulation period. The Basic Forest Study Scenario generates an even development of the growing stock, at the same level as the initial level for the handbook conditions, for all species.

The average growth rate and average potential harvest for the whole simulation period is slightly lower in the Basic Forest Study Scenario than in the Basic Handbook Scenario. The differences are 0.1 cubic meters o.b. per hectare for each year (total growth), about 7 million cubic meters o.b. per year (total harvest). Thus, we estimate the average total potential harvest to be 89.3 million cubic meters o.b. per year in the Central aggregate. The corresponding figures for the different species groups are 44.3 million cubic

Table 5.3. Central aggregate.

	Basic Handbook	Basic Forest Study
Selected data on harvests and growing stock		
Total		
Growing stock[a]	140–141	140–157
Fellings[b]		
Year 1	171.00	88.10
Year 40	90.30	89.80
Year 80	93.70	90.00
Coniferous		
Growing stock[a]	150–149	150–167
Fellings[b]		
Year 1	95.90	43.50
Year 40	43.80	44.60
Year 80	47.80	44.60
Soft deciduous		
Growing stock[a]	127–131	127–144
Fellings[b]		
Year 1	72.50	43.50
Year 40	45.10	44.10
Year 80	44.70	44.30
Hard deciduous		
Growing stock[a]	162–119	162–161
Fellings[b]		
Year 1	2.60	1.10
Year 40	1.40	1.10
Year 80	1.20	1.10
Summary of results		
Potential harvest (mill. m^3 o.b. yr^{-1})[c]		
Total	96.40	89.30
Coniferous	48.80	44.30
Soft deciduous	46.20	43.90
Hard deciduous	1.40	1.10
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]		
Total	3.70	3.60
Coniferous	3.50	3.40
Soft deciduous	3.90	3.80
Hard deciduous	2.50	2.30
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)		
Total	140–141	140–157
Coniferous	150–149	150–167
Soft deciduous	127–131	127–144
Hard deciduous	162–119	162–161

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

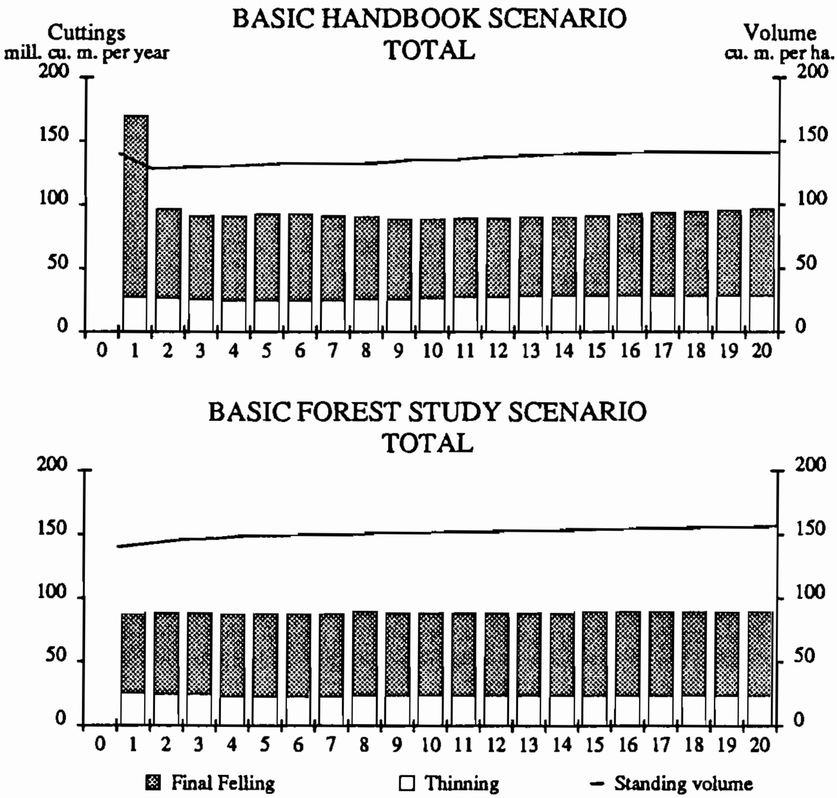

Figure 5.4. Projections of total potential harvest and growing stock in the Central aggregate under the basic scenarios. Current fellings are 69.7 million cubic meters o.b.

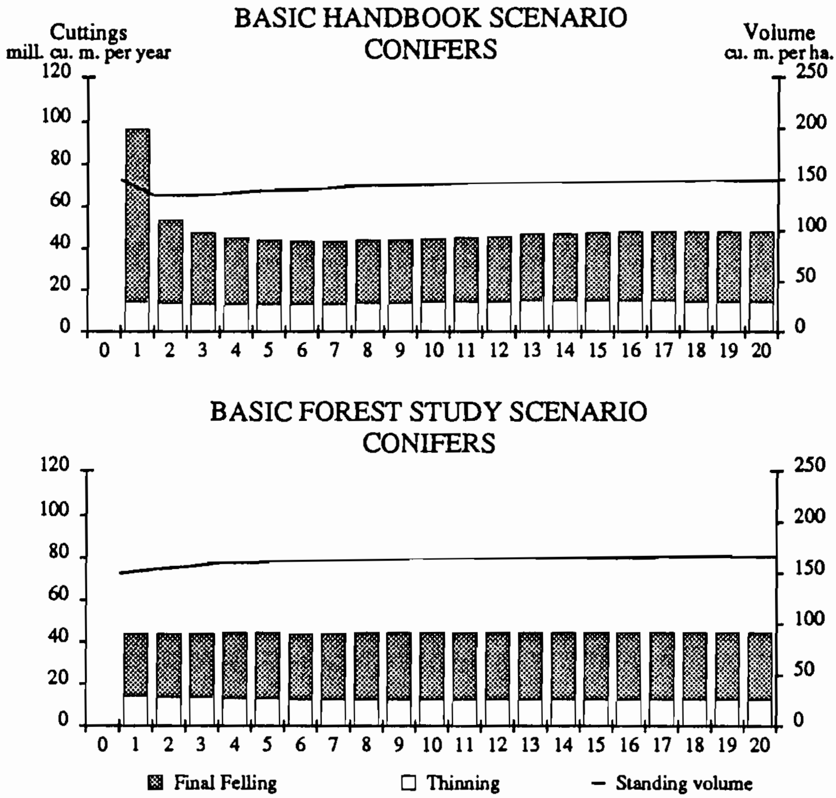

Figure 5.5. Projections of potential harvest and growing stock of coniferous species in the Central aggregate under the basic scenarios. Current fellings are 30.0 million cubic meters o.b.

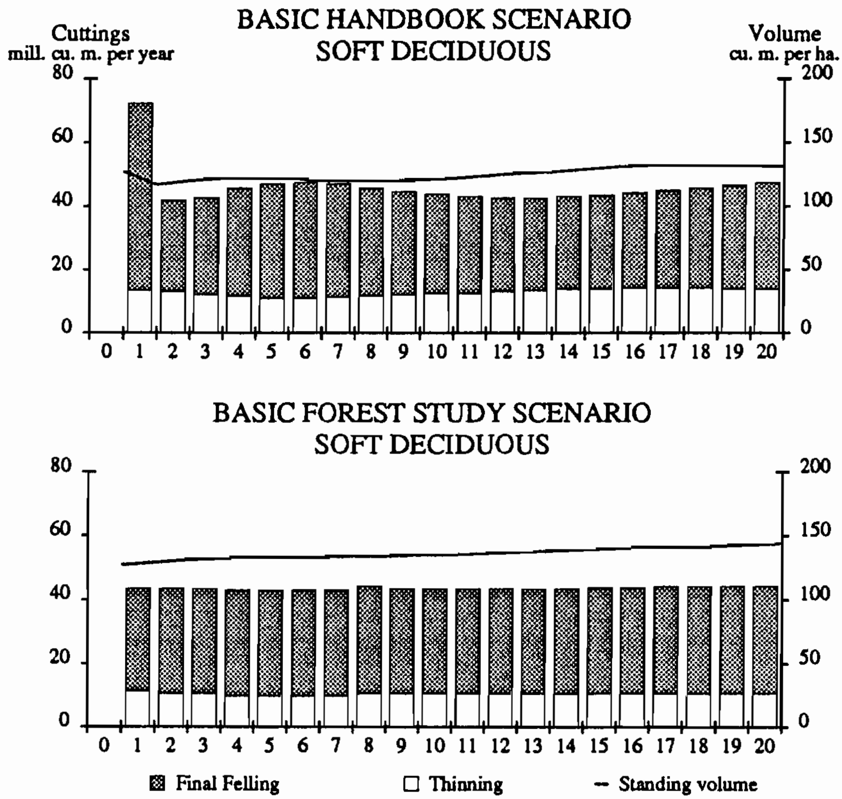

Figure 5.6. Projections of potential harvest and growing stock of soft deciduous species in the Central aggregate under the basic scenarios. Current fellings are 38.2 million cubic meters o.b.

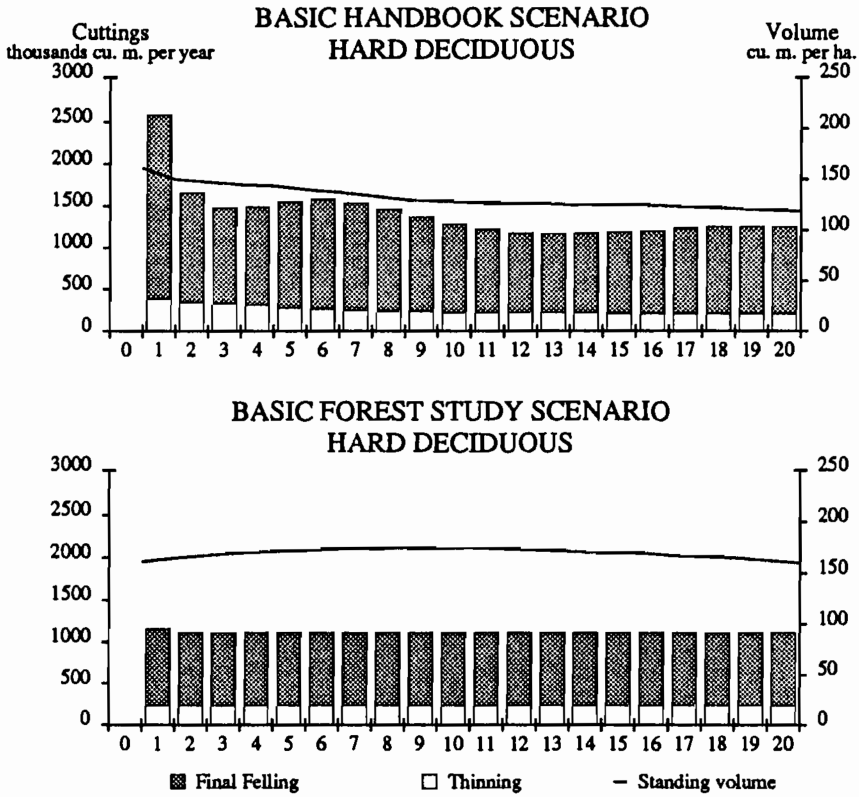

Figure 5.7. Projections of potential harvest and growing stock of hard deciduous species in the Central aggregate under the basic scenarios. Current fellings are 1.5 million cubic meters o.b.

meters o.b. per year for coniferous species, 43.9 million cubic meters o.b. per year for soft deciduous species, and 1.1 million cubic meters o.b. per year for hard deciduous species.

5.2.3 Baltic aggregate (Table 5.4 and Figures 5.8 to 5.11)

In the Baltic aggregate there is a much more even initial age structure of the forest resources in comparison with the Northern and Central aggregates. This is reflected in the Basic Handbook Scenario without the initial harvest pulse. Due to the age structure, there is a peak in the harvests in the middle of the simulation period. This is valid for coniferous and soft deciduous species, the major types in the aggregate. The growing stock also has a rather stable development during the simulation period in this scenario.

However, the potential harvest level shows rather big fluctuations over time in the Basic Handbook Scenario. These fluctuations should not be allowed. The Basic Forest Study Scenario has an objective of generating a more even harvest potential over time. This scenario also generates an increase of the growing stock over the simulation period.

The better balance in the initial forest structure is reflected in the differences between the two scenarios concerning average potential harvests and average growth rates. The differences are not as big as those for the Northern and the Central aggregates. The average total harvest potential is 3 million cubic meters lower in the Basic Forest Study Scenario than in the Basic Handbook Scenario. The total average growth rate is about the same in the two scenarios. For coniferous and hard deciduous species the growth rate is lower in the Basic Handbook Scenario than in the Basic Forest Study Scenario.

Thus, we estimate the average total potential harvest to be 26.6 million cubic meters o.b. per year in the Baltic aggregate. The corresponding figures for the different species groups are 17.2 million cubic meters o.b. per year for coniferous species, 8.5 million cubic meters o.b. per year for soft deciduous species, and 0.9 million cubic meters o.b. per year for hard deciduous species.

5.2.4 Ural aggregate (Table 5.5 and Figures 5.12 to 5.15)

The Ural region is the only economic region in the Ural aggregate. This region has the same characteristics as the Northern aggregate, namely, many overmature forests and overharvests in subregions. Therefore, there are many alternatives for the establishment of a management policy with an objective of long-term sustainable development of growing stock and potential harvest. The management strategy chosen in the Basic Forest Study

Table 5.4. Baltic aggregate.

	Basic Handbook	Basic Forest Study
Selected data on harvests and growing stock		
Total		
Growing stock[a]	147–137	147–167
Fellings[b]		
Year 1	21.90	23.00
Year 40	35.20	27.20
Year 80	28.40	27.20
Coniferous		
Growing stock[a]	152–134	152–172
Fellings[b]		
Year 1	14.60	15.00
Year 40	21.80	17.60
Year 80	19.30	17.60
Soft deciduous		
Growing stock[a]	138–141	138–153
Fellings[b]		
Year 1	6.80	7.20
Year 40	12.50	8.70
Year 80	8.10	8.70
Hard deciduous		
Growing stock[a]	130–161	130–175
Fellings[b]		
Year 1	0.60	0.80
Year 40	0.90	0.90
Year 80	1.00	0.90
Summary of results		
Potential harvest (mill. m^3 o.b. yr^{-1})[c]		
Total	29.80	26.60
Coniferous	19.30	17.20
Soft deciduous	9.60	8.50
Hard deciduous	0.90	0.90
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]		
Total	3.30	3.30
Coniferous	3.10	3.20
Soft deciduous	3.70	3.40
Hard deciduous	3.30	3.50
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)		
Total	147–137	147–167
Coniferous	152–134	152–172
Soft deciduous	138–141	138–153
Hard deciduous	130–161	130–175

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

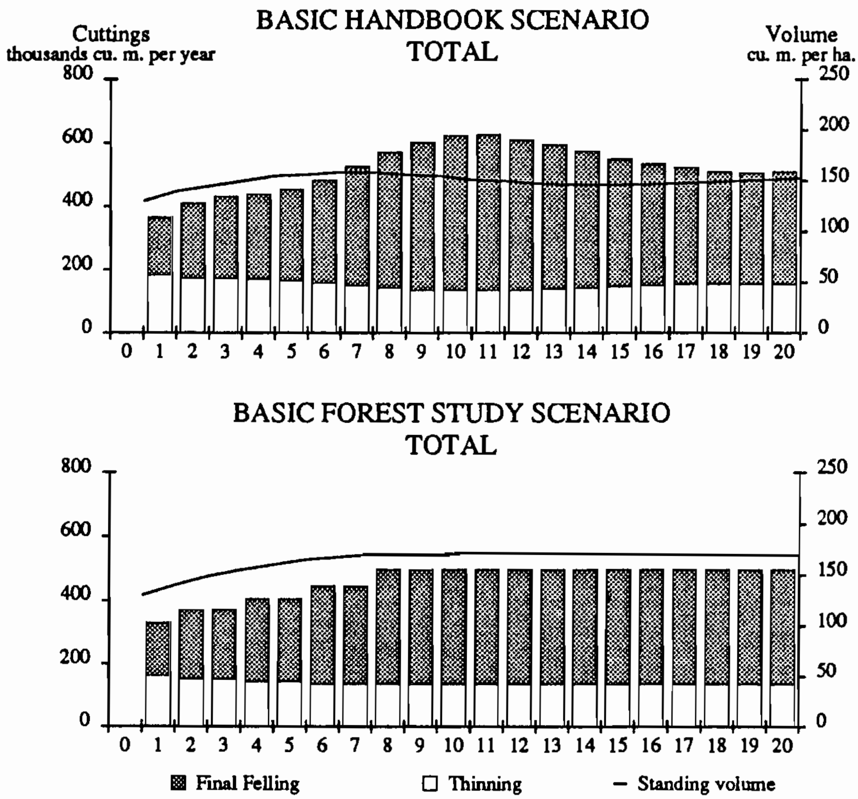

Figure 5.8. Projections of total potential harvest and growing stock in the Baltic aggregate under the basic scenarios. Current fellings are 18.7 million cubic meters o.b.

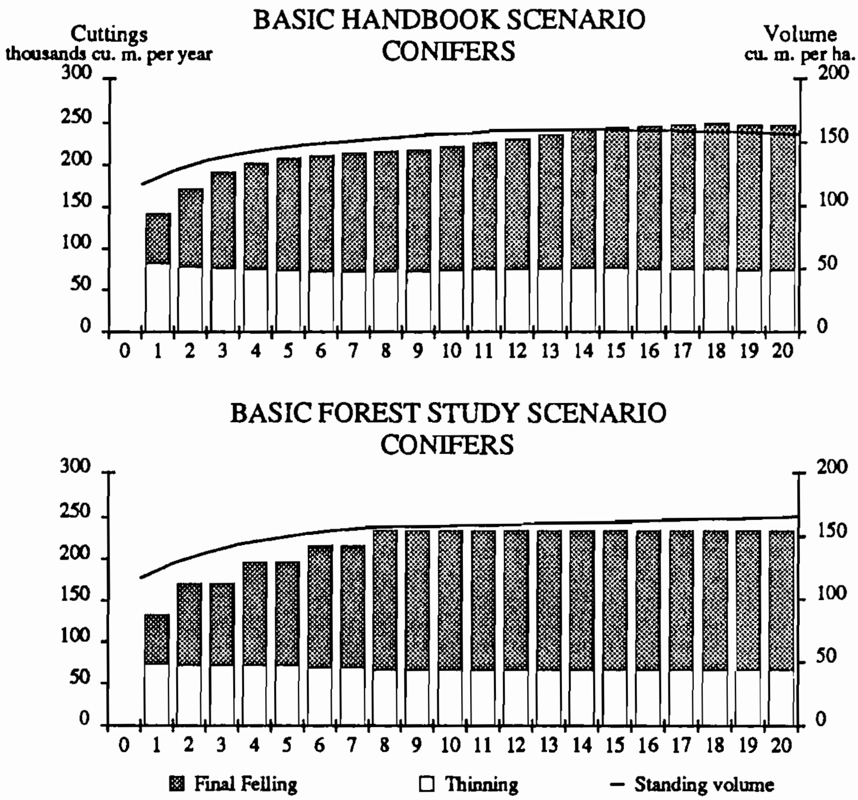

Figure 5.9. Projections of potential harvest and growing stock of coniferous species in the Baltic aggregate under the basic scenarios. Current fellings are 9.2 million cubic meters o.b.

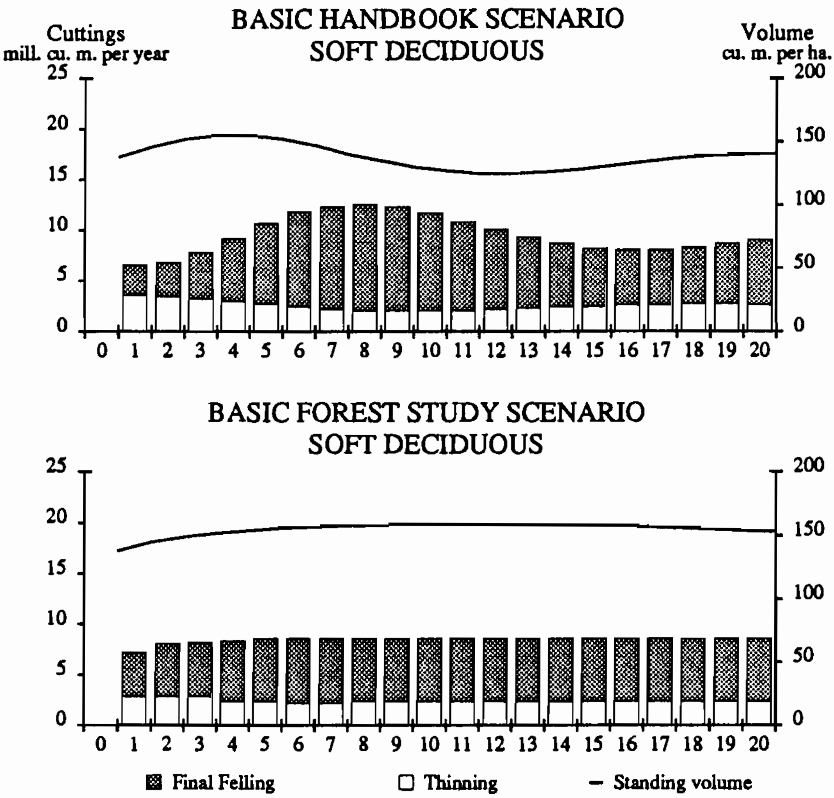

Figure 5.10. Projections of potential harvest and growing stock of soft deciduous species in the Baltic aggregate under the basic scenarios. Current fellings are 8.5 million cubic meters o.b.

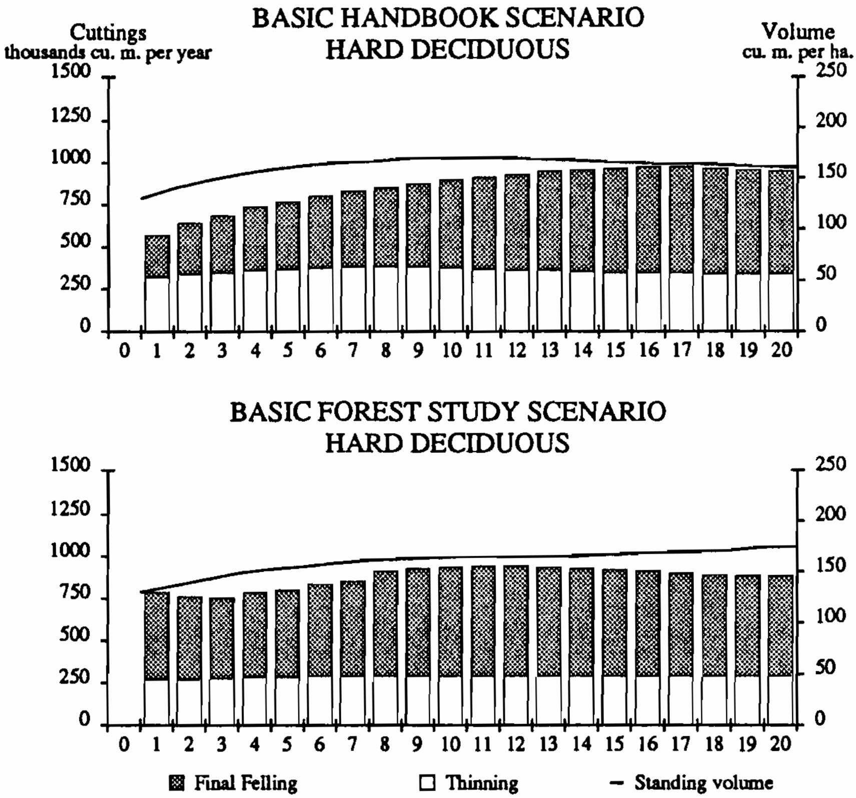

Figure 5.11. Projections of potential harvest and growing stock of hard deciduous species in the Baltic aggregate under the basic scenarios. Current fellings are 1.0 million cubic meters o.b.

Table 5.5. Ural aggregate.

	Basic Handbook	Basic Forest Study
Selected data on harvests and growing stock		
Total		
Growing stock[a]	129–114	129–113
Fellings[b]		
Year 1	277.0	74.2
Year 40	60.6	76.8
Year 80	74.4	75.5
Coniferous		
Growing stock[a]	141–117	141–113
Fellings[b]		
Year 1	178.8	37.0
Year 40	25.1	37.0
Year 80	35.5	37.0
Soft deciduous		
Growing stock[a]	114–111	114–114
Fellings[b]		
Year 1	92.7	36.0
Year 40	34.5	38.5
Year 80	37.3	37.2
Hard deciduous		
Growing stock[a]	120–95	120–91
Fellings[b]		
Year 1	5.5	1.2
Year 40	1.0	1.3
Year 80	1.6	1.3
Summary of results		
Potential harvest (mill. m^3 o.b. yr^{-1})[c]		
Total	78.5	76.0
Coniferous	39.1	37.0
Soft deciduous	37.8	37.7
Hard deciduous	1.6	1.3
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]		
Total	3.0	2.9
Coniferous	2.6	2.4
Soft deciduous	3.5	3.5
Hard deciduous	2.8	2.2
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)		
Total	129–114	129–113
Coniferous	141–117	141–113
Soft deciduous	114–111	114–114
Hard deciduous	120–95	120–91

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

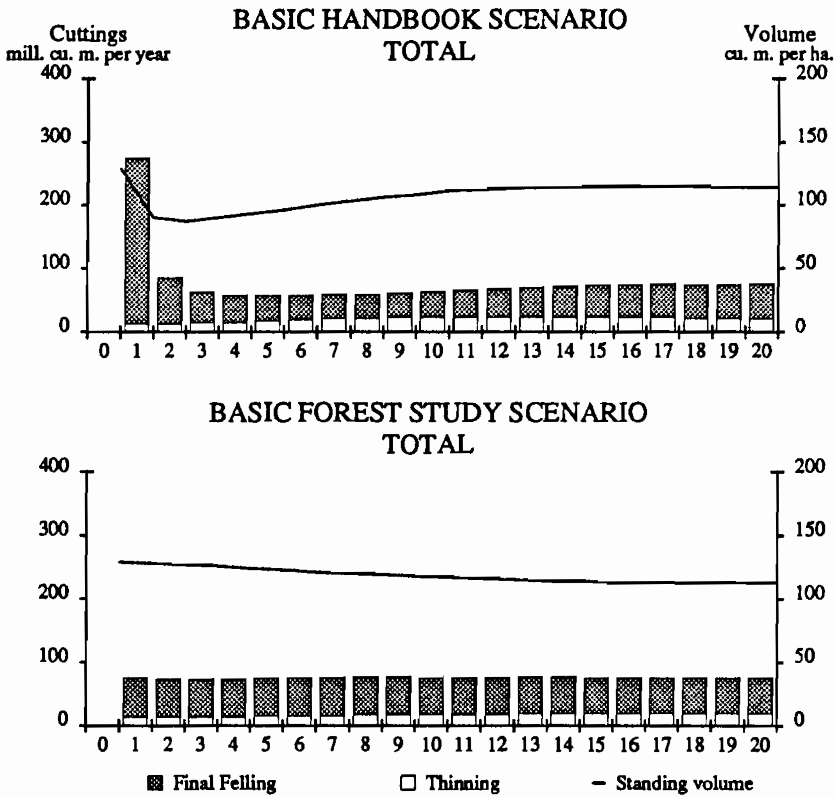

Figure 5.12. Projections of total potential harvest and growing stock in the Ural aggregate under the basic scenarios. Current fellings are 56.3 million cubic meters o.b.

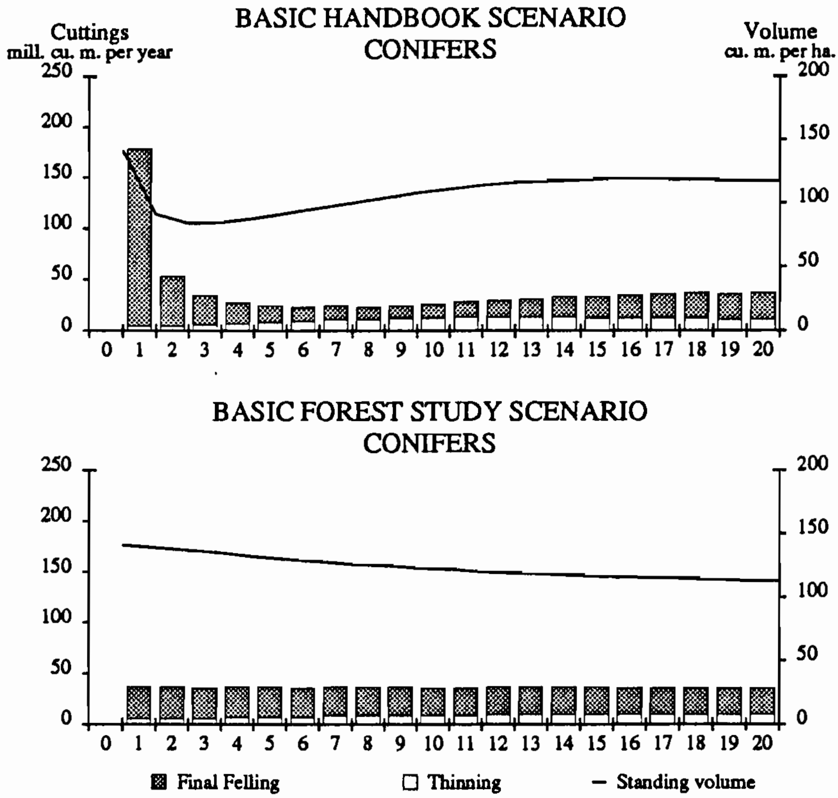

Figure 5.13. Projections of potential harvest and growing stock of coniferous species in the Ural aggregate under the basic scenarios. Current fellings are 33.0 million cubic meters o.b.

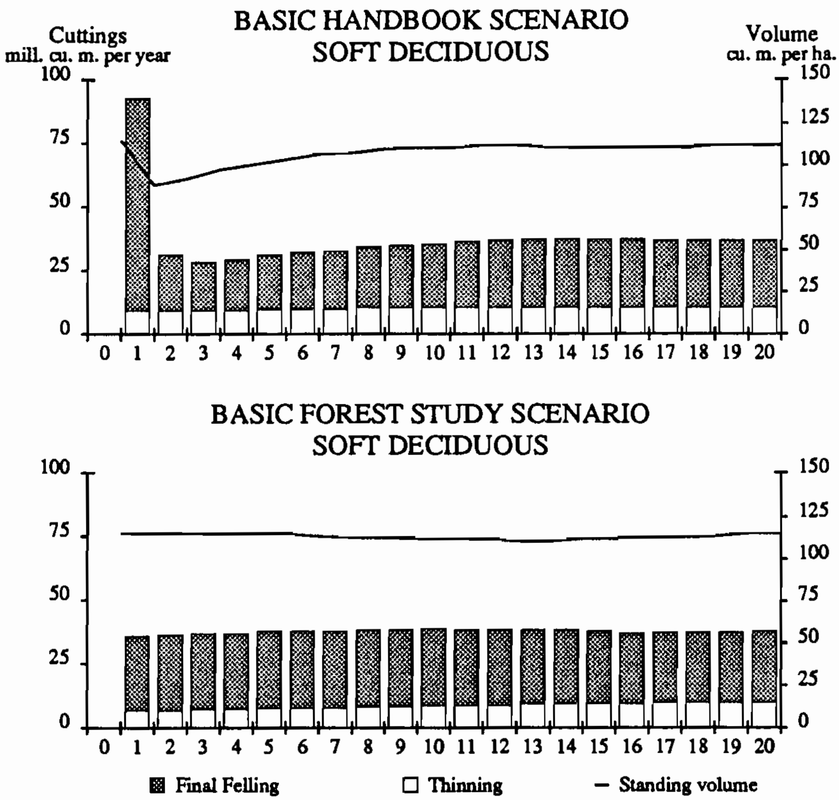

Figure 5.14. Projections of potential harvest and growing stock of soft deciduous species in the Ural aggregate under the basic scenarios. Current fellings are 22.5 million cubic meters o.b.

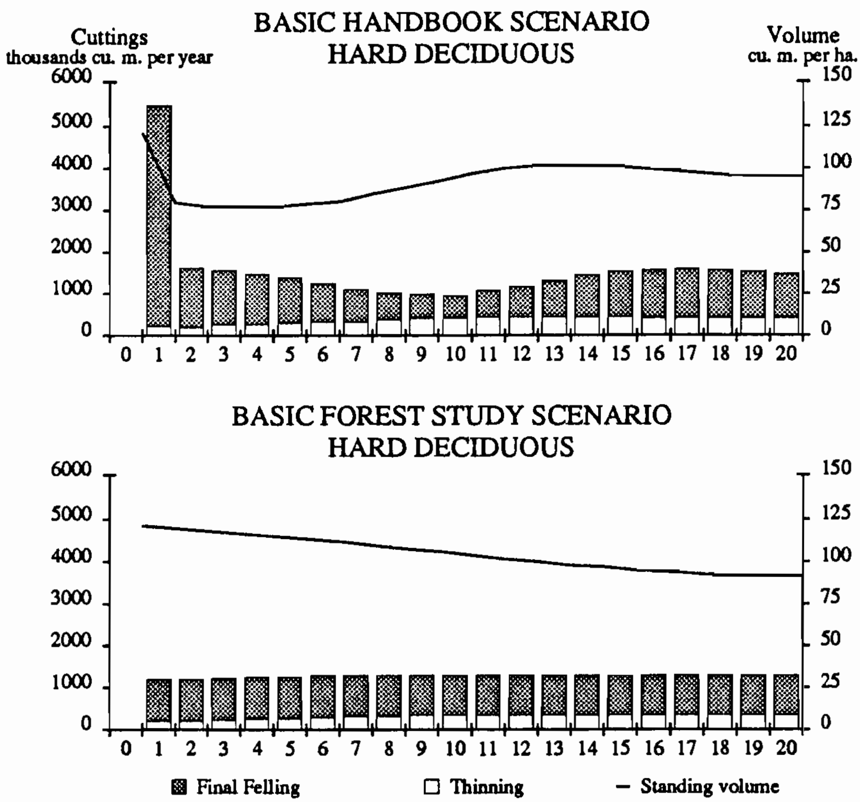

Figure 5.15. Projections of potential harvest and growing stock of hard deciduous species in the Ural aggregate under the basic scenarios. Current fellings are 0.8 million cubic meters o.b.

Scenario is the alternative which is most similar to the strategy identified as most suitable by Soviet researchers. Alternative management policies for the Ural region are presented in Appendix A.

The Basic Handbook Scenario shows a strong overall discord between the initial forest structure and the structure that would develop if handbook silviculture were implemented. This scenario generates a strong harvest pulse in the beginning of the simulation period. The growing stock declines over the simulation period. However, this decline does not indicate a collapse of the growing stock; it will again increase after the 100-year simulation period. This is an effect of the existing structure of the forest resources and the relatively low growth rate in the Ural aggregate.

The potential harvests show a much more stable level in the Basic Forest Study Scenario than under handbook conditions. This is valid for coniferous and soft deciduous species, the major species group. In this scenario there is a decline over time in coniferous and hard deciduous species.

The average growth rate is 0.1 cubic meters o.b. per hectare per year lower and the average total harvest potential is about 2.5 million cubic meters o.b. per year lower in the Basic Forest Study Scenario than in the Basic Handbook Scenario.

Thus, we estimate the average total harvest potential in the Ural aggregate to be 76.0 million cubic meters o.b. per year. The corresponding figures for the major species groups are 37.0 million cubic meters o.b. per year for coniferous species, 37.7 million cubic meters o.b. per year for soft deciduous species, and 1.3 million cubic meters o.b. per year for hard deciduous species.

5.2.5 Southern aggregate (Table 5.6 and Figures 5.16 to 5.19)

The Southern aggregate is dominated by young and middle-aged forests, but the hard deciduous species (beech, oak, ash, locust, and hornbeam) in this aggregate are mainly mature and overmature forests. This species group constitutes about one-third of the forests. The condition of this species is evident in the Basic Handbook Scenario by the harvest pulse in the beginning of the simulation period for hard deciduous species. For coniferous and soft deciduous species there is no such pronounced harvest pulse. The development of the growing stock for the coniferous and soft deciduous species is rather stable; the hard deciduous group declines over the simulation period. This is mainly a result of the harvest pulse in the beginning of the simulation.

Thus, for the group all species and hard deciduous species an uneven harvest pattern is observed over the simulation period in the Basic Handbook Scenario. A more even harvesting pattern over time is generated by the

Table 5.6. Southern aggregate.

	Basic Handbook	Basic Forest Study
Selected data on harvests and growing stock		
Total		
Growing stock[a]	165–158	165–195
Fellings[b]		
Year 1	48.30	29.90
Year 40	39.10	35.20
Year 80	38.10	35.20
Coniferous		
Growing stock[a]	177–176	177–231
Fellings[b]		
Year 1	14.00	10.50
Year 40	16.10	13.70
Year 80	14.60	13.70
Soft deciduous		
Growing stock[a]	131–141	131–154
Fellings[b]		
Year 1	11.70	7.90
Year 40	10.80	9.30
Year 80	9.70	9.30
Hard deciduous		
Growing stock[a]	176–153	176–189
Fellings[b]		
Year 1	22.60	11.50
Year 40	12.20	12.20
Year 80	13.80	12.20
Summary of results		
Potential harvest (mill. m^3 o.b. yr^{-1})[c]		
Total	38.30	34.20
Coniferous	14.50	13.00
Soft deciduous	10.10	9.10
Hard deciduous	13.70	12.10
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]		
Total	4.20	4.10
Coniferous	4.70	4.80
Soft deciduous	4.50	4.20
Hard deciduous	3.50	3.40
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)		
Total	165–158	165–195
Coniferous	177–176	177–231
Soft deciduous	131–141	131–154
Hard deciduous	176–153	176–189

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

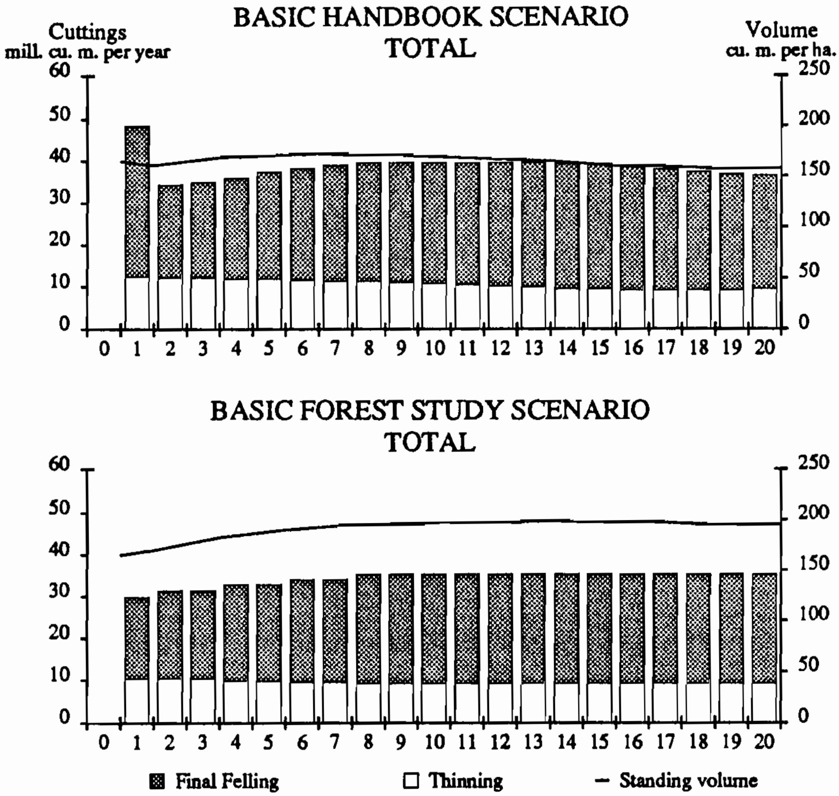

Figure 5.16. Projections of total potential harvest and growing stock in the Southern aggregate under the basic scenarios. Current fellings are 29.5 million cubic meters o.b.

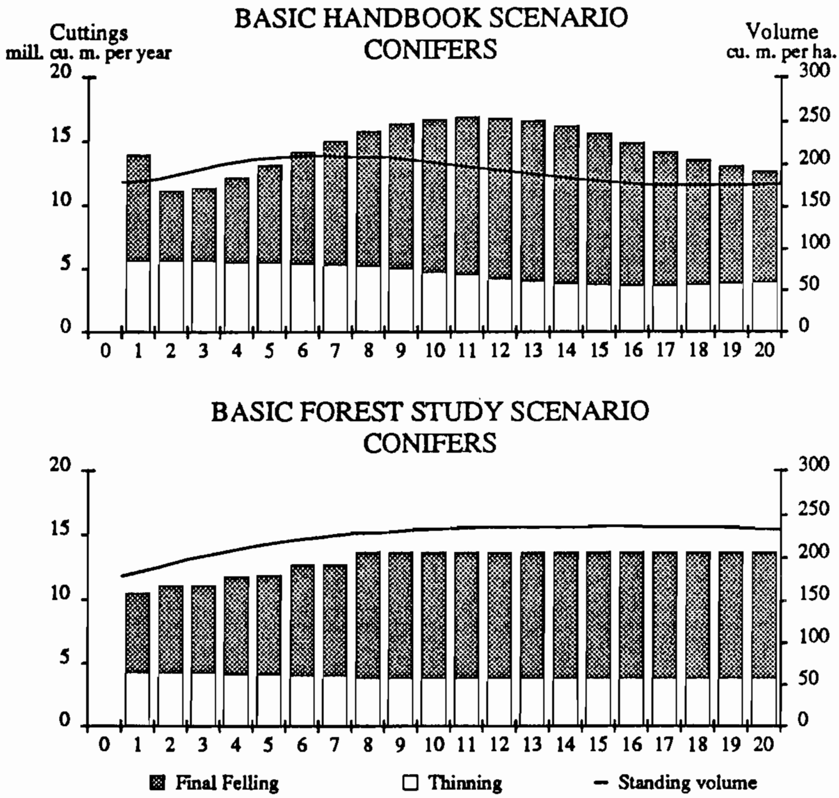

Figure 5.17. Projections of potential harvest and growing stock of coniferous species in the Southern aggregate under the basic scenarios. Current fellings are 8.8 million cubic meters o.b.

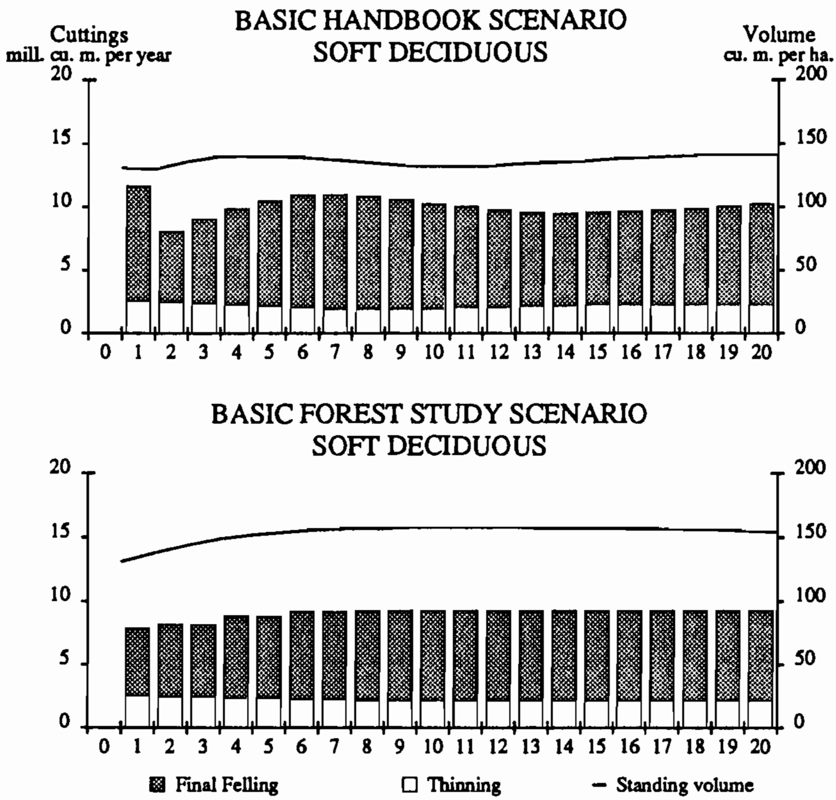

Figure 5.18. Projections of potential harvest and growing stock of soft deciduous species in the Southern aggregate under the basic scenarios. Current fellings are 7.9 million cubic meters o.b.

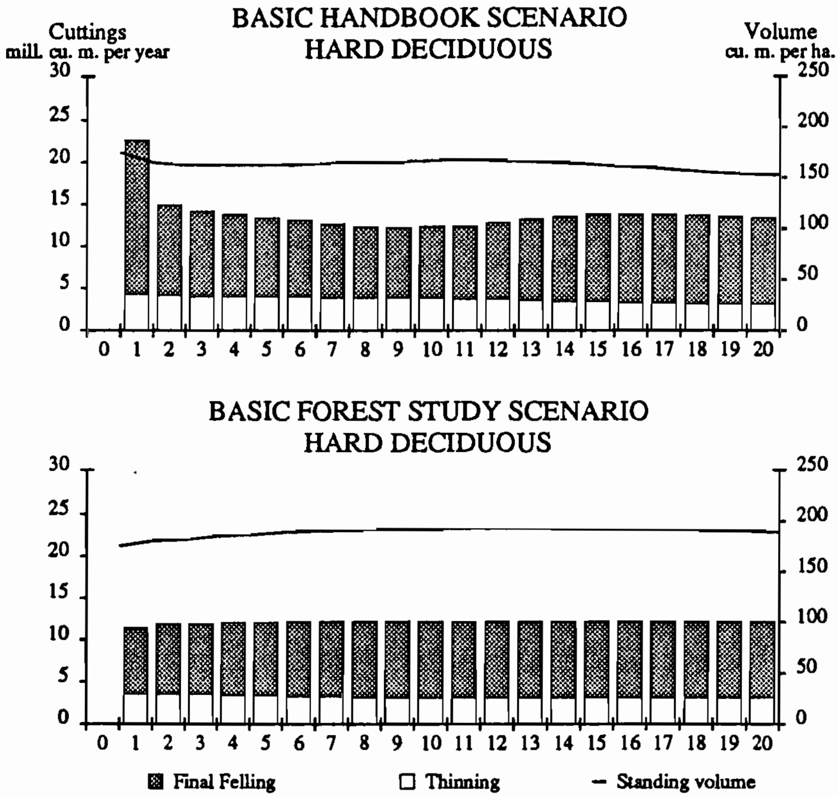

Figure 5.19. Projections of potential harvest and growing stock of hard deciduous species in the Southern aggregate under the basic scenarios. Current fellings are 12.8 million cubic meters o.b.

Basic Forest Study Scenario. The harvest potential slightly increases for all species groups over time in this scenario. In this case, the growing stock also increases over the simulation period for all species groups.

The average total harvest level and the average total growth rate are lower in the Basic Forest Study Scenario than in the Basic Handbook Scenario. The harvest level for the Basic Forest Study Scenario is about 4 million cubic meters o.b. per year, whereas the harvest level for the Basic Handbook Scenario is 0.1 cubic meters o.b. per hectare per year.

Thus, we estimate the average total potential harvest in the Southern aggregate to be 34.2 million cubic meters o.b. per year. The corresponding figures for the major species groups are 13.0 million cubic meters o.b. per year for coniferous species, 9.1 million cubic meters o.b. per year for soft deciduous species, and 12.1 million cubic meters o.b. per year for hard deciduous species.

5.2.6 Total European USSR (Table 5.7 and Figures 5.20 to 5.23)

For the total European USSR there is a low correspondence between the initial forest structure and the structure that would develop if handbook silviculture were implemented. This is a result of a large extent of overmature forests in the Northern and Ural aggregates. The imbalance results in an extremely strong harvest pulse in the beginning of the simulation of the Basic Handbook Scenario. This scenario suggests a total potential harvest of nearly 1.5 billion cubic meters in year 1 of the simulation. Such a harvest level is unrealistic but illustrates the magnitude of the balancing problem in the European USSR. In principle, the same pattern is achieved for all species groups in the Basic Handbook Scenario but is extremely pronounced for coniferous species.

The Basic Forest Study Scenario gives a slightly increasing potential harvest level over the simulation period for all species groups. The total growing stock decreases slightly in both scenarios, but this is not an indication of declining sustainability. The positive effects on the growing stock of the harvesting of the overmature forests will be visible after the time horizon of the simulation period.

The Basic Forest Study Scenario gives a lower average total potential yearly harvest (38 million cubic meters o.b. per year) and growth rate (0.2 cubic meters o.b. per hectare per year) than the Basic Handbook Scenario. This is a result of a less rapid reduction of the overmature forests in the Basic Forest Study Scenario. Thus, we estimate the average total potential harvest to be 321.3 million cubic meters o.b. per year in the total European USSR.

Table 5.7. Total European USSR.

	Basic Handbook	Basic Forest Study
Selected data on harvests and growing stock		
Total		
Growing stock[a]	129–108	129–117
Fellings[b]		
Year 1	1,407.50	303.41
Year 40	278.70	324.90
Year 80	323.40	325.30
Coniferous		
Growing stock[a]	138–108	138–114
Fellings[b]		
Year 1	1,138.60	181.91
Year 40	145.00	194.30
Year 80	189.80	195.00
Soft deciduous		
Growing stock[a]	105–103	105–113
Fellings[b]		
Year 1	237.70	106.90
Year 40	118.30	115.10
Year 80	116.00	114.80
Hard deciduous		
Growing stock[a]	166–144	166–176
Fellings[b]		
Year 1	31.20	14.60
Year 40	15.50	15.50
Year 80	17.60	15.50
Summary of results		
Potential harvest (mill. m^3 o.b. yr^{-1})[c]		
Total	359.20	321.20
Coniferous	220.20	192.30
Soft deciduous	121.50	113.60
Hard deciduous	17.50	15.30
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]		
Total	2.60	2.40
Coniferous	2.30	2.00
Soft deciduous	3.10	3.00
Hard deciduous	3.30	3.20
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)		
Total	129–108	129–117
Coniferous	138–108	138–114
Soft deciduous	105–103	105–113
Hard deciduous	166–144	166–176

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

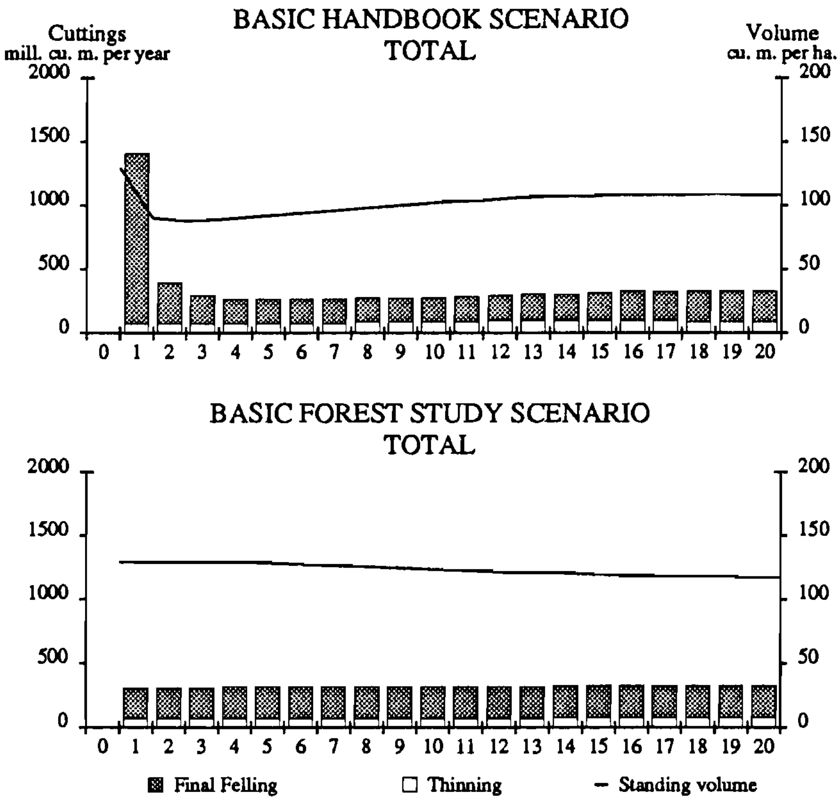

Figure 5.20. Projections of total potential harvest and growing stock in the total European USSR under the basic scenarios. Current fellings are 256.7 million cubic meters o.b.

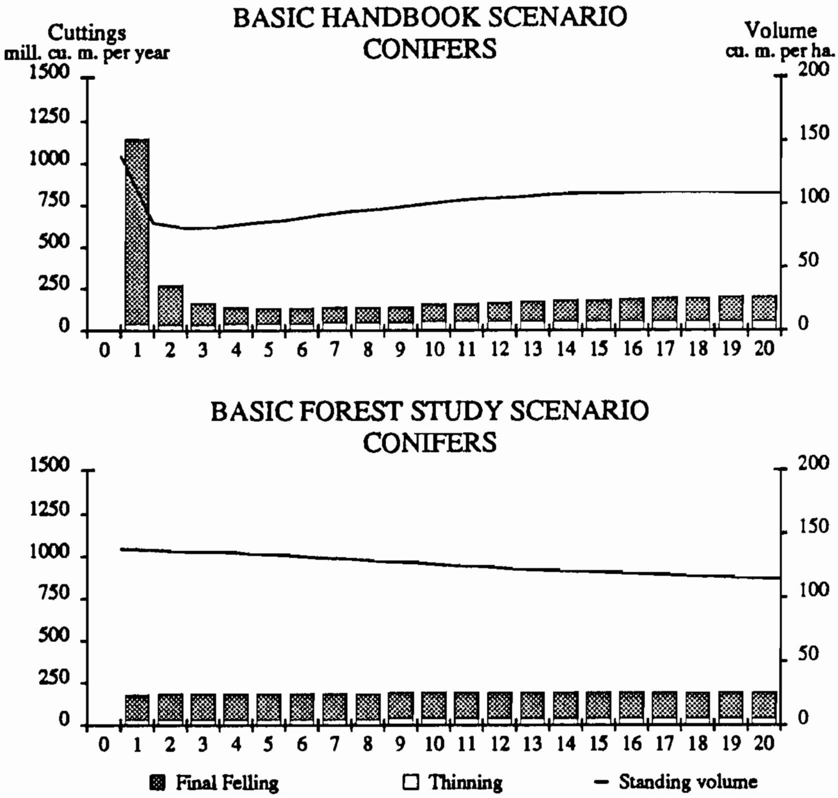

Figure 5.21. Projections of potential harvest and growing stock of coniferous species in the total European USSR under the basic scenarios. Current fellings are 151.4 million cubic meters o.b.

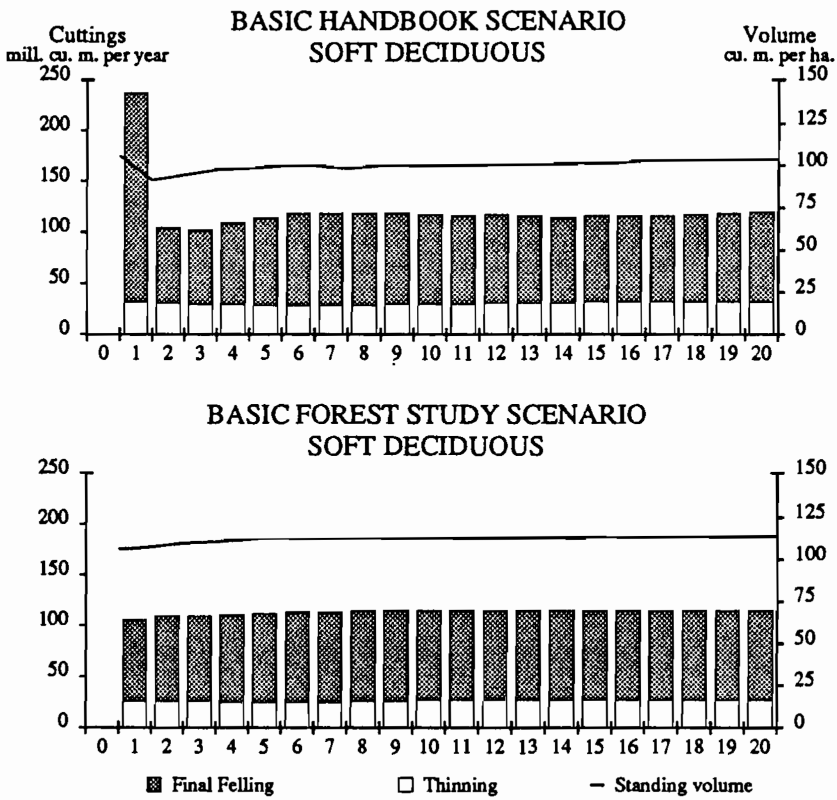

Figure 5.22. Projections of potential harvest and growing stock of soft deciduous species in the total European USSR under the basic scenarios. Current fellings are 89.2 million cubic meters o.b.

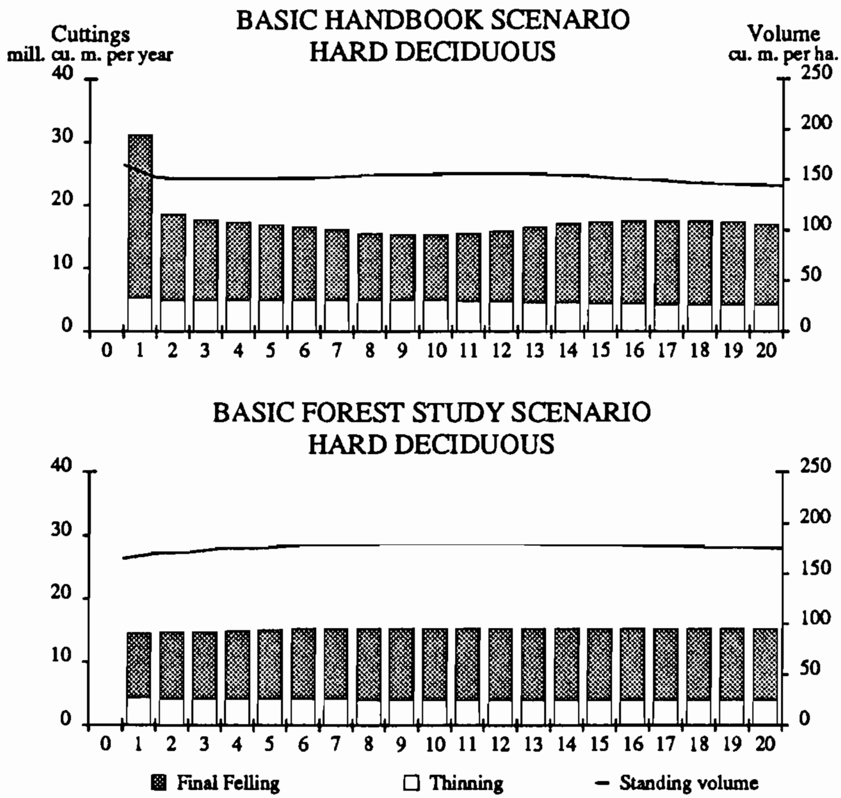

Figure 5.23. Projections of potential harvest and growing stock of hard deciduous species in the total European USSR under the basic scenarios. Current fellings are 16.1 million cubic meters o.b.

Table 5.8. Average growth rates in the European USSR under the Basic Forest Study Scenario over 100 years, in cubic meters per hectare per year.

Aggregate	Coniferous	Deciduous Soft	Deciduous Hard	Total
Northern aggregate	1.2	1.2	–	1.2
Central aggregate	3.4	3.8	2.3	3.6
Baltic aggregate	3.2	3.4	3.5	3.2
Ural aggregate	2.4	3.6	2.2	2.9
Southern aggregate	4.8	4.2	3.4	4.1
Total European USSR	2.0	3.0	3.2	2.4

Table 5.9. Average growth rates in Western and Eastern Europe under the Basic Forest Study Scenario over 100 years, in cubic meters per hectare per year.

Region	Coniferous	Deciduous	Coppice	Total
Nordic	3.8	3.9	–	3.8
EEC-9	7.3	4.1	2.4	5.0
Central	7.0	6.2	–	6.9
Southern	3.2	4.6	1.3	2.8
Eastern	5.8	4.8	2.9	5.3
Total	4.7	4.5	1.9	4.2

Source: Nilsson *et al.*, 1992.

The values for the major species groups are 192.3 million cubic meters o.b. per year for coniferous species, 113.6 million cubic meters o.b. per year for soft deciduous species, and 15.3 million cubic meters o.b. per year for hard deciduous species.

5.3 Growth Rates

The average growth rates under the Basic Forest Study Scenario are presented in *Table 5.8*. These rates for the European USSR are low in comparison with growth rates for the rest of Europe. This is especially true for the Northern and Ural aggregates. The average growth rates calculated on the same methodology for the rest of Europe are presented in *Table 5.9*. A comparison between the two tables shows that the average growth rates are lower in the USSR aggregates than in regions under similar conditions in Western and Eastern Europe.

A comparison between recent harvests (reported in January 1988) and the harvest potentials according to the Basic Forest Study Scenario is

Table 5.10. Comparison of results from the Basic Forest Study scenarios with current harvest levels for two species groups in the European USSR, in millions of cubic meters o.b. per year.

	Current harvest level			Basic Forest Study			Difference		
Aggregate	Coniferous	Deciduous	Total	Coniferous	Deciduous	Total	Coniferous mill. m^3(%)	Deciduous mill. m^3 (%)	Total mill. m^3 (%)
Northern aggregate	70.4	12.1	82.5	80.8	14.4	95.2	10.4 (115)	2.3 (119)	12.7 (115)
Central aggregate	30.0	39.7	69.7	44.3	44.8	89.1	14.3 (148)	5.1 (113)	19.4 (128)
Baltic aggregate	9.2	9.5	18.7	17.2	9.4	26.6	8.0 (187)	−0.1 (99)	7.9 (142)
Ural aggregate	33.0	23.3	56.3	37.0	39.0	76.0	4.0 (112)	15.7 (167)	19.7 (135)
Southern aggregate	8.8	20.7	29.5	13.0	21.2	34.2	4.2 (163)	0.5 (102)	4.7 (116)
Total European USSR	151.4	105.3	256.7	192.3	128.8	321.1	40.9 (127)	23.5 (123)	64.4 (125)

Table 5.11. Per capita consumption of different forest industry products from 1985 to 1987 in the USSR.

Lumber	0.3281 m^3/capita
Plywood	0.0064 m^3/capita
Particle board	0.0218 m^3/capita
Fiber board	0.0121 m^3/capita
Paper board	0.0251 ton/capita
Paper	0.0099 ton/capita

presented in *Table 5.10*. It should be re-emphasized that the Basic Forest Study Scenario deals with the biological, sustainable potential harvest and the current harvest level is the actual harvest of the late 1980s. Based on the results in *Table 5.10*, there seems to be a possibility of increasing the yearly average biological total sustainable harvest (in relation to current harvest level) in the European USSR by some 60 million cubic meters o.b. The biggest potential is in coniferous species. The potentials for increased coniferous harvests are most pronounced in the Baltic, Central, and Southern aggregates.

As presented in Chapter 1, a common view is that the deciduous forests have been and are underharvested in the European USSR. The Basic Forest Study Scenario results support this conclusion strongly for the Ural aggregate and slightly for the Northern and Central aggregates.

The overall conclusion is that the current total harvest level can be sustained on a long-term basis in the European USSR. This statement is based on the condition that the silviculture stipulated in the management programs of the Basic Forest Study Scenario is carried out.

5.4 Demand and Supply Balances

Based on actual consumption of forest industrial products in 1985–1987 (FAO, 1990), and the population information collected in UN (1989b), it has been possible to estimate the per capita consumption for different forest products for the total USSR in the late 1980s. The estimate is presented in *Table 5.11*.

UN (1989a) presents an outlook on the forest and the forest products sector. This study was carried out by Soviet experts and also includes an estimate of the future demand for forest products. Based on information from the UN report it has been possible to estimate the per capita consumption in the year 2000 (*Table 5.12*). A comparison between *Tables 5.11* and *5.12*

Table 5.12. Estimated per capita consumption of forest industry products in year 2000 in the USSR.

Lumber	0.3231–0.3728 m^3/capita
Plywood	0.0091–0.0101 m^3/capita
Particle board	0.0399–0.0511 m^3/capita
Fiber board	0.0171–0.0189 m^3/capita
Paper board	0.0631–0.0828 ton/capita
Paper	0.0158–0.0164 ton/capita

shows that the strongest estimated increase is found in particle board and paper board.

Dykstra and Kallio (1987) present an estimate of lumber consumption up to year 2010, and FAO (1988) presents an estimate for the demand on the major products up to the year 2000. Baudin (1988) made special analyses for the IIASA Forest Study on future global demand for forest products. WRA (1988) has made an analysis that is similar to FAO and Baudin. Nilsson (1991a) has estimated the consumption for major products up to the year 2010. The results from these studies are presented in *Table 5.13*.

By using the population information in *Table 4.2* and population information in UN (1989b) as a basis for a regionalization of the total demand (*Table 5.13*) from subregions it is possible to get a rough estimate of future regional demand. By using global conversion factors (see FAO, 1990; EEC, 1986; UN, 1989a) the demand for forest products has been calculated and is expressed in roundwood equivalents. The efficiency in wood utilization in the industry is, in these calculations, estimated to increase by 2 percent between 1985 and 2000. By combining the estimates of regional future potential wood supply in *Table 5.10* and the regionalized demand information based on information in *Table 5.13* for the aggregates there is a possibility of getting an approximation of the regional future wood balances. The estimate by Dykstra and Kallio (1987) is not taken into account in this balance calculation because this study deals with only lumber and not the other major forest products. The wood balances are presented in *Table 5.14*.

The demand values only include the traditional forest industry products such as lumber, wood panels, and paper. Thus, demands from other forest industries, chemical production, and energy production are not included in the balances.

Based on these calculations it can be concluded that there should not be any supply problems (based on a sustainable biological supply) to support the domestic demand in the medium term for the total European USSR.

Table 5.13. Estimated demand for forest products in the USSR.

	1985	2000	2010
Dykstra and Kallio (1987)			
Lumber (million m^3)	90.8	78.4	60.0
Baudin (1988)			
Lumber (million m^3)	90.8	92.3	
Wood-based panels (million m^3)	12.1	19.3	
Total paper (million ton)	9.7	11.5	
FAO (1988)			
Lumber & sleepers (million m^3)	90.8	109.8	
Wood-based panels (million m^3)	12.1	19.8	
Total paper (million ton)	9.7	16.3	
Woodbridge, Reed, and Associates (1988)			
Lumber (million m^3)	90.8	98.0	
Wood-based panels (million m^3)	12.1	17.0	
Total paper (million ton)	9.7	13.1	
Based on UN (1989a)			
Lumber (million m^3)	90.8	99.4–114.7	
Plywood (million m^3)	1.8	2.8–3.1	
Particle board (million m^3)	6.0	12.3–15.7	
Fiber board (million m^3)	3.4	5.3–5.8	
Paper board (million ton)	6.9	19.4–25.5	
Paper (million ton)	2.8	4.9–5.1	
Nilsson (1991a)			
Lumber (million m^3)	90.8	99.0	108.0
Wood-based panels (million m^3)	12.1	17.0	20.0
Total paper (million ton)	9.7	14.0	16.0

There is only one major deficit aggregate: the Southern aggregate. In this aggregate the deficit is huge, some 50 million cubic meters in 2000.

5.5 Potential Wood Supplies and Industrial Capacities

Every region concerned about the future of its forest sector strives for a reasonable balance between actual wood supply (or potential wood supply) and industrial wood-processing capacities. *Table 5.15* lists the current and possible balances or imbalances between wood supply and industrial capacities for the European USSR aggregates. The estimate of the current industrial capacity, expressed in roundwood equivalents, is based on information in *Table 4.6*. Future removals (average total of biological wood supply) is based on the Basic Forest Study Scenario (*Table 5.10*).

Table 5.14. Outlook for regional wood demand (lumber, panels, and paper) and supply balances in the European USSR aggregates, in million cubic meters of roundwood equivalents.

Aggregate/variable	Balances at year 1985	2000
Northern		
Domestic demand[a]	4.5	4.7 – 6.4
Surpluses/deficits with:		
Actual harvest	78.0	76.11 – 77.8
Basic Forest Study Scenario[b]		88.8 – 90.5
Central		
Domestic demand	34.3	36.2 – 48.6
Surpluses/deficits with:		
Actual harvest	35.4	21.1 – 33.5
Basic Forest Study Scenario		40.7 – 53.1
Baltic		
Domestic demand	13.9	14.7 – 19.7
Surpluses/deficits with:		
Actual harvest	4.8	–1.0 – 4.0
Basic Forest Study Scenario		6.9 – 11.9
Ural		
Domestic demand	14.9	15.7 – 21.1
Surpluses/deficits with:		
Actual harvest	41.4	35.2 – 40.6
Basic Forest Study Scenario		54.9 – 60.3
Southern		
Domestic demand	70.7	74.6 – 100.2
Surpluses/deficits with:		
Actual harvest	–41.2	–70.7 – –45.1
Basic Forest Study Scenario		–66.0 – –40.4
Total European USSR		
Domestic demand	138.3	145.9 – 196.0
Surpluses/deficits with:		
Actual harvest	118.4	60.7 – 110.8
Basic Forest Study Scenario		125.3 – 175.4

[a]Roundwood demand to meet domestic consumption of final products.
[b]Potential biological wood supply according to the Basic Forest Study Scenario.

Table 5.15. Industrial capacities (ICs) and comparisons with actual harvests in 1988 and total potential harvests under the Basic Forest Study Scenario. Data for the scenario are 100-year averages, in roundwood equivalents.

Aggregate	IC (mill. m^3) Traditional forest industry	All industry	All industry & energy production	Current removals in mill. m^3 (% of all industry & energy production)	Basic Forest Study Scenario In mill. m^3 (% of traditional forest industry)	In mill. m^3 (% of all industry)	In mill. m^3 (% of all industry & energy production)
Northern	38.92	51.53	61.92	82.5 (133%)	95.2 (245%)	95.2 (185%)	95.2 (154%)
Central	30.89	53.94	66.68	69.7 (105%)	89.3 (289%)	89.3 (166%)	89.3 (134%)
Baltic	19.41	30.57	37.65	18.9 (50%)	26.6 (137%)	26.6 (87%)	26.6 (71%)
Ural	27.07	41.29	50.59	56.3 (111%)	76.0 (281%)	76.0 (184%)	76.0 (150%)
Southern	24.32	44.53	51.07	29.5 (58%)	34.2 (141%)	34.2 (77%)	34.2 (67%)
European USSR	140.61	221.86	267.91	256.9 (96%)	321.3 (229%)	321.3 (145%)	321.3 (120%)

As illustrated in *Table 5.15* the current harvest can barely support existing industry requirements including wood consumption for energy in the total European USSR under the conditions of the Basic Forest Study Scenario. The Baltic and Southern aggregates have the largest deficit in the current situation.

If the future average biological wood potential (the Basic Forest Study Scenario) were considered, there should not be any problem in meeting the demand for industrial production in traditional forest industry with the existing capacities in any of the aggregates. If the current industrial consumption for purposes other than traditional forest industry and energy consumption were taken into account, the Baltic and Southern aggregates would be deficit regions.

Chapter 6

Accessible Harvests and Wood Waste

In the earlier chapters we presented the average, biologically sustainable harvest potential according to the IIASA Forest Study (Chapter 5) and actual annual allowable cut (AAC) calculations in the USSR (Chapter 1). Neither the estimate on the potential harvest produced by IIASA nor the AACs can illustrate the actual volume of accessible wood for harvest and use in different industries. The accessibility depends on a number of factors such as infrastructure development, demand for forest products, industrial capacities, and economic conditions. In Chapter 1 we explained that there is a rather low rate of AAC utilization in the USSR. The utilization rates of the AACs in 1990 for the regions in the European USSR are presented in *Table 6.1*. The discrepancies between the actual AACs and actual harvests presented in *Table 6.1* can be explained by the accessibility factors. Limited data are available on the influence of these factors on the accessibility of AACs in the USSR.

In this chapter, some of the accessibility factors are discussed. But first the impact of aggregated data on the AACs or potential harvest calculations is explained.

6.1 Impact of Aggregated Data on the AAC Calculations

The use of aggregated data (instead of specific data for the individual stands) in the AAC calculations or the IIASA Forest Study analyses overestimates the potential volumes in relation to real conditions. Studies in the USSR show that the aggregated estimates based on sample plot information have

Table 6.1. Annual allowable cuts (AACs) and their utilization rate in 1990 in the European USSR.

	AAC (mill. m^3)				Utilization of AAC (%)			
		Conif-	Deciduous			Conif-	Deciduous	
Region	Total	erous	Hard	Soft	Total	erous	Hard	Soft
North	85.90	66.0	–	19.90	75	81	–	55
Northwest	14.60	6.4	–	8.20	59	55	–	46
Central	27.00	9.9	0.40	16.70	73	82	50	68
Pre-Baltic	0.30	0.1	–	0.20	86	87	86	84
Volgo-Vyatsky	22.60	8.5	0.20	13.90	77	79	56	76
Central Chernozyomny	1.30	0.2	0.40	0.70	88	100	88	84
Povolzhsky	6.20	1.0	1.30	3.90	87	99	68	91
Ural	60.70	28.9	2.20	29.60	61	77	10	58
North Caucasia	1.70	0.1	1.30	0.30	82	80	84	74
Ukraine – total (regions 10-12)	6.00	3.0	2.00	1.00	96	96	97	95
Moldavia	0.14	–	0.11	0.03	89	–	87	96
Byelorussia	6.20	3.2	0.20	2.80	90	98	90	82
Estonia	1.50	0.8	–	0.70	80	95	–	62
Latvia	2.30	1.1	–	1.20	104	123	43	88
Lithuania	1.70	0.7	–	1.00	94	95	72	93
Total European USSR	238.14	129.9	8.11	100.13	73	81	63	64

to be reduced to determine real stand conditions. The available, aggregated sample plot information on the forest resources in the USSR does not include information on the technical accessibility of the forest stands. Using only the sample plot information directly in the analyses results in an overestimation of potential harvests. Soviet experts have suggested that the reduction factors in *Table 6.2* should be used to calculate the estimates.

6.2 Areas with Low Levels of Growing Stocks in Mature and Overmature Forests

Areas with low levels of growing stocks in mature and overmature forests are regarded as inaccessible for any form of industrial use in the USSR. The limit of inaccessibility from low levels of growing stock due to stocking is 40 cubic meters per hectare in the European USSR and 50 cubic meters per hectare in Siberia and the Far East.

The potential harvests or AAC in understocked stands constitute 13.4 million cubic meters per year for the European USSR. Soviet experts estimate that a total of 12 million cubic meters of this volume is situated in the

Table 6.2. Reduction factor of calculated estimates due to usage of aggregated data.

Regions	Reduction factor
North, Ural	8–10%
North Caucasia	6%
Northwest, Central, Volgo-Vyatsky, and Carpathians	5%
Central Chernozyomny	3–5%
Polesye, Forest Steppe, Byelorussia, Moldavia, Estonia, Latvia, and Lithuania	3–4%
Pre-Baltic and Povolzhsky	3%

Table 6.3. Deduction factor for calculated sustainable harvest level due to lack of infrastructure used by IIASA Forest Study.

Region	Mill. $m^3\ yr^{-1}$
North	12.4
Ural	7.6
Northwest	0.8
Volgo-Vyatsky	1.6
Central	1.7

Northern region (11.3 million cubic meters in coniferous species and 0.7 in deciduous species) and a total of about 0.7 million cubic meters (all coniferous species) is located in the Ural region. This means that the estimate of the sustainable average of potential harvests produced by the IIASA Forest Study should be deducted by these amounts for the Northern and Ural regions. In other regions the understocked stands are of minor importance.

6.3 Lack of Infrastructure

The estimates of the sustainable harvesting potential presented in Chapter 5 and in Appendix A assume that all commercial forests have an efficient infrastructure and that all land is accessible for harvesting. In reality, this is not the case. Soviet collaborators have estimated the required deduction of the calculated potential of sustainable harvests from these conditions in 1989. These estimates are presented in *Table 6.3*.

For other regions, the deduction factor is estimated at less than 2 percent and is not taken into account in the calculations (see Chapter 9) on future wood supply possibilities of the European USSR.

6.4 Economic Accessibility

The factors discussed in Sections 6.1, 6.2, and 6.3 are in some way linked to the question of the economic accessibility of the forests. But even if there are areas with good productivity, efficient infrastructure, and so on, they can still be economically inaccessible due to economic conditions such as demand, price, and cost. These factors are important components of a market economy. The USSR has been a centrally planned economy and is now changing to a market economy. Therefore, there are no statistics available on these parameters. It is not known how the demand and prices will change after the transition to a full-scale market economy. Therefore, for the moment, there are no possibilities of estimating how the economy will influence future accessibility of potential harvests.

We can only illustrate the development of stumpage prices, wood costs at roadside, and wood costs at mill site from 1964 to 1990. This information was produced by Burdin (forthcoming). The cost information is presented in *Figure 6.1*. Stumpage prices have had a rather flat development during the period, but this will surely change in the future. How prices will change after a stabilization of the market economy is unknown.

6.5 Wood Waste

As discussed in Chapter 1, there are no satisfactory statistics available on the amount of wood wasted in the USSR. It can be concluded that the waste rate is high in the USSR and that the usage of waste ranges between 30 and 50 percent. Some scientific investigations have been carried out (Drojhalov *et al.*, 1990; Goskomles, 1989–1990; Manokov and Mocholova, 1990). The results from these investigations are presented in *Table 6.4*.

As expected, there are rather high variations in the rates of wood wasted among different regions. The waste rate depends on logging and transportation conditions, original wood quality, and management of the site, among other factors.

The average loss in logging and transportation in the sample is estimated at 6.8 percent, with industrial production estimated at 19.4 percent of the total actual harvest. This equals to a total waste rate of 26.2 percent of the volume harvested which is in line with the overall figures presented in Chapter 1. This means that the calculations on sustainable harvesting potential presented in Chapter 5 and Appendix A must be reduced to estimate the volume which can realistically be used for production. If we have an optimistic view on the utilization of the wasted wood – about 50 percent – the

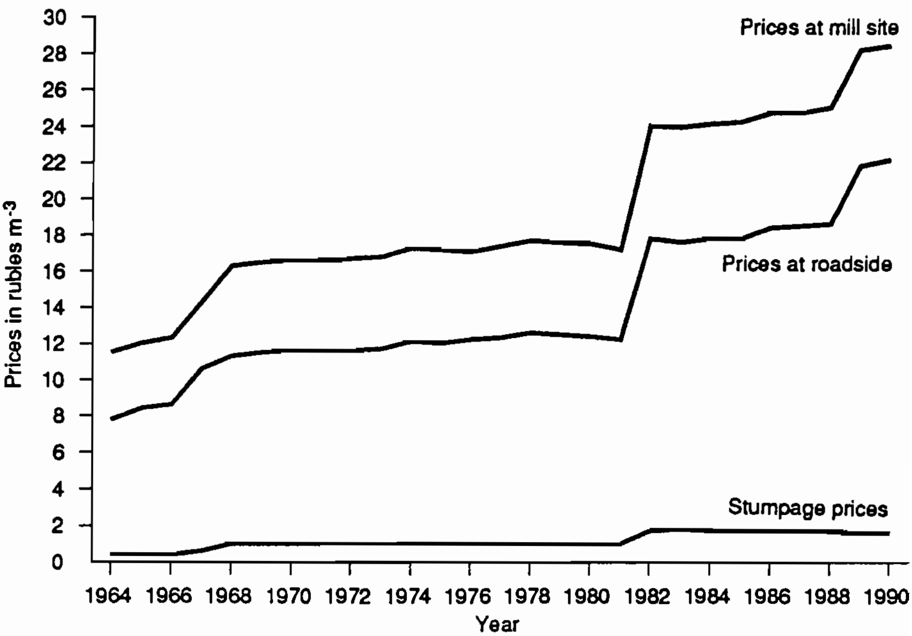

Figure 6.1. Price development for roundwood in the USSR from 1964 to 1990, average for all assortments, in current rubles per cubic meters. Source: Burdin, forthcoming.

Table 6.4. Wood waste in some regions of the USSR in 1989.

Region	Waste in logging and transport (mill. m^3)	Waste in industrial production (mill. m^3)	Total waste (mill. m^3)	Actual total harvest (mill. m^3)	% of waste: Logging & transp.	% of waste: Industry
Arkhangelsk	0.6–2.8	5.1	5.7–7.9	23.8	2.5–11.8	21.4
Komi ASSR	1.1	1.9	3.0	23.5	4.7	8.1
Perm	1.2–1.9	2.2	3.4–4.1	17.0	7.1–11.2	12.9
Sverdlovsk	1.3	3.6	4.9	19.5	6.7	18.5
Krasnoyarsk	0.8–2.3	4.6	5.4–6.9	26.3	3.0–8.9	17.5
Sub-Volga	0.5	1.7	2.2	6.5	7.7	26.2
North Caucasia	0.2	1.0	1.2	3.2	6.3	31.3
Total/average	5.7–10.1	20.1	25.9–29.3	119.8	6.8%	19.4

average harvest potentials presented would have to be reduced by about 13 percent. However, it should be pointed out that UN (1989a) has presented a waste production of 79 million cubic meters per year, of which 68 million is utilized, which gives a utilization rate of 86 percent. This figure seems to be very high in relation to all other available information on utilization of wood waste in the USSR. The factors discussed in this chapter are used in Chapter 9 in the adjustment of the potential biological wood supply presented in Chapter 5 and Appendix A.

Chapter 7

Effects of Air Pollutants

Pollution was "viewed as a temporary anomaly" in the socialist system (Ziegler, 1987). Today the pollution problem in the USSR is openly discussed and debated (Mathews, 1991).

7.1 Depositions

The USSR is second in the world in the amount of emissions released into the atmosphere. In 1988, the USSR discharged about 18 percent of the world's emissions. The same year, the country emitted 96.8 million tons of major pollutants, of which 63.6 percent were classified as industrial emissions and 36.4 percent were classified as being generated by vehicles and households. The total discharge of CO_2 in 1988 was 1,212 million tons (Goskomgidromet, 1989).

The overall situation concerning emissions of pollutants in the USSR is presented in *Table 7.1*. This table covers all of the USSR; the division of regions does not correspond to the division employed for the European part of the USSR presented in Chapter 2. The regions corresponding to *Table 7.1* are shown in *Figure 7.1*. The discrepancies between the regional reports on the emissions and the total reported emissions for USSR in *Table 7.1* are due to rounding errors.

Table 7.1 shows that sulfur emissions are a major problem in the Northern and Central parts of the European USSR, the Urals, and Siberia. The largest amount of emissions of NO_x are concentrated in the Central part of the European USSR, the Urals, and West Siberia.

The overall deposition pattern for sulfur and nitrogen in the USSR is presented in *Table 7.2*. The deposition of sulfur and nitrogen by area unit is highest in the European USSR.

Table 7.1. Annual emissions from stationary sources in the USSR into the atmosphere, according to data issued by Goskomgidromet (1990).

Region	Solid matter in million tons	Sulfurous anhydride in million tons	Nitrogen oxides in million tons	Sulfuric acid in thousand tons	Hydrogen sulfate in thousand tons	Lead in thousand tons	Mercury in tons
USSR, total[a]	14.675	17.734	4.492	61.818	99.239	7.913	45.592
North (I)	0.664	1.130	0.137	0.694	17.797	0.001	0.152
Northwest (II)	0.292	0.309	0.093	0.432	0.344	0.026	0.003
Central (III)	1.012	1.067	0.397	1.871	4.234	0.066	0.386
Volgo-Vyatsky (IV)	0.288	0.334	0.105	0.478	0.741	0.081	0.069
Central Chernozyomny (V)	0.259	0.186	0.102	0.461	4.477	0.057	0.178
Povolzhsky (VI)	0.325	0.831	0.288	0.856	5.624	0.059	1.275
North Caucasia (VII)	0.304	0.428	0.144	1.055	2.133	0.350	[b]
Ural (VIII)	2.201	2.335	0.700	6.513	12.990	2.430	4.122
West Siberia (IX)	1.200	0.712	0.552	1.388	3.090	0.064	0.103
East Siberia (X)	0.924	2.763	0.173	31.735	5.887	0.059	3.357
Far East (XI)	0.823	0.397	0.129	0.191	1.279	0.059	0.005
Donetsko-Pridneprovskaya (XII)	1.736	2.196	0.556	3.248	28.459	0.100	12.829
Southwest (XIII)	0.449	0.843	0.203	1.324	3.170	0.065	2.920
South (XIV)	0.155	0.172	0.029	7.772	0.200	0.002	[b]
Baltic (XV)	0.365	0.534	0.084	0.470	0.475	0.102	0.020
Transcaucasia (XVI)	0.398	0.329	0.135	0.441	0.178	0.058	0.037
Central Asia (XVII)	0.497	0.629	0.175	1.986	3.447	0.050	19.725
Kazakhstan (XVIII)	2.153	1.570	0.316	0.351	1.907	4.304	0.411
Byelorussia (XIX)	0.163	0.637	0.104	0.520	2.804	0.023	[b]
Moldavia (XX)	0.082	0.273	0.048	0.028	0.001	0.000	[b]

[a]Columns do not total due to rounding.
[b]Absence of emissions.

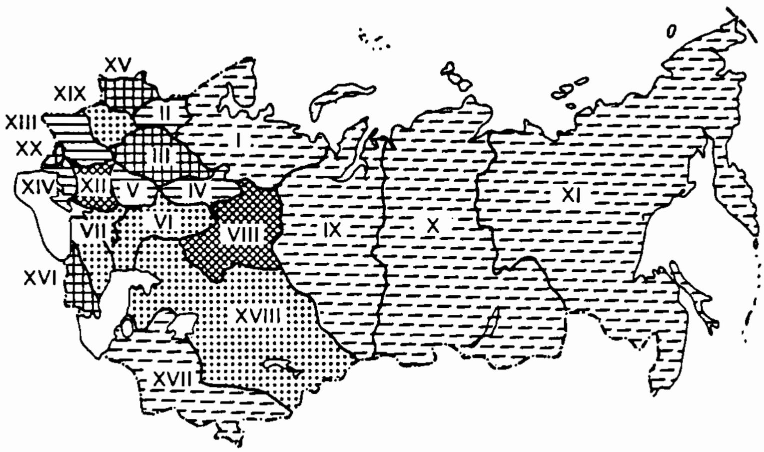

Figure 7.1. Division of the USSR into regions listed in *Table 7.1*.

Table 7.2. Deposition of sulfur and nitrogen in 1988.

	Sulfur	Nitrate nitrogen	Ammonium nitrogen	Total nitrogen
European USSR				
Deposition (g m^{-2})	1.04	0.24	0.40	0.64
Total emission (million tons yr^{-1})	5.60	1.30	2.20	3.50
Asian USSR				
Deposition (g m^{-2})	0.44	0.09	0.22	0.31
Total emission (million tons yr^{-1})	7.40	1.50	3.60	5.10
Total USSR				
Deposition (g m^{-2})	0.60	0.13	0.26	0.39
Total emission (million tons yr^{-1})	13.00	2.80	5.80	8.60

Source: USSR State Committee on Statistics.

Most of the sulfur depositions in the European USSR are produced within the country (EMEP, 1989). The domestically produced depositions of sulfur constitute about 62 percent of the total depositions (EMEP, 1989). The major external contributors are the CSFR, eastern Germany, Hungary, and Poland. Finland receives the highest proportion of sulfur depositions from the European USSR.

The major sources for the total nitrogen deposition in the European USSR are domestic sources (about 43 percent). Major imports come from Poland, western Germany, and the CSFR (EMEP, 1989).

The annual sulfur and nitrogen depositions in 1988 – based on statistics from the USSR – for the individual regions in the European USSR (the

Table 7.3. Annual average sulfur and nitrogen oxide depositions in 1988 in the European USSR.

Region	g S m^{-2}	g NO_x m^{-2}
North	0.31	1.00
Northwest	0.61	0.47
Central	1.00	0.81
Pre-Baltic	13.82	5.56
Volgo-Vyatsky	0.50	0.40
Central Chernozyomny	1.06	0.61
Povolzhsky	0.61	0.54
Ural	1.12	0.85
North Caucasia	0.48	0.41
Carpathians (Ukraine)	8.42	1.38
Polesye (Ukraine)	1.65	1.21
Forest Steppe (Ukraine)	3.18	0.36
Moldavia	3.16	1.44
Byelorussia	1.23	0.65
Estonia	2.76	1.08
Latvia	0.85	0.43
Lithuania	2.03	0.55

Source: State Committee on Statistics.

division of regions used in this book for analysis of the forest resources) are presented in *Table 7.3*.

A comparison between the Soviet regions and other countries of Europe shows that the Pre-Baltic and Carpathian regions have a higher average deposition of sulfur than any other country in Europe (Nilsson, 1991b). The average deposition of sulfur in the Baltic regions, Moldavia, and parts of the Ukraine is similar to the average deposition in Belgium, the Netherlands, the Federal Republic of Germany, the United Kingdom, and Austria. A similar comparison for nitrogen shows that the Pre-Baltic, Carpathians, Polesye, Moldavia, and Estonia have a higher level of nitrogen depositions than the level in any of the Western or Eastern European countries (Nilsson, 1991b).

7.2 Forest Decline Scenarios

To present the assumptions underlying the analysis on decline and the decline-modeling approach two decline scenarios have been prepared: adjusted handbook silviculture (Handbook Decline Scenario) and Forest Study estimates of reasonable future silviculture and harvest levels (Forest Study Decline Scenario).

Table 7.4. Average critical loads for ecosystems in the European part of the USSR.

Stockholm Environment Institute (1990)		UN-ECE (1991)			
Critical loads of acidity in ecosystems		Critical loads of acidity in forests		Critical nutrient nitrogen in forests	
keqH^+ $km^{-2}yr^{-1}$	Distribution in %	keqH^+ $km^{-2}yr^{-1}$	Distribution in %	kg ha^{-1}	Distribution in %
0–20	4	0–20	10	0–8	8
20–40	7	20–50	22	8–20	19
40–80	22	50–100	27	20–30	40
80–160	9	100–200	21	30–40	29
160+	58	200–240	20	40–45	4

The first step in the process was to calculate the distribution of the forests over several sensitivity classes with respect to depositions. The Stockholm Environment Institute (Chadwick and Kuylenstierna, 1990) has presented general distributions of the sensitivity classes of ecosystems in Europe to acidic depositions. UN-ECE (1991) has presented similar distributions for Europe and the European USSR and for forest ecosystems. In the case of the European USSR the information was delivered by Soviet experts to the UN-ECE study. In both studies, the information covers about two-thirds of the area we have classified as belonging to the European part of the USSR. The average distributions for the European USSR are presented in *Table 7.4*.

The UN-ECE calculations result in a higher sensitivity in comparison with estimates of the Stockholm Environment Institute. Both studies identify the northern part of the European USSR as the most sensitive. Areas with relatively high sensitivity are also identified in both studies in the southeast corner of the European USSR.

We have used the distribution of sensitivity classes produced by the Stockholm Environment Institute and the former Beijer Institute. The measurement was chosen because the sensitivities of different forest species groups are considered and classified accordingly.

The existing sensitivity calculations cover only two-thirds of what we have classified as the European USSR. The input data for calculations of this region are scarce. Therefore, we have used the average sensitivity distributions for the total European USSR instead of the specific distributions for each subregion. Thus, this procedure simplifies the natural conditions and provides a conservative estimate of the sensitivity according to UN-ECE (1991). Identified acceptable loads (target loads) for sulfur and nitrogen depositions are linked to the sensitivity classes. These target loads have been

Table 7.5. Relation between sensitivity classes and target loads for sulfur and nitrogen depositions set by the Beijer Institute.

	g S m^{-2}		g N m^{-2}	
Sensitivity class	Coniferous	Deciduous	Coniferous	Deciduous
Low	2.0	4.0	1.5	2.0
Medium	1.0	2.0	1.0	1.2
High	0.5	1.0	0.3	0.5

Table 7.6. Average distribution of sensitivity classes for different species groups in the European USSR, in percent.

Coniferous forests			Deciduous forests		
Low	Medium	High	Low	Medium	High
58	24	18	77	16	7

set by the Beijer Institute. The relation between the sensitivity classes and target loads is presented in *Table 7.5*. The average distribution of sensitivity classes for different species groups employed for the European USSR is presented in *Table 7.6*.

The distribution of depositions in the individual regions of the European USSR was produced by the RAINS model developed at IIASA (see Alcamo *et al.*, 1990). The distribution of sulfur depositions for the individual regions of the European USSR was calculated for 1985 and 2000. For the year 2000, the existing international agreements on reductions of air pollutants valid until 1995 were considered. The detailed distribution patterns for sulfur in the individual regions are presented in Nilsson (1991b). Only one scenario has been developed for nitrogen depositions for the entire period from 1985 to 2000.

The USSR signed the protocol on the reduction of sulfur emissions and their transboundary fluxes by at least 30 percent in Helsinki in 1985. The country also signed the agreement for a stabilization of the emissions of nitrogen oxides in Sofia in November 1988. These conditions are considered in the calculations made by the RAINS model concerning future deposition patterns. Whether the USSR will be able to fulfill these agreements is uncertain.

By combining the Forest Study database of the forest resources on the individual regions of the USSR with the RAINS model, it is possible to estimate the extent of forest area with depositions exceeding the target loads at present and in the future. In these calculations, it is assumed that the same distribution of deposition pattern in all sensitivity classes exists.

The extent of forests in individual regions that exceed target loads of sulfur and nitrogen is presented in *Table 7.7*. Discrepancies exist between average depositions reported by the USSR sources (see *Table 7.3*) and those determined by the RAINS model (see Nilsson, 1991, for details). Generally, smaller regions receive a lower rate of deposition according to the RAINS model than the deposition rates reported by USSR authorities. The differences in deposition are especially high for the Pre-Baltic, the Carpathians, Moldavia, and the Forest Steppe regions. For other regions, there is good correspondence between the reported and calculated depositions.

It should be stressed that for the Volgo-Vyatsky, Povolzhsky, and the Ural regions it was not possible to produce specific distribution curves with the RAINS model: this is due to a lack of registration grids in the basic database produced by EMEP. In these cases, the principal shape of the average distribution curve for surrounding regions was used. The average deposition values reported by the USSR Goskomstat (1989) and Goskomgidromet (1990) for these regions were used as shifters of this generated average distribution curve.

In general, the percentage of forests exceeding the sulfur target load is lower in the European USSR than in Western and Eastern Europe. The situation with nitrogen depositions is the reverse; the nitrogen load is lower in Western and Eastern Europe (see Nilsson *et al.*, 1991). At the time this study was conducted, reliable information was not available on ozone concentrations in the European part of the USSR.

A specific analytical tool has been employed in estimating the decline effects on forests if depositions were to exceed the target loads. The system developed is described in more detail by Bellmann *et al.* (1992) and by Nilsson *et al.* (1992). The basic concepts of this analytical tool are the following:

- The observed decline (needle losses) is caused by a direct impact process (air pathway) as a noncumulative process or by an indirect impact process (soil pathway) as a cumulative process or by both.
- The decline caused through the soil pathway is a result of a cumulative and filtered dose of air-pollution concentrations. The size of the filtered dose depends on the site capability to buffer the actual dose.
- The decline is mainly caused by the combined effect of sulfur and nitrogen under moderate ozone concentrations.
- The decline is further increased by the water stress and extreme temperatures.

Table 7.7. Percent of closed and productive forest area with sulfur and nitrogen depositions exceeding target loads for coniferous and deciduous species in 1985 and expected in 2000.

		Sulfur		Nitrogen	
Region	Year	Coniferous	Deciduous	Coniferous	Deciduous
North	1985	12	1	7	1
	2000	10	0	27	10
Northwest	1985	55	10	19	7
	2000	36	6	91	62
Central	1985	47	10	23	7
	2000	33	6	87	64
Pre-Baltic	1985	59	12	26	23
	2000	42	7	100	100
Volgo-Vyatsky	1985	2	0	17	0
	2000	2	0	25	8
Central Chernozyomny	1985	43	7	25	11
	2000	37	5	76	54
Povolzhsky	1985	43	7	22	7
	2000	37	5	76	54
Ural	1985	44	7	24	9
	2000	31	5	78	61
North Caucasia	1985	2	0	17	0
	2000	2	0	25	8
Carpathians (Ukraine)	1985	91	21	42	23
	2000	91	21	100	100
Polesye (Ukraine)	1985	48	9	42	23
	2000	42	7	100	100
Forest Steppe (Ukraine)	1985	68	14	42	23
	2000	64	13	100	100
Moldavia	1985	47	8	40	12
	2000	38	6	100	100
Byelorussia	1985	47	8	42	13
	2000	38	6	100	100
Estonia	1985	47	8	18	7
	2000	39	6	88	54
Latvia	1985	42	7	22	7
	2000	36	5	100	85
Lithuania	1985	42	7	37	7
	2000	42	7	100	97

The actual model (called PEMU) generates a damage cycle with corresponding growth losses. The expression *damage cycle* requires an explanation. The international criterion used for monitoring forest decline attributed to air pollutants is loss of foliage. Different degrees of foliage loss define different decline classes (UN-ECE, 1986). The damage cycle indicates the number of years a forest stand of a particular sensitivity class will remain in various defoliation classes at a specific rate of pollutant deposition. Based on the PEMU study, it has been possible to generate some basic quantitative estimates of damage cycles. These basic cycles have been supplemented with other similar studies (for example, Materna, 1988; Ulrich and Cerny, 1990).

Growth effects are linked to the loss of foliage. The analyses by the PEMU model also generate an estimate of these growth effects. Many studies have been conducted in various areas concerning the relations between loss of foliage and growth rates. These studies have been reviewed by Nilsson (1986) and Nilsson *et al.* (1992), and the results have been used to supplement the information on growth effects determined by the PEMU system. The detailed results concerning the damage cycle and growth effects in Eastern and Western Europe have been discussed by Nilsson *et al.* (1992).

To mitigate the negative effects of the decline process in forests, some silvicultural measures can be taken. The objectives of such silvicultural measures are to increase stand vitality, delay the decline process, and save commercial wood. Examples of such measures are intensified thinning, shortened rotation periods, and changed species composition. Several research organizations have been engaged by the Forest Study to formulate explicit silvicultural responses to the decline (see Nilsson and Posch, 1989). The quantified responses include changes in thinning regimes, changes in expected time durations between stand establishment and final felling, and delays in the regeneration. The quantifications of these responses are presented in Nilsson *et al.* (1992).

The current vitality of the forests is used in the scenarios as the parameter that describes the historical stress effects (air pollution and other forces) on the forests. As an estimate of its vitality, the current crown density (loss of foliage) according to the methodology of the UN-ECE (1986) has been employed. The parameter crown density can be used as a starting point for the decline scenarios because the loss of foliage is used both as the main current vitality criterion and as a key parameter in the quantification of the effects attributed to air pollutants.

For Western and Eastern Europe there are good monitoring results following the UN-ECE (1986) methodology concerning the vitality (crown density) available. For European USSR this information is more sparse. Monitoring of the vitality according to the UN-ECE methodology has only been performed in 1989 and 1990 for the following subregions of the European USSR: Pre-Baltic, Ukraine, Byelorussia, Estonia, Latvia, Lithuania, Archangelsk (in 1990 part of the Northern region in this study), Murmansk (in 1990 part of the Northern region in this study), and Karelia (in 1990 part of the Northwestern region in this study). The results from monitoring the vitality of these regions are presented in *Table 7.8*.

Thus, we have limited information about the present vitality of the forest resources of the total European USSR. Nevertheless, it has been demonstrated that there is a strong link between the rate of deposition and the degree of defoliation (see Bellmann *et al.*, 1992; Nilsson *et al.*, 1992). Therefore, we have estimated the current vitality of the forest resources in the regions that have not been monitored in the European USSR by combining the results in *Table 7.8* and the information about current deposition patterns in *Table 7.3*.

Four high-deposition regions have been identified: the Pre-Baltic region, the Carpathians, the Forest Steppe, and Moldavia. Further, two medium-deposition regions have been identified: Lithuania and Estonia. The remaining regions have relatively low-deposition rates. Starting values for the scenarios on forest decline of current vitality have been determined by combining current vitality and deposition rates (*Table 7.9*).

In the estimations in *Table 7.9*, the values for Archangelsk, Murmansk, and Karelia have not been used because the monitoring results were only available for one year. However, it can be seen that these three regions are classified as low-deposition regions although they have a much lower vitality than the corresponding group in *Table 7.9*. This can be an indication that the estimate of the current vitality in the European USSR is not overestimated. However, it should be emphasized that the basic data concerning the decline model have some serious shortcomings, implying that simplifications have to be made.

According to Alekseev (1990) and Isaev (1991), there are large local areas with forests damaged by air pollutants in the USSR. For Siberia, the researchers report that the Krasnoyarsk region has 2 million hectares of forests with deposition damage, of which about 170,000 hectares are completely dead forests. Other damage centers in Siberia are Bratsk, Irkutsk, and Chelyabinsk. In the European USSR the major damage centers with dying forests are the Murmansk region, Lithuania, the Ukraine, Byelorussia, and the Central region.

The Lithuanian Research Forestry Institute estimates that the annual growth rate of the Lithuanian forests has decreased by 17 percent due to depositions of air pollutants.

Table 7.8. Vitality of the forest in some subregions of the European USSR. Vitality is expressed as number of trees with loss of foliage as a percentage of total number of monitored trees.

			Loss of foliage in percent			
Region	Year	Species	0–10	11–25	26–60	60+
Pre-Baltic	1989	Coniferous	11.0	46.0	41.0	2.0
		Deciduous	33.0	35.0	28.0	4.0
	1990	Coniferous	9.1	58.2	30.6	2.1
		Deciduous	40.0	49.8	7.5	2.7
Ukraine (Polesye)	1989	Coniferous	83.5	15.1	1.4	0.0
		Deciduous	88.9	9.7	1.3	0.1
	1990	Coniferous	61.4	35.6	2.9	0.1
		Deciduous	74.9	22.4	2.4	0.3
Byelorussia	1989	Coniferous	12.0	12.0	68.0	8.0
		Deciduous	26.7	39.9	30.7	2.7
	1990	Coniferous	13.0	30.0	52.0	5.0
		Deciduous	24.0	31.0	40.0	5.0
Estonia	1989	Coniferous	38.8	32.7	27.8	0.7
		Deciduous	–	–	–	–
	1990	Coniferous	37.0	43.0	20.0	–
		Deciduous	–	–	–	–
Latvia	1990	Coniferous	23.0	34.0	41.0	2.0
		Deciduous	59.0	14.0	27.0	–
Lithuania	1989	Coniferous	32.0	44.0	22.0	2.0
		Deciduous	50.0	34.0	14.0	2.0
	1990	Coniferous	26.3	50.8	21.3	1.6
		Deciduous	41.4	42.8	14.0	1.8
Archangelsk Northern region	1990	Coniferous	45.8	42.0	11.7	0.4
Murmansk Northern region	1990	Coniferous	59.6	35.3	4.8	0.2
Karelia Northwest region	1990	Coniferous	80.8	19.2	0.0	0.0

Source: Goskomles, 1991.

Table 7.9. Starting values of current vitality in the forest decline scenarios, expressed as number of trees with loss of foliage as percentage of total number of trees monitored.

	Loss of foliage in percent			
Species group	0–10	11–25	26–60	60+
High deposition				
Coniferous	11.5	46.5	40.0	2.0
Deciduous	29.9	37.7	29.4	3.0
Medium deposition				
Coniferous	39.8	38.7	20.5	1.0
Deciduous	46.5	37.6	14.4	1.5
Low deposition				
Coniferous	72.4	23.4	4.2	0.0
Deciduous	78.4	17.9	3.6	0.1

7.3 Decline–Modeling Approach

The basic modeling concept described in Chapter 3 was changed in two aspects to consider the decline effects. First, the basic state description scheme was expanded by two variables: decline class and sensitivity class. Second, the transition rates were made changeable over time. The decline model is illustrated in *Figure 7.2*.

The decline model has been described in Nilsson *et al.* (1992), but it is expanded in this chapter at two different levels: sensitivity classes are related to the state of the land or the site and decline classes refer to the stand of the trees. Consequently, the distribution of the forest land over different sensitivity classes was regarded as a constant pattern. This pattern was separated over species groups since the target loads differ between these groups. There are no transitions between different species groups in the model; therefore, even if the sensitivity dimension were included in the site description, the site would be regarded as stable over time.

Three classes, the definitions of which differ between coniferous and deciduous types, were used to express the sensitivity distribution (see *Table 7.5*). The forest in the decline context is described not only by age and volume, but also by the decline class. Four classes coinciding with internationally accepted definitions were used (see *Tables 7.8* and *7.9* and UN-ECE, 1986). It was assumed that the distribution over decline classes is equal in all sensitivity classes. By using this assumption and information on changed thinning regimes, changed time duration before final felling, delay in regeneration time (see Nilsson *et al.*, 1992, for a further description of

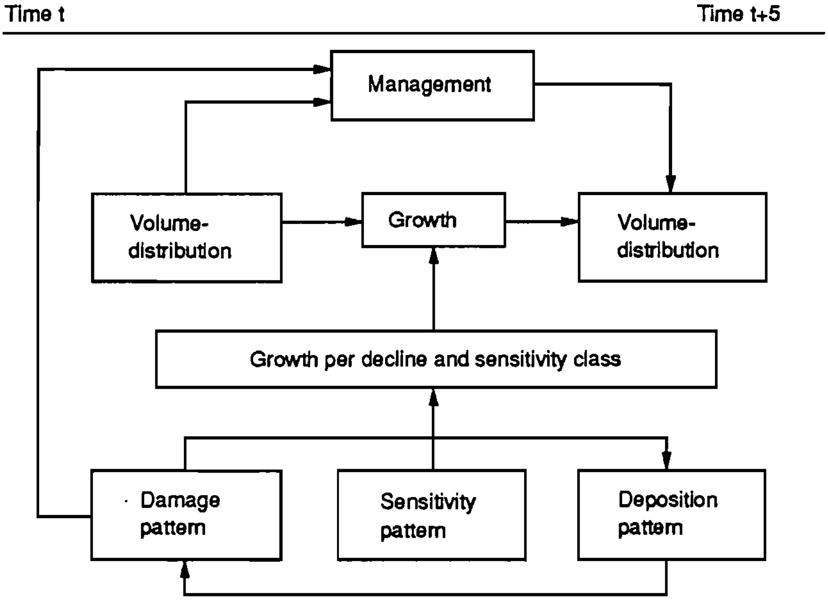

Figure 7.2. Flowchart of the decline model.

these parameters), and current vitality (discussed in Section 7.2), the initial forest-state description was enhanced with new variables.

7.4 Transition Rates

The transition rates corresponding to volume growth were changed to relate to the decline-class pattern and depositions. In addition, new transitions between the decline classes were added to the model. For every simulation period of five years, a distribution of the forest area was calculated over six different deposition classes. Combined with the sensitivity structure, the decline cycles, and growth-reduction scheme (discussed in Nilsson *et al.*, 1992), a new set of transition rates could be deduced for every forest state and every simulation period. Correspondingly, the transition rates between decline classes could be calculated.

7.4.1 Management

The basic management programs were altered for thinnings, rotation periods, and regeneration times according to data presented in Nilsson *et al.* (1992).

Thus, earlier fellings and higher thinning intensities were carried out with increasing damage class.

7.4.2 Regeneration

Regeneration was assumed to be at a slower rate if the forest area to be regenerated was found in the higher decline classes at the time of final felling. Therefore, the coefficients representing transitions from the bare-land classes to the ordinary matrices were decreased for areas classified as being part of the higher decline classes.

7.4.3 Summary

As illustrated above, some of the input parameters for the analysis of the effects of air pollutants on the forest resources of the European USSR are very weak and incomplete. This is especially valid for the distribution of sensitivity classes and the current vitality of the forest resources.

We have calculated decline effects mainly on sulfur and nitrogen emissions, without considering the full combination of effects from other pollutants. In addition, we have assumed no pollutant emissions after 2005 above critical levels, which is an overoptimistic view.

We have implemented only those kinds of silvicultural and managerial interventions that are already structured into the modeling framework, for example, changed thinning regions and rotations. Other silvicultural means of mitigating the effects of air pollutants, such as better matching of regenerated species with sites, genetic improvements in stock for regeneration, and fertilization, have not been explored. However, when considering the basic assumptions (even if some of the input data are weak), the overall results with respect to the possible impacts of air pollution on forest resources and potential wood supplies are considered to be conservative.

7.5 Decline Scenarios

As for the basic scenarios, all the simulations have a time horizon of 100 years, with 1988 as the starting point. The forest areas presented in *Table 2.3* are used throughout all simulations. Although, we illustrate the effects of emissions only until the year 2000, we know from the PEMU analyses (Bellmann *et al.*, 1988) that there are long-lasting effects of the depositions even if the emissions, contrary to expectations, should cease by the year 2000. Based on the PEMU analyses, we have considered the following long-lasting effects in the decline scenarios:

- Full decline effects to the year 2005, after which growth rates will recover slowly over time.
- Recovery rates ranging between 10 and 40 years, depending on site conditions and historical deposition rates.

In the Handbook Decline Scenario the forests are, in principle, treated strictly in accordance with the silviculture programs identified in the Soviet handbooks. However, to keep the vitality of the forests as close as possible to the ideal, silvicultural programs have been adjusted. The basic handbook silvicultural programs have been used as a platform and adjusted in accordance with assumptions discussed in Section 7.2, that is, shorter rotation, higher thinning intensity, and delayed regeneration in damaged forests. As in the Basic Handbook Scenario, no restrictions on the total harvest level have been imposed.

In the Forest Study Decline Scenario the objective is to strive for consistently high levels of both growing-stock and harvest levels over the simulation time period. In this case, the silviculture programs employed in the basic scenario have been adjusted as in the Handbook Decline Scenario. In many cases in this scenario, there are no possibilities of achieving these high levels of both harvests and growing stock as in the Basic Scenarios. In cases with conflicts between these two goals, the primary objective has been to keep the growing stock at a consistent, high level similar to that of the Basic Forest Study Scenario. Thus, in these cases, the effect of the decline will be illustrated by comparing potential harvest results with those of the Basic Forest Study Scenario.

7.6 Guide to the Results

The simulation results are described at the aggregate level. For each aggregate (Northern, Central, Baltic, Ural, and Southern) and total European USSR, one table and three sets of diagrams are presented. The tables and diagrams convey information from the two scenarios. The tables present selected projection data on growing-stock and annual harvest volumes at the beginning of the simulation and at specific points in the simulation (*Tables 7.10* to *7.15*). In the tables, the results for the Basic Forest Study Scenarios are presented to provide an easy numerical comparison with the decline scenarios.

These data are also contained in the diagrams. Bar charts on projected development of growing-stock and annual harvest levels for each five-year period are given for total forests (*Figures 7.3, 7.6, 7.10, 7.14, 7.18, 7.22*), coniferous forests (*Figures 7.4, 7.7, 7.11, 7.15, 7.19, 7.23*), and hard and soft deciduous forests (*Figures 7.5, 7.8, 7.9, 7.12, 7.13, 7.16, 7.17, 7.20, 7.21, 7.24, 7.25*). Results from the Basic Forest Study Scenario have been inserted into the bar charts to make the comparison with the decline scenarios easier. Results for the decline effects on the individual regions (17 regions) are presented in Appendix A.

7.6.1 The Northern aggregate (Table 7.10 and Figures 7.3 to 7.5)

A comparison of the average total potential harvest level between the basic and the decline scenarios show that under handbook conditions the harvest will increase by nearly 10 million cubic meters per year over 100 years under air-pollution stress. The increased harvest, forced by the decline conditions, is due to a much faster replacement of the overmature and mature forests, in comparison with conditions without pollution. Under the conditions of the Forest Study Scenarios the decline is 6 million cubic meters per year in the total harvest level.

In the Forest Study Decline Scenario, the declining forests cannot be replaced as quickly as in the Handbook Scenario due to restrictions on the total harvest level. The Forest Study Decline Scenario will result in a decline of the long-term sustainable harvest level in comparison with the Basic Forest Study Scenario.

The results from the Basic Forest Study Scenario denote a rather modest influence of the air pollutants in the Northern aggregate. However, Section 7.2 points out that the severe subregional air-pollution problems in this region have not been considered in the calculations. Therefore, it is reasonable to assume that the total effects of air pollutants are underestimated in the Forest Study Decline Scenario.

From the tables and the figures it can be seen that the effects of the air pollutants are mainly visible in the coniferous species.

There will be a smaller growing stock at the end of the simulation period in the Handbook Decline Scenario than in the Basic Handbook Scenario. In the two Forest Study Scenarios, there is a possibility of maintaining roughly the same development of the growing stock.

The growth rates will decline under air-pollution conditions by about 0.1 cubic meters per hectare per year for all species groups in both scenarios. There is a tendency toward an increase in final fellings of the total harvest under the decline conditions.

Table 7.10. Northern aggregate.

Variable	Basic Handbook	Basic Forest Study	Handbook Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	116–80	116–82	116–61	116–81
Fellings[b]				
Year 1	889.4	88.2	942.5	83.8
Year 40	53.6	95.9	76.5	89.8
Year 80	88.8	97.2	85.0	90.5
Coniferous				
Growing stock[a]	129–87	129–86	129–65	129–85
Fellings[b]				
Year 1	835.2	76.0	887.4	72.6
Year 40	38.2	81.4	61.1	76.5
Year 80	72.6	82.0	69.9	76.5
Soft deciduous				
Growing stock[a]	63–51	63–64	63–45	63–64
Fellings[b]				
Year 1	54.2	12.2	55.1	11.2
Year 40	15.4	14.5	15.4	13.3
Year 80	16.2	15.2	15.1	14.0
Hard deciduous				
Growing stock[a]	0–0	0–0	0–0	0–0
Fellings[b]				
Year 1	0.0	0.0	0.0	0.0
Year 40	0.0	0.0	0.0	0.0
Year 80	0.0	0.0	0.0	0.0
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	116.3	95.2	126.1	89.2
Coniferous	98.5	80.8	108.5	76.0
Soft deciduous	17.8	14.4	17.6	13.2
Hard deciduous	0.0	0.0	0.0	0.0
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	1.6	1.2	1.5	1.1
Coniferous	1.6	1.2	1.6	1.1
Soft deciduous	1.4	1.2	1.3	1.1
Hard deciduous	0.0	0.0	0.0	0.0
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	116–80	116–82	116–61	116–81
Coniferous	129–87	129–86	129–65	129–85
Soft deciduous	63–51	63–64	63–45	63–64
Hard deciduous	0–0	0–0	0–0	0–0

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

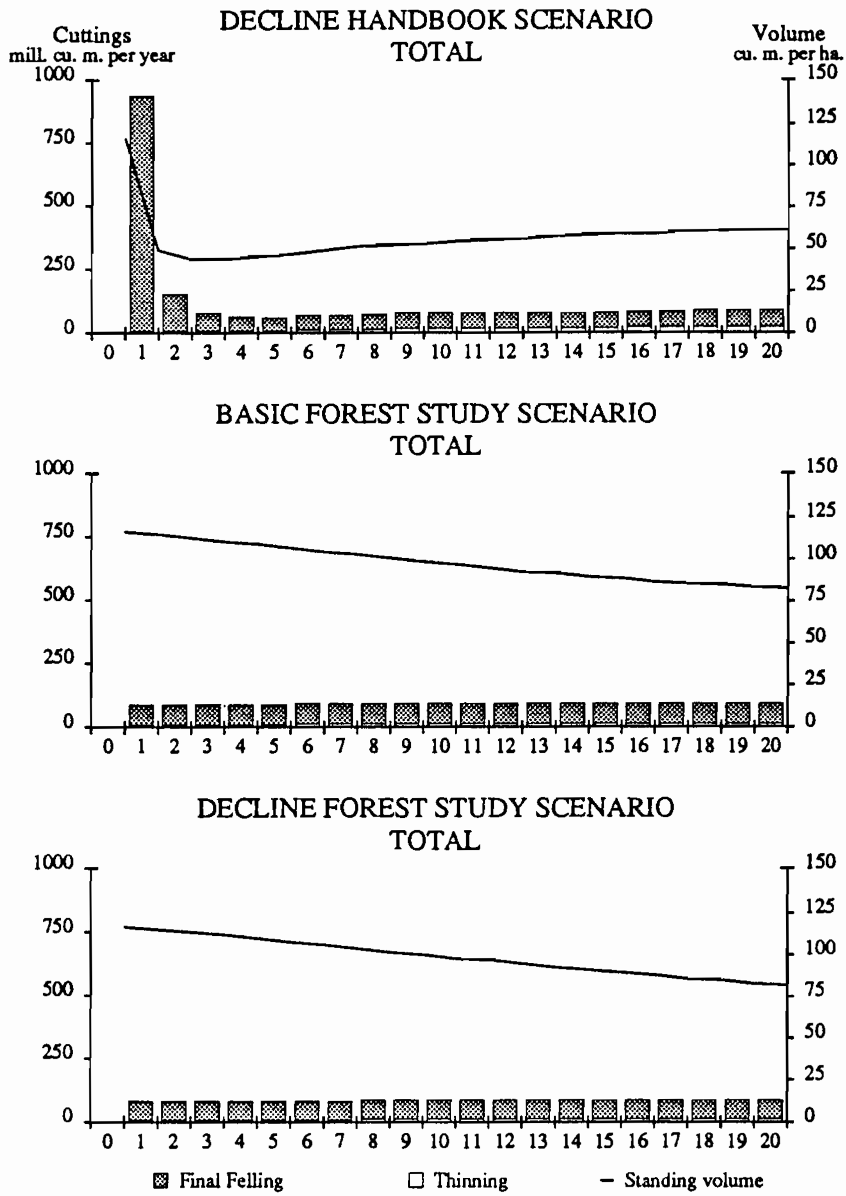

Figure 7.3. Projections of total potential harvest and growing stock in the Northern aggregate under the decline scenarios. Current fellings are 82.5 million cubic meters o.b.

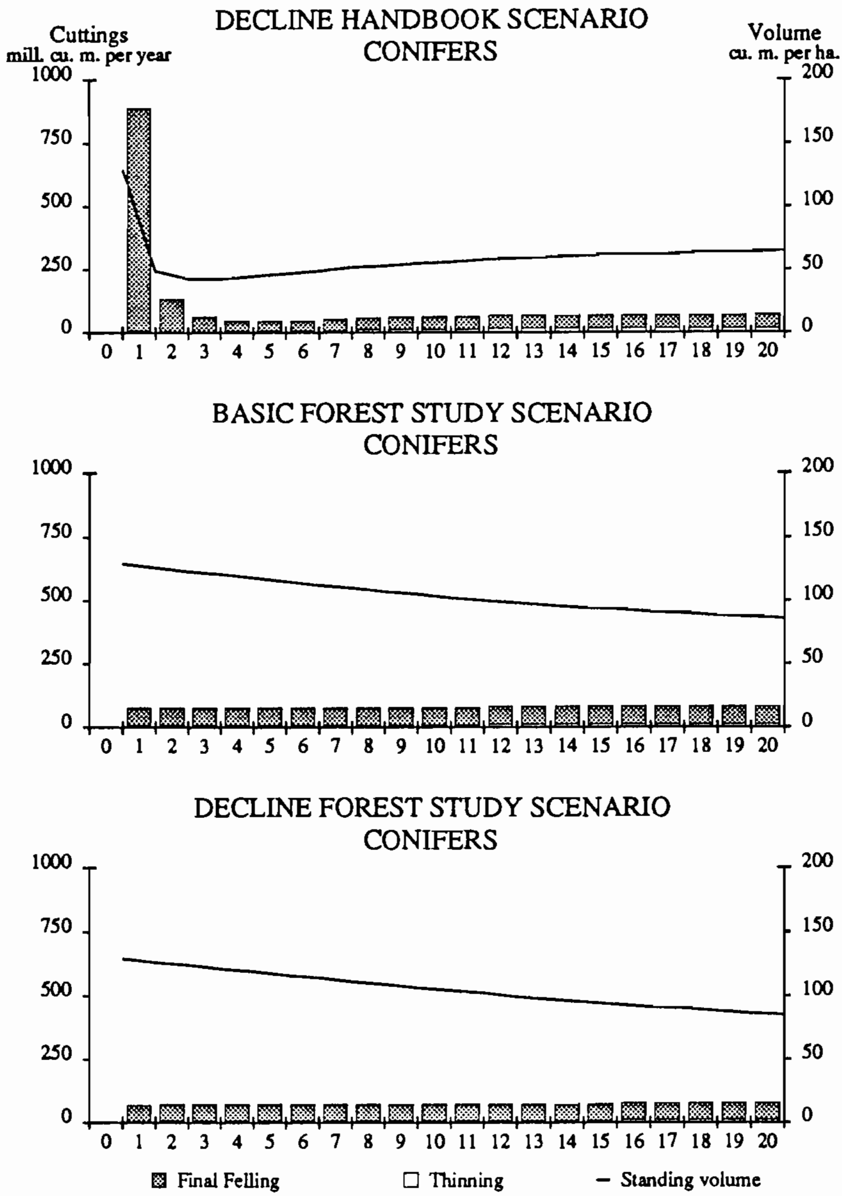

Figure 7.4. Projections of potential harvest and growing stock for coniferous species in the Northern aggregate under the decline scenarios. Current fellings are 70.4 million cubic meters o.b.

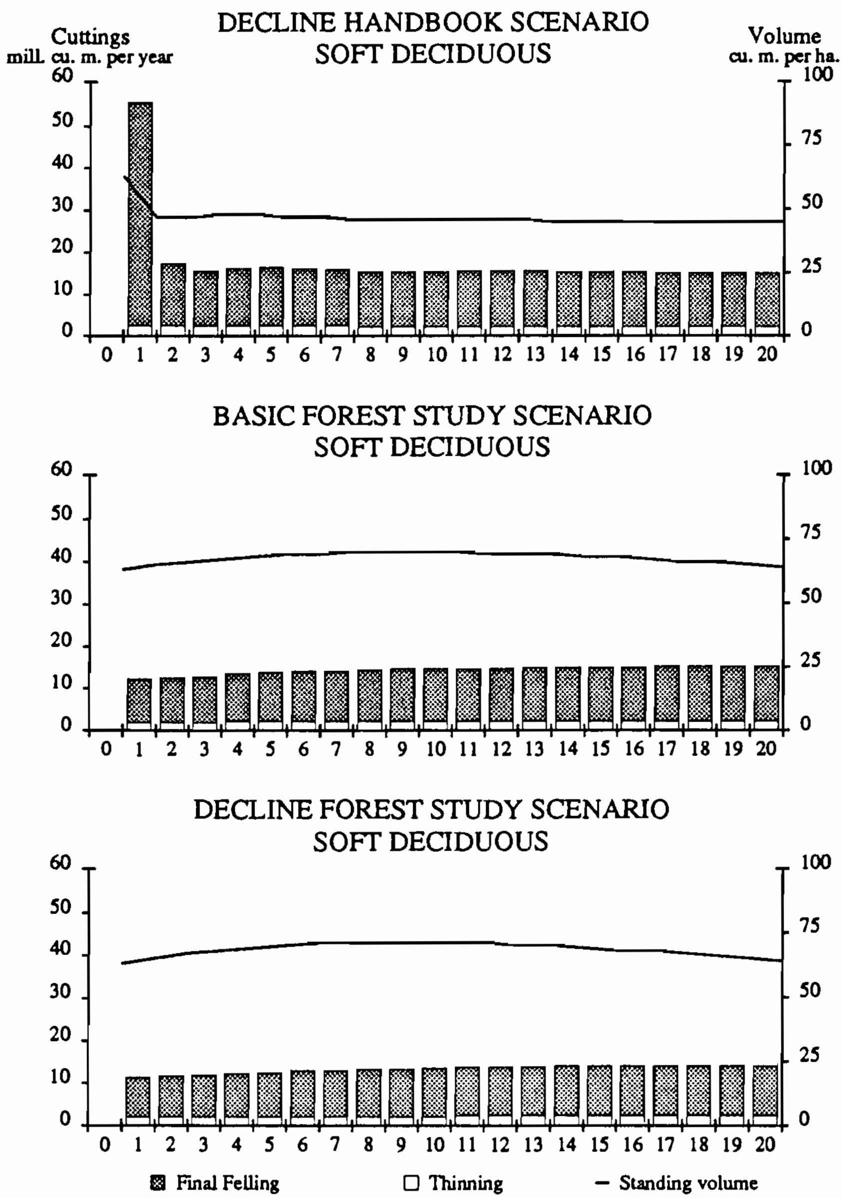

Figure 7.5. Projections of potential harvest and growing stock for soft deciduous species in the Northern aggregate under the decline scenarios. Current fellings are 12.1 million cubic meters o.b.

7.6.2 The Central aggregate (Table 7.11 and Figures 7.6 to 7.9)

The overall discord between the initial structure of the forest resources and the structure that would be developed if the handbook silviculture is implemented in the Central aggregate is most pronounced in the Handbook Decline Scenario. Like in the Handbook Decline Scenario for the Northern aggregate, the Handbook Decline Scenario for the Central aggregate gives a higher average total harvesting potential than the Basic Handbook Scenario. The difference is nearly 1 million cubic meters per year. Again, this is the result of a more rapid replacement of the overmature forests under the decline conditions. The Forest Study Decline Scenario gives a harvesting potential that is nearly 7.5 million cubic meters lower per year than the Basic Forest Study Scenario. The major effect of air pollutants occurs in coniferous and soft deciduous species. The decline of the harvesting potential in the Central aggregate under decline conditions in the Forest Study Scenarios is 7.2 million cubic meters per year.

In the Handbook Decline Scenario the final growing stock (at the end of the simulation period) is 10–20 cubic meters per hectare lower for the different species groups than in the Basic Handbook Scenario.

The growth rates are decreased by about 0.1 cubic meters per hectare per year for all species groups under the decline conditions and with handbook silviculture. Under the conditions of the Forest Study Scenarios, the growth rate will decrease by 0.2–0.3 cubic meters per hectare per year for all species groups under the decline caused by air pollutants, but the development of the growing stock is similar in the two scenarios.

Again, there is a tendency toward an increase in the proportion of final fellings under air-pollution conditions. The estimated decline of the average total harvesting potential in the Central aggregate from air pollutants is about 8 percent of the total potential in the Central aggregate.

7.6.3 The Baltic aggregate (Table 7.12 and Figures 7.10 to 7.13)

In the Basic Handbook Scenario (*Figure 5.8*) there are no initial harvest pulses in the beginning of the simulation. In contrast, in the Handbook Decline Scenario there is an increased harvest over time in the beginning of the simulation period. In the Handbook Decline Scenario we find very pronounced harvest pulses in the beginning of the simulation period for total species, coniferous species, and hard deciduous species. The forests of the Baltic aggregate have a medium load of depositions from air pollutants. This

Table 7.11. Central aggregate.

Variable	Basic Handbook	Basic Forest Study	Handbook Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	140–141	140–157	140–127	140–158
Fellings[b]				
Year 1	171.0	88.1	194.2	82.9
Year 40	90.3	89.8	85.6	81.7
Year 80	93.7	90.0	87.6	81.7
Coniferous				
Growing stock[a]	150–149	150–167	150–131	150–173
Fellings[b]				
Year 1	95.9	43.5	117.2	40.9
Year 40	43.8	44.6	43.8	40.1
Year 80	47.8	44.6	43.6	40.1
Soft deciduous				
Growing stock[a]	127–131	127–144	127–123	127–141
Fellings[b]				
Year 1	72.5	43.5	74.1	41.0
Year 40	45.1	44.1	40.5	40.7
Year 80	44.7	44.3	43.0	40.7
Hard deciduous				
Growing stock[a]	162–119	162–161	162–99	162–167
Fellings[b]				
Year 1	2.6	1.1	2.9	1.0
Year 40	1.4	1.1	1.3	0.9
Year 80	1.2	1.1	1.0	0.9
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	96.4	89.3	97.3	81.9
Coniferous	48.8	44.3	50.0	40.2
Soft deciduous	46.2	43.9	45.9	40.8
Hard deciduous	1.4	1.1	1.4	0.9
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	3.7	3.6	3.6	3.3
Coniferous	3.5	3.4	3.4	3.2
Soft deciduous	3.9	3.8	3.8	3.6
Hard deciduous	2.5	2.3	2.3	2.0
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	140–141	140–157	140–127	140–158
Coniferous	150–149	150–167	150–131	150–173
Soft deciduous	127–131	127–144	127–123	127–141
Hard deciduous	162–119	162–161	162–99	162–167

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

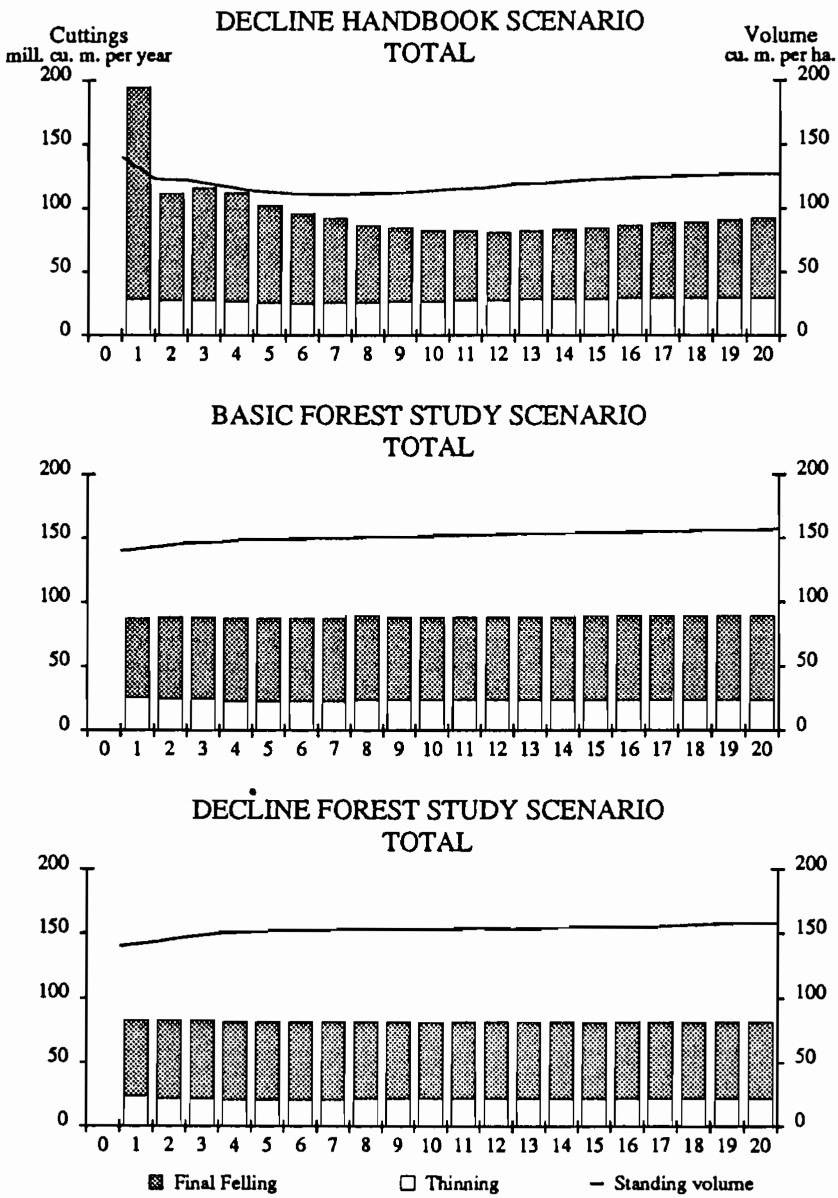

Figure 7.6. Projections of total potential harvest and growing stock in the Central aggregate under the decline scenarios. Current total fellings are 69.7 million cubic meters o.b.

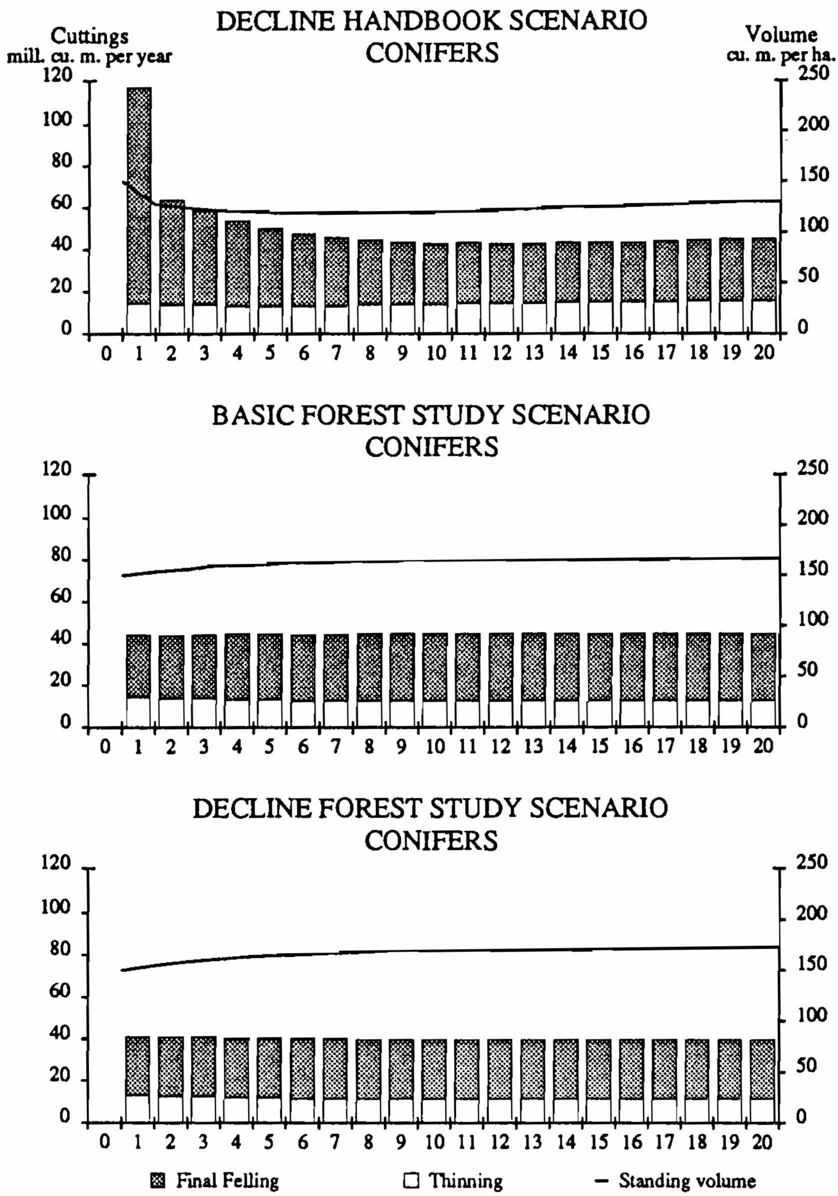

Figure 7.7. Projections of potential harvest and growing stock for coniferous species in the Central aggregate under the decline scenarios. Current fellings are 30.0 million cubic meters o.b.

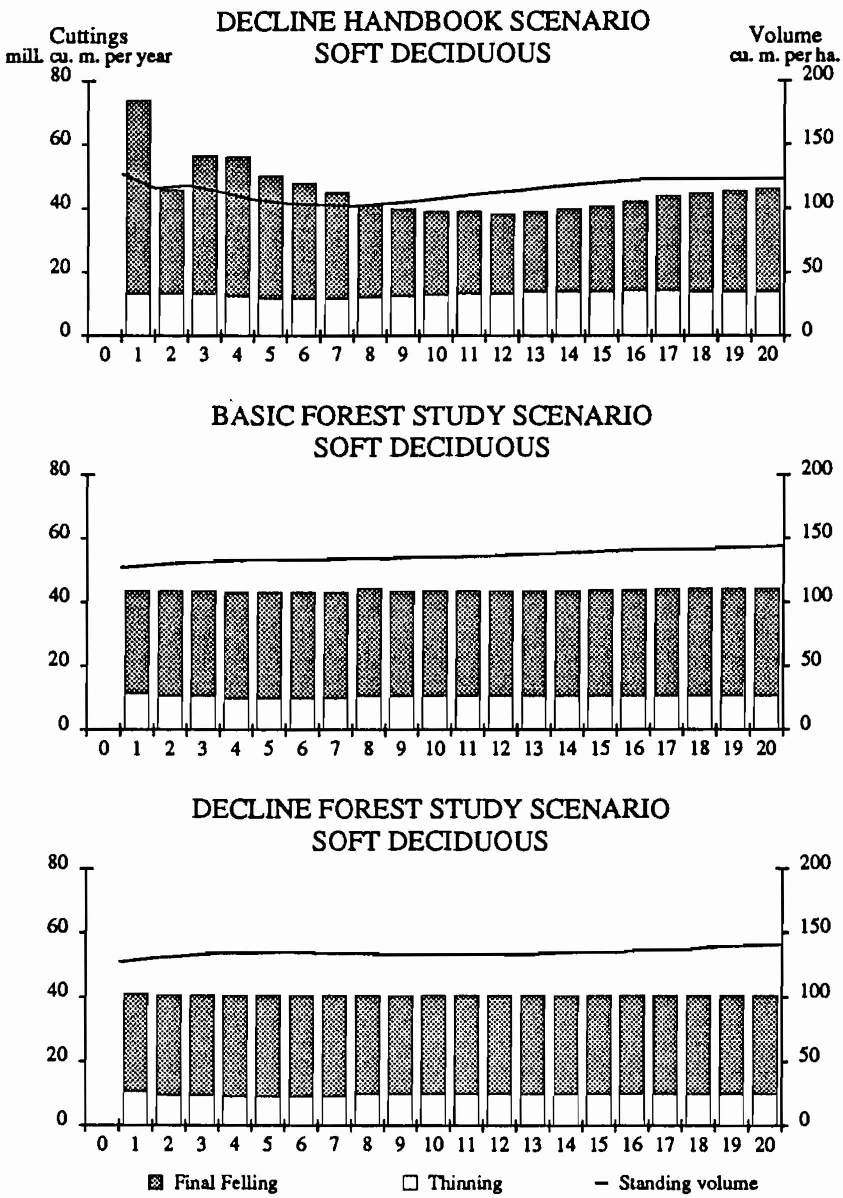

Figure 7.8. Projections of potential harvest and growing stock for soft deciduous species in the Central aggregate under the decline scenarios. Current fellings are 38.2 million cubic meters o.b.

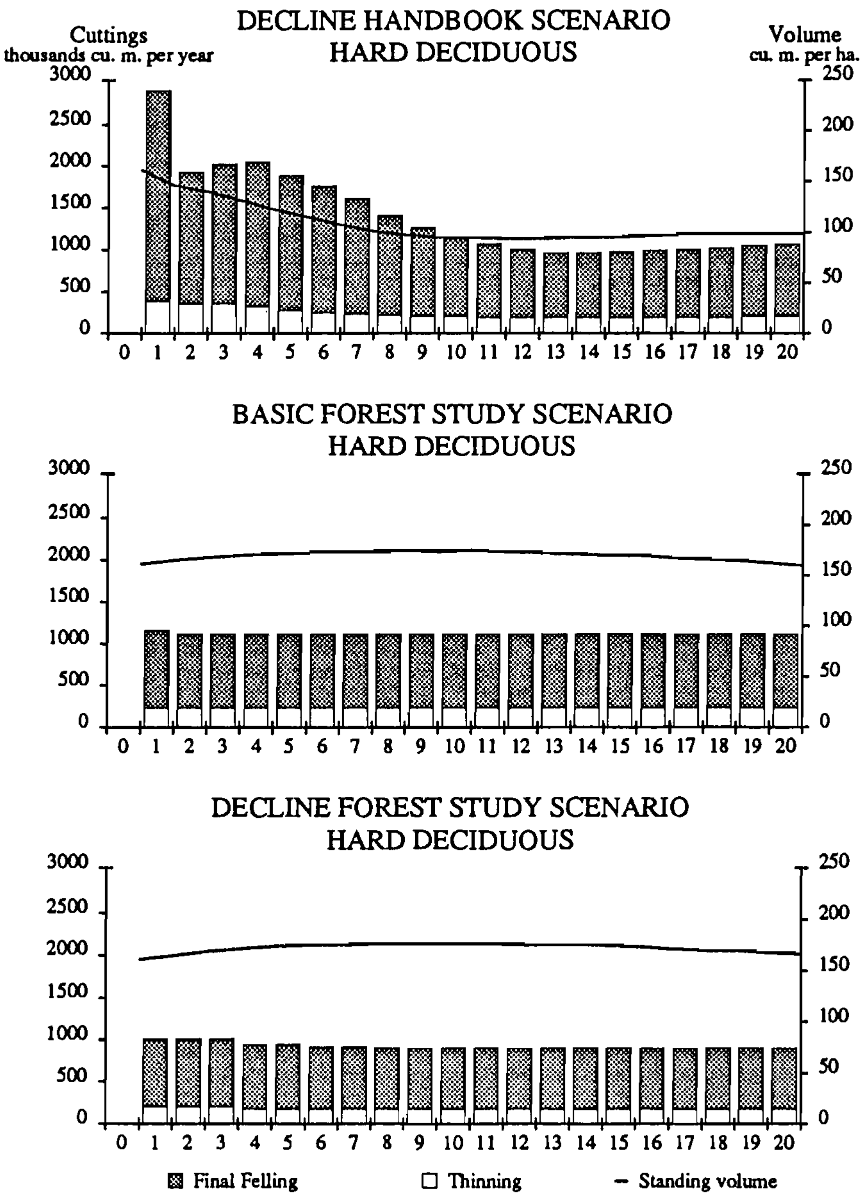

Figure 7.9. Projections of potential harvest and growing stock for hard deciduous species in the Central aggregate under the decline scenarios. Current fellings are 1.5 million cubic meters o.b.

Table 7.12. Baltic aggregate.

Variable	Basic Handbook	Basic Forest Study	Handbook Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	143–137	147–167	147–119	147–166
Fellings[b]				
Year 1	21.9	23.0	50.8	19.8
Year 40	35.2	27.2	25.8	20.6
Year 80	28.4	27.2	21.8	20.6
Coniferous				
Growing stock[a]	152–134	152–172	152–114	152–173
Fellings[b]				
Year 1	14.6	15.0	38.1	13.2
Year 40	21.8	17.6	17.0	13.6
Year 80	19.3	17.6	14.0	13.6
Soft deciduous				
Growing stock[a]	138–141	138–153	138–127	138–149
Fellings[b]				
Year 1	6.7	7.2	11.3	6.0
Year 40	12.5	8.7	8.0	6.4
Year 80	8.1	8.7	7.1	6.4
Hard deciduous				
Growing stock[a]	130–161	130–175	130–140	130–176
Fellings[b]				
Year 1	0.6	0.8	1.4	0.6
Year 40	0.9	0.9	0.8	0.6
Year 80	1.0	0.9	0.7	0.6
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	29.8	26.6	28.3	20.4
Coniferous	19.3	17.2	18.4	13.5
Soft deciduous	9.6	8.5	9.0	6.3
Hard deciduous	0.9	0.9	0.9	0.6
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	3.3	3.3	3.0	2.5
Coniferous	3.1	3.2	2.8	2.5
Soft deciduous	3.7	3.4	3.4	2.5
Hard deciduous	3.3	3.5	3.1	2.6
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	147–137	147–167	147–119	147–166
Coniferous	152–134	152–172	152–114	152–173
Soft deciduous	138–141	138–153	138–127	138–149
Hard deciduous	130–161	130–175	130–140	130–176

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

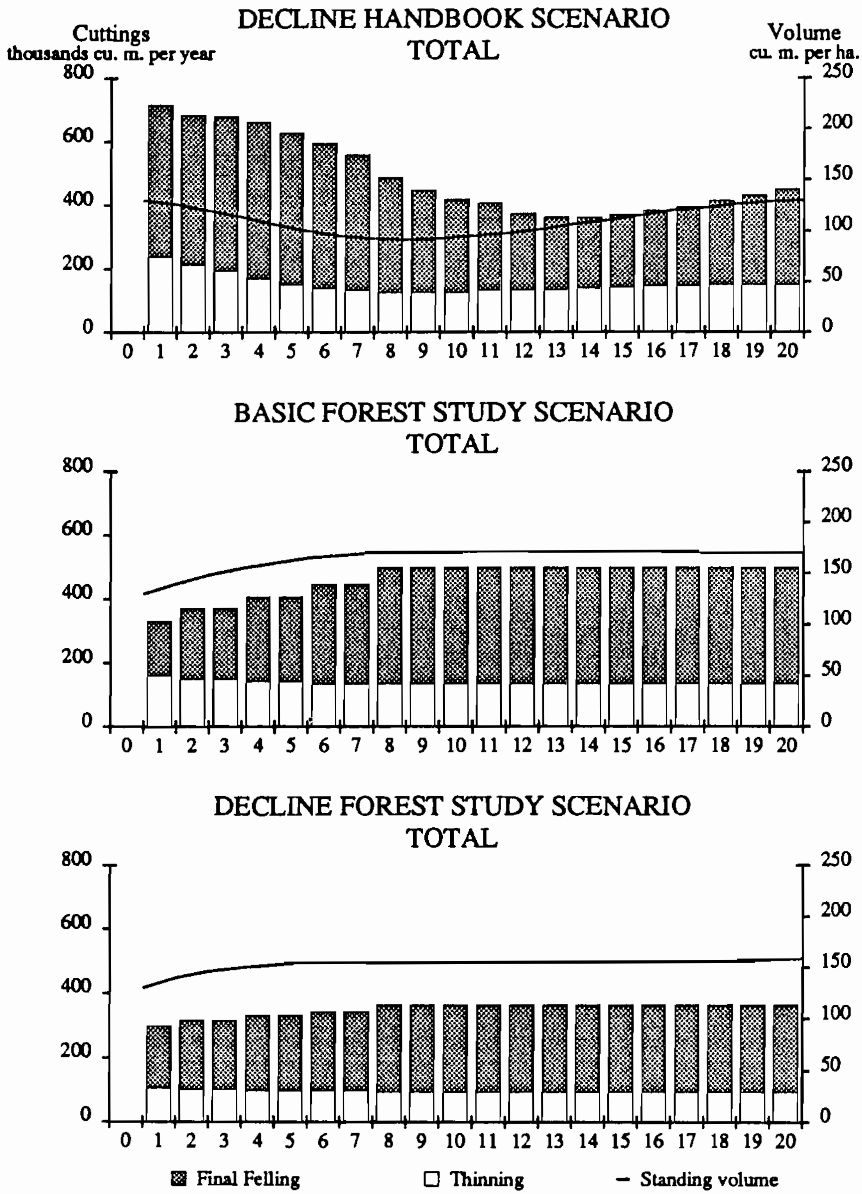

Figure 7.10. Projections of total potential harvest and growing stock in the Baltic aggregate under the decline scenarios. Current total fellings are 18.7 million cubic meters o.b.

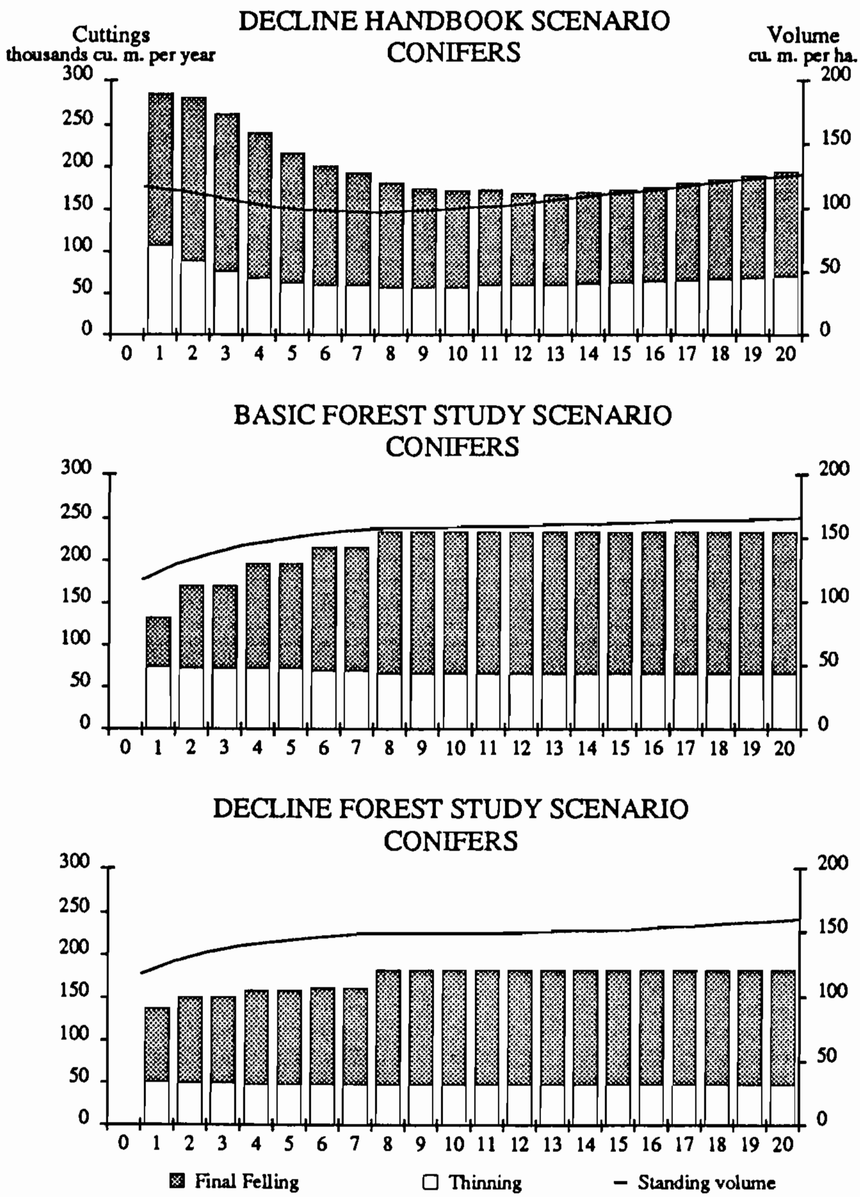

Figure 7.11. Projections of potential harvest and growing stock for coniferous species in the Baltic aggregate under the decline scenarios. Current fellings are 9.2 million cubic meters o.b.

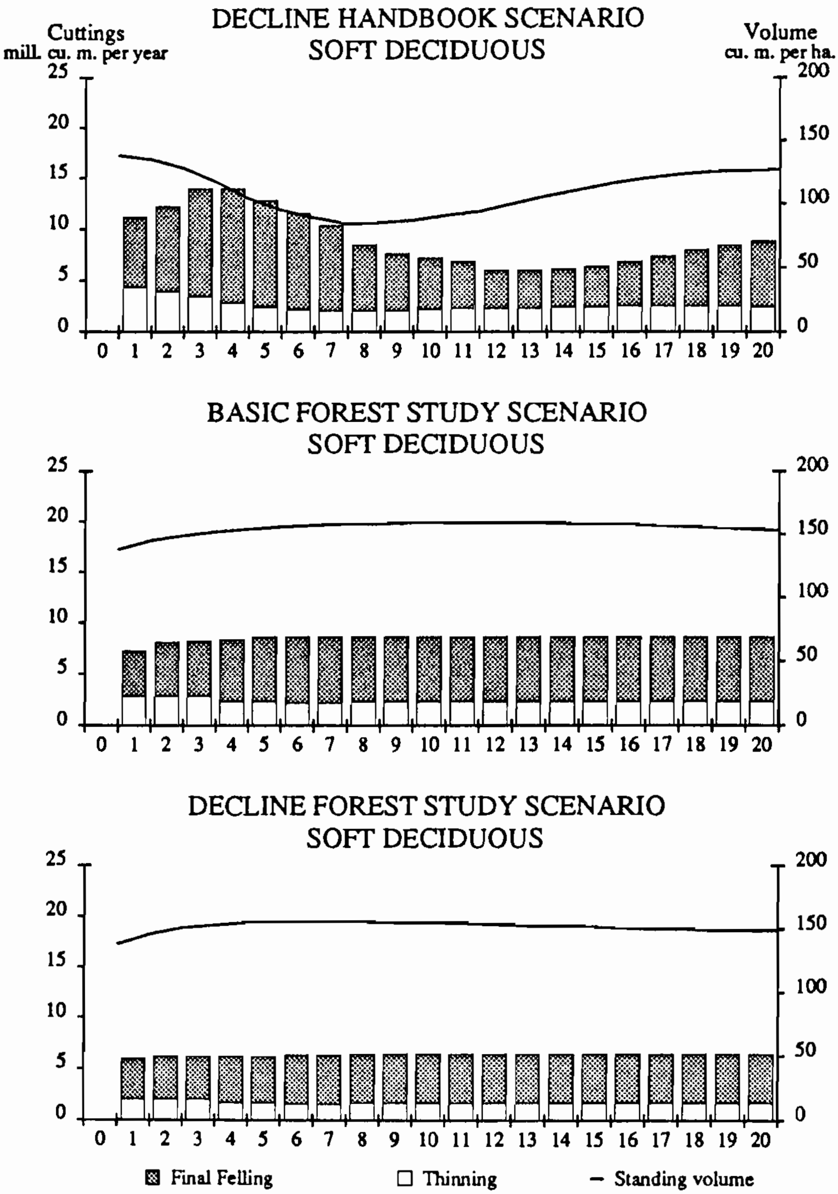

Figure 7.12. Projections of potential harvest and growing stock for soft deciduous species in the Baltic aggregate under the decline scenarios. Current fellings are 8.5 million cubic meters o.b.

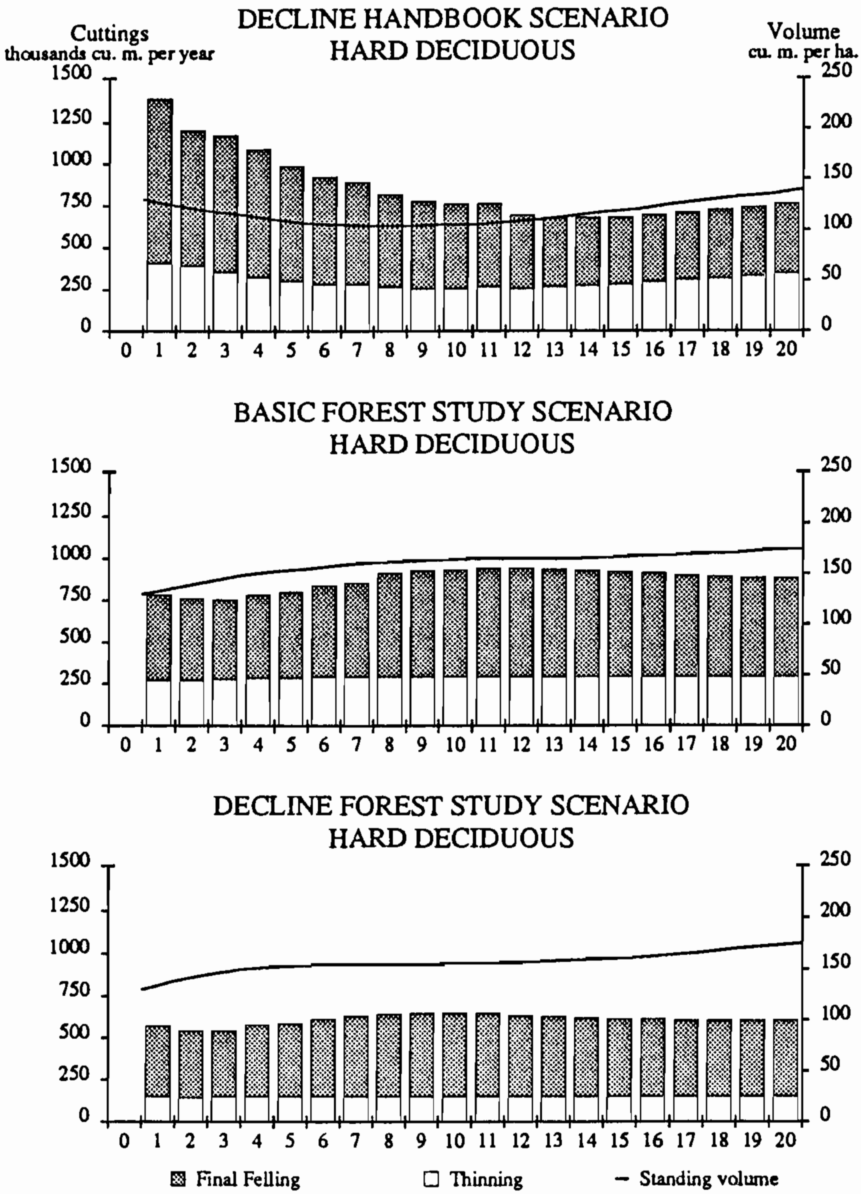

Figure 7.13. Projections of potential harvest and growing stock for hard deciduous species in the Baltic aggregate under the decline scenarios. Current fellings are 1.0 million cubic meters o.b.

load produces shorter rotation periods and intensified thinnings which, under handbook silvicultural conditions, result in rapid replacement of affected stands and harvest peaks in the beginning of the simulation period.

The difference in average total harvesting potential between the two handbook scenarios is 1.5 million cubic meters per year; the potential is lower in the Handbook Decline Scenario. The Forest Study Decline Scenario gives a total harvesting potential that is 6.2 million cubic meters per year lower than the Basic Forest Study Scenario. In the former scenario coniferous species and soft deciduous species are most affected by air pollutants.

The two Forest Study Scenarios present a similar development of the growing stock for the different species groups over time. Thus, in spite of the rather high amount of deposition, there are possibilities of keeping a sustainable stock, but at the expense of a lower harvesting potential. The growing stock of different species is roughly 25–50 cubic meters per hectare lower in the Handbook Decline Scenario than in the Basic Handbook Scenario. This is a result of an increased harvest in the beginning of the simulation under the decline conditions.

In the Handbook Decline Scenario the growth rate will decline, in comparison with the Basic Handbook Scenarios, by 0.2–0.3 cubic meters per hectare per year for the different species. The corresponding figures for the two Forest Study Scenarios are 0.7–0.9 cubic meters per hectare per year. Under the conditions of the Forest Study Scenarios, it can be seen that the effects of air pollutants will decrease the average total harvesting potential by some 10 percent.

7.6.4 The Ural aggregate (Table 7.13 and Figures 7.14 to 7.17)

The Ural aggregate has an extensive amount of overmature coniferous forests. This influences the harvest pattern in the Handbook Decline Scenario. The harvest pulse from the overmaturity of the forests, identified in the Basic Handbook Scenario, will further increase under the decline conditions. However, the total average harvest potential will not differ much between the two handbook scenarios. Both have an average total harvest level of some 78 million cubic meters o.b. per year. Under the decline conditions the potential average harvest level is higher for coniferous species than under the conditions of the Basic Handbook Scenario. The overmaturity is most pronounced in the coniferous species in the Ural aggregate where the air pollutants will bring about a rapid replacement of those forests. Also under the conditions of the Handbook Decline Scenario the average harvesting potential will be decreased by about 1.5 million cubic meters per year.

Table 7.13. Ural aggregate.

Variable	Basic Handbook	Basic Forest Study	Handbook Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	129–114	129–113	129–98	129–113
Fellings[b]				
Year 1	276.3	74.2	304.4	64.0
Year 40	60.6	76.8	60.8	65.8
Year 80	74.4	75.5	65.4	66.4
Coniferous				
Growing stock[a]	141–117	141–113	141–94	141–114
Fellings[b]				
Year 1	178.1	37.0	204.0	32.9
Year 40	25.1	37.0	29.4	32.9
Year 80	35.5	37.0	31.3	33.4
Soft deciduous				
Growing stock[a]	114–111	114–114	114–103	114–112
Fellings[b]				
Year 1	92.7	36.0	94.8	30.2
Year 40	34.5	38.5	30.4	31.8
Year 80	37.3	37.2	32.8	31.8
Hard deciduous				
Growing stock[a]	120–95	120–91	120–90	120–92
Fellings[b]				
Year 1	5.5	1.2	5.6	0.9
Year 40	1.0	1.3	1.0	1.1
Year 80	1.6	1.3	1.3	1.2
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	78.5	76.0	78.7	65.8
Coniferous	39.1	37.0	41.1	33.1
Soft deciduous	37.8	37.7	36.1	31.6
Hard deciduous	1.6	1.3	1.5	1.1
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	3.0	2.9	2.8	2.5
Coniferous	2.6	2.4	2.5	2.1
Soft deciduous	3.5	3.5	3.3	3.0
Hard deciduous	2.8	2.2	2.7	1.9
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	129–114	129–113	129–98	129–113
Coniferous	141–117	141–113	141–94	141–114
Soft deciduous	114–111	114–114	114–103	114–112
Hard deciduous	120–95	120–91	120–90	120–92

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

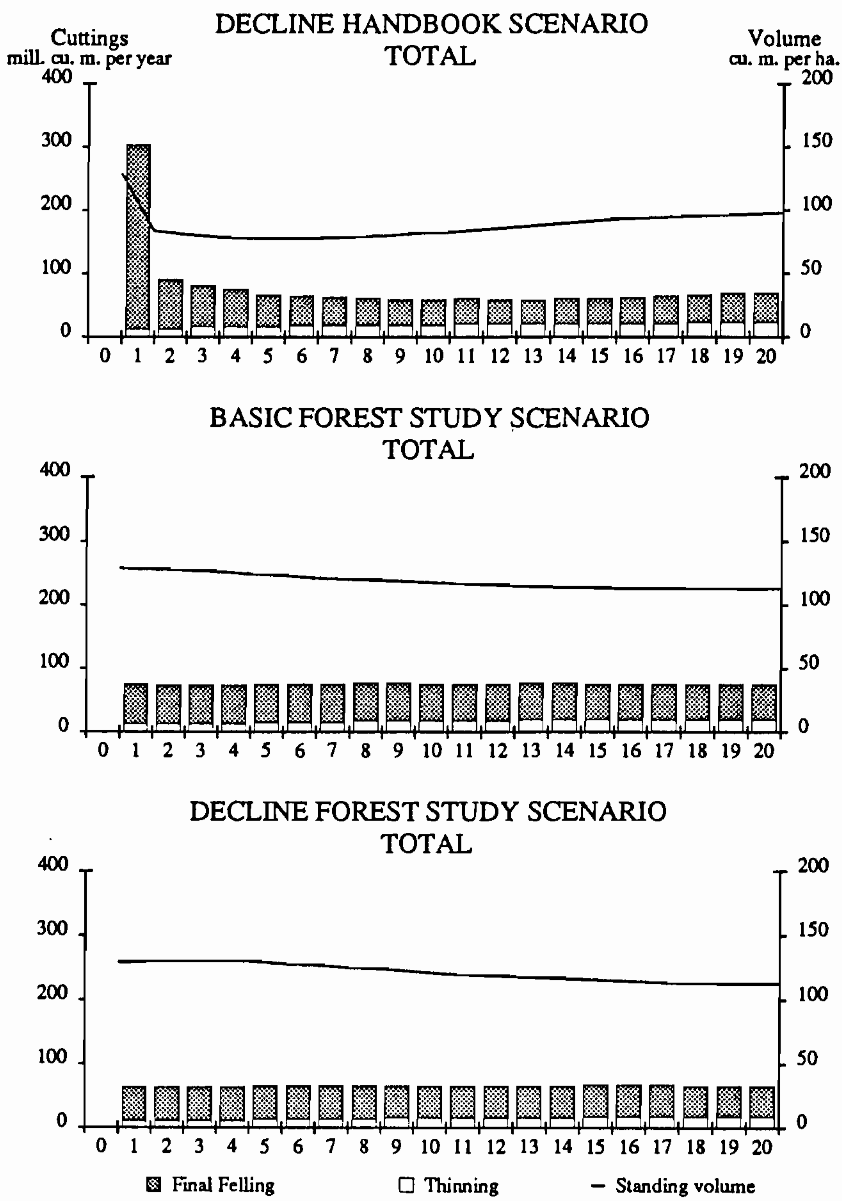

Figure 7.14. Projections of total potential harvest and growing stock in the Ural aggregate under the decline scenarios. Current total fellings are 56.3 million cubic meters o.b.

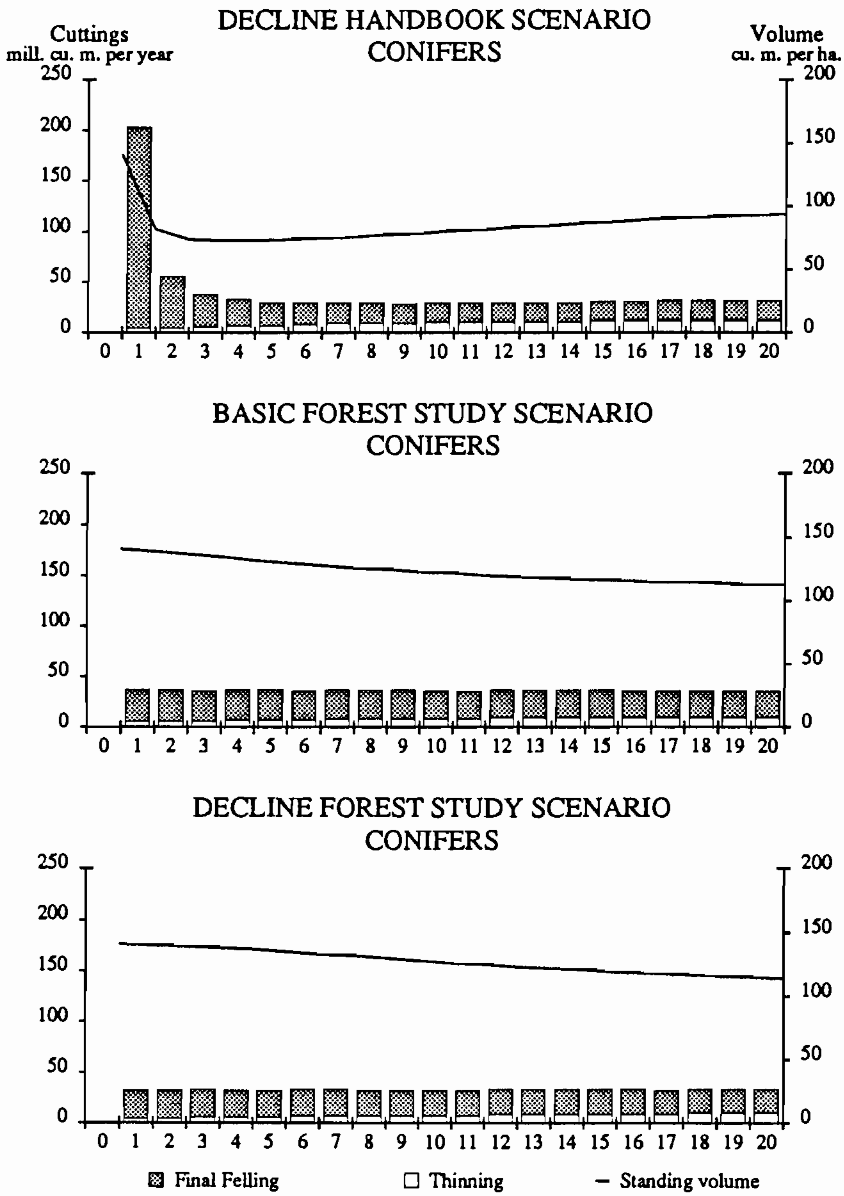

Figure 7.15. Projections of potential harvest and growing stock for coniferous species in the Ural aggregate under decline scenarios. Current fellings are 33.0 million cubic meters o.b.

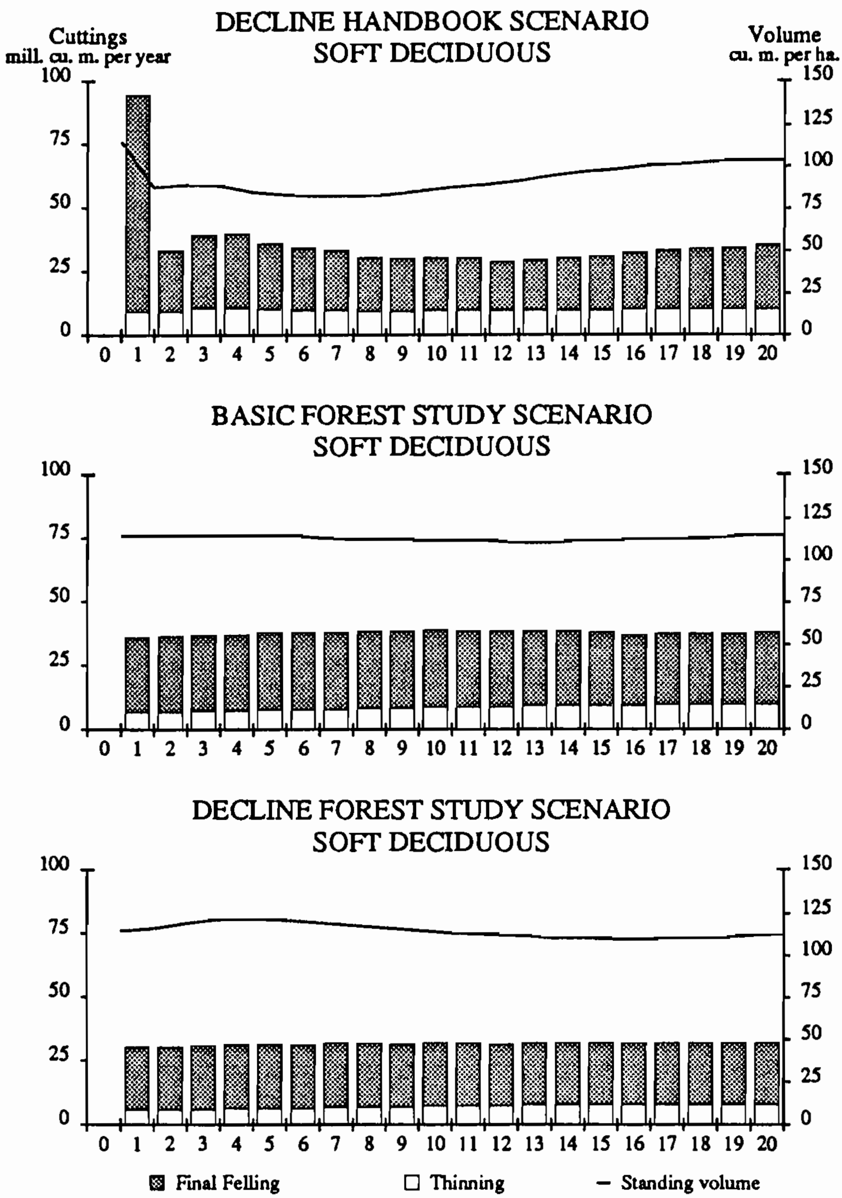

Figure 7.16. Projections of potential harvest and growing stock for soft deciduous species in the Ural aggregate under the decline scenarios. Current fellings are 22.5 million cubic meters o.b.

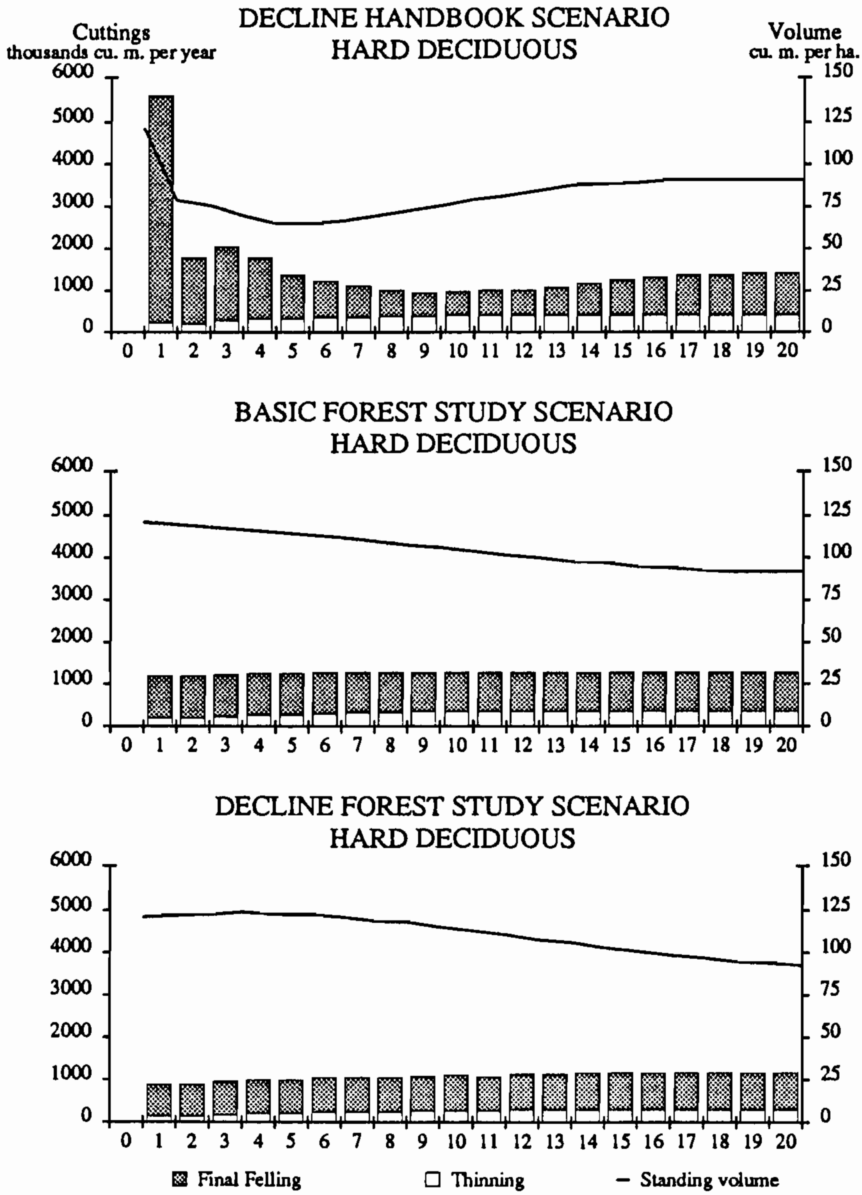

Figure 7.17. Projections of potential harvest and growing stock for hard deciduous species in the Ural aggregate under the decline scenarios. Current fellings are 0.8 million cubic meters o.b.

A comparison between the two Forest Study Scenarios shows a decline in the average total harvest potential of some 10 million cubic meters per year from air pollution.

Air pollutants mainly affect coniferous species and soft deciduous species; the decrease of the harvesting potential is 3.9 million cubic meters per year for coniferous species and 6.1 million cubic meters per year for soft deciduous species.

In the Forest Study Scenarios, there is a possibility of maintaining the same development of the growing stock under pollution conditions as under no-pollution conditions. In the Handbook Decline Scenario there will be a slight decrease over time in the growing stock in comparison with the Basic Handbook Scenario. This decrease ranges between 5 and 20 cubic meters per hectare for different species groups.

There will be a decrease in the growth rate by from 0.1 to 0.2 cubic meters per hectare per year under the decline conditions in the Basic Handbook Scenario and in the Handbook Decline Scenario. The decrease in the growth rate under the conditions of the two scenarios is from 0.3 to 0.5 cubic meters per hectare per year for the different species.

The estimated effect on the average total harvesting level from air pollutants, according to the Forest Study Scenarios, is a decline of about 14 percent.

7.6.5 The Southern aggregate (Table 7.14 and Figures 7.18 to 7.21)

The coniferous and soft deciduous species are located in primarily young and middle-aged forests, but the hard deciduous species are in primarily mature and overmature forest. These conditions result in a harvest pulse in total harvest in the Basic Handbook Scenario; for hard deciduous species this occurs in the beginning of the simulation period. The harvest pulse in the beginning of the simulation period for all species groups is more pronounced in hard deciduous species and for the total under conditions of the Handbook Decline Scenario than under no-pollution conditions. The harvest pattern is similar in the two Forest Study Scenarios, but at a lower level under decline conditions.

The decrease in average total harvesting potential under the conditions in the Handbook Decline Scenario is 1.7 million cubic meters per year. The corresponding figure for the conditions employed by the Forest Study Scenarios is 5.7 million cubic meters per year. According to these latter scenarios,

Table 7.14. Southern aggregate.

Variable	Basic Handbook	Basic Forest Study	Handbook Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	165–158	165–195	165–140	165–196
Fellings[b]				
Year 1	48.3	29.9	59.2	25.8
Year 40	39.1	35.2	36.3	29.1
Year 80	38.1	35.2	30.7	29.1
Coniferous				
Growing stock[a]	177–176	177–231	177–160	177–236
Fellings[b]				
Year 1	14.0	10.5	17.7	9.5
Year 40	16.1	13.7	14.9	11.4
Year 80	14.6	13.7	11.4	11.4
Soft deciduous				
Growing stock[a]	131–141	131–154	131–130	131–158
Fellings[b]				
Year 1	11.7	7.9	13.0	6.9
Year 40	10.8	9.3	9.5	7.9
Year 80	9.7	9.3	8.8	7.9
Hard deciduous				
Growing stock[a]	176–153	176–189	176–131	176–188
Fellings[b]				
Year 1	22.6	11.5	28.5	9.4
Year 40	12.2	12.2	11.9	9.8
Year 80	13.8	12.2	10.5	9.8
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	38.3	34.2	36.7	28.5
Coniferous	14.5	13.0	13.7	11.0
Soft deciduous	10.1	9.1	9.6	7.7
Hard deciduous	13.7	12.1	13.4	9.8
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	4.2	4.1	3.8	3.5
Coniferous	4.7	4.8	4.3	4.2
Soft deciduous	4.5	4.2	4.2	3.6
Hard deciduous	3.5	3.4	3.2	2.8
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	165–158	165–195	165–140	165–196
Coniferous	177–176	177–231	177–160	177–236
Soft deciduous	131–141	131–154	131–130	131–158
Hard deciduous	176–153	176–189	176–131	176–188

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

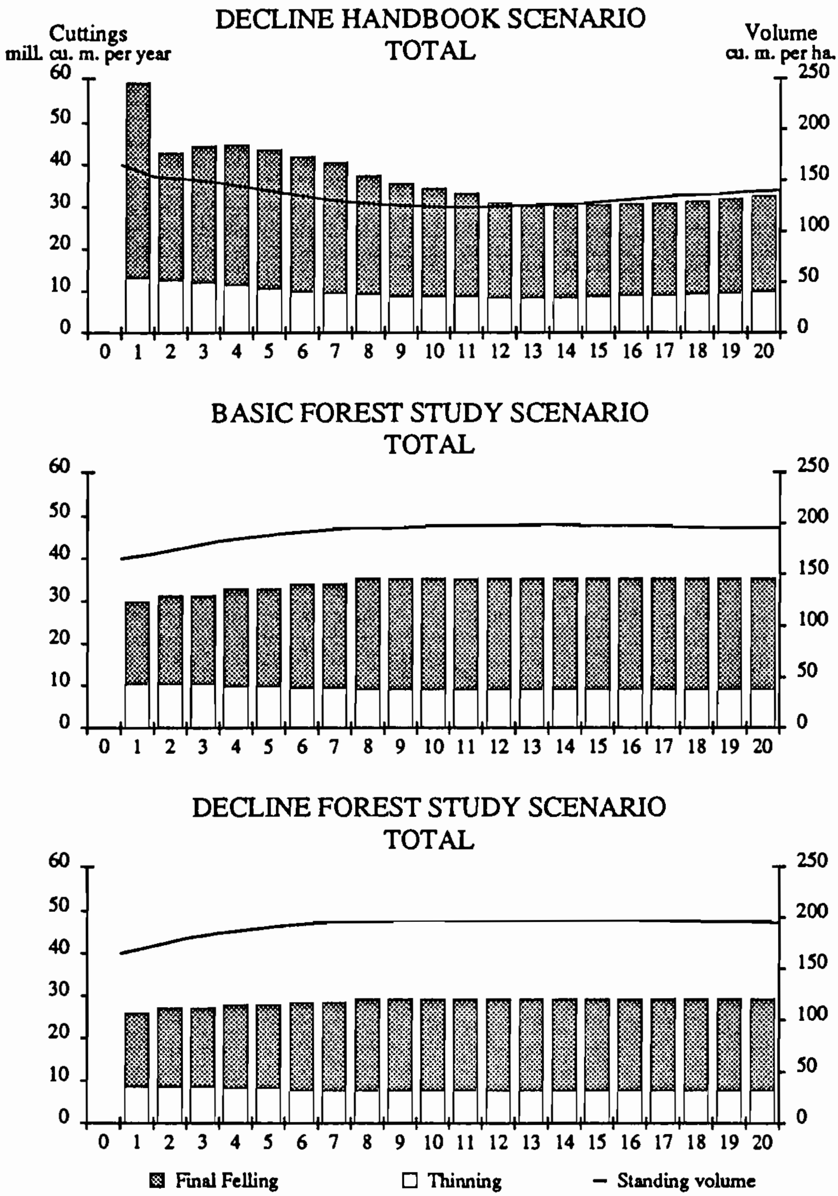

Figure 7.18. Projections of total potential harvest and growing stock in the Southern aggregate under the decline scenarios. Current fellings are 29.5 million cubic meters o.b.

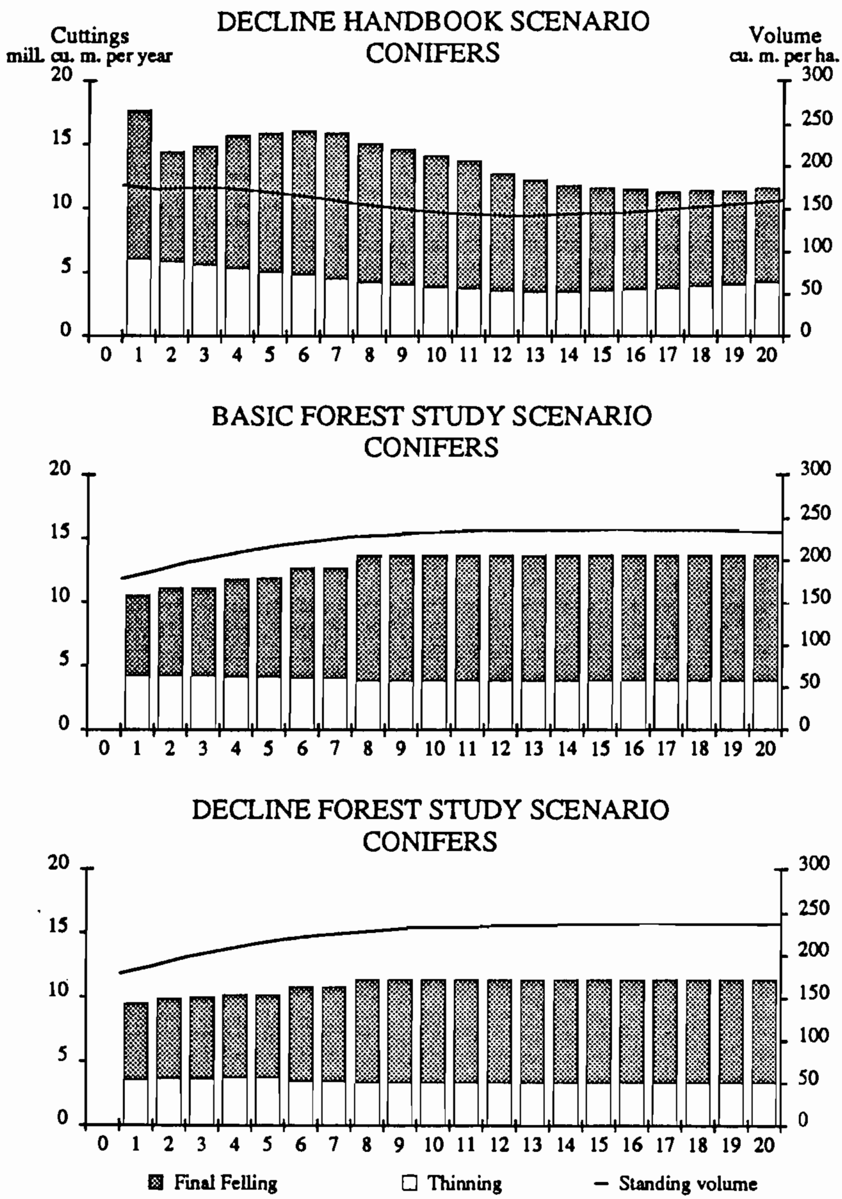

Figure 7.19. Projections of potential harvest and growing stock for coniferous species in the Southern aggregate under the decline scenarios. Current fellings are 8.8 million cubic meters o.b.

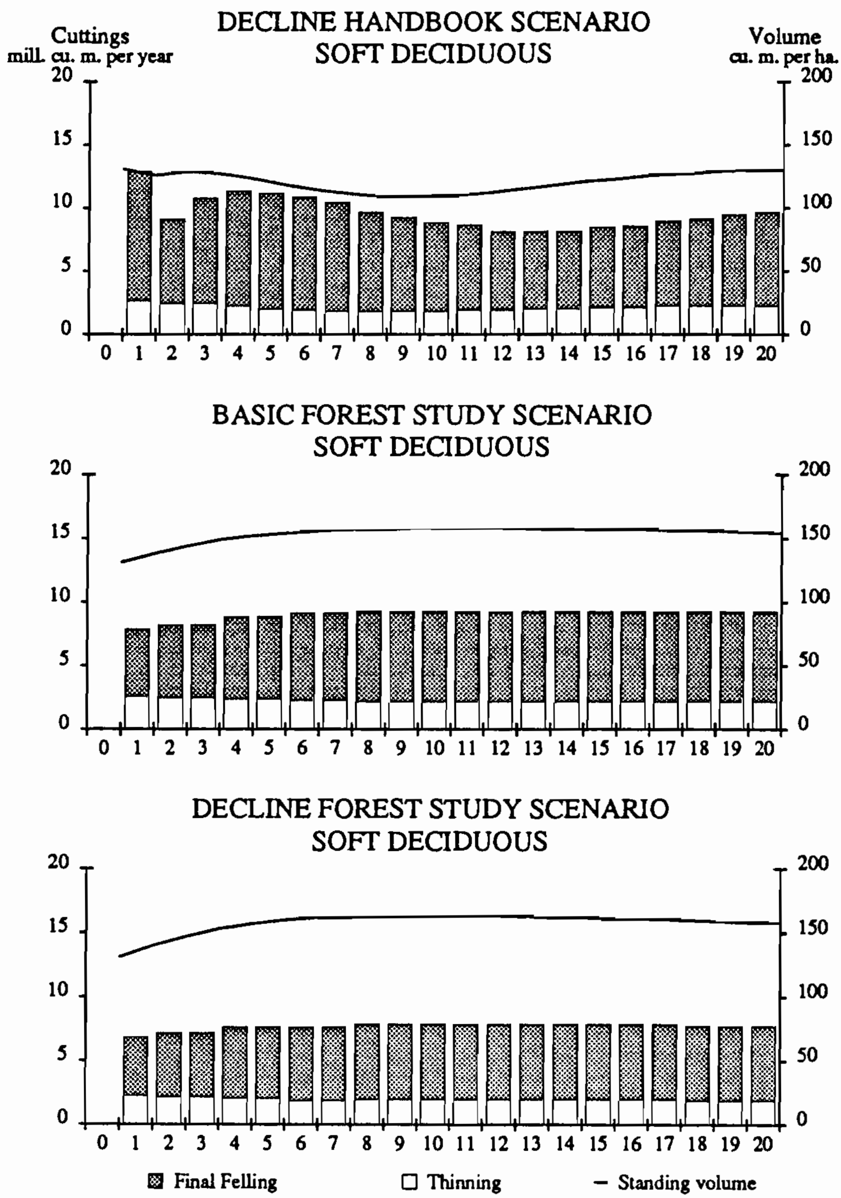

Figure 7.20. Projections of potential harvest and growing stock for soft deciduous species in the Southern aggregate under the decline scenarios. Current fellings are 7.9 million cubic meters o.b.

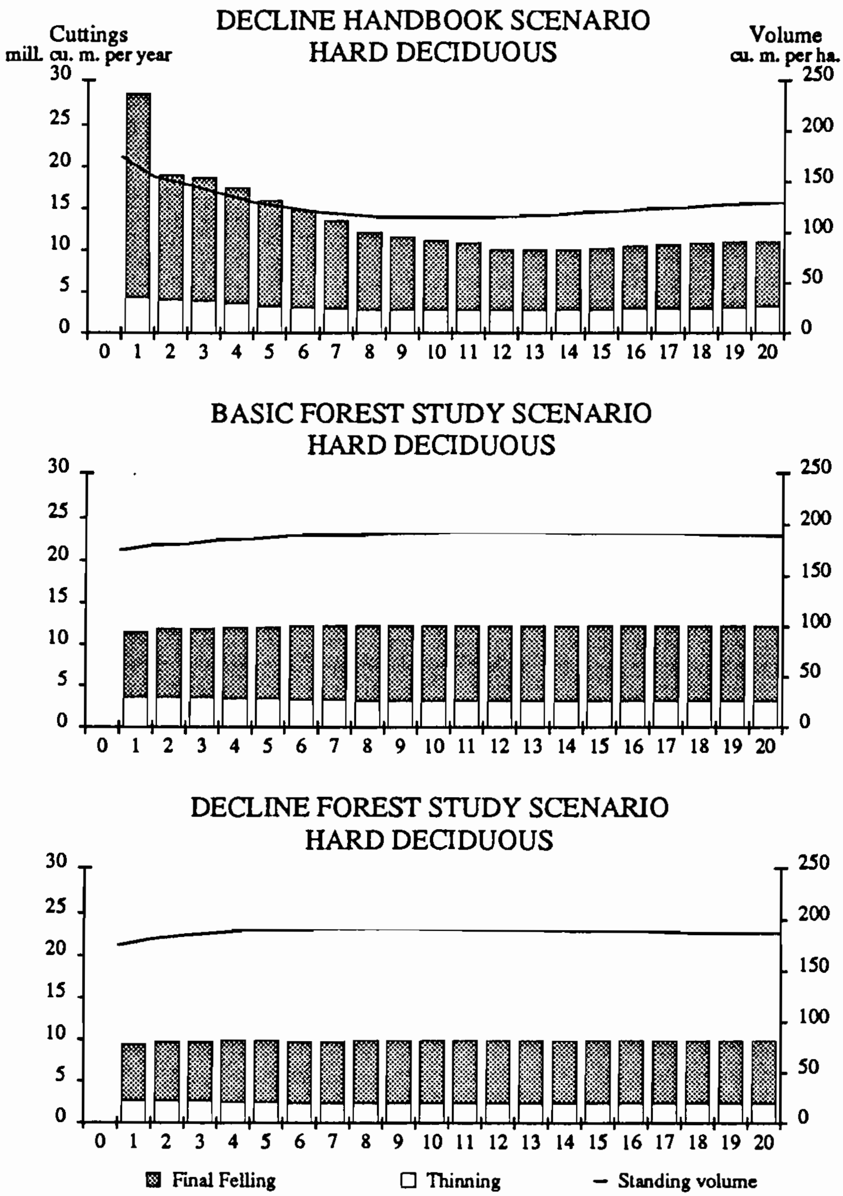

Figure 7.21. Projections for potential harvest and growing stock for hard deciduous species in the Southern aggregate under the decline scenarios. Current fellings are 12.8 million cubic meters o.b.

coniferous species will decline by 2 million cubic meters per year; soft deciduous, by 1.4 million cubic meters per year; and hard deciduous, by 2.3 million cubic meters per year.

Under the conditions of the Handbook Decline Scenarios, the growing-stock development will decrease. The size of the decline is from 10 to 20 cubic meters per hectare per year for different species groups. Under the conditions of the Forest Study Scenarios, there is a possibility of achieving the same level and development of the growing stock even under air-pollution stress. The growth rates are decreased by between 0.3 and 0.4 cubic meters per hectare per year under the conditions of the Handbook Decline Scenario. The corresponding figure under the Forest Study Decline Scenarios is 0.6 cubic meters per hectare per year for all species. There is also a tendency toward an increase in the proportions of final fellings under the decline conditions. Thus, the effect on the average total harvesting potential from air pollutants in the Southern aggregate is some 17 percent of the average total harvesting potential.

7.6.6 Total European USSR (Table 7.15 and Figures 7.22 to 7.25)

The aggregated information on forests for total European USSR shows that under the basic conditions a low correspondence between initial forest structure and a structure implemented according to the handbook silviculture occurs. This is a result of the large extent of overmature forests in mainly the Northern and Ural aggregates. This discrepancy is further evident in the Handbook Decline Scenario in the form of a more pronounced pulse in the beginning of the simulation period. This is valid for all species groups. The total harvest level is 8 million cubic meters higher per year in the Handbook Decline Scenario than in the Basic Handbook Scenario. This is a result of a more rapid liquidation of the overmature and mature forests under the decline conditions. Under the conditions of the Forest Study Scenarios the air pollutants are estimated to cause a decline of the average total potential harvest by 35.5 million cubic meters per year. The species most affected are coniferous species with a reduced potential of 18.5 million cubic meters per year and soft deciduous species with a reduced potential of 14.0 million cubic meters per year.

By reducing the harvest level in the Forest Study Decline Scenario it is possible to maintain a sustainable development of the growing stock that is similar to conditions without pollution. Such a stable development of the growing stock is not possible to achieve in the Handbook Decline Scenario. In this scenario the growing stock will decline by from 10 to 20 cubic meters per

Table 7.15. Total European USSR.

Variable	Basic Handbook	Basic Forest Study	Handbook Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	129–108	129–117	129–91	129–116
Fellings[b]				
Year 1	1,407.4	303.4	1,551.1	276.3
Year 40	278.7	324.9	285.0	287.1
Year 80	323.4	325.3	290.6	288.3
Coniferous				
Growing stock[a]	138–108	138–114	138–87	138–115
Fellings[b]				
Year 1	1,138.6	181.9	1,264.5	169.0
Year 40	145.0	194.3	166.2	174.6
Year 80	189.8	195.0	170.1	175.1
Soft deciduous				
Growing stock[a]	105–103	105–113	105–95	105–112
Fellings[b]				
Year 1	237.7	106.9	248.3	95.4
Year 40	118.3	115.1	103.8	100.1
Year 80	116.0	114.8	106.9	100.8
Hard deciduous				
Growing stock[a]	166–144	166–176	166–125	166–175
Fellings[b]				
Year 1	31.2	14.6	38.3	11.9
Year 40	15.5	15.5	15.0	12.4
Year 80	17.6	15.5	13.6	12.5
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	359.2	321.2	367.0	285.8
Coniferous	220.2	192.3	231.6	173.8
Soft deciduous	121.5	113.6	118.3	99.6
Hard deciduous	17.5	15.3	17.1	12.4
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	2.6	2.4	2.4	2.1
Coniferous	2.3	2.0	2.2	1.8
Soft deciduous	3.1	3.0	2.9	2.6
Hard deciduous	3.3	3.2	3.0	2.6
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	129–108	129–117	129–91	129–116
Coniferous	138–108	138–114	138–87	138–115
Soft deciduous	105–103	105–113	105–95	105–112
Hard deciduous	166–144	166–176	166–125	166–175

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

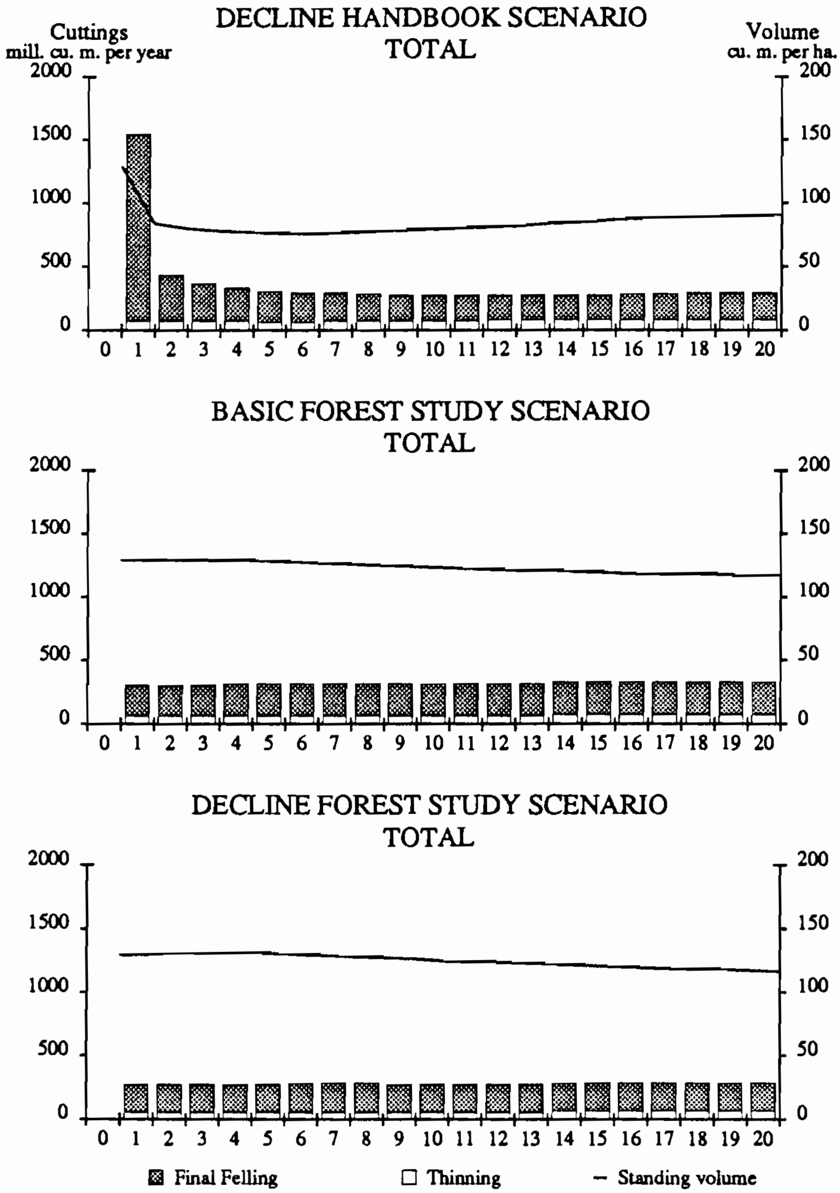

Figure 7.22. Projections of total potential harvest and growing stock in total European USSR under the decline scenarios. Current fellings are 256.7 million cubic meters o.b.

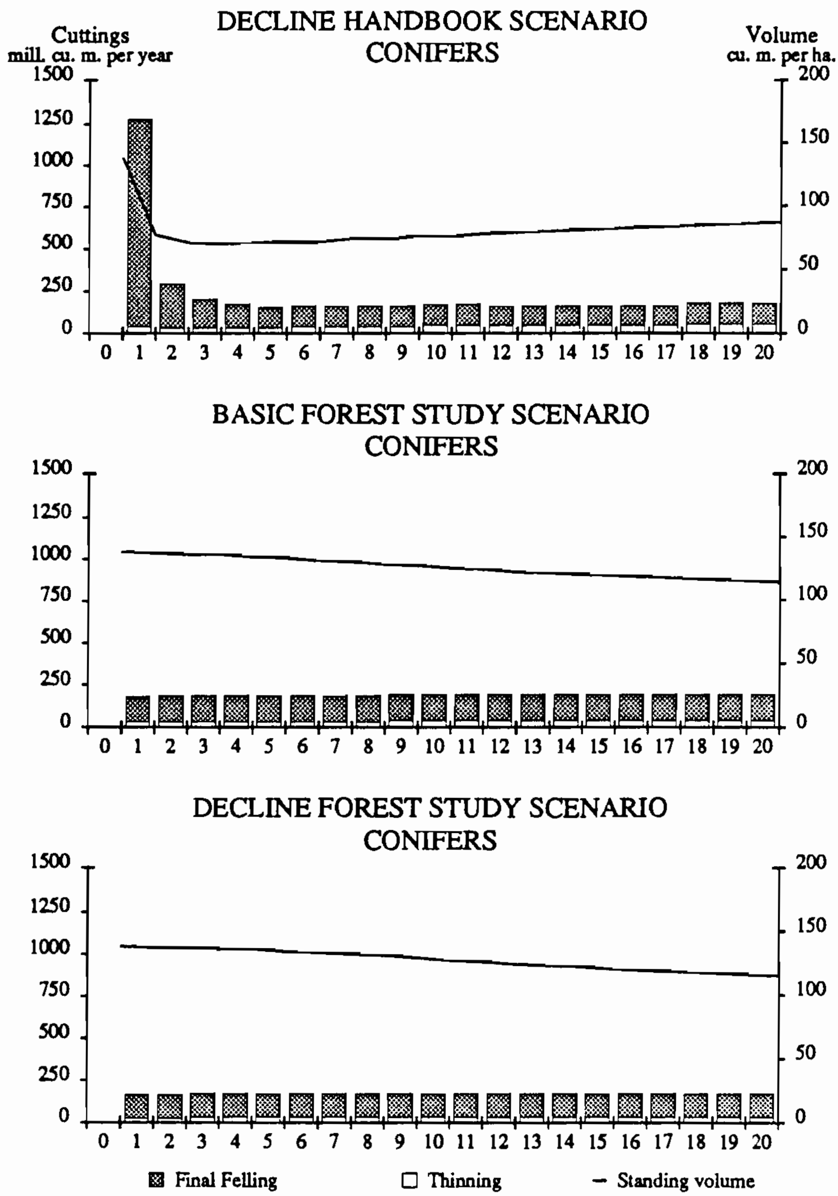

Figure 7.23. Projections of potential harvest and growing stock for coniferous species in total European USSR under the decline scenarios. Current fellings are 151.4 million cubic meters o.b.

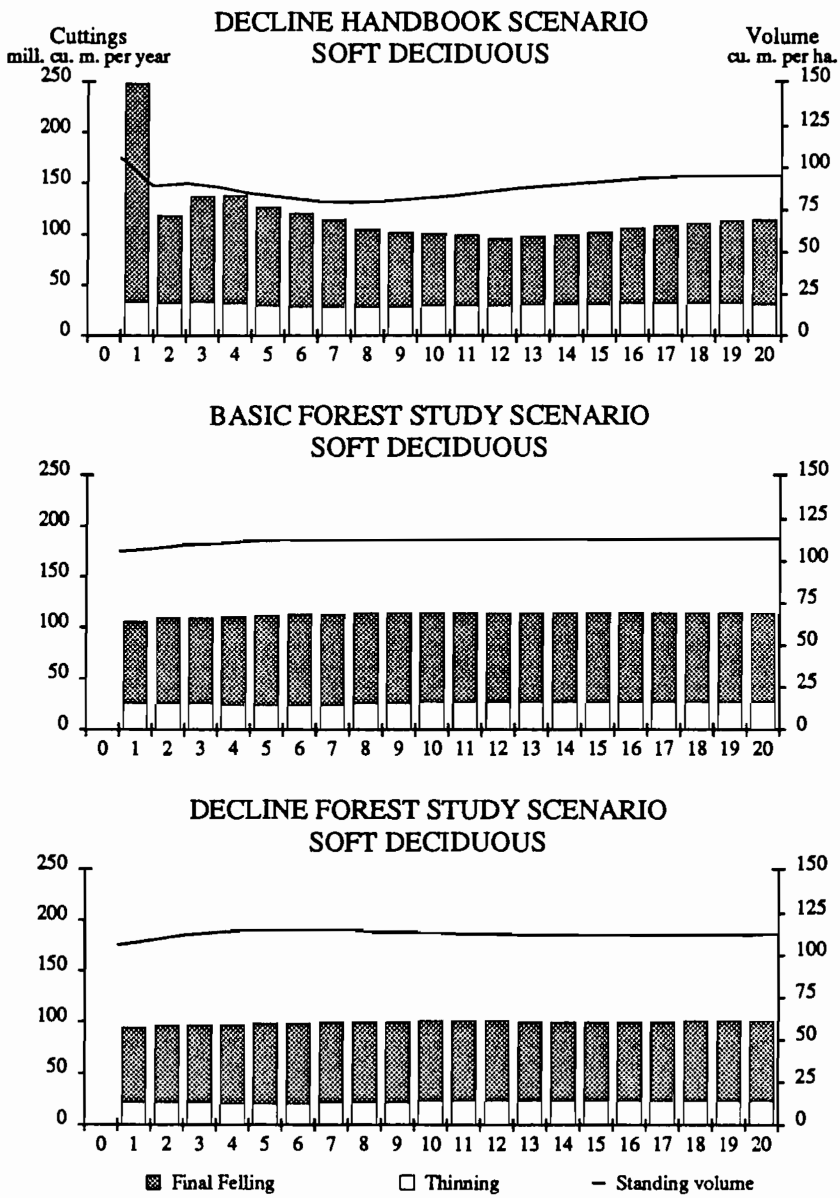

Figure 7.24. Projections of potential harvest and growing stock for soft deciduous species in total European USSR under the decline scenarios. Current fellings are 89.2 cubic meters o.b.

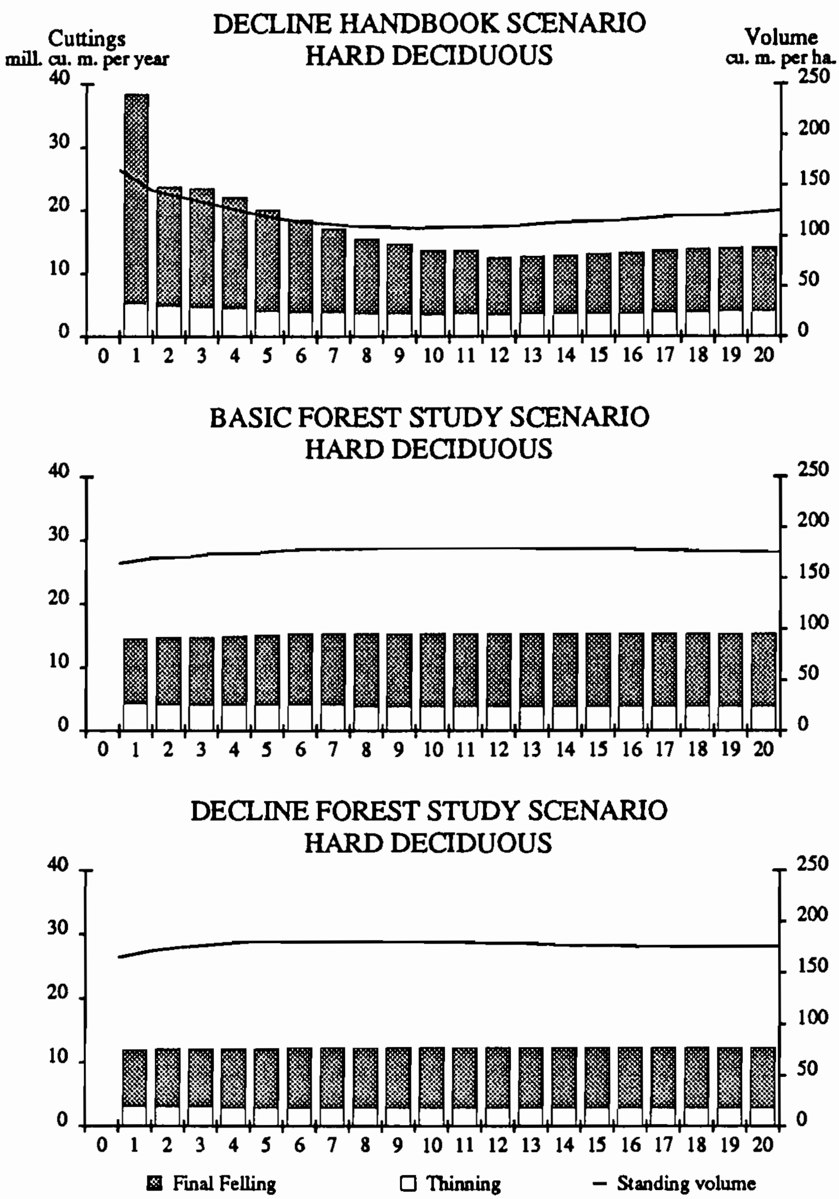

Figure 7.25. Projections of potential harvest and growing stock for hard deciduous species in total European USSR under the decline scenarios. Current fellings are 16.1 million cubic meters o.b.

hectare for different species groups over the simulation period in comparison with the results for the Basic Handbook Scenario. This decline is imposed by a more rapid liquidation scheme of the overmature forests under the air-pollutant conditions.

The growth rates will, under the conditions of the Handbook Decline Scenarios, decline by between 0.1 and 0.3 cubic meters per hectare per year for different species. The growth rates under the conditions of the Forest Study Decline Scenario will decline by between 0.2 and 0.6 cubic meters per hectare per year.

The proportion of final fellings from the total fellings will increase under the decline conditions.

The estimated decrease of the average total harvest potential in the European USSR due to air pollutants corresponds to about 11 percent of the average total potential.

7.7 Growth Rates and Wood Balances

The effects on the aggregated growth rates due to air pollutants are listed in *Table 7.16*. For a comparison the growth rates from the Basic Forest Study Scenario are presented in the same table. The overall growth rate is estimated to decline by 0.3 cubic meters per hectare per year from air-pollution effects. The most affected group is hard deciduous species with a decrease in the growth rate by 0.6 cubic meters per hectare per year, followed by soft deciduous species with a decrease of 0.4 cubic meters per hectare per year. The strongest effects from air pollutants on the overall growth rates are expected to be in the Baltic and Southern aggregates.

A comparison between current harvest levels and the harvest levels estimated in the two Forest Study Scenarios is presented in *Table 7.17* for the different aggregates. Based on these results, there seems to be a possibility of increasing the current harvest (compared with the biological sustainable harvest) in the European USSR by some 30 million cubic meters o.b. per year even under the existing load of air pollutants. However, the potential increase of the biological harvest level is only half as large under pollution conditions in comparison with the basic conditions with no air-pollution effects. The potentials for increasing the harvest level under the air-pollution conditions are most pronounced in coniferous species.

A balance between current harvest levels and the average biological harvesting potential under the conditions of the Forest Study Decline Scenario is presented in *Table 7.18* for the aggregates. Even under pollution conditions there is a potential for a sustainable increased harvest of coniferous

Table 7.16. Aggregated results of the Forest Study Scenarios in the European USSR, average growth rates (m^3 ha^{-1} yr^{-1}) during 100 years.

	Basic Forest Study				Forest Study Decline			
		Deciduous				Deciduous		
Region	Coniferous	Hard	Soft	Total	Coniferous	Hard	Soft	Total
Northern aggregate	1.2	–	1.2	1.2	1.1	–	1.1	1.1
Central aggregate	3.4	2.3	3.8	3.6	3.2	2.0	3.6	3.3
Baltic aggregate	3.2	3.5	3.4	3.2	2.5	2.6	2.5	2.5
Ural aggregate	2.4	2.2	3.6	2.9	2.1	1.8	3.0	2.5
Southern aggregate	4.8	3.4	4.2	4.1	4.2	2.8	3.6	3.4
All regions	2.0	3.2	3.0	2.4	1.8	2.6	2.6	2.1

Table 7.17. Comparison of aggregated results from the Forest Study Scenarios with current harvest levels for two species groups (m^3 o.b. yr^{-1}), average for 100 years.

	Current harvest level			Basic Forest Study			Forest Study Decline		
Region	Coniferous	Deciduous	Total	Coniferous	Deciduous	Total	Coniferous	Deciduous	Total
Northern aggregate	70.4	12.1	82.5	80.8	14.4	95.2	76.0	13.2	89.2
Central aggregate	30.0	39.7	69.7	44.3	44.8	89.1	40.2	41.7	81.9
Baltic aggregate	9.2	9.5	18.7	17.2	9.4	26.6	13.5	6.9	20.4
Ural aggregate	33.0	23.3	56.3	37.0	39.0	76.0	33.1	32.6	65.7
Southern aggregate	8.8	20.7	29.5	13.0	21.2	34.2	11.0	17.5	28.5
Total	151.4	105.3	256.7	192.3	128.8	321.1	173.8	111.9	285.7

Table 7.18. Difference between current harvest levels and average harvesting potentials according to the Forest Study Decline Scenario.

	Coniferous mill. m^3 (%)	Deciduous mill. m^3 (%)	Total mill. m^3 (%)
Northern aggregate	5.6 (108)	1.1 (109)	6.7 (108)
Central aggregate	10.2 (134)	2.0 (105)	12.2 (118)
Baltic aggregate	4.3 (147)	−2.6 (73)	1.7 (109)
Ural aggregate	0.1 (100)	9.3 (140)	9.4 (117)
Southern aggregate	2.2 (125)	−3.2 (85)	−1.0 (97)
Total European USSR	22.4 (115)	6.6 (106)	29.0 (111)

species in the Central, Baltic, and Southern aggregates. The situation is different for deciduous species under the decline conditions. The Baltic and Southern aggregates are clearly deficit regions. The only aggregate where there seems to be a good potential for an increased deciduous harvest under air-pollution conditions is in the Ural aggregate.

Chapter 8

Validation of the Results

The results from this study have been validated by comparing them with analyses from Soviet experts. However, it has only been possible to carry out validation of the results from the Basic Forest Study Scenarios (Chapter 5) for 13 of the 17 subregions.

The results obtained, according to the Forest Study analyses (the biological potential harvest), were compared with results from models used to estimate the annual allowable cut (AAC) in the USSR. In the USSR the AAC is set on the basis of the existing forest inventory data (which are revised every 10 years). It takes into account the availability of mature stands and established silviculture rules (according to silvicultural handbooks), and is the upper limit of the harvest during the next 5 to 10 years. The calculations of the AACs aim to generate a sustainable and even AAC for the next 20 to 50 years. The calculations are based on the commercial compartments of the forests and are carried out by the management units within the boundaries of each individual forest enterprise.

To estimate the long-term sustainable use of forests (for 100 year and more), different models have been used. The Ukrainian Agricultural Academy (Shvidenko *et al.*, 1987) has developed a model (the UKRAA model) which is most suitable for calculations of AACs in regions with a shortage of mature and overmature forests. There are several regions in the European USSR with such conditions. The concept of this model is based on a combination of formal mathematical rules and simple logic. The goal of the model is to optimize the transition of the current age-class distribution toward a long-term, even, and consistent age-class distribution. At the same time, the model attempts to achieve the following by imposing a number of restrictions:

- To avoid a substantial decrease of the final felling areas and volume over time.
- In cases with possibilities of increased final fellings, to follow a steady pattern over time.
- To transfer temporary management units to permanent ones over the planning horizon.

The calculation of thinning volumes are based on management programs which maximize the volume production in the rotation period (Shvidenko, 1986). In the validation tests conducted using this model, aggregated data for the regions were employed. The basic data used by the UKRAA (distribution of forest areas and growing stock over age classes and species) were collected and aggregated from the detailed input data used in the IIASA analyses of the forest resources in the European USSR. Experiences in the USSR show, by using regional input data instead of the individual forest enterprise data, an overestimate of the AAC of between 5 and 10 percent occurs. Thus, it can be concluded that the AACs calculated by the Ukrainian Agricultural Academy Model in the validation tests probably overestimate the suitable AACs by between 5 and 10 percent.

The All-Union Research Institute for Forestry and Mechanization has developed a model, the VNIILM Model (Komkov and Moiseev, 1981; Komkov *et al.*, 1987), which has proved to be practical for AAC calculations in regions with mature stands.

This model uses forest area and average standing volume in cubic meters per hectare over 10-year periods within management units as basic parameters. The management units are defined by common measures of reforestation (species and reforestation methods). In addition, several rules of forest management play an important role in this model. With these rules, which in essence are a long-term program for sustainable management of the forests, the impact of different management strategies of future AACs can be tested in this simulation model.

The major features of the algorithm of the VNIILM model for AAC calculations can be illustrated by

$$l_k = \frac{1}{k}\left(\sum_{j=0}^{k-1} S_j + \frac{1}{2}S_k\right) \quad , \quad (k = 1, 2, \ldots, n) \; ,$$

where l is allowable cut; k is the index for the period of calculation ($k = 1, 2, \ldots, n$); and S_0 is the area in age classes above felling age, S_1 is the area of the age class next to final felling age, etc.

At the first iteration the AACs for all management units are calculated. In the next step, the acceptable allowable cut $[L(t)]$ is calculated according to the following formula:

$$L(t) = \min_k(l_k) \ , \quad (k = 1, 2, \ldots, n) \ .$$

Even with the VNIILM model, aggregated data from the detailed data used in the Forest Study Scenarios were employed in the validation tests. The Soviet models used in the validation tests were less detailed and less dynamic than the Forest Study Model.

The validation tests were conducted by Soviet experts. In this section a numerical comparison of the results of the AAC calculations from the USSR models and the Basic Forest Study Scenario is carried out. The results for the regions analyzed are discussed individually. It should be underlined that rounding errors exist in the tables. These rounding errors also cause, in some cases, a variation in the results in Appendix A.

Only the results of the estimated fellings are presented. However, it should be emphasized that the Soviet models work within restrictions on the development of the growing stocks; the future growing stocks may not decrease below the current growing stock of the individual age classes. By that, a sustainable development of the growing stock is secured and, therefore, a separate presentation of the development of the growing stocks is not necessary.

It should also be stressed that estimated fellings calculated on the Soviet models in the tests and presented in *Tables 8.1* to *8.14* include all fellings (industrial wood and wood assortments other than industrial wood). Thus the Soviet calculations are not standard AAC calculations, which only deal with final fellings of industrial wood. It means that the volumes calculated are comparable with the results of the IIASA model.

The results for the Northern region are presented in *Table 8.1*. The validation shows a good correspondence between the two calculations for final fellings of both coniferous species and deciduous species, although a large visible difference occurs in thinnings. The Basic Forest Study Scenario estimates twice as much thinned volume as the Soviet calculations. This is a logical result. Thinnings are currently carried out, to a limited extent, in the Northern region, and the silviculture management programs are more intensive (including thinnings) in the Basic Forest Study Scenario. The difference in the total average harvesting volume is 9.7 million cubic meters or 11 percent higher in the Basic Forest Study Scenario than in the Soviet calculations. Most of this discrepancy stems from different thinning levels in the two simulations.

Table 8.1. Comparison between calculations according to USSR models and the Basic Forest Study Scenario for the Northern region. Volume is expressed in million cubic meters o.b.

	VNIILM Model				Basic Forest Study Scenario				Deviation total volumes	
	Final fellings				Final fellings					
Period (5 years)	Coniferous	Soft deciduous	Total thinnings	Total	Coniferous	Soft deciduous	Total thinnings	Total	In m^3	In %
1	67.9	11.8	2.7	82.4	66.0	9.9	12.3	88.2	+5.8	+7
2	69.5	10.7	2.9	83.1	66.4	10.3	12.9	89.6	+6.5	+8
3	71.0	9.5	3.1	83.6	66.8	10.6	13.6	91.0	+7.4	+9
4	65.5	13.0	4.0	82.5	67.2	11.0	14.2	92.4	+9.9	+12
5	59.9	16.5	4.4	80.8	67.6	11.2	14.9	93.7	+12.9	+16
6	60.7	15.3	5.9	81.9	67.6	11.5	15.3	94.4	+12.5	+15
7	61.5	14.0	7.1	82.6	67.6	11.7	15.7	95.0	+12.4	+15
8	63.7	12.9	8.0	84.6	67.6	11.8	16.2	95.6	+11.0	+13
9	65.9	11.8	9.0	86.7	67.6	12.0	16.6	96.2	+9.5	+11
10	66.5	10.9	9.3	86.7	67.4	12.1	17.0	96.5	+9.8	+11
11	67.1	10.0	9.8	86.9	67.2	12.2	17.4	96.8	+9.9	+11
12	67.7	9.3	10.2	87.2	66.8	12.3	17.8	96.9	+9.7	+11
13	68.2	8.5	10.2	86.9	66.6	12.4	18.0	97.0	+10.1	+12
14	68.6	7.9	11.0	87.5	66.4	12.4	18.3	97.1	+9.6	+11
15	69.0	7.2	11.2	87.4	66.2	12.5	18.5	97.2	+9.8	+11
16	69.4	6.7	11.4	87.5	66.0	12.6	18.7	97.3	+9.8	+11
17	69.8	6.1	11.8	87.7	65.8	12.6	18.9	97.3	+9.6	+11
18	70.2	5.7	11.9	87.8	65.6	12.6	19.1	97.3	+9.5	+11
19	70.5	5.2	12.0	87.7	65.6	12.6	19.1	97.3	+9.6	+11
20	70.6	5.0	12.2	87.8	65.6	12.6	19.1	97.3	+9.5	+11
Average	67.2	9.9	8.4	85.5	66.7	11.8	16.7	95.2	+9.7	+11

As discussed in Chapter 5 and Appendix A, several alternative basic scenarios have been employed in the Northern region in an attempt to balance the liquidation of a huge extent of overmature forests in this region. The alternatives are the USSR Path, the Rapid Liquidation, and the Increased Harvesting scenarios. The USSR Path Scenario features harvesting levels identified by Soviet experts. These levels are binding input to this simulation. In other respects, the conditions are equal to those of the Basic Forest Study Scenario. The Rapid Liquidation Scenario simulates a rapid liquidation of the overmature forests during the first 50 years, then, for the remainder of the simulation period, the harvest level is in line with a harvest level suggested by Soviet experts. In the Increased Harvesting Scenario the stock of overmature forest is used to increase the harvesting of wood gradually from its present level; after 30 years the harvesting level is slowly decreased over the remainder of the simulation period.

These alternative scenarios change, in some cases, the different harvesting patterns over time in comparison with the Basic Forest Study Scenario. They also generate (in two cases) a much higher average total harvesting level than the Basic Forest Study Scenario. This higher average harvesting level in the two alternative scenarios is a logical result of a much faster replacement of the overmature forests. The results of the alternative basic scenarios are discussed in Appendix A.

The comparison of total fellings in the Northern region between the Soviet calculation and all the Forest Study Scenarios is presented in *Table 8.2.* All of the scenarios produced by the Forest Study generate higher average total harvest volumes than the Soviet calculation. The range of the excess harvesting level in the different Forest Study Scenarios is between 8 and 27 million cubic meters more per year (or between 9 and 31 percent) than the Soviet calculation.

The validation results of the Central region are presented in *Table 8.3.* From this table it can be seen that the Forest Study Scenario has lower average total final fellings in coniferous species than the USSR calculations. The difference is about 3.5 million cubic meters per year. For the other species and final fellings there is good agreement between the two calculations. Again, there is a big difference for the thinning levels in the two analyses. The Forest Study Scenario gives double the average total of the thinned volume (or 6 million cubic meters more per year) in comparison with the Soviet calculation. There is a small deviation between the two calculations for the average total volume harvested. The difference is 2.9 million cubic meters more (or 8 percent) in the Basic Forest Study Scenario than in

Table 8.2. Comparison between calculations according to USSR models and different Basic Forest Study Scenarios for the Northern region. Volume is expressed in million cubic meters o.b.

	Total fellings						
Period	VNIILM	Basic Forest	USSR	Rapid	Increased	Deviation	
(5 years)	Model	Study	Path	Liquidation	Harvest	Volume	Percent
1	82.4	88.2	89.8	236.9	84.0	+154.5 – (+)1.6	+188 – (+)2
2	83.1	89.6	90.6	217.2	96.0	+134.1 – (+)6.5	+161 – (+)8
3	83.6	91.0	91.1	197.5	119.0	+113.9 – (+)7.4	+136 – (+)9
4	82.5	92.4	89.9	17.8	141.0	+95.3 – (+)7.4	+116 – (+)9
5	80.8	93.7	88.1	158.1	163.0	+82.2 – (+)7.3	+102 – (+)9
6	81.9	94.4	89.3	138.4	184.0	+102.1 – (+)7.4	+125 – (+)9
7	82.6	95.0	90.0	118.7	167.4	+84.8 – (+)7.4	+103 – (+)9
8	84.6	95.6	92.2	99.0	150.8	+66.2 – (+)7.6	+78 – (+)9
9	86.7	96.2	94.5	81.0	134.2	+47.5 – (–)5.7	+55 – (–)7
10	86.7	96.5	94.5	70.0	117.6	+30.9 – (–)16.7	+36 – (–)19
11	86.9	96.8	94.7	66.2	101.7	+14.8 – (–)20.7	+17 – (–)24
12	87.2	96.9	95.1	62.7	89.8	+9.7 – (–)24.5	+11 – (–)28
13	86.9	97.0	94.7	64.1	80.6	+10.1 – (–)22.8	+12 – (–)26
14	87.5	97.1	95.4	67.0	75.3	+9.6 – (–)20.5	+11 – (–)23
15	87.4	97.2	95.3	70.7	75.3	+9.8 – (–)16.7	+11 – (–)19
16	87.5	97.3	95.4	74.7	75.4	+9.8 – (–)12.8	+11 – (–)15
17	87.7	97.3	95.6	79.0	75.9	+9.6 – (–)11.8	+11 – (–)13
18	87.8	97.3	95.7	83.1	76.5	+9.5 – (–)11.3	+11 – (–)13
19	87.7	97.3	95.6	87.0	77.1	+9.6 – (–)10.6	+11 – (–)12
20	87.8	97.3	95.7	90.5	77.6	+9.5 – (–)10.2	+11 – (–)12
Average	85.5	95.2	93.2	112.0	108.1	+26.5 – (+)7.7	+31 – (+)9

Table 8.3. Comparison between calculations according to USSR models and the Basic Forest Study Scenario for the Central region. Volume is expressed in million cubic meters o.b.

	UKRAA Model					Basic Forest Study Scenario					Deviation	
	Final fellings					Final fellings					total volumes	
Period		Deciduous		Total			Deciduous		Total			
(5 years)	Coniferous	Soft	Hard	thinnings	Total	Coniferous	Soft	Hard	thinnings	Total	In m^3	In %
1	19.0	14.0	0.7	7.1	40.8	14.0	12.7	0.6	13.4	40.7	−0.1	±0
2	18.6	14.0	0.7	6.9	40.2	14.4	13.3	0.6	12.4	40.7	+0.5	+1
3	18.5	14.1	0.7	6.8	40.1	14.4	13.3	0.6	12.4	40.7	+0.6	+2
4	18.5	14.1	0.7	6.6	39.9	14.8	13.9	0.6	11.4	40.7	+0.8	+2
5	18.5	13.6	0.7	6.4	39.2	14.8	13.9	0.6	11.4	40.7	+1.5	+4
6	18.5	13.4	0.7	6.2	38.8	15.2	13.7	0.6	11.2	40.7	+1.9	+5
7	18.5	13.3	0.7	6.1	38.6	15.2	13.7	0.6	11.2	40.7	+2.1	+5
8	18.5	13.1	0.7	5.9	38.2	16.0	13.6	0.6	12.0	42.2	+4.0	+11
9	18.5	13.1	0.8	5.8	38.2	16.0	13.6	0.6	12.0	42.2	+4.0	+11
10	18.5	13.1	0.8	5.8	38.2	16.0	13.6	0.6	12.0	42.2	+4.0	+11
11	18.6	13.0	0.8	5.7	38.1	16.0	13.6	0.6	12.0	42.2	+4.1	+11
12	18.8	13.0	0.8	5.5	38.1	16.0	13.6	0.6	12.0	42.2	+4.1	+11
13	18.9	13.0	0.8	5.5	38.2	16.0	13.6	0.6	12.0	42.2	+4.0	+11
14	19.1	13.0	0.8	5.5	38.4	16.0	13.6	0.6	12.0	42.2	+3.8	+10
15	19.1	13.0	0.8	5.4	38.3	16.0	13.6	0.6	12.0	42.2	+3.9	+10
16	19.2	13.0	0.8	5.2	38.2	16.0	13.6	0.6	12.0	42.2	+4.0	+11
17	19.4	13.0	0.8	5.2	38.4	16.0	13.6	0.6	12.0	42.2	+3.8	+10
18	19.4	13.0	0.8	5.2	38.4	16.0	13.6	0.6	12.0	42.2	+3.8	+10
19	19.4	13.0	0.8	5.2	38.4	16.0	13.6	0.6	12.0	42.2	+3.8	+10
20	19.4	13.0	0.8	5.2	38.4	16.0	13.6	0.6	12.0	42.2	+3.8	+10
Average	18.9	13.3	0.8	5.9	38.8	15.5	13.6	0.6	12.0	41.7	+2.9	+8

the Soviet calculation. From the analysis it is apparent that intensified *thinnings* will play an important role in the future wood supply of the Central region.

For the Central Chernozyomny region there is a good correlation between the calculations in the validation test, which can be seen in *Table 8.4*. There is a good match for individual species groups within final fellings and for total thinnings. The deviation between the two calculations is only 0.2 million cubic meters less per year (or 6 percent) in the Basic Forest Study Scenario than in the Soviet calculation. One reason for this correlation may be the small harvesting level in the region.

For the Ural region, the two calculations show a good correspondence for the coniferous species and soft deciduous species at an average level in final fellings (*Table 8.5*). The Basic Forest Study Scenario shows only half the potential of the final fellings of the hard deciduous species in comparison with the Soviet AAC calculation. However, the total harvesting potential of this species group is rather small. The difference in thinnings is larger than the difference in total harvesting potential. Again, the Basic Forest Study Scenario shows nearly double the average total of the thinned volume than the Soviet calculation. This is a natural result of more intensive silvicultural programs taken into consideration in the former calculation. The average total harvesting potential is 5.4 million cubic meters more per year (or 8 percent) in the Basic Forest Study Scenario. This difference can be explained by the higher thinning intensity in the silvicultural program of this scenario.

The Ural region has a skewed age-class distribution, similar to the distribution in the Northern region. Therefore, the same alternative basic scenarios have been carried out for this region. The results concerning the total fellings for all the Basic Forest Study Scenarios and the Soviet calculation are presented in *Table 8.6*. The alternative scenarios generate a different harvesting pattern over time and different average total harvest levels from the Basic Forest Study Scenario. This is a natural result of the different conditions for the various scenarios. The results for these alternative scenarios for the Ural region are discussed in Appendix A.

In *Table 8.6* it can be seen that all of the Forest Study scenarios generate a higher average total harvest volume than the Soviet calculation. The difference ranges between 4.3 and 6.0 million cubic meters per year or between 6 and 8 percent.

In the Carpathian region (*Table 8.7*) there is a good correspondence between the estimations of the two models. The total average deviation is only 6 percent, with the lower estimate from the IIASA model. There also is good correspondence between the two models concerning the distribution of the estimated fellings on final fellings, thinnings, and individual species. The

Table 8.4. Comparison between calculations according to USSR models and the Basic Forest Study Scenario for the Central Chernozyomny region. Volume is expressed in million cubic meters o.b.

Period	UKRAA Model					Basic Forest Study Scenario					Deviation total volumes	
	Final fellings					Final fellings						
		Deciduous		Total			Deciduous		Total			
(5 years)	Coniferous	Soft	Hard	thinnings	Total	Coniferous	Soft	Hard	thinnings	Total	In m^3	In %
1	0.5	0.5	0.8	1.1	2.9	0.6	0.3	0.8	0.9	2.6	−0.3	−10
2	0.5	0.5	0.8	1.1	2.9	0.6	0.4	1.0	0.9	2.9	±0.0	0
3	0.5	0.5	0.9	1.1	3.0	0.6	0.4	1.0	0.9	2.9	−0.1	−3
4	0.5	0.5	0.9	1.1	3.0	0.6	0.4	1.0	0.9	2.9	−0.1	−3
5	0.6	0.5	1.0	1.0	3.1	0.6	0.4	1.0	0.9	2.9	−0.2	−6
6	0.6	0.5	1.0	1.0	3.1	0.7	0.4	1.1	0.9	3.1	±0.0	0
7	0.7	0.5	1.1	0.9	3.2	0.7	0.4	1.1	0.9	3.1	−0.1	−3
8	0.7	0.5	1.1	0.9	3.2	0.8	0.5	1.1	0.8	3.2	±0.0	0
9	0.7	0.5	1.2	0.9	3.3	0.8	0.5	1.1	0.8	3.2	−0.1	−3
10	0.7	0.5	1.2	0.9	3.3	0.8	0.5	1.1	0.8	3.2	−0.1	−3
11	0.8	0.5	1.2	0.8	3.3	0.8	0.5	1.1	0.8	3.2	−0.1	−3
12	0.8	0.5	1.2	0.8	3.3	0.8	0.5	1.1	0.8	3.2	−0.1	−3
13	0.9	0.6	1.2	0.8	3.5	0.8	0.5	1.1	0.8	3.2	−0.3	−9
14	0.9	0.6	1.2	0.8	3.5	0.8	0.5	1.1	0.8	3.2	−0.3	−9
15	1.0	0.6	1.2	0.8	3.6	0.8	0.5	1.1	0.8	3.2	−0.4	−11
16	1.0	0.6	1.2	0.8	3.6	0.8	0.5	1.1	0.8	3.2	−0.4	−11
17	1.1	0.6	1.2	0.8	3.7	0.8	0.5	1.1	0.8	3.2	−0.5	−14
18	1.1	0.6	1.2	0.8	3.7	0.8	0.5	1.1	0.8	3.2	−0.5	−14
19	1.1	0.6	1.2	0.8	3.7	0.8	0.5	1.1	0.8	3.2	−0.5	−14
20	1.1	0.6	1.2	0.8	3.7	0.8	0.5	1.1	0.8	3.2	−0.5	−14
Average	0.8	0.5	1.1	0.9	3.3	0.7	0.5	1.1	0.8	3.1	−0.2	−6

Table 8.5. Comparison between calculations according to USSR models and the Basic Forest Study Scenario for the Ural region. Volume is expressed in million cubic meters o.b.

Period	UKRAA Model					Basic Forest Study Scenario					Deviation	
	Final fellings					Final fellings					total volumes	
		Deciduous		Total			Deciduous		Total			
(5 years)	Coniferous	Soft	Hard	thinnings	Total	Coniferous	Soft	Hard	thinnings	Total	In m^3	In %
1	33.6	37.1	1.8	7.2	79.7	30.4	28.8	1.0	14.0	74.2	−5.5	−7
2	33.4	36.5	1.8	7.4	79.1	30.0	29.0	1.0	14.6	74.6	−4.5	−6
3	33.4	33.2	1.8	7.6	78.0	29.6	29.2	1.0	15.3	75.1	−2.9	−4
4	33.2	31.4	1.8	8.1	74.5	29.3	29.4	1.0	15.9	75.6	+1.1	+1
5	32.8	30.9	1.8	8.6	74.1	28.8	29.6	1.0	16.5	75.9	+1.8	+2
6	32.0	30.3	1.8	9.0	73.1	28.5	29.8	1.0	17.0	76.3	+3.2	+4
7	31.6	29.1	1.8	9.4	71.9	28.2	29.8	1.0	17.5	76.5	+4.6	+6
8	31.2	28.5	1.8	9.8	71.3	27.9	29.8	0.9	18.1	76.7	+5.4	+8
9	30.6	28.2	1.8	10.2	70.8	27.6	29.8	0.9	18.6	76.9	+6.1	+9
10	29.8	27.8	1.8	10.6	70.0	27.4	29.6	0.9	19.0	76.9	+6.9	+10
11	29.0	27.2	1.8	11.0	69.0	27.2	29.3	0.9	19.4	76.8	+7.8	+11
12	28.2	26.0	1.8	11.3	67.3	27.0	29.0	0.9	19.8	76.7	+9.4	+14
13	27.7	26.5	1.8	11.6	67.6	26.8	28.9	0.9	20.2	76.8	+10.2	+15
14	26.6	26.6	1.8	11.8	66.8	26.6	28.8	0.9	20.5	76.8	+10.0	+15
15	26.0	27.3	1.7	12.0	67.0	26.4	28.2	0.9	20.8	76.3	+9.3	+14
16	26.0	27.3	1.7	12.0	67.0	26.2	27.4	0.9	21.1	75.6	+8.6	+13
17	26.0	27.3	1.7	12.0	67.0	26.0	27.2	0.9	21.4	75.5	+8.5	+13
18	26.0	27.3	1.7	12.0	67.0	26.0	27.2	0.9	21.4	75.5	+8.5	+13
19	26.0	27.3	1.7	12.0	67.0	26.0	27.3	0.9	21.4	75.6	+8.6	+13
20	26.0	27.3	1.7	12.0	67.0	26.0	27.6	0.9	21.4	75.9	+8.9	+13
Average	29.5	29.0	1.8	10.3	70.6	27.6	28.8	0.9	18.7	76.0	+5.4	+8

Table 8.6. Comparison between calculations according to USSR models and different Basic Forest Study Scenarios for the Ural region. Volume is expressed in million cubic meters o.b.

Period	Total fellings					Deviation	
	UKRAA	Basic Forest	USSR	Rapid	Increased		
(5 years)	Model	Study	Path	Liquidation	Harvest	Volume	Percent
1	79.7	74.2	86.9	103.4	70.8	+23.7 - (−)9.1	+30 - (−)11
2	79.1	74.6	86.2	99.3	75.7	+20.2 - (−)4.5	+26 - (−)6
3	78.0	75.1	82.8	95.2	80.6	+17.2 - (−)2.9	+22 - (−)4
4	74.5	75.6	80.7	91.2	85.6	+16.7 - (+)1.1	+22 - (+)1
5	74.1	75.9	80.3	87.1	90.5	+16.4 - (+)1.8	+22 - (+)2
6	73.1	76.3	76.2	83.0	94.4	+21.3 - (+)3.2	+29 - (+)4
7	71.9	76.5	74.3	78.9	89.4	+17.5 - (+)2.4	+24 - (+)3
8	71.3	76.7	72.9	74.5	84.4	+13.1 - (+)1.6	+18 - (+)2
9	70.8	76.9	72.7	70.5	79.3	+8.5 - (−)0.3	+12 - (±)0
10	70.0	76.9	72.5	66.6	74.3	+6.9 - (−)3.4	+10 - (−)5
11	69.0	76.8	72.6	63.7	70.9	+7.8 - (−)5.3	+11 - (−)8
12	67.3	76.7	71.7	62.8	67.6	+9.4 - (−)4.5	+14 - (−)7
13	66.6	76.8	72.3	63.8	65.4	+10.2 - (−)2.8	+15 - (−)4
14	66.8	76.8	71.4	65.4	66.1	+10.0 - (−)1.4	+15 - (−)2
15	67.0	76.3	71.1	67.2	66.9	+9.3 - (−)0.1	+14 - (±)0
16	67.0	75.6	70.7	68.9	67.6	+8.6 - (+)0.6	+13 - (+)1
17	67.0	75.5	70.6	70.5	68.3	+8.5 - (+)1.3	+13 - (+)2
18	67.0	75.5	70.6	71.9	69.0	+8.5 - (+)2.0	+13 - (+)3
19	67.0	75.6	70.7	73.1	69.7	+8.4 - (+)2.7	+13 - (+)4
20	67.0	75.9	70.8	73.9	70.4	+8.9 - (+)3.4	+13 - (+)5
Average	70.6	76.0	74.9	76.6	75.4	+4.3 - (+)6.0	+6 - (+)8

Table 8.7. Comparison between calculations according to USSR models and the Basic Forest Study Scenario for the Carpathian region. Volume is expressed in million cubic meters o.b.

Period	UKRAA Model					Basic Forest Study Scenario					Deviation total volumes	
	Final fellings					Final fellings						
		Deciduous		Total			Deciduous		Total			
(5 years)	Coniferous	Soft	Hard	thinnings	Total	Coniferous	Soft	Hard	thinnings	Total	In m^3	In %
1	1.2	0.02	0.8	1.2	3.2	0.8	0.04	0.9	1.1	2.8	–0.4	–13
2	1.2	0.02	0.8	1.2	3.2	0.9	0.04	0.9	1.1	2.9	–0.3	–9
3	1.2	0.02	0.8	1.2	3.2	0.9	0.04	0.9	1.1	2.9	–0.4	–13
4	1.2	0.02	0.8	1.1	3.1	0.9	0.04	0.9	1.1	2.9	–0.3	–10
5	1.2	0.02	0.9	1.1	3.2	0.9	0.04	0.9	1.1	2.9	–0.3	–9
6	1.3	0.02	0.9	1.0	3.2	1.0	0.04	1.0	1.0	3.0	–0.2	–6
7	1.3	0.03	0.9	1.0	3.2	1.0	0.04	1.0	1.0	3.0	–0.2	–6
8	1.3	0.03	0.9	1.0	3.2	1.0	0.04	1.0	1.0	3.0	–0.2	–6
9	1.3	0.03	0.9	1.0	3.2	1.0	0.04	1.0	1.0	3.0	–0.2	–6
10	1.3	0.03	0.9	1.0	3.2	1.0	0.04	1.0	1.0	3.0	–0.2	–6
11	1.3	0.03	0.9	1.0	3.2	1.0	0.04	1.0	1.0	3.0	–0.2	–6
12	1.3	0.03	1.0	0.9	3.2	1.0	0.04	1.0	1.0	3.0	–0.2	–6
13	1.3	0.03	1.0	0.9	3.2	1.0	0.04	1.0	1.0	3.0	–0.2	–6
14	1.3	0.03	1.0	0.9	3.2	1.0	0.04	1.0	1.0	3.0	–0.2	–6
15	1.3	0.03	1.0	0.9	3.2	1.0	0.04	1.0	1.0	3.0	–0.2	–6
16	1.4	0.03	1.0	0.9	3.3	1.0	0.04	1.0	1.0	3.0	–0.3	–9
17	1.4	0.03	1.0	0.9	3.3	1.0	0.04	1.0	1.0	3.0	–0.3	–9
18	1.4	0.03	1.0	0.9	3.3	1.0	0.04	1.0	1.0	3.0	–0.3	–9
19	1.4	0.03	1.0	0.9	3.3	1.0	0.04	1.0	1.0	3.0	–0.3	–9
20	1.3	0.03	1.0	0.9	3.3	1.0	0.04	1.0	1.0	3.0	–0.3	–9
Average	1.3	0.03	0.9	1.0	3.2	1.0	0.04	1.0	1.0	3.0	–0.2	–6

UKRAA model gives somewhat higher fellings in final fellings of coniferous species.

The total average deviation between the two different estimates is rather small for the Polesye region (*Table 8.8*). The IIASA model gives a 3 percent lower total average estimate in comparison with the USSR model. The largest difference is in final felling of coniferous species, with the UKRAA model giving a higher average potential for the harvest in this group.

For the Forest Steppe region (*Table 8.9*) there is a very good match between the two models for the total average estimates. There also is a good match between the estimates of final fellings of conifers and total thinnings. There is a discrepancy for soft and hard deciduous species. The average harvest potential of soft deciduous species determined by the IIASA model is twice that of the UKRAA model; a somewhat smaller difference between the two models is found for hard deciduous species.

For the Byelorussian region (*Table 8.10*), the two calculations generate similar results. The difference is only 0.2 million cubic meters per year (or 1 percent) for the average total harvests, with the Basic Forest Study Scenario giving the higher estimate (15.9). There are minor deviations for individual species groups between the two calculations.

There is a rather large deviation for the average total harvest level between the two calculations for Estonia (*Table 8.11*). The difference is 17 percent, with the Basic Forest Study Scenario giving the lower estimate. The difference in the volume is only 0.4 million cubic meters per year. The Forest Study calculation results in a lower estimate for each species.

In Latvia (*Table 8.12*), there is a minor deviation between the two calculations concerning the average total harvest level. The difference is only 0.2 million cubic meters per year (or 4 percent). The Basic Forest Study Scenario provides the lower estimate on the average total harvest level. The majority of this difference can be found in the coniferous species group in final fellings. For this group the Forest Study calculation results in a lower harvest level of 0.4 million cubic meters per year.

The two calculations give nearly the same results, at both total and individual species levels in Lithuania (*Table 8.13*). The deviation for average total harvest level is only 0.1 million cubic meters per year (or 3 percent). The lower estimate of the harvest level is produced by the Basic Forest Study Scenario.

From the validation tests, it can be seen that there are no systematic trends in the deviations between the Soviet calculations and the Basic Forest Study Scenario. The results generated by the Forest Study have, at different stages, been debated at three meetings with Soviet experts. The Soviet

Table 8.8. Comparison between calculations according to USSR models and the Basic Forest Study Scenario for the Polesye region. Volume is expressed in million cubic meters o.b.

Period	UKRAA Model					Basic Forest Study Scenario					Deviation total volumes	
	Final fellings					Final fellings						
		Deciduous		Total			Deciduous		Total			
(5 years)	Coniferous	Soft	Hard	thinnings	Total	Coniferous	Soft	Hard	thinnings	Total	In m^3	In %
1	1.6	0.8	0.5	3.3	6.2	1.9	0.2	0.3	2.7	5.1	−1.1	−18
2	1.8	1.0	0.5	3.3	6.6	2.4	0.5	0.4	2.7	6.0	−0.6	−9
3	1.8	1.0	0.5	3.2	6.5	2.4	0.5	0.4	2.7	6.0	−0.5	−8
4	2.0	1.0	0.5	2.9	6.4	2.9	0.9	0.5	2.5	6.8	+0.4	+6
5	2.4	1.1	0.5	2.7	6.7	2.9	0.9	0.5	2.5	6.8	+0.1	+1
6	3.2	1.1	0.5	2.6	7.4	3.4	1.2	0.7	2.4	7.7	+0.3	+4
7	4.4	1.1	0.5	2.4	8.4	3.4	1.2	0.7	2.4	7.7	−0.7	−8
8	4.8	1.1	0.5	2.2	8.6	4.0	1.3	0.7	2.1	8.1	−0.5	−6
9	4.8	1.1	0.7	2.0	8.6	4.0	1.3	0.7	2.1	8.1	−0.5	−6
10	4.8	1.1	0.7	1.9	8.5	4.0	1.3	0.7	2.1	8.1	−0.4	−5
11	4.9	1.0	0.7	1.8	8.4	4.0	1.3	0.8	2.1	8.2	−0.2	−2
12	4.9	1.0	0.7	1.9	8.5	4.0	1.3	0.8	2.1	8.2	−0.3	−4
13	4.9	1.0	0.8	1.8	8.5	4.0	1.3	0.8	2.1	8.2	−0.3	−4
14	4.9	1.0	0.8	1.7	8.4	4.1	1.3	0.8	2.1	8.3	−0.1	−1
15	4.9	1.0	0.8	1.6	8.3	4.1	1.3	0.8	2.1	8.3	±0.0	±0
16	4.9	1.0	0.8	1.6	8.3	4.1	1.3	0.8	2.1	8.3	±0.0	±0
17	4.9	1.0	0.8	1.7	8.4	4.1	1.3	0.8	2.1	8.3	−0.1	−1
18	4.9	1.0	0.8	1.7	8.4	4.1	1.3	0.8	2.1	8.3	−0.1	−1
19	5.0	1.0	0.8	1.7	8.5	4.1	1.3	0.8	2.1	8.3	−0.2	−2
20	5.0	1.0	0.8	1.7	8.5	4.1	1.3	0.8	2.1	8.3	−0.2	−2
Average	4.0	1.0	0.7	2.2	7.9	3.6	1.1	0.7	2.3	7.7	−0.2	−3

Table 8.9. Comparison between calculations according to USSR models and the Basic Forest Study Scenario for the Forest Steppe region. Volume is expressed in million cubic meters o.b.

Period	UKRAA Model					Basic Forest Study Scenario					Deviation	
	Final fellings					Final fellings					total volumes	
		Deciduous		Total			Deciduous		Total			
(5 years)	Coniferous	Soft	Hard	thinnings	Total	Coniferous	Soft	Hard	thinnings	Total	In m^3	In %
1	0.8	0.3	1.2	2.0	4.3	1.2	0.7	0.9	1.7	4.5	+0.2	+5
2	1.0	0.3	1.2	2.0	4.5	1.5	0.7	0.9	1.7	4.8	+0.3	+7
3	1.0	0.3	1.2	2.0	4.5	1.5	0.7	1.0	1.7	4.9	+0.4	+9
4	1.0	0.3	1.2	2.0	4.5	1.6	0.7	1.1	1.7	5.1	+0.6	+13
5	1.3	0.3	1.3	1.9	4.8	1.6	0.7	1.1	1.7	5.1	+0.3	+6
6	1.5	0.3	1.5	1.9	5.2	1.7	0.7	1.3	1.7	5.4	+0.2	+4
7	1.5	0.3	1.5	1.9	5.2	1.7	0.7	1.3	1.7	5.4	+0.2	+4
8	1.5	0.3	1.5	1.8	5.1	1.7	0.7	1.3	1.7	5.4	+0.3	+6
9	1.6	0.3	1.6	1.8	5.3	1.7	0.7	1.3	1.7	5.4	−0.1	+2
10	1.8	0.3	1.8	1.8	5.7	1.7	0.7	1.3	1.7	5.4	−0.3	−5
11	1.9	0.3	1.9	1.8	5.9	1.7	0.7	1.3	1.7	5.4	−0.5	−8
12	2.1	0.3	1.9	1.7	6.0	1.7	0.7	1.3	1.7	5.4	−0.6	−10
13	2.1	0.3	1.9	1.7	6.0	1.7	0.7	1.3	1.7	5.4	−0.6	−10
14	2.1	0.3	1.9	1.7	6.0	1.7	0.7	1.4	1.7	5.5	−0.5	−8
15	2.1	0.3	1.9	1.7	6.0	1.7	0.7	1.4	1.7	5.5	−0.5	−8
16	2.1	0.3	1.9	1.7	6.0	1.7	0.7	1.4	1.7	5.5	−0.5	−8
17	2.1	0.3	1.9	1.6	5.9	1.7	0.7	1.4	1.7	5.5	−0.4	−7
18	2.1	0.3	1.9	1.6	5.9	1.7	0.7	1.4	1.7	5.5	−0.4	−7
19	2.1	0.3	1.9	1.6	5.9	1.7	0.7	1.4	1.7	5.5	−0.4	−7
20	2.1	0.3	1.9	1.6	5.9	1.7	0.7	1.4	1.7	5.5	−0.4	−7
Average	1.7	0.3	1.6	1.8	5.4	1.7	0.7	1.3	1.7	5.4	±0.0	±0

Table 8.10. Comparison between calculations according to USSR models and the Basic Forest Study Scenario for the Byelorussian region. Volume is expressed in million cubic meters o.b.

	UKRAA Model					Basic Forest Study Scenario					Deviation	
	Final fellings					Final fellings					total volumes	
Period		Deciduous		Total			Deciduous		Total			
(5 years)	Coniferous	Soft	Hard	thinnings	Total	Coniferous	Soft	Hard	thinnings	Total	In m^3	In %
1	3.4	2.4	0.3	5.2	11.3	5.0	1.9	0.4	5.7	13.0	+1.7	+15
2	3.6	3.0	0.3	5.1	12.0	5.3	2.7	0.4	5.7	14.1	+2.1	+18
3	3.7	3.5	0.3	5.0	12.5	5.6	2.8	0.4	5.7	14.5	+2.0	+16
4	3.9	4.1	0.3	4.9	13.2	6.7	3.3	0.4	5.1	15.5	+2.3	+17
5	5.2	4.4	0.3	4.9	14.8	6.7	3.5	0.4	5.1	15.5	+0.7	+5
6	6.2	4.4	0.3	4.8	15.7	7.5	3.7	0.4	4.7	16.3	+0.6	+4
7	7.0	4.4	0.3	4.6	16.3	7.5	3.7	0.4	4.7	16.3	+0.0	+0
8	7.6	4.4	0.3	4.5	16.8	7.9	3.6	0.4	4.4	16.3	−0.5	−3
9	7.7	4.4	0.3	4.4	16.8	7.9	3.6	0.4	4.4	16.3	−0.5	−3
10	7.7	4.4	0.3	4.4	16.8	7.9	3.6	0.4	4.4	16.3	−0.5	−3
11	7.9	4.5	0.3	4.2	16.9	7.9	3.6	0.4	4.4	16.3	−0.6	−4
12	8.1	4.3	0.3	4.1	16.8	7.9	3.6	0.4	4.4	16.3	−0.5	−3
13	8.2	4.2	0.3	4.0	16.7	7.9	3.6	0.4	4.4	16.3	−0.4	−2
14	8.2	4.2	0.3	4.0	16.7	7.9	3.6	0.4	4.4	16.3	−0.4	−2
15	8.2	4.2	0.3	4.0	16.7	7.9	3.6	0.4	4.4	16.3	−0.4	−2
16	8.2	4.2	0.3	4.0	16.7	7.9	3.6	0.4	4.4	16.3	−0.4	−2
17	8.2	4.2	0.3	4.0	16.7	7.9	3.6	0.5	4.4	16.4	−0.3	−2
18	8.2	4.2	0.3	4.0	16.7	7.9	3.6	0.5	4.4	16.4	−0.3	−2
19	8.2	4.2	0.3	4.0	16.7	7.9	3.6	0.5	4.4	16.4	−0.3	−2
20	8.2	4.2	0.3	4.0	16.7	7.9	3.6	0.5	4.4	16.4	−0.3	−2
Average	6.9	4.1	0.3	4.4	15.7	7.4	3.4	0.4	4.7	15.9	+0.2	+1

Table 8.11. Comparison between calculations according to USSR models and the Basic Forest Study Scenario for the Estonian region. Volume is expressed in million cubic meters o.b.

	UKRAA Model					Basic Forest Study Scenario						
	Final fellings					Final fellings					Deviation	
Period		Deciduous		Total			Deciduous		Total		total volumes	
(5 years)	Coniferous	Soft	Hard	thinnings	Total	Coniferous	Soft	Hard	thinnings	Total	In m^3	In %
1	1.0	0.6		0.7	2.3	0.7	0.4		0.7	1.8	–0.5	–22
2	1.0	0.6		0.7	2.3	0.7	0.4		0.6	1.7	–0.6	–26
3	1.0	0.6		0.7	2.3	0.7	0.5		0.6	1.8	–0.5	–22
4	1.0	0.6		0.7	2.3	0.8	0.6		0.5	1.9	–0.4	–17
5	1.0	0.7		0.7	2.4	0.8	0.6		0.5	1.9	–0.5	–21
6	1.0	0.7		0.7	2.4	0.9	0.6		0.5	2.0	–0.4	–17
7	1.1	0.7		0.7	2.5	0.9	0.6		0.5	2.0	–0.5	–20
8	1.1	0.7		0.7	2.5	1.0	0.6		0.5	2.1	–0.4	–16
9	1.1	0.7		0.6	2.4	1.0	0.6		0.5	2.1	–0.3	–13
10	1.1	0.7		0.6	2.4	1.0	0.6		0.5	2.1	–0.3	–13
11	1.1	0.7		0.6	2.4	1.0	0.6		0.5	2.1	–0.3	–13
12	1.1	0.7		0.6	2.4	1.0	0.5		0.5	2.0	–0.4	–17
13	1.1	0.7		0.6	2.4	1.0	0.5		0.5	2.0	–0.4	–17
14	1.1	0.7		0.6	2.4	1.0	0.5		0.5	2.0	–0.4	–17
15	1.1	0.7		0.6	2.4	1.0	0.5		0.5	2.0	–0.4	–17
16	1.1	0.7		0.6	2.4	1.0	0.5		0.5	2.0	–0.4	–17
17	1.1	0.7		0.6	2.4	1.0	0.5		0.5	2.0	–0.4	–17
18	1.1	0.7		0.6	2.4	1.0	0.5		0.5	2.0	–0.4	–17
19	1.1	0.7		0.6	2.4	1.0	0.5		0.5	2.0	–0.4	–17
20	1.1	0.7		0.6	2.4	1.0	0.5		0.5	2.0	–0.4	–17
Average	1.1	0.7		0.6	2.4	0.9	0.5		0.5	1.9	–0.4	–17

Table 8.12. Comparison between calculations according to USSR models and the Basic Forest Study Scenario for the Latvian region. Volume is expressed in million cubic meters o.b.

Period	UKRAA Model					Basic Forest Study Scenario					Deviation total volumes	
	Final fellings					Final fellings						
		Deciduous		Total			Deciduous		Total			
(5 years)	Coniferous	Soft	Hard	thinnings	Total	Coniferous	Soft	Hard	thinnings	Total	In m^3	In %
1	2.4	1.1		1.1	4.6	2.1	1.1		1.2	4.4	–0.2	–4
2	2.4	1.1		1.1	4.6	2.1	1.1		1.1	4.3	–0.3	–7
3	2.4	1.1		1.1	4.6	2.1	1.1		1.1	4.3	–0.3	–7
4	2.4	1.1		1.1	4.6	2.1	1.2		1.1	4.4	–0.2	–4
5	2.5	1.2		1.0	4.7	2.1	1.2		1.1	4.4	–0.3	–6
6	2.5	1.2		1.0	4.7	2.2	1.2		1.0	4.4	–0.3	–6
7	2.5	1.2		0.9	4.6	2.2	1.2		1.0	4.4	–0.1	–2
8	2.5	1.2		0.9	4.6	2.2	1.2		1.1	4.5	–0.1	–2
9	2.5	1.2		0.9	4.6	2.2	1.2		1.1	4.5	–0.1	–2
10	2.5	1.2		0.9	4.6	2.2	1.2		1.1	4.5	–0.1	–2
11	2.5	1.2		0.9	4.6	2.2	1.2		1.1	4.5	–0.1	–2
12	2.5	1.2		0.9	4.6	2.2	1.2		1.1	4.5	–0.1	–2
13	2.6	1.2		0.9	4.7	2.2	1.2		1.1	4.5	–0.2	–4
14	2.6	1.2		0.9	4.7	2.2	1.1		1.1	4.4	–0.3	–6
15	2.7	1.2		0.9	4.8	2.2	1.1		1.1	4.4	–0.4	–8
16	2.7	1.2		0.9	4.8	2.2	1.1		1.1	4.4	–0.4	–8
17	2.7	1.2		0.9	4.8	2.2	1.1		1.1	4.4	–0.4	–8
18	2.7	1.2		0.9	4.8	2.2	1.1		1.1	4.4	–0.4	–8
19	2.7	1.2		0.9	4.8	2.2	1.1		1.1	4.4	–0.4	–8
20	2.7	1.2		0.9	4.8	2.2	1.1		1.1	4.4	–0.4	–8
Average	2.6	1.2		1.0	4.7	2.2	1.2		1.1	4.5	–0.2	–4

Table 8.13. Comparison between calculations according to USSR models and the Basic Forest Study Scenario for the Lithuanian region. Volume is expressed in million cubic meters o.b.

Period	UKRAA Model					Basic Forest Study Scenario					Deviation total volumes	
	Final fellings					Final fellings						
		Deciduous		Total			Deciduous		Total			
(5 years)	Coniferous	Soft	Hard	thinnings	Total	Coniferous	Soft	Hard	thinnings	Total	In m^3	In %
1	1.6	0.5	0.1	1.1	3.3	1.5	0.7	0.07	1.2	3.5	+0.2	+6
2	1.6	0.7	0.1	1.1	3.5	1.4	0.8	0.05	1.2	3.5	±0.0	0
3	1.7	0.8	0.1	1.1	3.7	1.6	0.8	0.03	1.2	3.6	−0.2	−5
4	1.7	0.8	0.1	1.1	3.7	1.7	0.8	0.05	1.2	3.8	+0.1	+3
5	1.7	0.9	0.1	1.1	3.8	1.7	0.8	0.07	1.2	3.8	±0.0	0
6	1.7	0.9	0.1	1.1	3.8	1.7	0.8	0.08	1.2	3.8	±0.0	0
7	1.7	0.9	0.1	1.2	3.9	1.7	0.8	0.11	1.2	3.8	−0.1	−3
8	1.7	0.9	0.1	1.2	3.9	1.7	0.8	0.12	1.2	3.8	−0.1	−3
9	1.7	1.0	0.1	1.2	4.0	1.7	0.8	0.13	1.2	3.8	−0.2	−5
10	1.7	1.0	0.1	1.2	4.0	1.7	0.8	0.13	1.2	3.8	−0.2	−5
11	1.7	1.0	0.1	1.2	4.0	1.7	0.8	0.14	1.2	3.8	−0.2	−5
12	1.7	1.0	0.1	1.2	4.0	1.7	0.8	0.13	1.2	3.8	−0.2	−5
13	1.7	1.0	0.1	1.2	4.0	1.7	0.8	0.13	1.2	3.8	−0.2	−5
14	1.7	1.0	0.1	1.2	4.0	1.7	0.8	0.12	1.2	3.8	−0.2	−5
15	1.7	1.0	0.1	1.2	4.0	1.8	0.8	0.11	1.2	3.9	−0.1	−3
16	1.7	1.0	0.1	1.2	4.0	1.8	0.8	0.10	1.2	3.9	−0.1	−3
17	1.7	1.0	0.1	1.3	4.1	1.8	0.8	0.10	1.2	3.9	−0.2	−5
18	1.7	1.0	0.1	1.3	4.1	1.8	0.8	0.09	1.2	3.9	−0.2	−5
19	1.7	1.0	0.1	1.3	4.1	1.8	0.8	0.09	1.2	3.9	−0.2	−5
20	1.7	1.0	0.1	1.3	4.1	1.8	0.8	0.08	1.1	3.8	−0.3	−7
Average	1.7	0.9	0.1	1.2	3.9	1.7	0.8	0.10	1.2	3.8	−0.1	−3

experts have made the following statement, "The model results produced by the Forest Study seem to be reliable according to Soviet experiences."

There is also a possibility of comparing actual harvest (in 1989), actual AAC (in 1989), and the Basic Forest Study Scenario averages for all subregions investigated (*Table 8.14*). It should be stressed that the AAC in *Table 8.14* includes only final felling of commercial wood and not the total volume, which is presented for the actual harvest and the Basic Forest Study Scenario. To adjust the estimated AAC to total volume, Soviet experts used a conversion factor of 1.12 for final fellings. For conversion of commercial thinnings to standing volume, a factor of between 1.2 and 1.3 is employed, depending on the type of thinning and other regional conditions.

From the results presented for the 17 region in *Table 8.14*, it can be seen that in 1989 only five regions had an actual harvest that was within the limits of the total harvest potential based on the 1989 AACs. In 1989 14 of the 17 regions had a harvest which was within the limit of a sustainable harvest determined by the Basic Forest Study Scenario. The sustainable harvest level (based on the Basic Forest Study Scenario) in the IIASA analysis, in general, is higher than the harvest potential based on the AACs in 1989.

Table 8.15 lists the actual harvests (with all types of harvests included), current annual allowable cut, and the simulation results from the models. A comparison of the calculations gives the following results:

- For final fellings there is good correspondence on the total of the different models. However, there are discrepancies between the model results for individual region, but these discrepancies are acceptable.
- For thinnings there is good correspondence between the models for regions with a well-developed infrastructure (Ukraine and Byelorussia). In regions with undeveloped infrastructure and a large proportion of mature and overmature forests, the Basic Forest Study Scenario gives a much higher amount of thinnings.

For the nine regions in *Table 8.15*, the volume of thinnings under conditions of the Basic Forest Study Scenario is nearly twice as much as under conditions of the Soviet scenarios. In connection with the discrepancies between the different models, it may be expedient to study the information on the natural mortality of the regions studied. According to data by VNIIZ Lesresurs, the natural mortality constituted 118 million cubic meters in 1988, of which 33 million cubic meters originated from thinning stands in the nine regions listed in *Table 8.15*. The results on natural mortality in 1988 for all European USSR regions are presented in *Table 8.16*.

Basic mortality information is collected from statistics generated by the forest enterprises. Mortality primarily occurs in mature and overmature

Table 8.14. Comparison of actual harvest of commercial volume in 1989, AAC in 1989, total harvest potential in 1989, and Basic Forest Study simulations, in million cubic meters.

Region	Actual harvest Total	Final felling	Thinning	Other harvests	AAC	Total harvest potential	Basic Forest Study Scenario average for 100 years
North	74.60	70.80	1.90	1.90	86.00	96.30	95.2
Northwest	11.00	9.00	1.60	0.40	14.70	16.50	14.5
Central	27.20	21.80	4.20	1.20	27.40	30.70	41.6
Pre-Baltic	0.45	0.25	0.20	0.00	0.26	0.30	0.5
Volgo-Vyatsky	23.40	19.60	3.20	0.60	22.60	25.30	33.2
Central Chernozyomny	2.20	1.20	0.90	0.10	1.30	1.50	3.1
Povolzhsky	8.30	5.60	2.60	0.10	6.20	6.90	9.9
Ural	51.60	44.20	4.90	2.50	60.90	68.20	76.0
North Caucasia	2.90	1.70	1.00	0.20	2.20	2.50	4.5
Carpathians	3.60	2.00	1.60	0.10	1.90	2.10	3.1
Polesye	5.70	2.50	3.00	0.20	2.50	2.80	7.7
Forest Steppe	4.40	1.50	2.70	0.20	1.50	1.70	5.3
Moldavia	0.33	0.14	0.19	0.01	0.14	0.16	0.6
Byelorussia	11.00	6.10	4.10	0.80	6.20	6.90	15.9
Estonia	2.20	1.30	0.90	0.00	1.50	1.70	2.0
Latvia	3.90	2.30	1.40	0.20	2.30	2.60	4.5
Lithuania	3.20	1.60	1.10	0.50	1.70	1.90	3.9
Total	236.00	191.60	35.50	9.00	239.30	268.10	321.6

Table 8.15. Comparison of actual harvest in 1988 (AH), current AAC (CAAC), long-term calculations by Soviet models (AACS), and the Basic Forest Study Simulation (BFSS), in million cubic meters.

	Final felling				Thinning			Total		
Region	AH	CAAC	AACS	BFSS	AH	AACS	BFSS	AH	AACS	BFSS
North	82.1	94.6	77.1	78.5	2.3	8.4	16.7	84.4	85.5	95.2
Central	24.9	30.1	32.9	29.7	5.8	5.9	12.0	30.7	38.8	41.7
Central Chernozyomny	1.4	1.5	2.4	2.3	1.1	0.9	0.8	2.6	3.3	3.1
Ural	52.0	67.1	60.3	57.3	6.1	10.3	18.7	58.1	70.6	76.0
Ukraine (total)	7.2	6.6	11.5	10.9	8.3	5.0	5.0	15.5	16.5	15.9
Byelorussia	7.7	6.8	11.3	11.2	4.6	4.4	4.7	12.3	15.7	15.9
Estonia	1.7	1.7	1.8	1.4	1.3	0.6	0.5	3.0	2.4	2.0
Latvia	2.7	2.3	3.8	3.4	1.8	1.0	1.1	4.5	4.7	4.5
Lithuania	2.0	1.8	2.7	2.6	1.4	1.2	1.2	3.4	3.9	3.8
Total European USSR	181.7	212.5	203.8	197.3	32.7	37.7	60.7	214.4	241.4	258.1

Table 8.16. Natural mortality during 1988 in the forests of the European USSR.

Region	Total natural mortality in million m^3 yr^{-1}	Natural mortality in thinning stands in million m^3 yr^{-1}
North	28.2	5.20
Northwest	11.5	2.30
Central	26.4	6.80
Pre-Baltic	0.5	0.20
Volgo-Vyatsky	17.9	5.00
Central Chernozyomny	1.8	1.00
Povolzhsky	14.6	4.50
Ural	30.5	6.50
North Caucasia	3.2	1.10
Ukraine (total)	11.4	7.10
Moldavia	0.2	0.15
Byelorussia	11.5	2.60
Estonia	1.8	0.60
Latvia	3.6	1.60
Lithuania	2.9	1.30
Total	166.0	45.95

Source: VNIIZ Lesresurs.

stands in the Northern and Ural regions and in unutilized deciduous species in the Central region. Information on mortality also includes noncommercial forests. The data on natural mortality for thinnings include not only natural mortality, but also the volumes taken out as thinnings. In *Table 8.17* information on delivered thinning volume (commercial volume), accessible thinning volumes, and required thinnings, from a silvicultural point of view, is presented for the European USSR. The relation between thinned commercial volume and thinned total volume is illustrated for some regions in *Table 8.18*. By combining the information in *Tables 8.16, 8.17*, and *8.18*, it can be concluded that the major part of the natural mortality reported for thinning stands in *Table 8.16* is commercial wood taken out in the form of thinnings. The real natural mortality in thinning stands seems to be some 10 million cubic meters per year. Although even with this correction, the natural mortality is extremely high in the USSR in comparison with other countries in Europe. The total natural mortality in *Table 8.16* corresponds to about 125 million to 130 million cubic meters per year or some 40 percent of the average sustainable harvesting potential identified in the Basic Forest Study Scenario (321 million cubic meters per year). The reported requirement upon thinnings listed in *Table 8.17* is 67 million cubic meters

Table 8.17. Actual delivery of thinned volume (commercial volume)[a], accessible thinning volumes, and required thinning volumes from silvicultural point of view in the European USSR.

Region	Delivered thinning volume 1988	Delivered thinning volume 1989	Accessible thinning volume	Required thinning
North	1.77	2.00	2.37	13.41
Northwest	1.63	1.59	1.03	3.09
Central	4.18	4.30	4.50	7.87
Pre-Baltic	0.21	0.18	0.24	0.28
Volgo-Vyatsky	3.20	3.18	3.13	6.97
Central Chernozyomny	0.80	0.90	1.10	1.13
Povolzhsky	2.69	2.59	2.79	3.50
Ural	4.85	5.06	5.33	15.73
North Caucasia	1.04	0.98	0.99	1.17
Ukraine (total)	7.49	6.92	6.66	6.66
Moldavia	0.20	0.19	0.19	0.20
Byelorussia	3.72	3.90	3.50	3.53
Estonia	0.95	0.94	0.92	0.92
Latvia	1.41	1.25	1.42	1.42
Lithuania	1.06	1.08	0.82	0.82
European USSR	35.20	35.06	34.99	66.70
Total USSR	43.56	42.93	43.82	164.26

[a]Delivered commercial thinned volume is roughly similar to the actual thinned volume.

Table 8.18. Relation between thinned commercial volume and total thinned volume in some regions in 1990.

Region	Thinned volume in million m^3		Thinned area in thousand ha
	Commercial	Total	
Ukraine	6.89	7.78	509
Moldavia	0.19	0.20	14
Byelorussia	3.90	4.29	302
Estonia	0.94	1.10	72
Latvia	1.24	1.80	89
Lithuania	1.09	1.32	144
European USSR	35.39	43.78	2,821
Total USSR	42.80	52.54	3,362

for the European USSR, which indicates that the thinning intensity suggested in the Basic Forest Study Scenario seems to be more relevant than the thinning volume suggested by the Soviet models in the validation tests.

Chapter 9

Summary of Results and Policy Implications

9.1 Adjustments to the Scenarios

In Chapters 5 and 7 and in Appendix A, scenarios on the average sustainable harvest potentials are presented. These estimates or scenarios are based on different conditions. Thus far the discussions on the future development of forest resources have been based on the Basic Forest Study Scenario. This scenario is not an estimate on the real supply to the market. Several factors must be considered in estimating the possible real (economic) wood supply in the European USSR. In this chapter, we adjust the Basic Forest Study Scenario for some of these factors. The adjustment at a regional level is presented in *Table 9.1*.

To determine the adjustments in *Table 9.1* the average harvest potential according to the Basic Forest Study Scenario is taken from the results presented in Appendix A. The data on the air-pollution effects from the Forest Study Decline Scenario listed in Appendix A are also used. The reduction for data aggregation is calculated on the average harvest potential after deduction of air-pollution effects from the Basic Forest Study Scenario. The reduction factors are the same as those in *Table 6.2*. The deductions for low productivity stands are taken from *Table 6.3*. The lack of infrastructure deduction is based on *Table 6.4*. The wasted wood deduction considers the part of the harvest which is not used in any production. According to the discussion in Chapter 6, the amount of waste is 13 percent of the final harvested volume, which is a conservative estimate.

It should be emphasized that each deduction in *Table 9.1* has a large component of uncertainty. But, it is the best estimate that we can produce

Table 9.1. Adjustment of the Basic Forest Study Scenario in the estimation of real supply or wood availability for industrial production, in million cubic meters.

Region	Basic Forest Study (BFSS)	Decline from air pollutants (DAP)	Data aggregation (DA)	Low productivity stands (LPS)	Lack of infrastructure (LI)	Wasted wood (WW)	Wood available for industry (WAI)
North	95.2	–6.0	–8.0	–12.0	–12.4	–7.4	49.4
Northwest	14.5	–1.9	–0.6		–0.8	–1.5	9.7
Central	41.6	–3.4	–1.9		–1.7	–4.5	30.1
Pre-Baltic	0.5	–0.1				–0.1	0.3
Volgo-Vyatsky	33.2	–2.1	–1.6		–1.6	–3.6	24.3
Central Chernozyomny	3.1	–0.3	–0.1			–0.4	2.3
Povolzhsky	9.9	–0.7	–0.3			–1.2	7.7
Ural	76.0	–10.2	–5.9	–0.7	–7.6	–6.7	44.9
North Caucasia	4.5	–0.4	–0.3			–0.5	3.3
Carpathian	3.1	–1.3	–0.1			–0.2	1.5
Polesye	7.7	–1.0	–0.2			–0.9	5.6
Forest Steppe	5.3	–1.6	–0.1			–0.5	3.1
Moldavia	0.6	–0.2				–0.1	0.3
Byelorussia	15.9	–4.4	–0.7			–1.4	9.4
Estonia	2.0	–0.4	–0.1			–0.2	1.3
Latvia	4.5	–0.7	–0.1			–0.5	3.2
Lithuania	3.9	–0.7	–0.1			–0.4	2.7
Total	321.5	–35.4	–20.1	–12.7	–24.1	–30.1	199.1

Table 9.2. Comparison of actual harvest, including thinning, with Forest Study estimates, in million cubic meters for total European USSR.

1 Basic Forest Study Scenario (BFSS)	2 Actual harvest 1988	3 Actual harvest 1989	4 Actual harvest 1990	5 BFSS deducted for data aggregation, low prod. stands, & lack of infrastructure	6 Column 5 & deduction for air-pollution effects
321.5	256.7	259.6	239.1	264.6	229.2

Table 9.3. Relationship between wood available for industrial production and different estimates produced by the Forest Study, in percentage for all of the European USSR. For abbreviations see *Table 9.1.*

Actual harvest in 1988	WAI BFSS	WAI BFSS-DA-LPS-LI	WAI BFSS-DA-LPS-LI-DAP
78%	62%	75%	87%

at this time. It should also be pointed out that in these deductions no consideration is made in the economic accessibility due to changes in the conditions of the Soviet economy. Neither has it been possible to consider losses caused by forest fires, insects, and diseases. As presented in Chapter 1, these losses are rather substantial in the USSR.

However, it might be interesting to compare the adjusted estimates with the actual harvests (*Table 9.2*). It is difficult to make any concrete statements based on the comparison in *Table 9.2*. However, it looks as though the actual harvest in 1988 and 1989 (the harvest level in 1990 was greatly influenced by political and economic events in the USSR) corresponds to what the Basic Forest Study Scenario determined to be an accessible harvest level for total European USSR.

If the wasted wood proportion (*Table 9.1*) were considered, the wood available for industrial production would be strongly reduced in comparison with the average potential biological harvest according to the Basic Forest Study Scenario. The relationship between wood available for industrial production (WAI from *Table 9.1*) and the different wood-supply estimates are presented in *Table 9.3* for all of the European USSR.

Based on the calculations in *Table 9.3*, it can be concluded that on average only 62 percent of the supply, according to the Basic Forest Study Scenario, would be available for industrial production. Estimates for the regions are presented in *Table 9.4*. In this table, it can be seen that the current harvest level is the same or above the sustainable harvest level calculated on the Basic Forest Study Scenario in Pre-Baltic, Carpathian, and Estonian

Table 9.4. Regional data on actual harvests and Forest Study estimates, in million cubic meters and percent. For abbreviations see *Table 9.1*.

Region	BFSS	Actual harvest AH-1988	AH-88 / BFSS	AH-88 / BFSS-DA-LPS-LI	AH-88 / BFSS-DA-LPS-LI-DAP
North	95.2	82.5	87%	131%	145%
Northwest	14.5	11.8	81%	90%	105%
Central	41.6	30.8	74%	81%	89%
Pre-Baltic	0.5	0.5	100%	100%	125%
Volgo-Vyatsky	33.2	27.1	82%	90%	97%
Central Chernozyomny	3.1	2.4	77%	80%	89%
Povolzhsky	9.9	9.2	93%	96%	103%
Ural	76.0	56.3	74%	91%	109%
North Caucasia	4.5	3.1	69%	73%	82%
Carpathian	3.1	3.9	126%	130%	229%
Polesye	7.7	6.3	82%	84%	96%
Forest Steppe	5.3	4.2	79%	81%	117%
Moldavia	0.6	0.4	67%	67%	133%
Byelorussia	15.9	8.7	56%	56%	82%
Estonia	2.0	2.6	130%	137%	143%
Latvia	4.5	3.9	87%	89%	105%
Lithuania	3.9	3.0	77%	79%	97%
Total	321.5	256.7	80%	97%	112%

regions. This is in agreement with the comparison of current harvest level and actual AAC for these regions in Chapter 8 (*Table 8.14*). If the Basic Forest Study Scenario were adjusted for the data aggregation, low productivity stands, and lack of infrastructure, the current harvest level would seriously abuse the sustainable harvest level in the Northern, Pre-Baltic, Carpathian, and Estonian regions. If the Basic Forest Study Scenario were also adjusted for the calculated effects of air pollutants, the current harvest would exceed the long-term sustainable harvest level in the Northern, Northwestern, Pre-Baltic, Povolzhsky, Ural, Carpathian, Forest Steppe, Moldavia, Estonian, and Latvian regions. In this case, the current harvest level is too high to sustain the harvest level in all of the European USSR. The harvest would be between 10 and 15 percent too high.

It is interesting to compare the current harvest distribution of species with the sustainable harvest-level distribution determined by the Basic Forest Study Scenario. This comparison is presented in *Table 9.5*. From this comparison, it can be seen that the current harvest level of coniferous species is not in line with the sustainable level calculated by the Forest Study in the Pre-Baltic, Central Chernozyomny, North Caucasian, Carpathian, and Estonian regions. It can also be seen that coniferous species seem to have an extremely low utilization rate in the Central, Povolzhsky, Forest Steppe, Byelorussian, Latvian, and Lithuanian regions. Based on this comparison there seems to be an overutilization of the deciduous species in the Pre-Baltic, Povolzhsky, Polesye, Forest Steppe, Estonian, Latvian, and Lithuanian regions. The only region with a strongly pronounced underutilization of deciduous species is Central Chernozyomny.

It is difficult to compare species for an adjusted Basic Forest Study Scenario because factors specified for these adjustments are not broken down by individual species groups. However, if the deduction factors were assumed in a distribution of species similar to the volume distribution of the species groups, the result for the wood availability for industrial production (WAI, see *Table 9.1*) would be similar to the results in *Table 9.6*. It should be pointed out that these results are uncertain.

From *Table 9.6* it can be seen that the harvest levels of 1988, taking into account all of the deduction components, will interfere with a sustainable harvest level in most regions for both coniferous and deciduous species. Exceptions for coniferous species are in the Central, Volgo-Vyatsky, Povolzhsky and Byelorussian regions; exceptions for deciduous species are in the Central Chernozyomny and North Caucasian regions.

Table 9.5. Comparison of total harvest in 1988 with wood supply according to the Basic Forest Study Scenario distributed by species groups, in million cubic meters and percent.

	Harvest level in 1988			Basic Forest Study			Comparison between 1988 harvest level and Basic Forest Study Scenario	
Region	Coniferous	Deciduous	Total	Coniferous	Deciduous	Total	Coniferous	Deciduous
North	70.4	12.1	82.5	80.8	14.4	95.2	87%	84%
Northwest	5.9	5.9	11.8	8.3	6.2	14.5	71%	95%
Central	12.5	18.3	30.8	22.5	19.1	41.6	56%	96%
Pre-Baltic	0.2	0.3	0.5	0.2	0.3	0.5	100%	100%
Volgo-Vyatsky	11.6	15.5	27.1	13.5	19.7	33.2	86%	79%
Central Chernozyomny	1.8	0.6	2.4	1.0	2.1	3.1	180%	29%
Povolzhysky	0.4	8.8	9.2	2.7	7.2	9.9	15%	122%
Ural	33.0	23.3	56.3	37.0	39.0	76.0	89%	60%
North Caucasia	0.2	2.9	3.1	0.2	4.3	4.5	100%	67%
Carpathian	2.4	1.5	3.9	1.5	1.6	3.1	160%	94%
Polesye	3.5	2.8	6.3	5.1	2.6	7.7	69%	108%
Forest Steppe	0.5	3.7	4.2	2.4	2.9	5.3	21%	128%
Moldavia	0.0	0.4	0.4	0.0	0.6	0.6		67%
Byelorussia	4.4	4.3	8.7	10.4	5.5	15.9	43%	80%
Estonia	1.5	1.1	2.6	1.3	0.7	2.0	115%	157%
Latvia	1.8	2.1	3.9	3.0	1.5	4.5	60%	140%
Lithuania	1.2	1.8	3.0	2.4	1.5	3.9	50%	120%
Total	151.6	105.2	256.7	192.3	129.0	321.3	79%	82%

Table 9.6. Comparison of total harvest in 1988 with wood availability for industry (WAI in *Table 9.1*) distributed on species groups, in million cubic meters and percent.

Region	Actual harvest level in 1988			Adjusted Basic Forest Study			Comparison between 1988 harvest level and adjusted Basic Forest Study	
	Coniferous	Deciduous	Total	Coniferous	Deciduous	Total	Coniferous	Deciduous
North	70.4	12.1	82.5	44.5	4.9	49.4	158%	247%
Northwest	5.9	5.9	11.8	5.9	3.8	9.7	100%	155%
Central	12.5	18.3	30.8	16.9	13.2	30.1	74%	139%
Pre-Baltic	0.2	0.3	0.5	0.1	0.2	0.3	200%	150%
Volgo-Vyatsky	11.6	15.5	27.1	13.1	11.2	24.3	89%	138%
Central Chernozyomny	1.8	0.6	2.4	0.8	1.5	2.3	225%	40%
Povolzhysky	0.4	8.8	9.2	2.3	5.4	7.7	17%	162%
Ural	33.0	23.3	56.3	27.4	17.5	44.9	120%	133%
North Caucasia	0.2	2.9	3.1	0.2	3.1	3.3	100%	94%
Ukraine	6.4	8.0	14.4	5.4	4.8	10.2	119%	167%
Moldavia	0.0	0.4	0.4	0.0	0.3	0.3		133%
Byelorussia	4.4	4.3	8.7	6.6	2.8	9.4	68%	157%
Estonia	1.5	1.1	2.6	0.9	0.4	1.3	167%	275%
Latvia	1.8	2.1	3.9	2.2	1.0	3.2	82%	210%
Lithuania	1.2	1.8	3.0	1.9	0.8	2.7	150%	225%
Total	151.6	105.2	256.7	128.2	70.9	199.1	118%	148%

9.2 Demand/Supply Balances for Roundwood

In Chapter 4, we presented statistics on the regionalized industrial capacities in 1988 in roundwood equivalents. In *Table 9.7* this information is combined with the wood potentials presented in Section 9.1.

From the results, it can be seen that under the conditions of the Basic Forest Study Scenario, there will be no problem fulfilling the demand for wood for total European USSR. However, several regions will not be self-sufficient: Pre-Baltic, Central Chernozyomny, Povolzhsky, North Caucasia, Ukraine, Moldavia, Estonia, and Latvia. With adjustments to the Basic Forest Study Scenario for data aggregation, low productivity stands, and lack of infrastructure (see *Table 9.1* and adjustment I in *Table 9.7*), Lithuania also will not be able to fulfill its wood-supply needs for domestic industry. When the effects of wasted wood (adjustment II in *Table 9.7*) are considered, the Northern region can be added to the list of those regions not being able to fulfill its need.

When we consider the factors data aggregation, low productivity stands, lack of infrastructure, and air-pollution effects (adjustment III in *Table 9.7*) in the adjustment of the Basic Forest Study Scenario, we get the same result as in adjustment II. When we add the wasted wood adjustment to this adjustment (adjustment IV in *Table 9.7*), only the Central and Byelorussian regions will be self-sufficient with the existing domestic industrial capacities. In this case there will be a total deficit of nearly 70 million cubic meters in total European USSR.

Based on the comparison in *Table 9.7* rather strong structural changes within the industry will be needed in the future based on the future wood availability for different industries in the European USSR.

In Chapter 5, we presented a regional demand and supply balances for the aggregates in the year 2000 based on the Basic Forest Study Scenario. The basic data on the demand side do not allow for a breakdown of this analysis from the aggregate level to the regional level. In this section we adjust the aggregated balances presented in Chapter 5 to the wood availability listed in *Table 9.7*. The adjusted balances are presented in *Table 9.8*. The balances only include the forest products: lumber, plywood, and paper. For other industries using wood as a raw material (energy, chemical, and so on), it is not possible to make any estimates on future demand.

As shown in *Table 9.8*, in the case of adjustment III, it may become difficult to satisfy the domestic demand for lumber, plywood, and paper products. Based on the other adjustments there would not be any problem in satisfying the total domestic demand for these products. However, these conclusions assume that the primary forest industry will be more competitive

Table 9.7. Industrial capacities in 1988 in roundwood equivalents and different wood supply estimates, in million cubic meters.

Region	Industry: Basic industry (mech. & pulp)	Wood for energy	Other ind. & chem.	Total	BFSS[b]	Adjustment I[c] BFSS	Adjustment II[d] BFSS	Adjustment III[e] BFSS	Adjustment IV[f] BFSS
North	38.99	10.39	12.54	61.9	95.2	62.8	56.8	55.4	49.4
Northwest	5.63	2.00	3.45	11.1	14.5	13.1	11.2	11.6	9.7
Central	14.14	5.30	10.76	30.2	41.6	38.0	34.6	33.5	30.1
Pre-Baltic	7.73	3.16	5.01	15.9	0.5	0.5	0.4	0.4	0.3
Volgo-Vyatsky	11.12	5.44	9.44	26.0	33.2	30.0	27.9	26.4	24.3
Central Chernozyomny	1.64	0.52	1.14	3.3	3.1	3.0	2.7	2.6	2.3
Povolzhsky	5.21	3.08	5.20	13.5	9.9	9.6	8.9	8.4	7.7
Ural	27.07	9.30	14.22	50.6	76.0	61.8	51.6	55.7	44.9
North Caucausia	3.50	1.14	3.31	8.0	4.5	4.2	3.8	3.7	3.3
Ukraine[a]	13.37	1.78	10.14	25.3	16.1	15.7	11.8	14.1	10.2
Moldavia	0.60	0.02	0.42	1.0	0.6	0.5	0.3	0.4	0.2
Byelorussia	6.06	0.84	2.29	9.2	15.9	15.2	10.8	13.8	9.4
Estonia	2.07	0.57	1.02	3.7	2.0	1.9	1.5	1.7	1.3
Latvia	1.58	1.84	2.34	5.8	4.5	4.4	3.7	3.9	3.2
Lithuania	1.97	0.67	1.30	3.9	3.9	3.8	3.1	3.4	2.7
Total	140.68	46.05	82.58	267.9	321.5	264.5	229.1	235.0	199.0

[a]Total Ukraine.
[b]Basic Forest Study Scenario (BFSS).
[c]Adjustment of BFSS for data aggregation, low productivity stands, and lack of infrastructure, see *Table 9.1*.
[d]Adjustment of BFSS for data aggregation, low productivity stands, lack of infrastructure, and wasted wood losses.
[e]Adjustment of BFSS for data aggregation, low productivity stands, lack of infrastructure, and air-pollution effects.
[f]Adjustment of BFSS for data aggregation, low productivity stands, lack of infrastructure, air-pollution effects, and wasted wood losses.

Table 9.8. Outlook for aggregated regional wood demand (lumber, plywood, and paper) and supply balances in the European USSR in the year 2000. Data are expressed in million cubic meters of roundwood equivalents.

Aggregate	Basic Forest Study Scenario	Adjusted Wood Supply I[a]	Adjusted Wood Supply II[b]	Adjusted Wood Supply III[c]	Adjusted Wood Supply IV[d]
Northern	88.8 – 90.5	56.4 – 58.1	49.0 – 50.7	50.4 – 52.1	43.0 – 44.7
Central	40.7 – 53.4	32.5 – 44.9	22.9 – 35.3	25.1 – 37.5	15.5 – 27.9
Baltic	6.9 – 11.9	5.9 – 10.9	3.3 – 7.6	–0.4 – 4.6	–3.0 – 2.0
Ural	54.9 – 60.3	40.7 – 46.1	34.0 – 39.4	30.5 – 35.9	23.8 – 29.2
Southern	–66.0 – –40.4	–67.1 – –41.5	–70.9 – –45.3	–72.6 – –47.0	–76.4 – –52.2
Total European USSR	125.3 – 175.4	68.4 – 118.5	38.3 – 87.7	33.0 – 83.1	2.9 – 51.3

[a] Adjustment of Basic Forest Study Scenario for data aggregation, low productivity stands, and lack of infrastructure, see *Table 9.1*.
[b] Adjustment I but also adjusted for wasted wood losses.
[c] Adjustment I but also adjusted for air-pollutant effects.
[d] Adjustment I but also adjusted for wasted wood losses and air-pollutant effects.

than other industries in using wood as a raw material (wood for energy, chemical industry, and other industries – see Chapter 4). If these latter consumers have a better paying capability for the raw material, the total demand/supply balance for primary forest industrial products may face rather big problems in the European USSR.

The big deficit region in the demand/supply balance is the Southern aggregate. In the worst case (adjustment IV) the Baltic aggregate may also face a deficit situation concerning the supply of primary forest products.

9.3 Policy Implications

Several policy questions must be answered. These questions are addressed in this section.

9.3.1 Forest policies

There is a strong need for improving forest policies in the European USSR. Policies must be directed toward more intensive and careful forest management. The intensification should take place in all aspects of silviculture, but especially in reforestation and thinning programs. The former State Forest Committee (Goskomles) was in the process of introducing such policies at the time of the political change in the USSR. It is extremely important that the independent countries and republics continue this work, otherwise there is a risk that the forest resources will become eroded during the economic transition. It should also be underlined that it is not enough just to produce a new forest policy on paper; it must be implemented. Therefore, it is crucial to educate and train local managers on the implementation of new forest policies. If these steps are not taken, there is a high risk that the European USSR will face supply problems in the near future.

It is obvious that there have been many difficulties in implementing earlier policies in the USSR. To be successful, strong efforts must made at all stages of practical implementation.

9.3.2 Economic wood supply

This book has mainly dealt with the biological potential supply of wood. We have tried to adjust the estimates to some of the economic constraints such as lack of infrastructure. But, the major influence on the economic wood supply will be from the ongoing economic transition occurring within the country, influences which are impossible to estimate. There is a strong need for analyses on the future economic wood supply. The economic transition to a market economy will probably have a significant influence on the future supply in the region. More studies must be conducted to determine how the existing infrastructure restricts the future wood supply. In this analysis on the effects of the existing infrastructure on the wood supply only overall analyses have been employed.

The possibilities of further development of the infrastructure is directly linked to future economic development. Therefore, analyses on the future infrastructure must be linked to the analyses of the effects of economic transition.

9.3.3 Wasteful management

Waste occurs during the entire process, from the stump to the final product. Education and training of the managers at different levels in the forest sector may solve some of the waste-management problems. In addition, access to the appropriate technology and improvements in the capacity to handle waste products in industrial production are needed. There is a strong need for industrial capacities for waste utilization in the region, such as the capacity for utilization of different deciduous species. If these steps are not taken, there is a high probability that the region will not be self-sufficient in the future.

9.3.4 Non-wood benefits and ecological values

This book has mainly dealt with the questions of sustainable production of industrial wood and the effects of air pollutants. The protected forests managed especially for non-wood benefits and ecological reasons (noncommercial forests) have not been included in the analyses. The future demand on non-wood benefits in the society must be quantified. The demand is predicted to change with the society's ongoing transition. After the future demand is identified, new policies and management plans concerning non-wood benefits have to be established. Linked to this activity is the theme of global change. Recent studies indicate that the Soviet forest ecosystems may play an important role in the process of global change of the environment. Analyses must be intensified in this area.

9.3.5 Air pollutants and forest decline

There is high probability that emissions of air pollutants will increase, instead of decrease, in the USSR in the near future. The basic data on the effects on forests from air pollutants are weak. Improved analyses on the vitality and sensitivity of forest ecosystems and decline effects from air pollutants have to be established.

There is no doubt that, at the regional level, there are severe forest decline problems caused by air pollutants. The extent of these problems will increase if the domestic emissions are not curbed. Therefore, analyses must be carried out concerning suitable strategies of reduction of emissions in the USSR as soon as possible.

9.3.6 Future demand for forest products

In our analyses we have assumed a rather modest increase in the domestic market in the mid-term. But, due to the transition of society and the economy, the demand will, in the long term, probably change rather dramatically. Therefore, there is a need for specific analyses on the subject of future demand for forest products in the USSR. The future demand will influence the forest policies and management as well as the reconstruction of the industry.

9.3.7 Improvement of the infrastructure

The existing infrastructure is not efficient from the point of view of forest and industrial production and supply to the domestic market. New strategies for improving all aspects of the existing infrastructure are needed.

9.3.8 Reconstruction and adjustment of the industry

Most of the existing industrial capacity is technically obsolete. The industrial capacity has to be updated so that the industry can at least satisfy the future domestic demand for both quantity and quality.

There will also be regional imbalances between the wood supply and the industrial capacities in the future. The industrial capacity must be adjusted as soon as possible to the regional sustainable wood-supply potential, including the import aspects from neighboring regions.

The whole forest sector of the European USSR faces a gigantic need for reconstruction. In this process, the international community is strongly urged to support the region with substantial technical and educational assistance.

9.4 Final Remarks

CINTRAFOR, at the University of Washington (Backman and Waggener, 1990, 1991), has carried out analyses that are independent of the IIASA study on the forest resources in the USSR based on current statistics of the forest inventory. The authors of the CINTRAFOR study estimate that in the medium term it would not have been possible to increase harvests in the European USSR by extensive forms of forest development. Our study, based on different data and analyses, supports this conclusion. Moreover, based on the accessibility studies, it even seems likely that the supply to the industry in the European USSR has to be decreased by about 20 percent, in comparison with the current harvest, to achieve long-term sustainability in forest production. Thus, it is important to point out that two independent studies have arrived at similar conclusions.

Appendix A

Detailed Results for Individual Regions of the European USSR

Detailed analyses have been carried out for 17 regions of the European USSR:

1.	North	7.	Povolzhsky	13.	Moldavia
2.	Northwest	8.	Ural	14.	Byelorussia
3.	Central	9.	North Caucasia	15.	Estonia
4.	Pre-Baltic	10.	Carpathians	16.	Latvia
5.	Volgo-Vyatsky	11.	Polesye	17.	Lithuania
6.	Central Chernozyomny	12.	Forest Steppe		

These regions are presented in *Figure 1.2.* Results for each region are given in this appendix. Each section begins with an explanation of the tables and charts of the simulation results of the respective region. Data on the current state of the forest resources of each region are given in Chapter 1. In this appendix individual species are aggregated into the species groups: coniferous and hard and soft deciduous. The scenarios presented are the same as previously discussed for the aggregated regions: Basic Handbook, Basic Forest Study, Handbook Decline, and Forest Study Decline. For the Northern and Ural regions, a few more scenarios are presented. These additional scenarios illustrate the balancing problem of overmature forests.

Northern Region (Tables A.1 and A.2 and Figures A.1 to A.9)

Basic Scenarios

The commercial forest area of the region is roughly 60 million hectares. A major part of the forest is found in the age classes above 140 years. The age-class distribution for coniferous forests is listed in *Table A.1.*

Table A.1. Age-class distribution of coniferous forests of the Northern region.

Age class	Area (1,000 ha)	Standing volume (m^3 ha^{-1})	Growth rate (m^3 ha^{-1} yr^{-1})
0–19	6,505	22	0.80
20–39	5,399	43	1.99
40–59	2,406	87	2.68
60–79	2,079	138	2.28
80–99	1,797	166	1.75
100–119	1,846	182	1.23
120–139	3,149	185	0.65
140–299	26,002	163	0.89

Age classes above 140 years contain a standing volume of some 4.3 billion cubic meters of coniferous forests. If these volumes were to be liquidated over a 50-year period, the annual volume harvested from these age classes would be some 90 million cubic meters per year. In this calculation no growth effects during the 50 years in the actual age classes are taken into account. Thus, there is a tremendous amount of overmature forest which needs to be liquidated. There are many different possible time profiles for the liquidation required. Therefore, we present in this case three alternative scenarios to the Basic Handbook Scenario and the Basic Forest Study Scenario with the objective of illustrating further the opportunities for different liquidation paths. These three additional scenarios are called USSR Path, Rapid Liquidation, and Increased Harvesting:

- USSR Path. This scenario features harvesting levels identified by different USSR models (and discussed in Chapter 8, "Validation of Results") as binding input to the simulations. In other respects the conditions are equal to those of the Basic Forest Study Scenario.
- Rapid Liquidation. This scenario illustrates a rapid liquidation of the overmature forests during the first 50 years, then, for the remainder of the simulation period, the harvest level is kept at the harvest level suggested by Soviet experts as a suitable average level. Thus, this scenario has similarities with the Basic Handbook Scenario.

Increased Harvesting. The stock of overmature forests is used to increase gradually the harvesting level from its present level (over a period of 30 years), and then a slow decrease over the rest of the period. Some of the "old growth" forests are kept during the entire simulation period.

Due to the large extent of overmature forests in the Northern region, the forest structure in the region does not correspond with the implementation of the handbook silviculture, as the initial harvest pulse in the results of the Basic Handbook Scenario indicates. This harvest pulse is, of course, unrealistic to implement but shows the magnitude of the transition problem of the overmature forest. The imbalance problem is pronounced for coniferous species. The same problem exists for soft deciduous species, but is not of the same size from the viewpoint of volume. The Basic Forest Study Scenario gives even harvest levels over time for both coniferous and soft deciduous species, and about the same growing-stock level at the end of the simulation period as in the Basic Handbook Scenario. From the conditions given for the USSR Path Scenario, the Rapid Liquidation Scenario, and the Increased Harvesting Scenario the harvest patterns will be different. The USSR Path Scenario development is similar to the Basic Forest Study Scenario, but with a slightly lower average harvesting level and a higher standing volume at the end of the simulation period. The Rapid Liquidation Scenario gives high harvesting levels during the first 50 years, and the Increased Harvesting Scenario gives a harvesting peak after roughly 30 years. These results are valid for total species and coniferous species. In the USSR Path Scenario it is not possible to maintain the harvest level suggested by the Soviet collaborators throughout the entire simulation period. The harvesting potential decreases over time for this species group.

By studying the different time profiles used for the liquidation of overmature forests, we find that the standing inventory is at the same level in all five scenarios. This tells us that there are many possibilities of achieving a sustained development of the forest resources in the Northern region. Thus, the choice of harvesting profile is more a question of policy and availability of resources than of securing the sustainability of the resources.

The Basic Forest Study Scenario and the USSR Path Scenario give an average potential harvesting level for the entire simulation period of about 95 million cubic meters per year. The other three scenarios result in an average harvesting level of about 110 to 115 million cubic meters per year. This is a result of more rapid replacements of the slow-growing overmature forest in the latter three scenarios than in the first two scenarios.

The growth rate is generally low in all of the basic scenarios (1.2 to 1.6 cubic meters per hectare per year). The highest growth rates are achieved in the simulations with the most rapid liquidation of overmature forests (Basic Handbook Scenario and Rapid Liquidation Scenario).

If the individual species behind the aggregates are studied, it can be seen that all species have a low growth rate, in comparison with other European republics and the rest of Europe. The only exception is aspen which has a rather high rate of increment. Birch has an extremely low standing volume for each hectare.

Decline Scenarios

The scenarios on the decline effects of air pollutants are illustrated in *Figures A.7* to *A.9.* The decline scenarios presented in these figures are the Handbook Decline Scenario and Forest Study Decline Scenario only. To make a comparison with the basic scenarios, the results from the Basic Forest Study Scenario are inserted.

The effects of air pollutants are limited in the Northern region. If the forest study scenarios are used for a comparison, it can be seen that the average harvesting potential declines by some 6 million cubic meters per year over the simulation period. The decline effects take place in up to 80 percent of the coniferous species. The total average growth rate declines by 0.1 cubic meters per hectare per year in the decline scenarios.

Thus, as a whole for the Northern region, the impact of air pollution is limited. But we also know that serious subregional air-pollution effects jeopardize the wood supply in these affected subregions.

Summary

The overall task in the Northern region is to balance the liquidation of overmature forests. Many different alternatives exist from the viewpoint of sustainability of the forest resources. The choice of harvesting profile is more a question of which policy the decision makers would like to implement and the availability of resources. A realistic estimate of the potential harvest level (average for the simulation period) seems to be approximately 95 million cubic meters per year. Nearly 10 percent of the total average harvest potential identified should at least be harvested in the form of thinnings. The effects of air pollutants on the Northern region are limited. The estimated losses from air pollutants are some 6 million cubic meters per year.

Table A.2. Northern region.

Variable	Basic Handbook	Basic Forest Study	Handbook Decline	Forest Study Decline	USSR Path	Rapid Liquidation	Increased Harvesting
Selected data on harvests and growing stock							
Total							
Growing stock[a]	116–80	116–82	116–61	116–81	116–92	116–79	116–76
Fellings[b]							
Year 1	889.4	88.2	942.5	83.8	89.8	236.9	84.0
Year 40	53.6	95.9	76.5	89.8	93.3	90.0	142.5
Year 80	88.8	97.2	85.0	90.5	95.4	76.9	75.6
Coniferous							
Growing stock[a]	129–87	129–86	129–65	129–85	129–92	129–86	129–82
Fellings[b]							
Year 1	835.2	76.0	887.4	72.6	76.5	214.2	71.0
Year 40	38.2	81.4	61.1	76.5	78.4	72.6	122.5
Year 80	72.6	82.0	69.9	76.5	87.4	61.1	60.7
Soft deciduous							
Growing stock[a]	63–51	63–64	63–45	63–64	63–91	63–51	63–51
Fellings[b]							
Year 1	54.2	12.2	55.1	11.2	13.3	22.7	13.0
Year 40	15.4	14.5	15.4	13.3	14.9	17.4	20.0
Year 80	16.2	15.2	15.1	14.0	8.0	15.8	14.9
Hard deciduous							
Growing stock[a]	0–0	0–0	0–0	0–0	0–0	0–0	0–0
Fellings[b]							
Year 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Year 40	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Year 80	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Summary of results							
Potential harvest (mill. m^3 o.b. yr^{-1})[c]							
Total	116.3	95.2	126.1	89.2	93.2	112.0	108.1
Coniferous	98.5	80.8	108.5	76.0	81.3	94.3	90.6
Soft deciduous	17.8	14.4	17.6	13.2	11.9	17.7	17.5
Hard deciduous	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]							
Total	1.6	1.2	1.5	1.1	1.3	1.5	1.4
Coniferous	1.6	1.2	1.6	1.1	1.3	1.5	1.4
Soft deciduous	1.4	1.2	1.3	1.1	1.3	1.4	1.4
Hard deciduous	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)							
Total	116–80	116–82	116–61	116–81	116–92	116–79	116–76
Coniferous	129–87	129–86	129–65	129–85	129–92	129–86	129–82
Soft deciduous	63–51	63–64	63–45	63–64	63–91	63–51	63–51
Hard deciduous	0–0	0–0	0–0	0–0	0–0	0–0	0–0

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

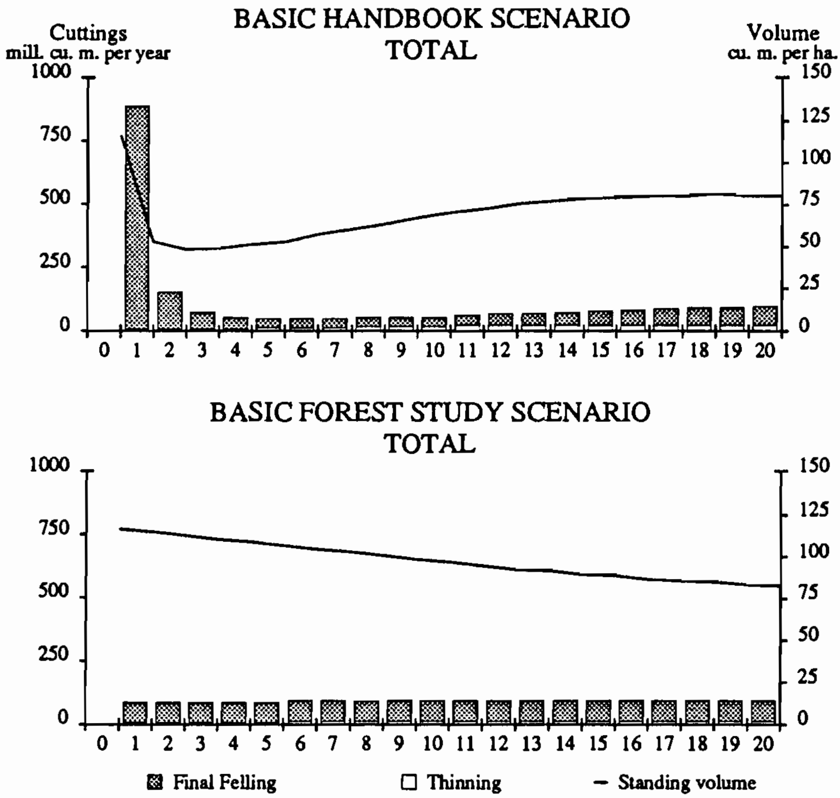

Figure A.1. Projections of total potential harvest and growing stock in the Northern region under the basic scenarios. Current total fellings are 82.5 million cubic meters o.b.

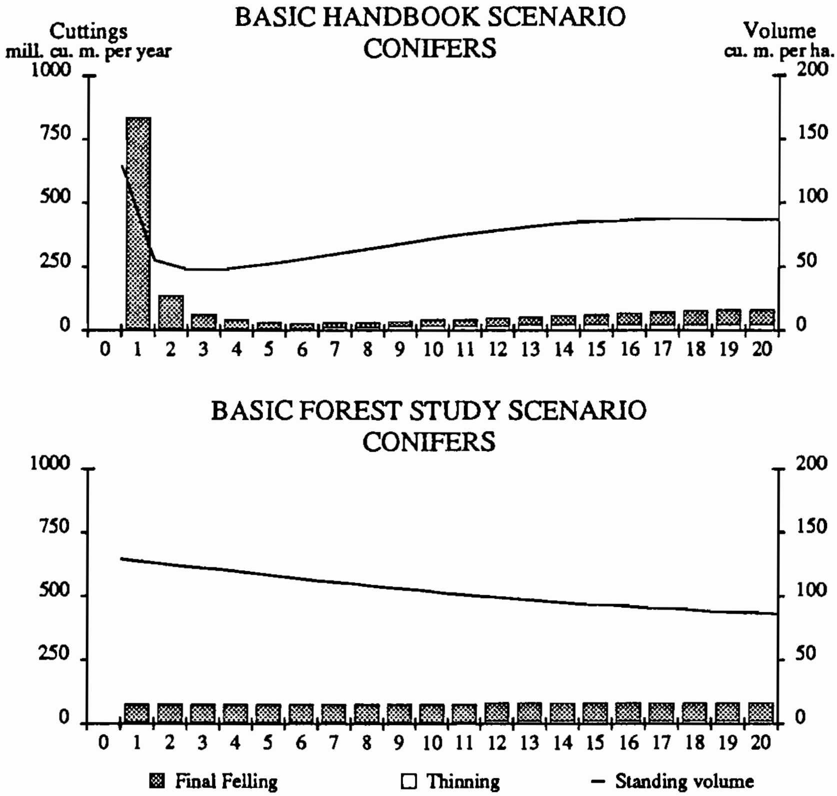

Figure A.2. Projections of potential harvest and growing stock of coniferous species in the Northern region under the basic scenarios. Current coniferous fellings are 70.4 million cubic meters o.b.

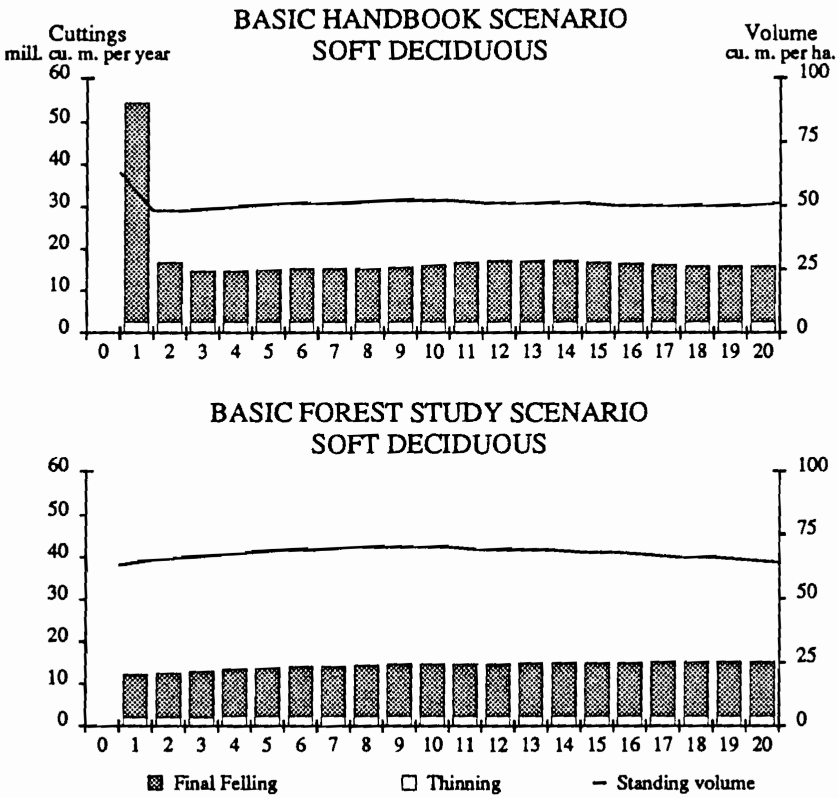

Figure A.3. Projections of potential harvest and growing stock of soft deciduous species in the Northern region under the basic scenarios. Current soft deciduous fellings are 12.1 million cubic meters o.b.

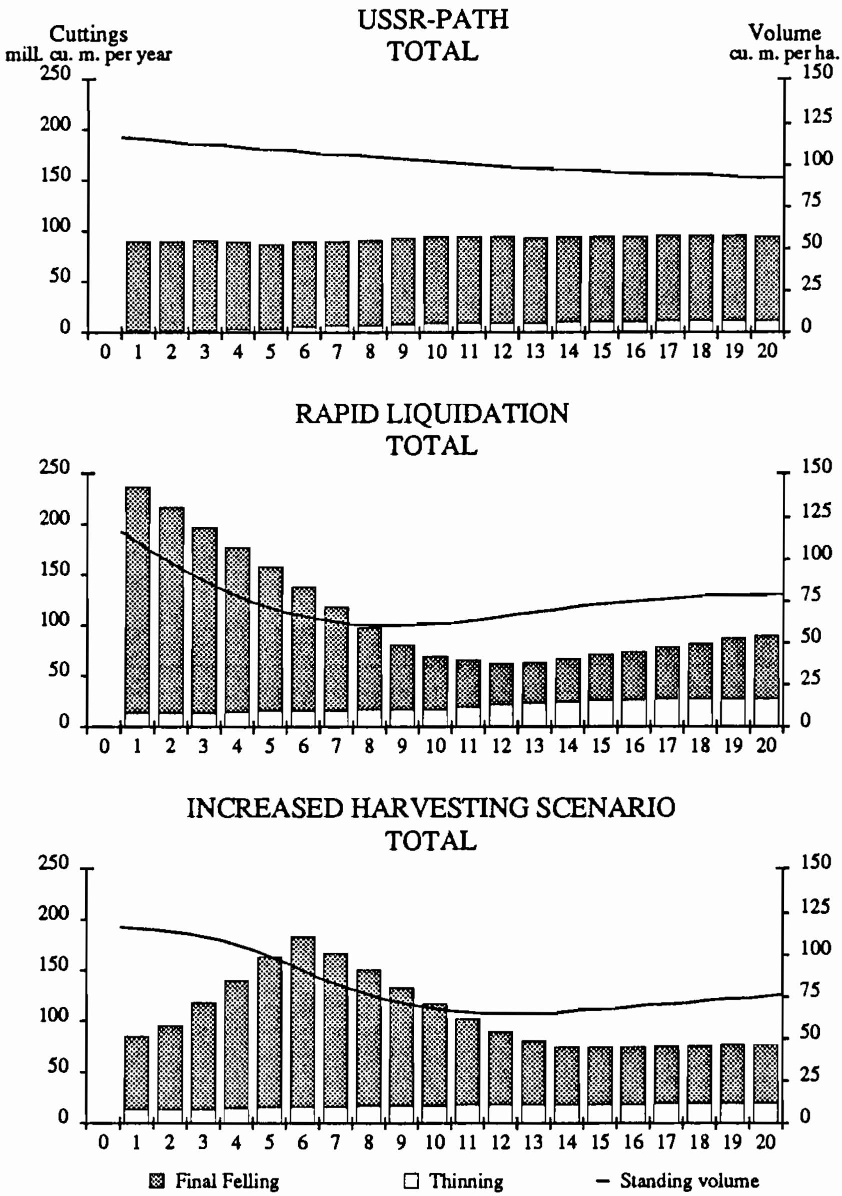

Figure A.4. Projections of total potential harvest and growing stock in the Northern region under the USSR Path Scenario, Rapid Liquidation Scenario, and Increased Harvesting Scenario. Current total fellings are 82.5 million cubic meters o.b.

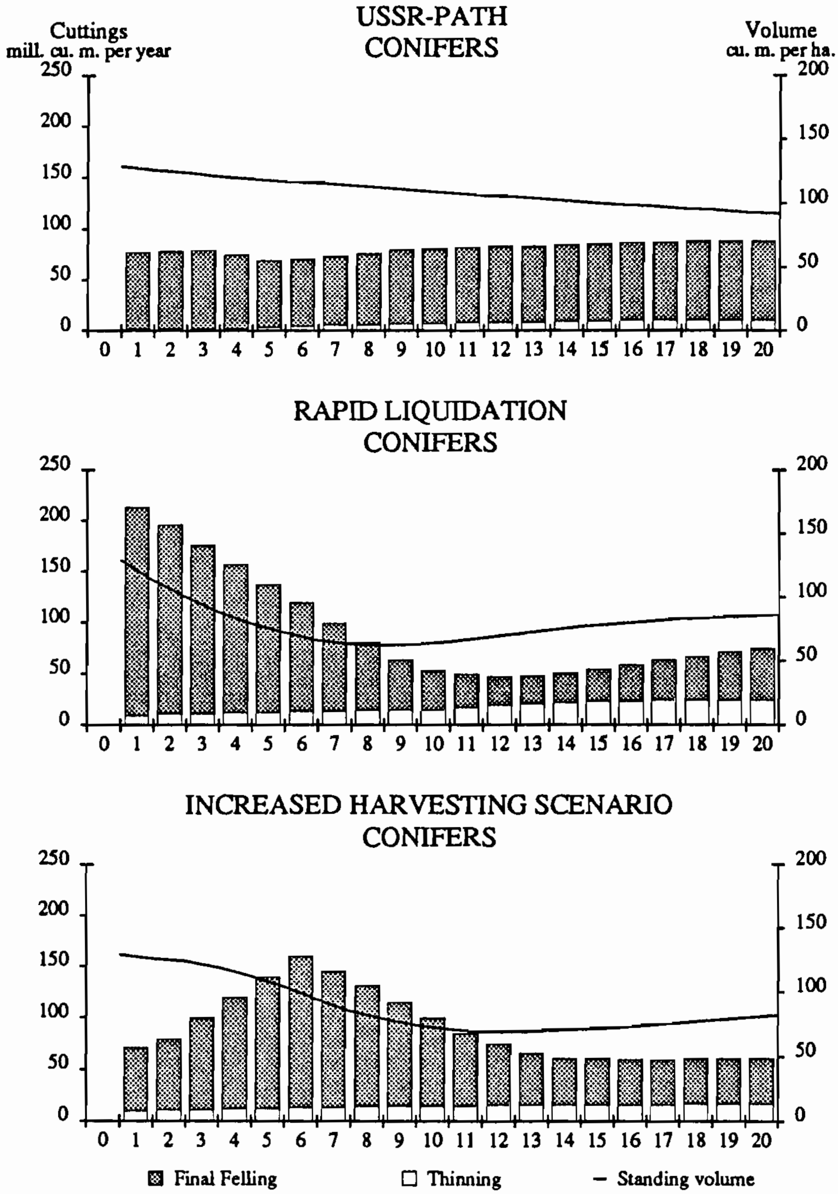

Figure A.5. Projections of potential harvest and growing stock of coniferous species in the Northern region under the USSR Path Scenario, Rapid Liquidation Scenario, and Increased Harvesting Scenario. Current coniferous fellings are 70.4 million cubic meters o.b.

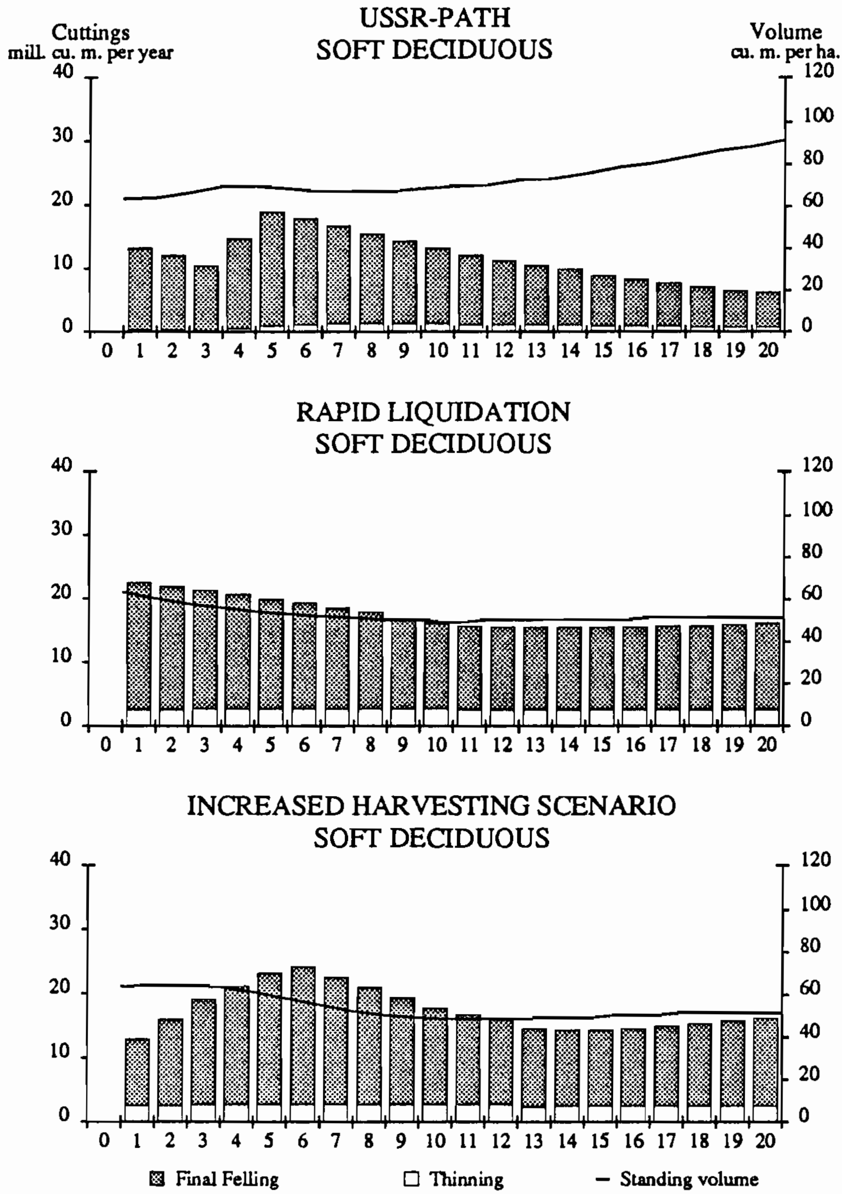

Figure A.6. Projections of potential harvest and growing stock of soft deciduous species in the Northern region under the USSR Path Scenario, Rapid Liquidation Scenario, and Increased Harvesting Scenario. Current soft deciduous fellings are 12.1 million cubic meters o.b.

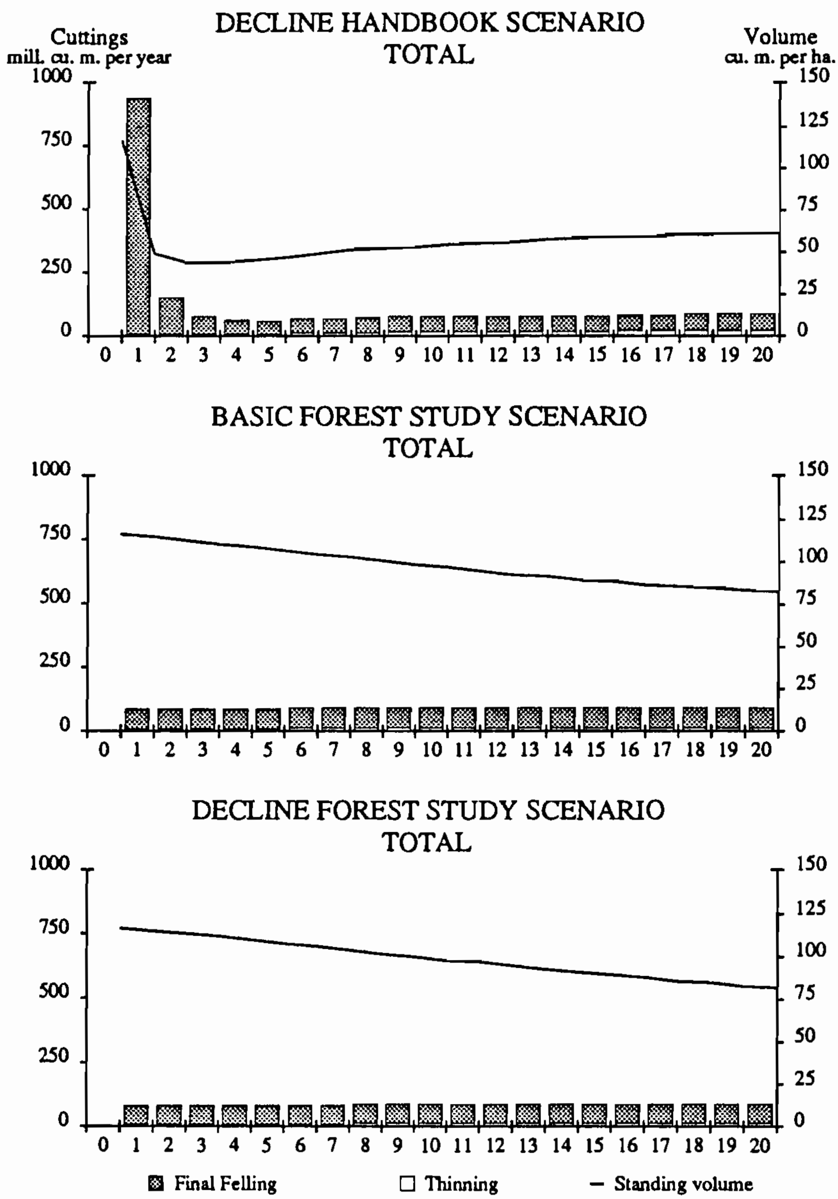

Figure A.7. Projections of total potential harvest and growing stock in the Northern region under the decline scenarios. Current total fellings are 82.5 million cubic meters o.b.

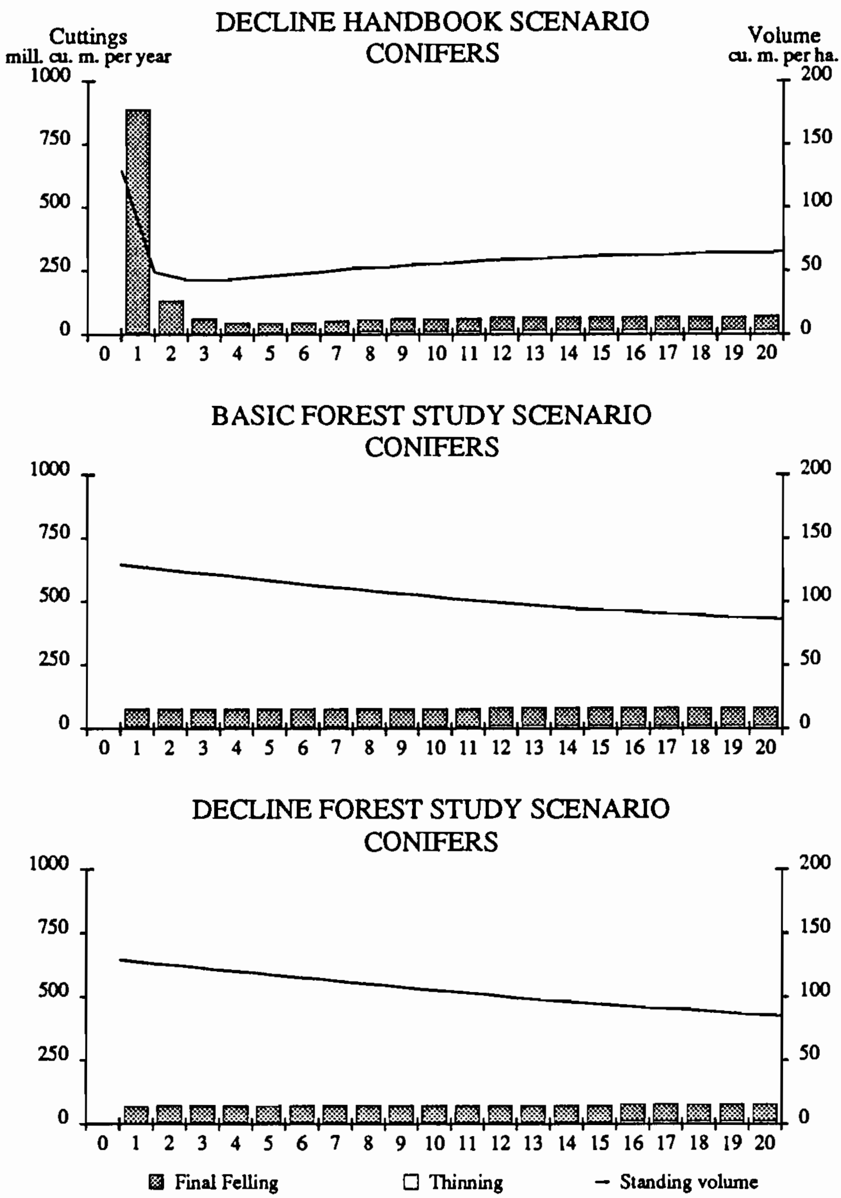

Figure A.8. Projections of potential harvest and growing stock of coniferous species in the Northern region under the decline scenarios. Current coniferous fellings are 70.4 million cubic meters o.b.

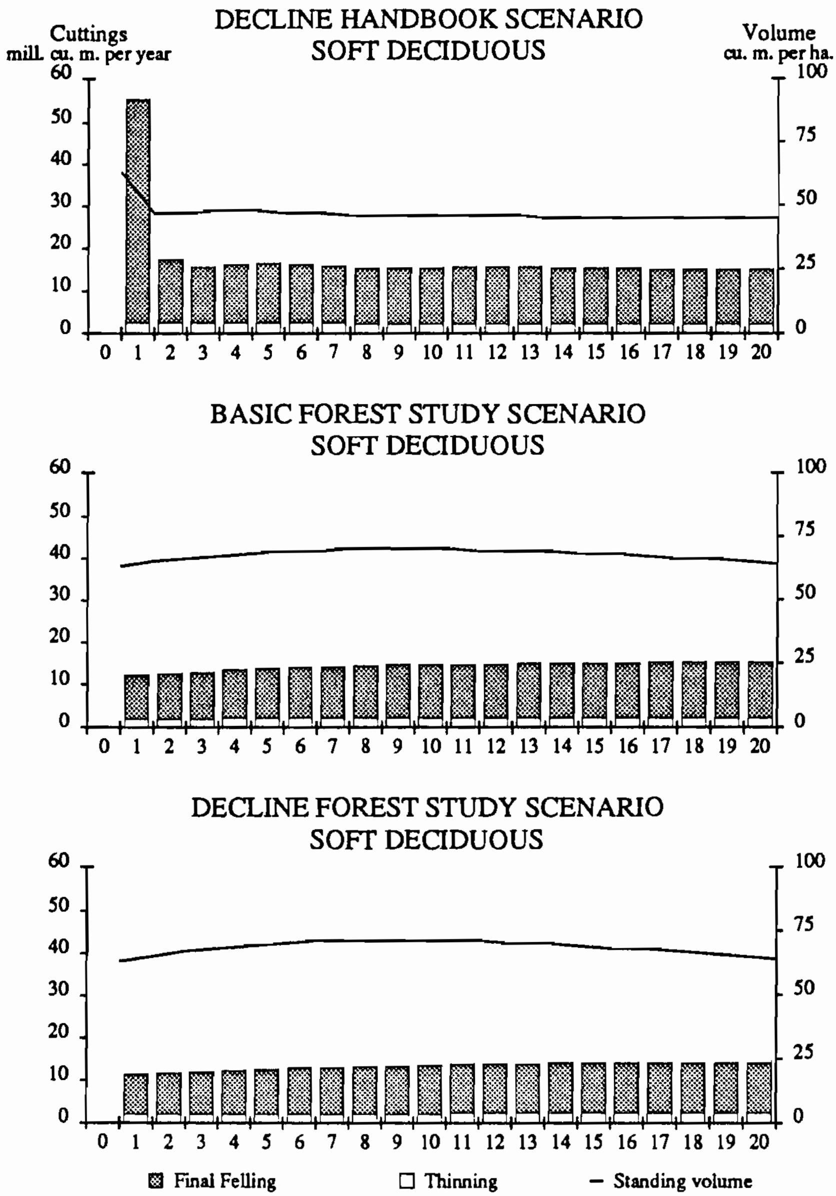

Figure A.9. Projections of potential harvest and growing stock of soft deciduous species in the Northern region under the decline scenarios. Current soft deciduous fellings are 12.1 million cubic meters o.b.

Northwestern Region (Table A.3 and Figures A.10 to A.15)

Basic Scenarios

Based on the results from the Basic Handbook Scenario there is a slight imbalance between the existing forest structure and the fully implemented handbook silviculture. The harvest pulse is in the beginning of the simulation and is most pronounced (in relative terms) in soft deciduous species.

The Basic Forest Study Scenario gives an even potential harvesting profile throughout the entire simulation period. The total average harvest level for the period is 14.5 million cubic meters per year. The average potential harvest is dominated by coniferous species (8.3 million cubic meters). The two basic scenarios result in an even and flat development of the standing volumes. The basic scenarios also give similar average growth rates, but with a slightly lower rate for the Basic Forest Study Scenario. From the basic material for the simulations, it can be identified that most of the species have what can be regarded as normal standing volume but with high figures for aspen and birch, which indicates a current underutilization of these species.

Decline Scenarios

The decline scenarios give a similar development. However, the harvest pulse in the Basic Handbook Scenario is much more pronounced for coniferous forest under the decline conditions. Air pollutants are estimated to reduce the total average harvest potential by nearly 2 million cubic meters per year. The effects are similar on coniferous and soft deciduous species. Air pollution will cause a decline in the growth rate of 0.3 cubic meters per year for coniferous and 0.4 cubic meters per year for soft deciduous. The standing volume will decrease in the Handbook Decline Scenario in relation to the Basic Handbook Scenario. The difference is about 15 cubic meters per hectare. In the forest study scenarios there are no major differences.

Summary

There is a good correspondence between the current structure of the forests in the Northwestern region and a fully implemented handbook silviculture. The basic scenarios give an even and flat development of the standing volume. There seems to be a current underutilization of soft deciduous species in this region. The impact of air pollutants is modest. The decline of the average total potential harvest is estimated at 2 million cubic meters over bark per year. It is suggested that about 20 percent of the total average harvest potential should be harvested as thinnings.

Table A.3. Northwestern region.

Variable	Basic Hand-book	Basic Forest Study	Hand-book Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	132–103	132–122	132–88	132–124
Fellings[b]				
Year 1	33.7	16.0	47.2	13.1
Year 40	14.6	14.0	11.9	12.4
Year 80	13.7	14.0	12.0	12.4
Coniferous				
Growing stock[a]	132–108	132–128	132–88	132–131
Fellings[b]				
Year 1	18.0	9.0	30.9	7.6
Year 40	8.5	8.0	7.3	7.3
Year 80	7.8	8.0	7.1	7.3
Soft deciduous				
Growing stock[a]	132–96	132–112	132–88	132–113
Fellings[b]				
Year 1	15.7	7.0	16.3	5.5
Year 40	6.2	6.0	4.6	5.1
Year 80	5.9	6.0	5.0	5.1
Hard deciduous				
Growing stock[a]	0–0	0–0	0–0	0–0
Fellings[b]				
Year 1	0.0	0.0	0.0	0.0
Year 40	0.0	0.0	0.0	0.0
Year 80	0.0	0.0	0.0	0.0
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	16.3	14.5	16.3	12.6
Coniferous	9.3	8.3	9.7	7.4
Soft deciduous	7.0	6.2	6.6	5.2
Hard deciduous	0.0	0.0	0.0	0.0
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	2.6	2.5	2.4	2.1
Coniferous	2.4	2.4	2.4	2.1
Soft deciduous	2.8	2.6	2.6	2.2
Hard deciduous	0.0	0.0	0.0	0.0
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	132–103	132–122	132–88	132–124
Coniferous	132–108	132–128	132–88	132–131
Soft deciduous	132–96	132–112	132–88	132–113
Hard deciduous	0–0	0–0	0–0	0–0

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

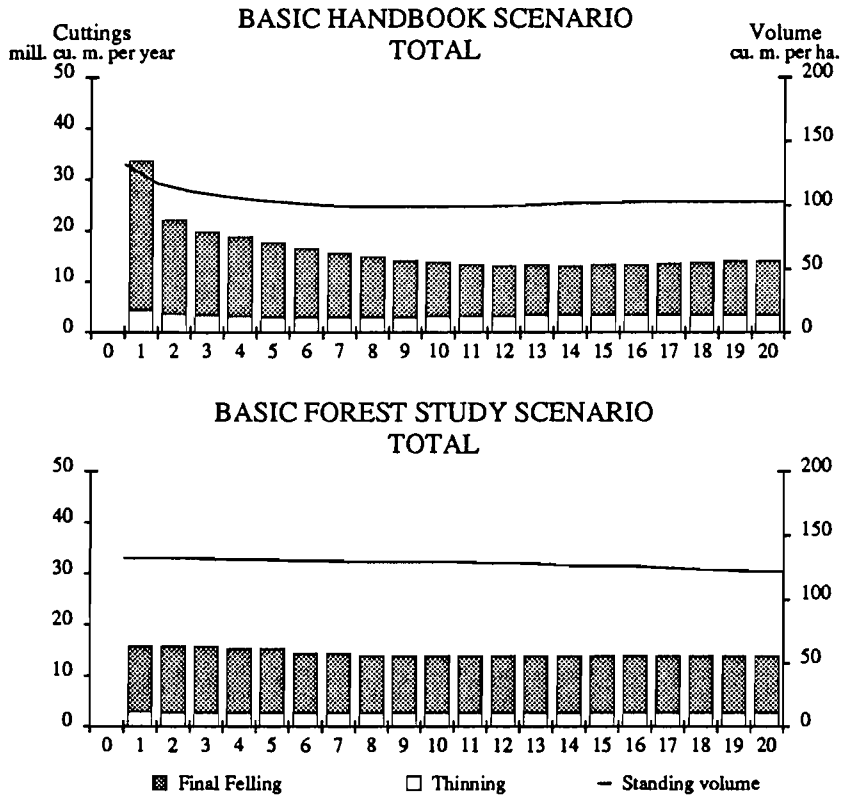

Figure A.10. Projections of total potential harvest and growing stock in the Northwestern region under the basic scenarios. Current total fellings are 11.8 million cubic meters o.b.

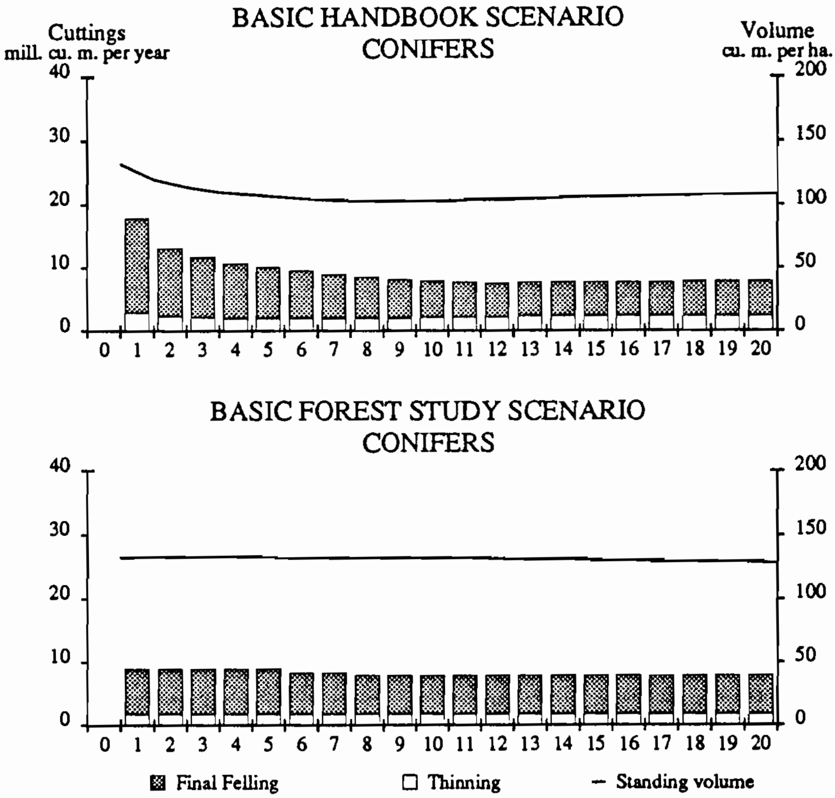

Figure A.11. Projections of potential harvest and growing stock of coniferous species in the Northwestern region under the basic scenarios. Current coniferous fellings are 5.9 million cubic meters o.b.

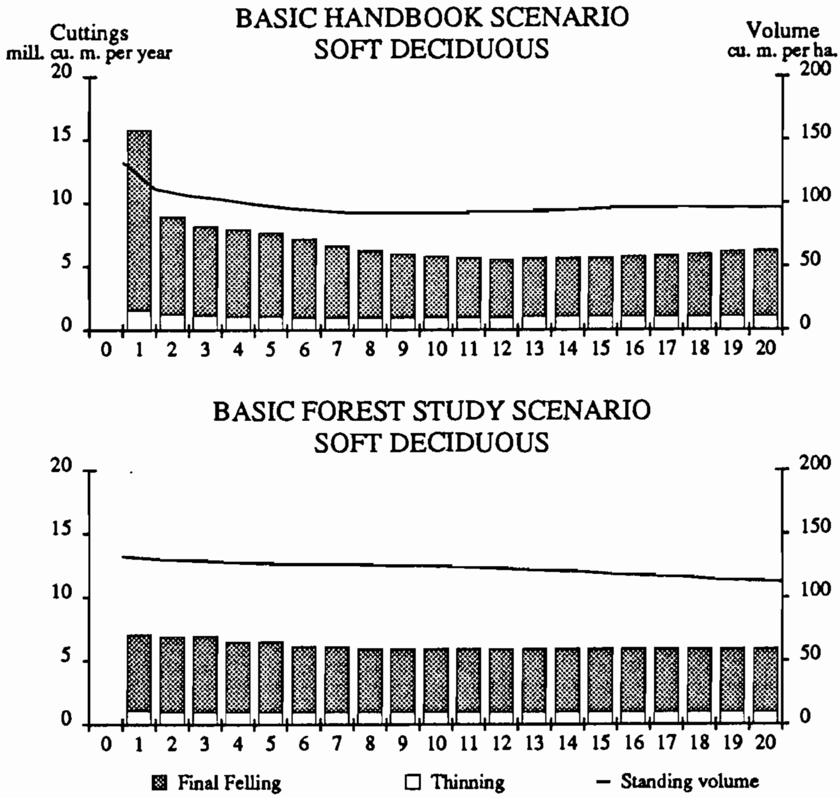

Figure A.12. Projections of potential harvest and growing stock of soft deciduous species in the Northwestern region under the basic scenarios. Current soft deciduous fellings are 5.9 million cubic meters o.b.

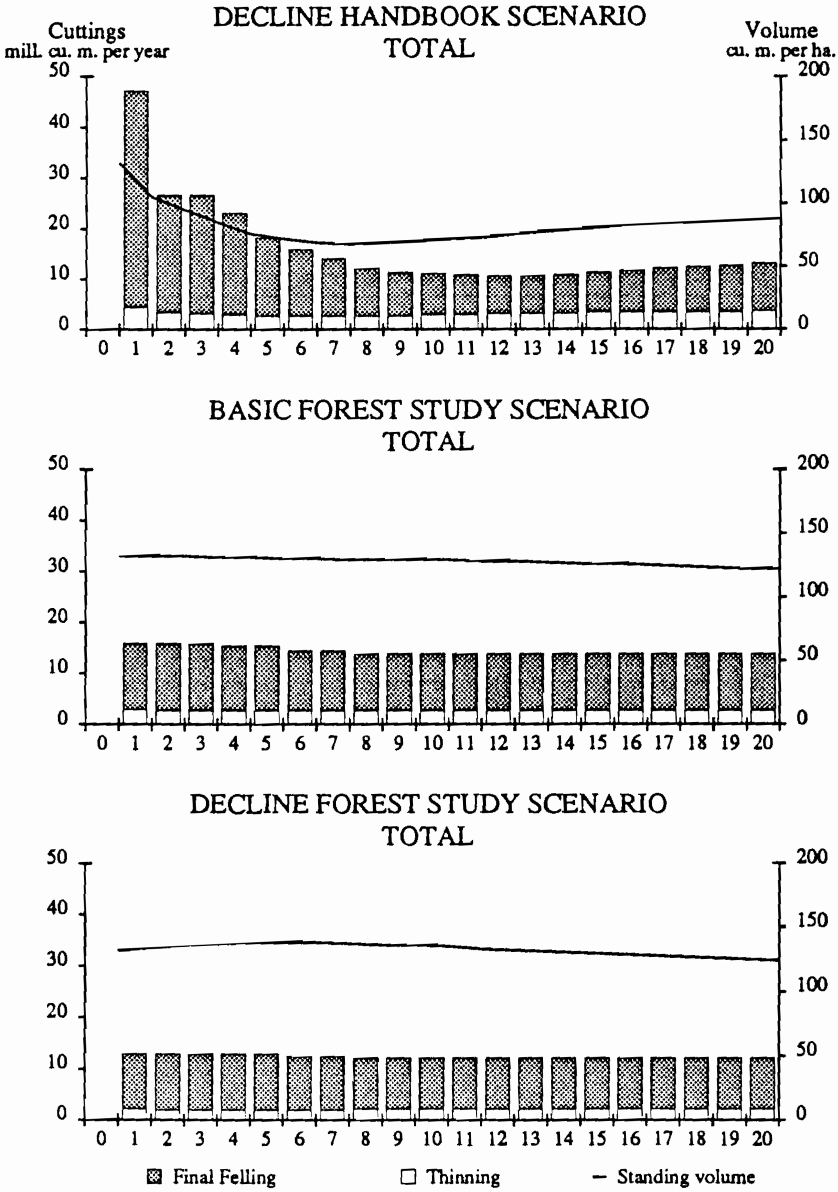

Figure A.13. Projections of total potential harvest and growing stock in the Northwestern region under the decline scenarios. Current total fellings are 11.8 million cubic meters o.b.

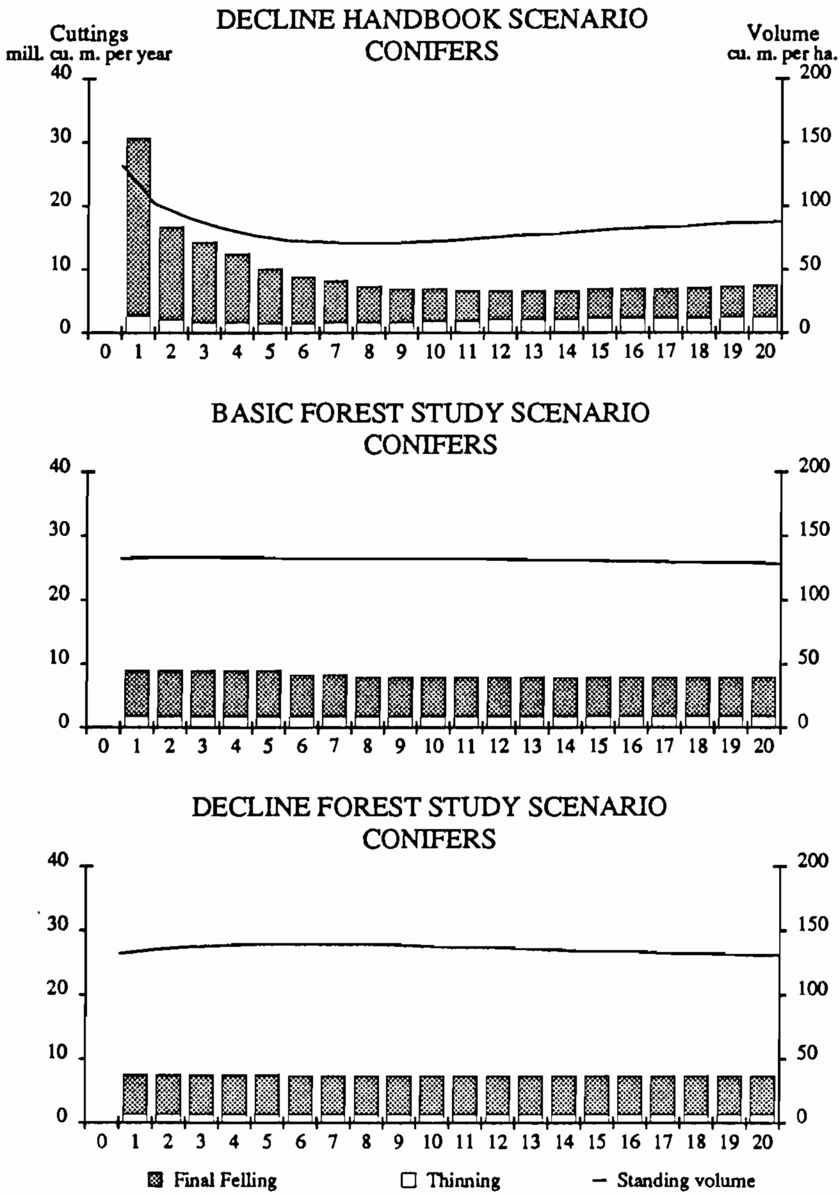

Figure A.14. Projections of potential harvest and growing stock of coniferous species in the Northwestern region under the decline scenarios. Current coniferous fellings are 5.9 million cubic meters o.b.

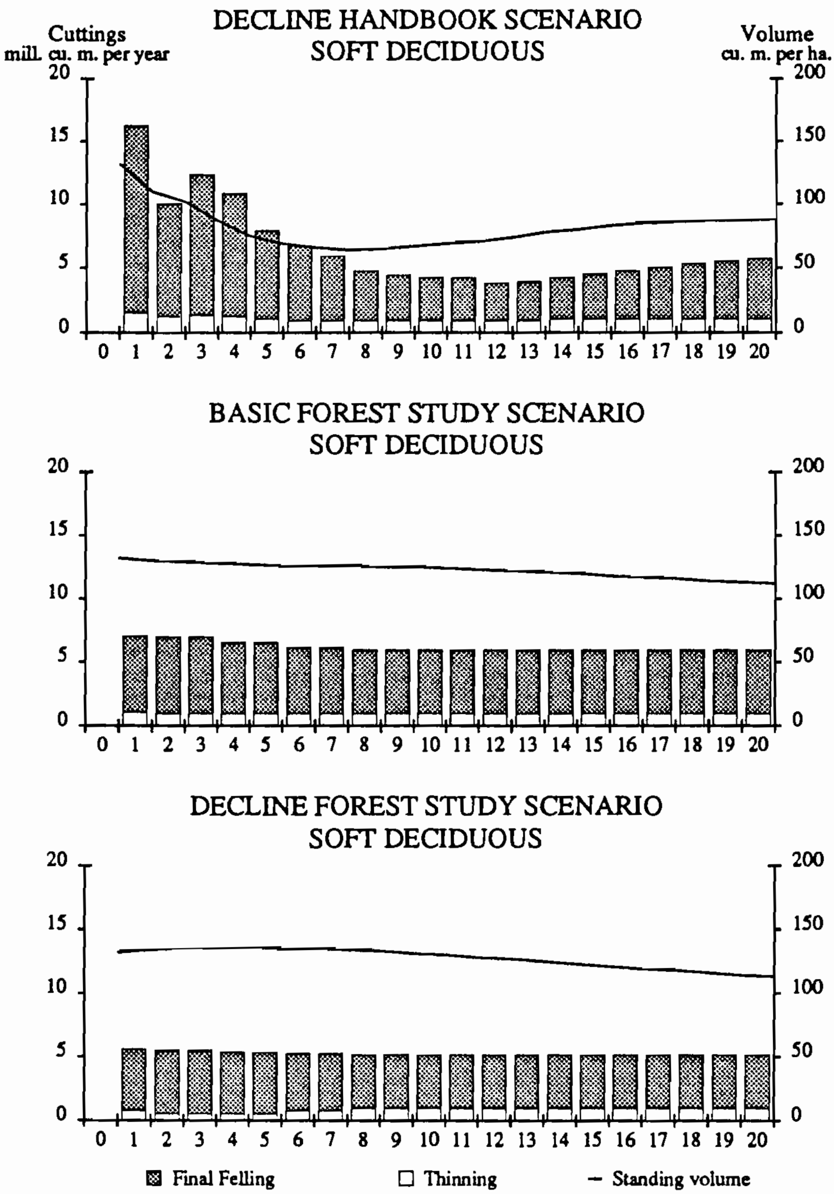

Figure A.15. Projections of potential harvest and growing stock of soft deciduous species in the Northwestern region under the decline scenarios. Current soft deciduous fellings are 5.9 million cubic meters o.b.

Central Region (Table A.4 and Figures A.16 to A.23)

Basic Scenarios

The Basic Handbook Scenario gives a modest harvesting pulse in the beginning of the simulation period. This result indicates a rather good balance between the current structure of the forests and fully implemented handbook silviculture. The Basic Handbook Scenario gives an average total harvesting potential of 44 million cubic meters over bark per year. The Basic Forest Study Scenario gives an average potential harvest of 41.6 million cubic meters over bark per year. The latter scenario also generates an increase of the standing volume throughout the simulation period.

The Basic Forest Study Scenario features a lower growth rate in comparison with the Basic Handbook Scenario. The difference is most noticeable for the deciduous species groups. Thus, there are no dramatic differences in the results between the two basic scenarios. For the soft deciduous species, the current standing volume is high which indicates an underutilization.

Decline Scenarios

Air pollutants have a modest impact on the average potential wood supply. The effect on the total harvesting potential is some 3.5 million cubic meters over bark per year. According to the Forest Study Decline Scenario, the dominating effects are in coniferous species. In this case the growth rate declines by between 0.3 and 0.4 cubic meters over bark per hectare per year.

Summary

There seems to be a good balance between the current structure of the forest resources and the fully implemented handbook silviculture. The two basic scenarios give roughly similar results for both potential harvesting level and the development of the standing volume. It is suggested that about 35 percent of the total harvest potential identified should be carried out as thinnings.

The impact of air pollutants is estimated to cause a decrease in the total harvest potential of 3.5 million cubic meters over bark per year. If the harvesting potentials identified in the scenarios are compared with the current harvest level it can be concluded that there is a big potential for increased harvest in softwood species in the Central region. The potential is some 10 million cubic meters under no air-pollution effects, and some 8 million cubic meters with air-pollution effects.

Table A.4. Central region.

Variable	Basic Hand-book	Basic Forest Study	Hand-book Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	148–150	148–161	148–136	148–161
Fellings[b]				
Year 1	60.5	40.6	64.8	39.2
Year 40	42.3	42.1	39.4	38.0
Year 80	43.2	42.1	40.1	38.0
Coniferous				
Growing stock[a]	166–173	166–183	166–153	166–188
Fellings[b]				
Year 1	32.4	22.0	35.8	21.0
Year 40	21.8	22.8	21.9	20.2
Year 80	23.5	22.8	20.8	20.2
Soft deciduous				
Growing stock[a]	126–127	126–137	126–120	126–133
Fellings[b]				
Year 1	26.4	17.9	27.1	17.5
Year 40	19.6	18.6	16.7	17.2
Year 80	19.0	18.6	18.7	17.2
Hard deciduous				
Growing stock[a]	196–134	196–172	196–107	196–177
Fellings[b]				
Year 1	1.7	0.7	1.9	0.7
Year 40	0.9	0.7	0.8	0.6
Year 80	0.7	0.7	0.6	0.6
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	44.0	41.6	44.1	38.2
Coniferous	23.2	22.5	23.3	20.3
Soft deciduous	19.9	18.4	19.9	17.3
Hard deciduous	0.9	0.7	0.9	0.6
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	4.0	3.9	3.9	3.6
Coniferous	4.4	4.3	4.2	4.0
Soft deciduous	3.8	3.6	3.7	3.3
Hard deciduous	2.8	2.6	2.5	2.2
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	148–150	148–161	148–136	148–161
Coniferous	166–173	166–183	166–153	166–188
Soft deciduous	126–127	126–137	126–120	126–133
Hard deciduous	196–134	196–172	196–107	196–177

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

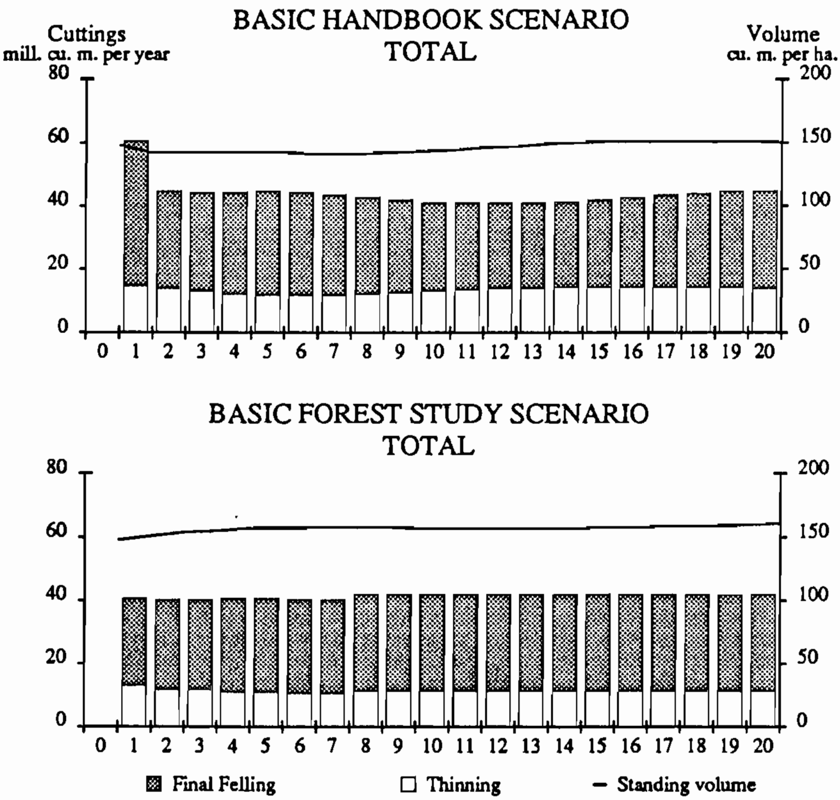

Figure A.16. Projections of total potential harvest and growing stock in the Central region under the basic scenarios. Current total fellings are 30.8 million cubic meters o.b.

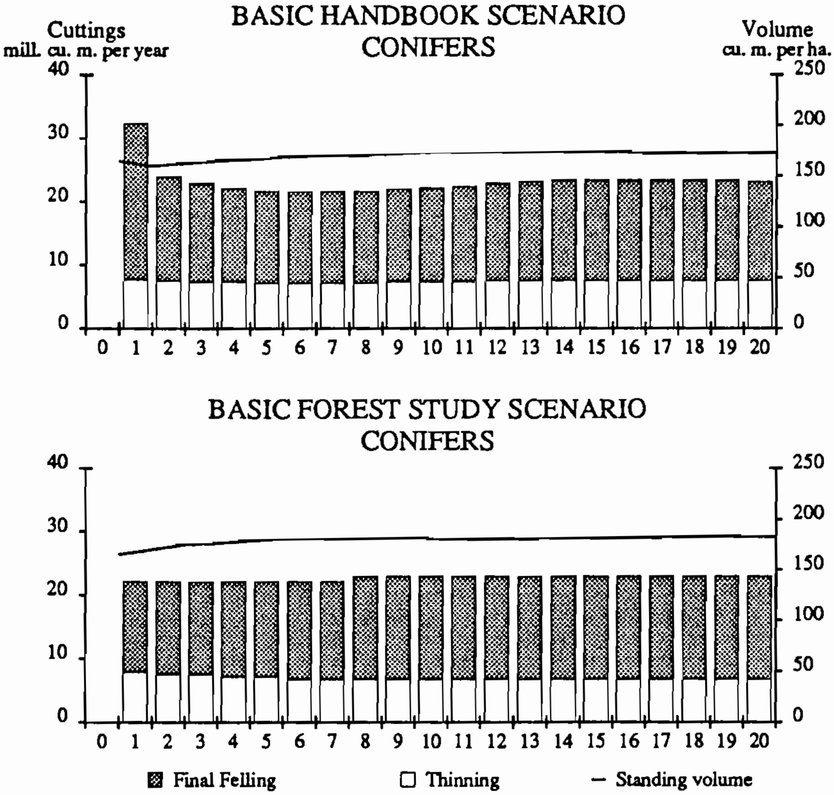

Figure A.17. Projections of potential harvest and growing stock of coniferous species in the Central region under the basic scenarios. Current coniferous fellings are 12.5 million cubic meters o.b.

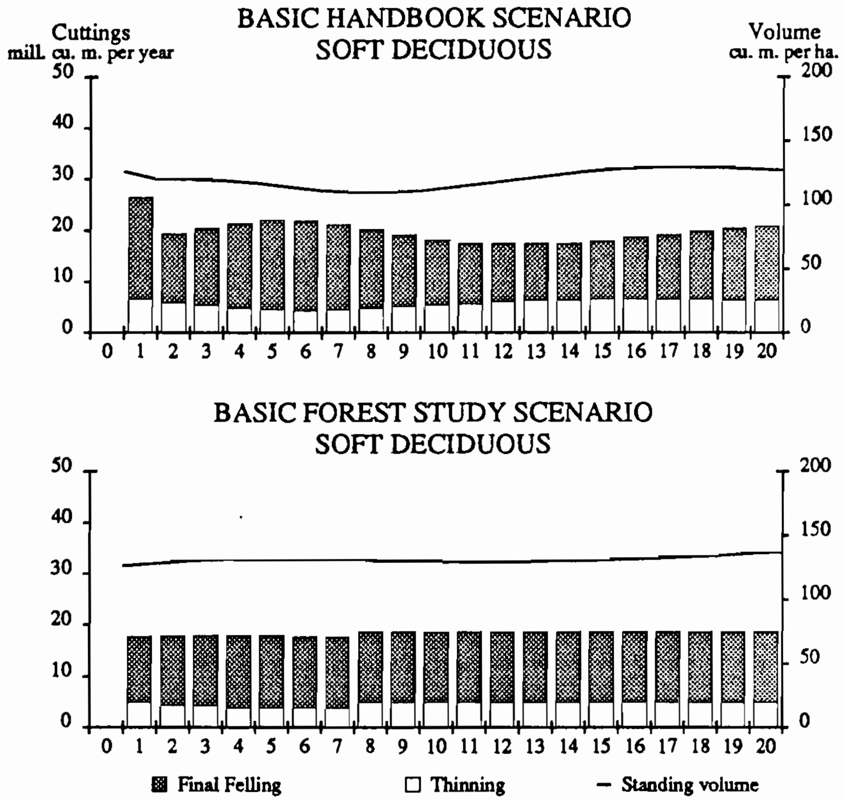

Figure A.18. Projections of potential harvest and growing stock of soft deciduous species in the Central region under the basic scenarios. Current soft deciduous fellings are 17.4 million cubic meters o.b.

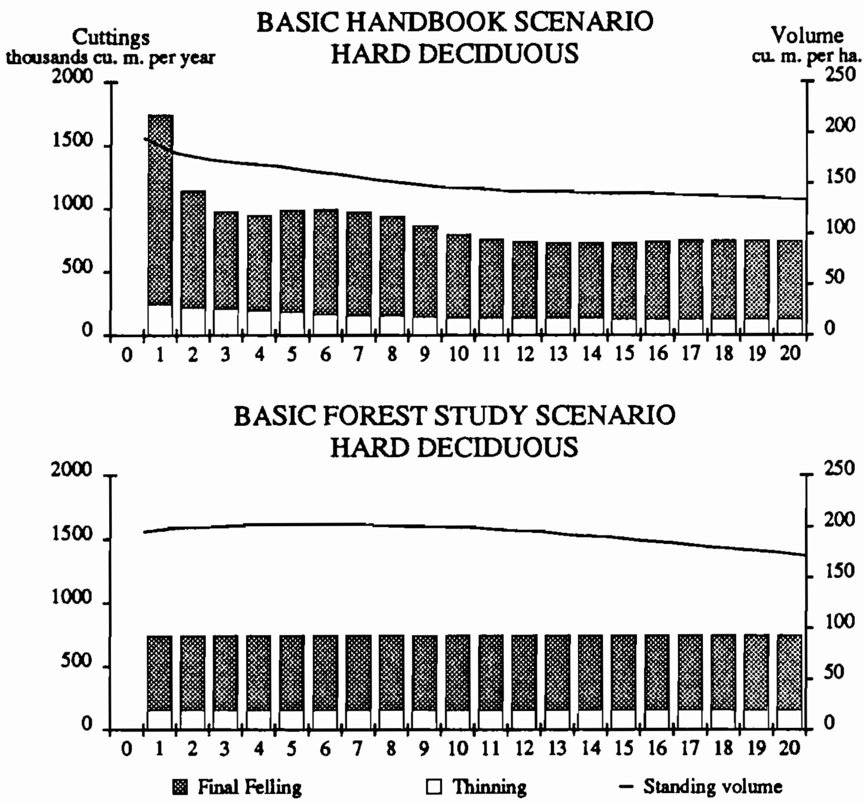

Figure A.19. Projections of potential harvest and growing stock of hard deciduous species in the Central region under the basic scenarios. Current hard deciduous fellings are 0.9 million cubic meters o.b.

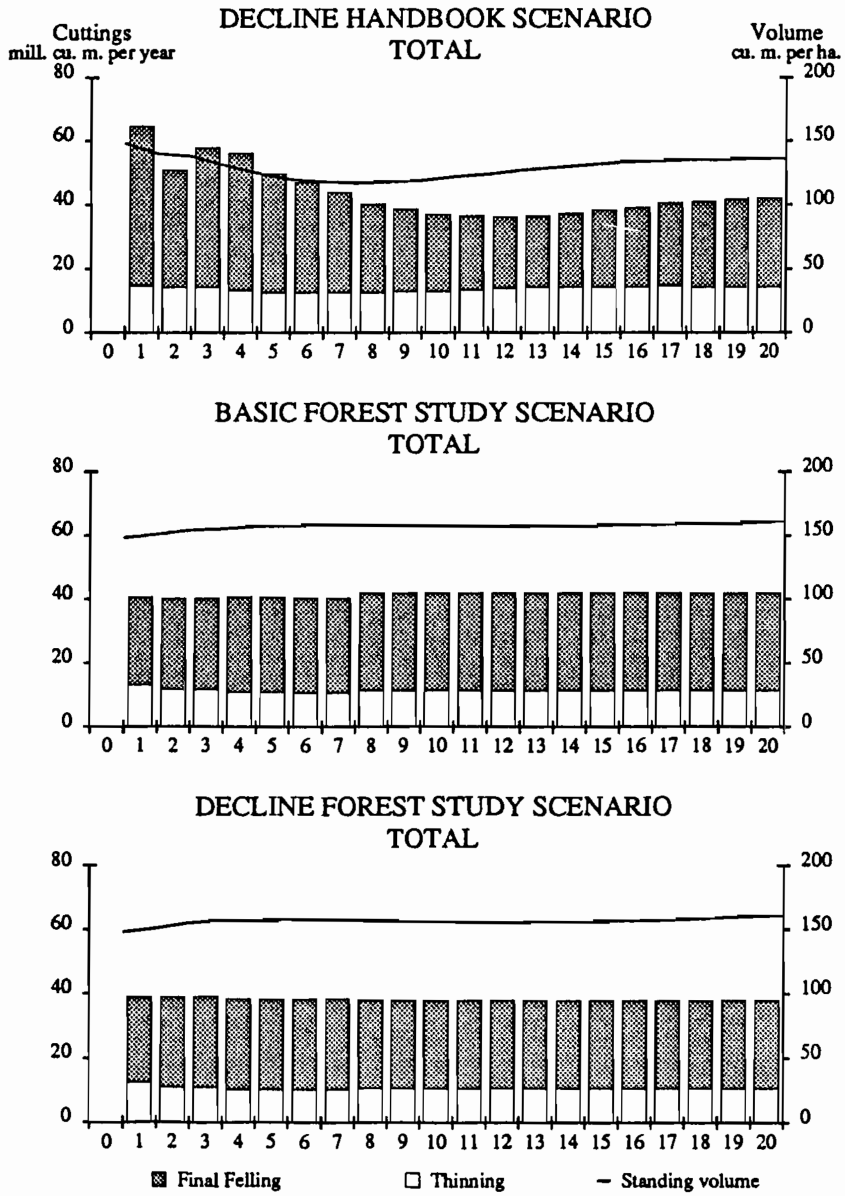

Figure A.20. Projections of total potential harvest and growing stock in the Central region under the decline scenarios. Current total fellings are 30.8 million cubic meters o.b.

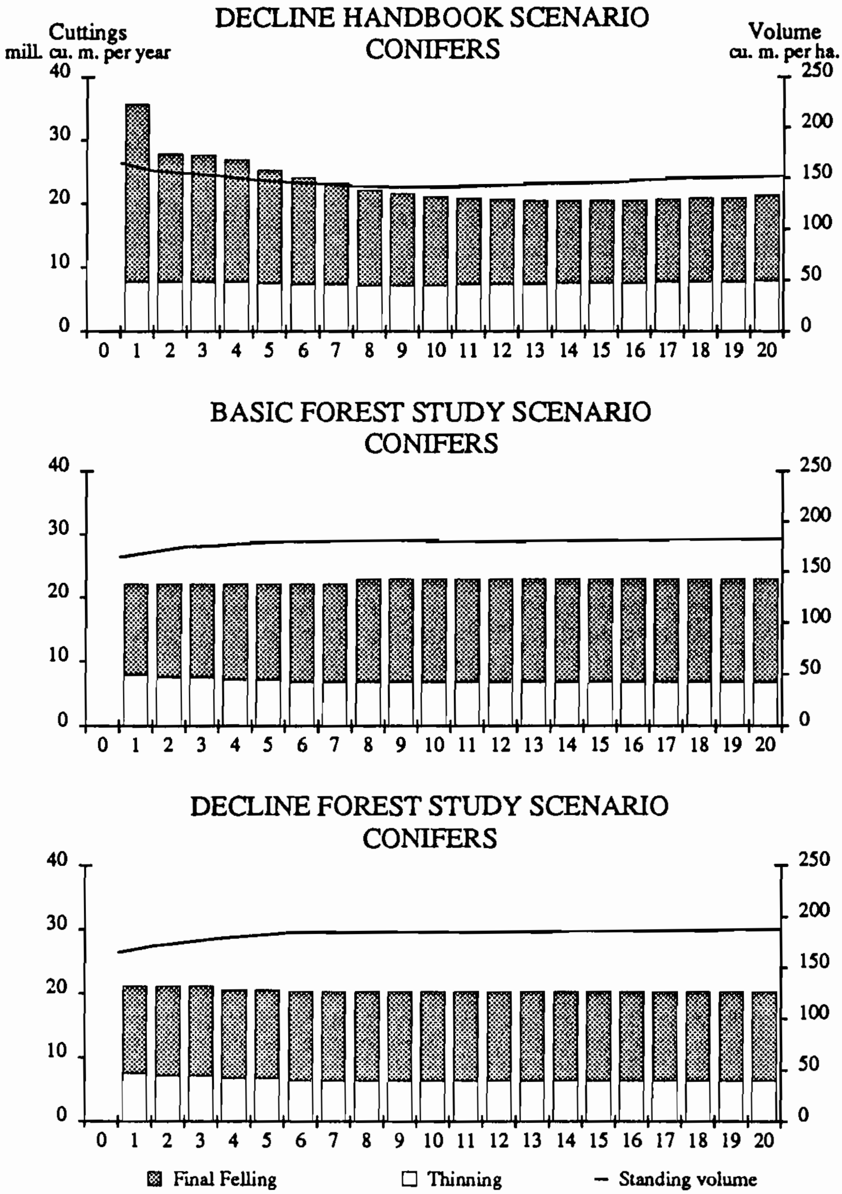

Figure A.21. Projections of potential harvest and growing stock of coniferous species in the Central region under the decline scenarios. Current coniferous fellings are 12.5 million cubic meters o.b.

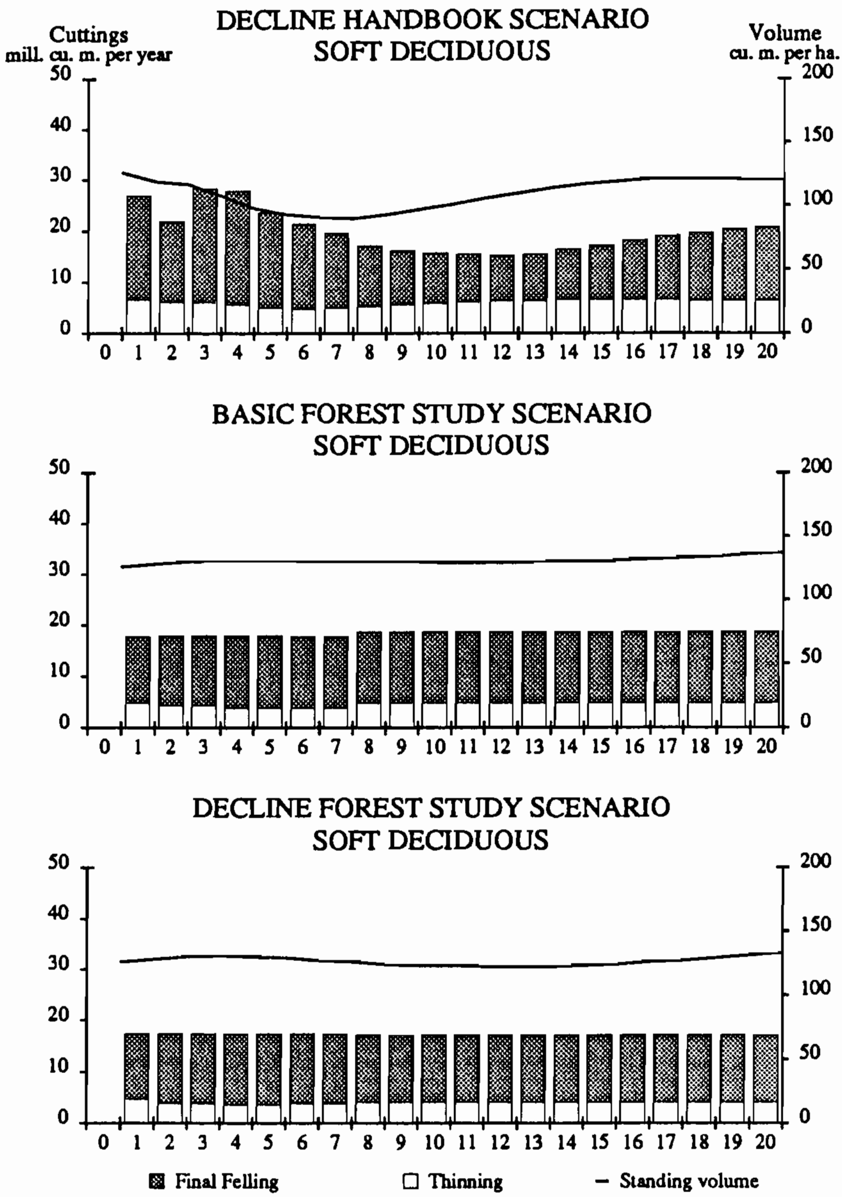

Figure A.22. Projections of potential harvest and growing stock of soft deciduous species in the Central region under the decline scenarios. Current soft deciduous fellings are 17.4 million cubic meters o.b.

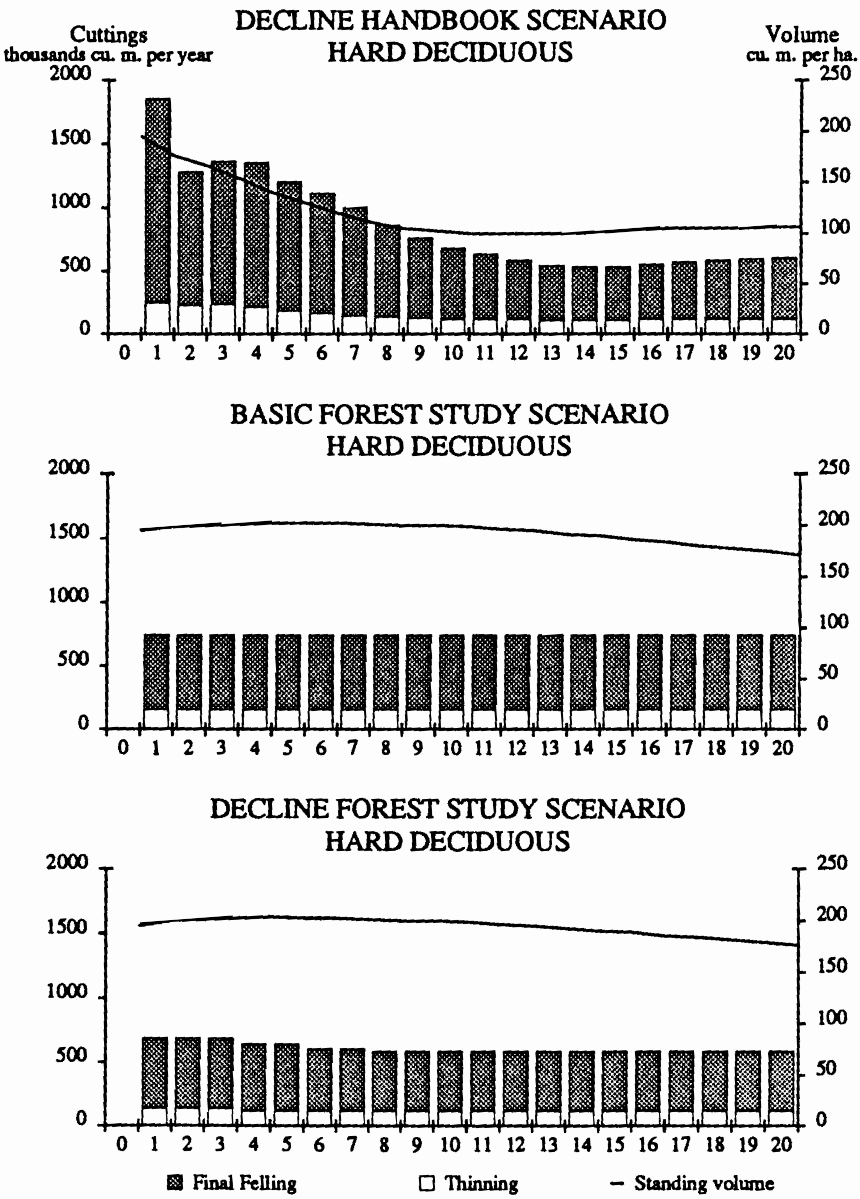

Figure A.23. Projections of potential harvest and growing stock of hard deciduous species in the Central region under the decline scenarios. Current hard deciduous fellings are 0.9 million cubic meters o.b.

Pre-Baltic Region (Table A.5 and Figures A.24 to A.31)

The total commercial forest area in the Pre-Baltic region is only 158,000 hectares. There is a concentration of the forest resources in the young age classes. The basic statistics also indicate a low utilization rate of the forest resources.

Basic Scenarios

In both the Basic Handbook Scenario and the Basic Forest Study Scenario, the harvests and growing stock increase during the first half of the simulation period. This is a result of the concentration of the forest resources in young age classes. The two basic scenarios give nearly identical results for coniferous species with respect to both potential harvesting level and growing stock. The Basic Handbook Scenario results in a more uneven harvesting potential and development of growing stock of soft deciduous species than the Basic Forest Study Scenario. However, the average total harvesting potentials are the same in the two scenarios. For hard deciduous species, the development of growing stock and harvesting potentials are similar in the two basic scenarios. The Basic Forest Study Scenario gives somewhat lower growth rates than the Basic Handbook Scenario, especially in the deciduous species groups.

Decline Scenarios

The effects of air pollutants have a rather strong impact in the Pre-Baltic region. The rates of depositions are high in this region. However, the effects on the harvesting potential are not indicated in *Table A.5* due to rounding errors, although the effects can be studied in *Figures A.28* to *A.31*. From the figures, it can be observed that the strongest effects of the air pollutants will occur in soft deciduous species and coniferous species. Both the harvesting potential and growing-stock level will be decreased. The effects of air pollutants on the hard deciduous species are minor in these respects. However, the growth rate will be strongly decreased in both deciduous species groups.

The Handbook Decline Scenario results in an increased harvesting potential during the first 30 years of the simulation. This pattern was not visible in the Basic Handbook Scenario. The high deposition rate in the Pre-Baltic region propels a move toward a rapid replacement of declining forests and forests with less vitality.

Summary

The current commercial forests are concentrated in young age classes. In the basic scenarios this condition results in an increase in both harvesting potential and growing stocks during the first half of the simulation period. About 25 percent of the total average harvest may be carried out as thinnings.

The decline effects of air pollutants are rather strong in the Pre-Baltic region (in relative terms). The average yearly total harvest potential is reduced by about 25 percent throughout the entire simulation period if the air-pollution effects are considered.

Table A.5. Pre-Baltic region.

Variable	Basic Handbook	Basic Forest Study	Handbook Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	131–153	131–170	131–131	131–159
Fellings[b]				
Year 1	0.4	0.3	0.7	0.2
Year 40	0.6	0.5	0.5	0.3
Year 80	0.5	0.5	0.4	0.3
Coniferous				
Growing stock[a]	117–156	117–166	117–126	117–160
Fellings[b]				
Year 1	0.1	0.1	0.3	0.1
Year 40	0.2	0.2	0.2	0.2
Year 80	0.2	0.2	0.2	0.2
Soft deciduous				
Growing stock[a]	132–144	132–173	132–130	132–152
Fellings[b]				
Year 1	0.2	0.2	0.3	0.1
Year 40	0.3	0.2	0.2	0.1
Year 80	0.2	0.2	0.2	0.1
Hard deciduous				
Growing stock[a]	164–168	164–175	164–149	164–175
Fellings[b]				
Year 1	0.1	0.0	0.1	0.0
Year 40	0.1	0.1	0.1	0.0
Year 80	0.1	0.1	0.0	0.0
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	0.5	0.5	0.5	0.4
Coniferous	0.2	0.2	0.2	0.2
Soft deciduous	0.2	0.2	0.2	0.1
Hard deciduous	0.1	0.1	0.1	0.1
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	3.5	3.3	3.1	2.5
Coniferous	3.9	4.0	3.3	3.2
Soft deciduous	3.5	3.1	3.1	2.2
Hard deciduous	2.5	2.2	2.7	1.6
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	131–153	131–170	131–131	131–159
Coniferous	117–156	117–166	117–126	117–160
Soft deciduous	132–144	132–173	132–130	132–152
Hard deciduous	164–168	164–175	164–149	164–175

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

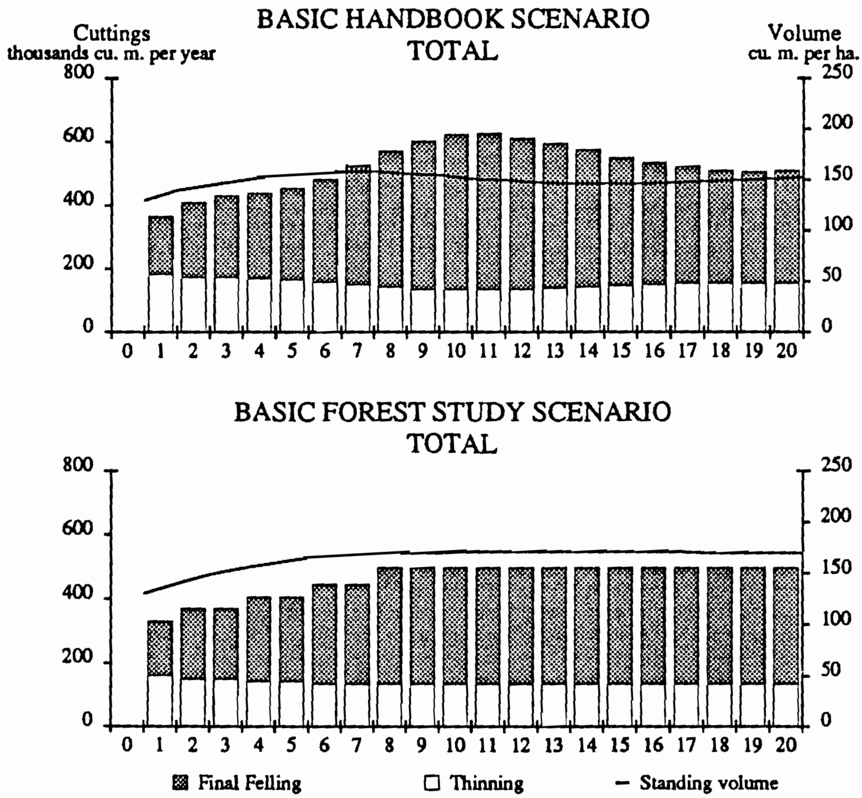

Figure A.24. Projections of total potential harvest and growing stock in the Pre-Baltic region under the basic scenarios. Current total fellings are 0.5 million cubic meters o.b.

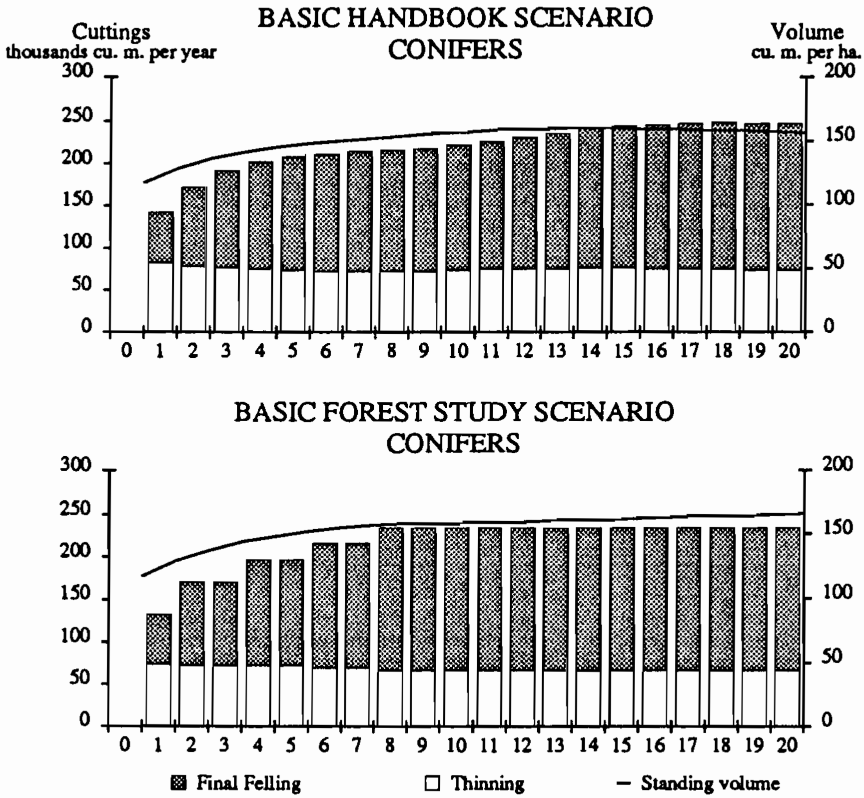

Figure A.25. Projections of potential harvest and growing stock of coniferous species in the Pre-Baltic region under the basic scenarios. Current coniferous fellings are 0.2 million cubic meters o.b.

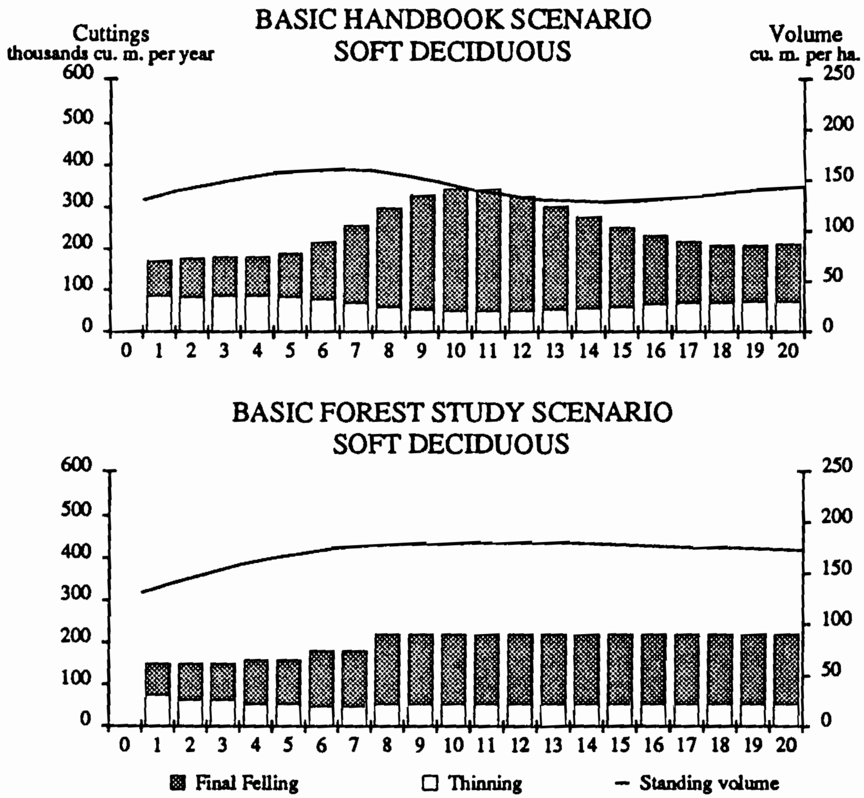

Figure A.26. Projections of potential harvest and growing stock of soft deciduous species in the Pre-Baltic region under the basic scenarios. Current soft deciduous fellings are 0.2 million cubic meters o.b.

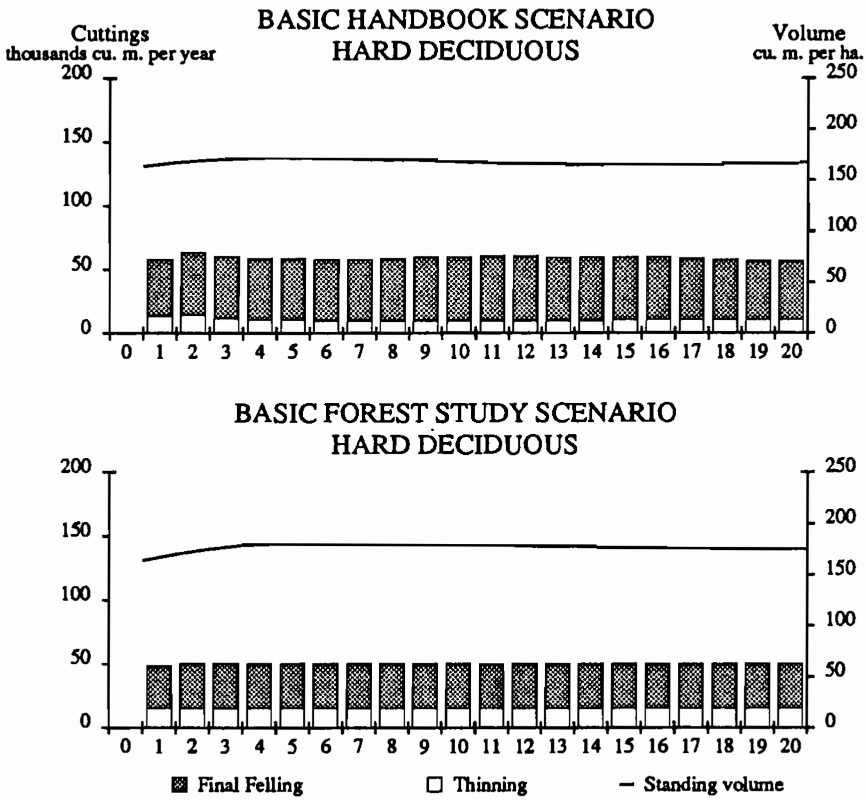

Figure A.27. Projections of potential harvest and growing stock of hard deciduous species in the Pre-Baltic region under the basic scenarios. Current hard deciduous fellings are 0.1 million cubic meters o.b.

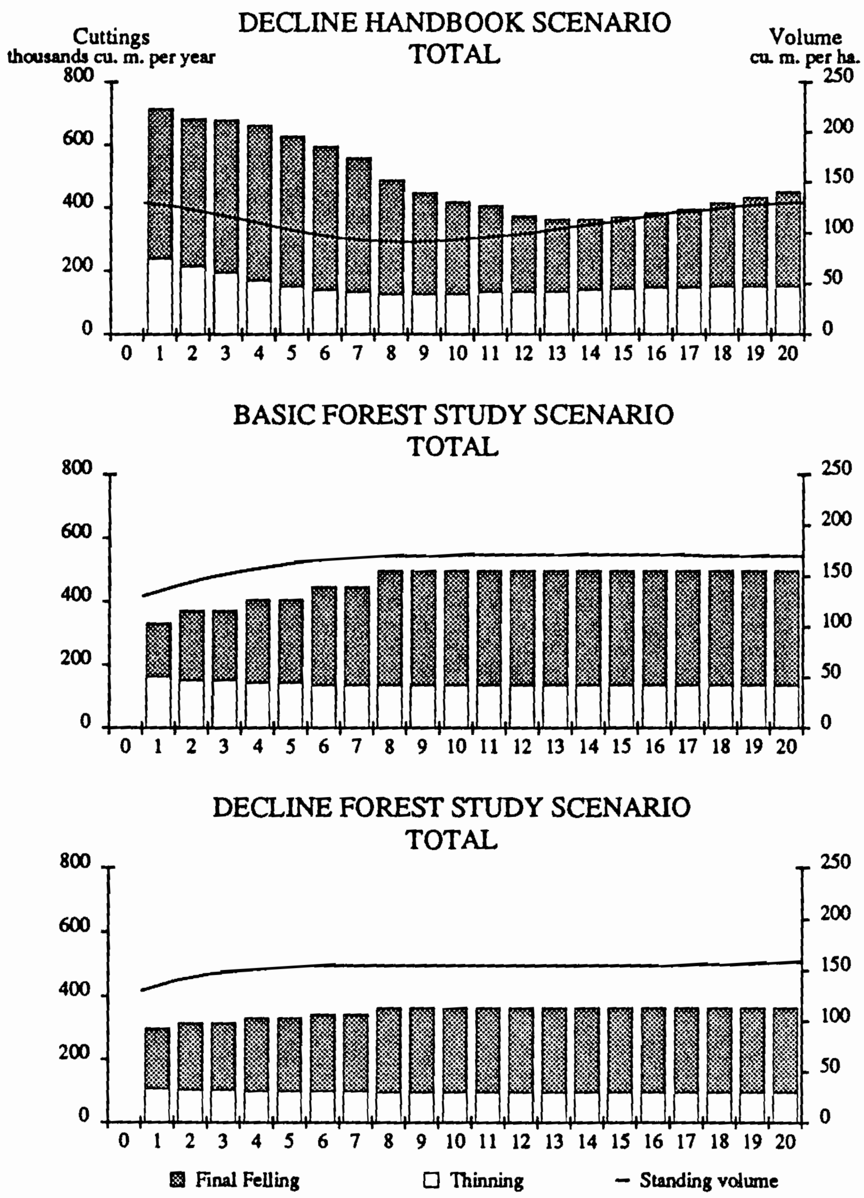

Figure A.28. Projections of total potential harvest and growing stock in the Pre-Baltic region under the decline scenarios. Current total fellings are 0.5 million cubic meters o.b.

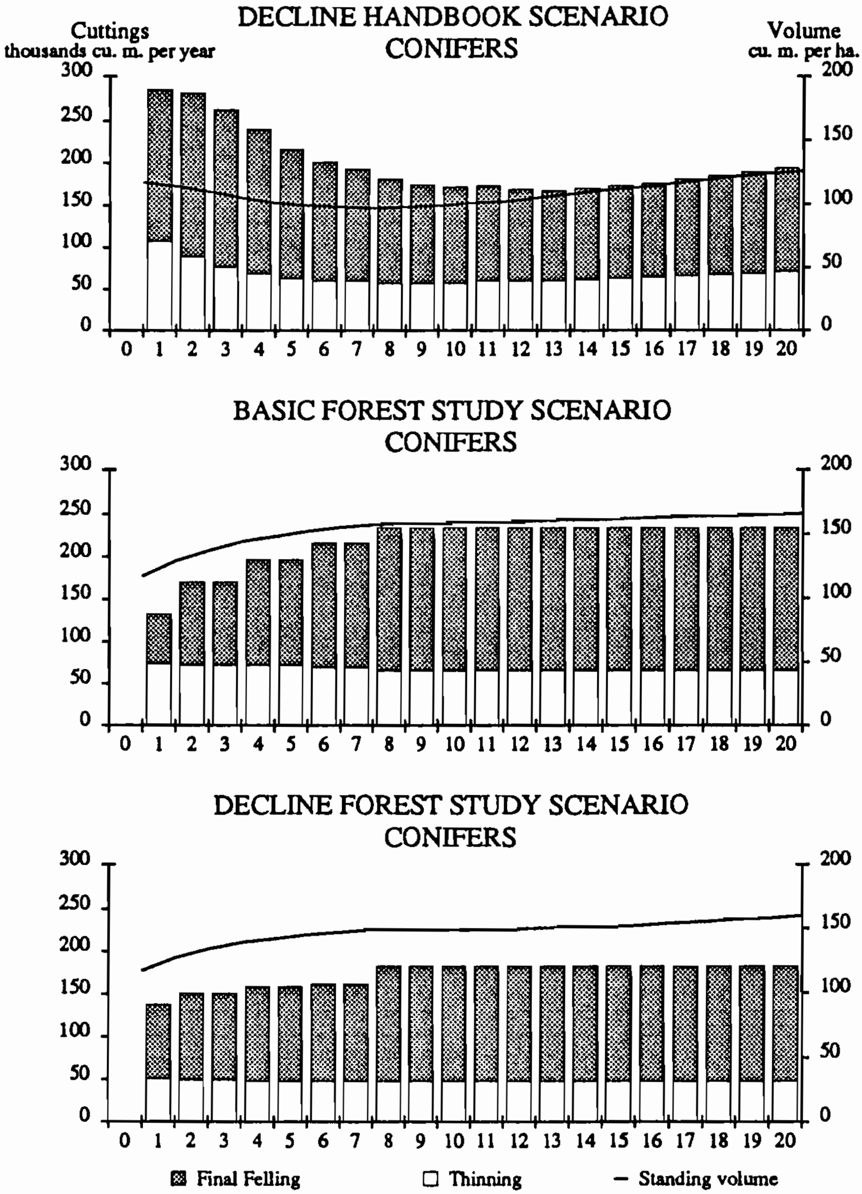

Figure A.29. Projections of potential harvest and growing stock of coniferous species in the Pre-Baltic region under the decline scenarios. Current coniferous fellings are 0.2 million cubic meters o.b.

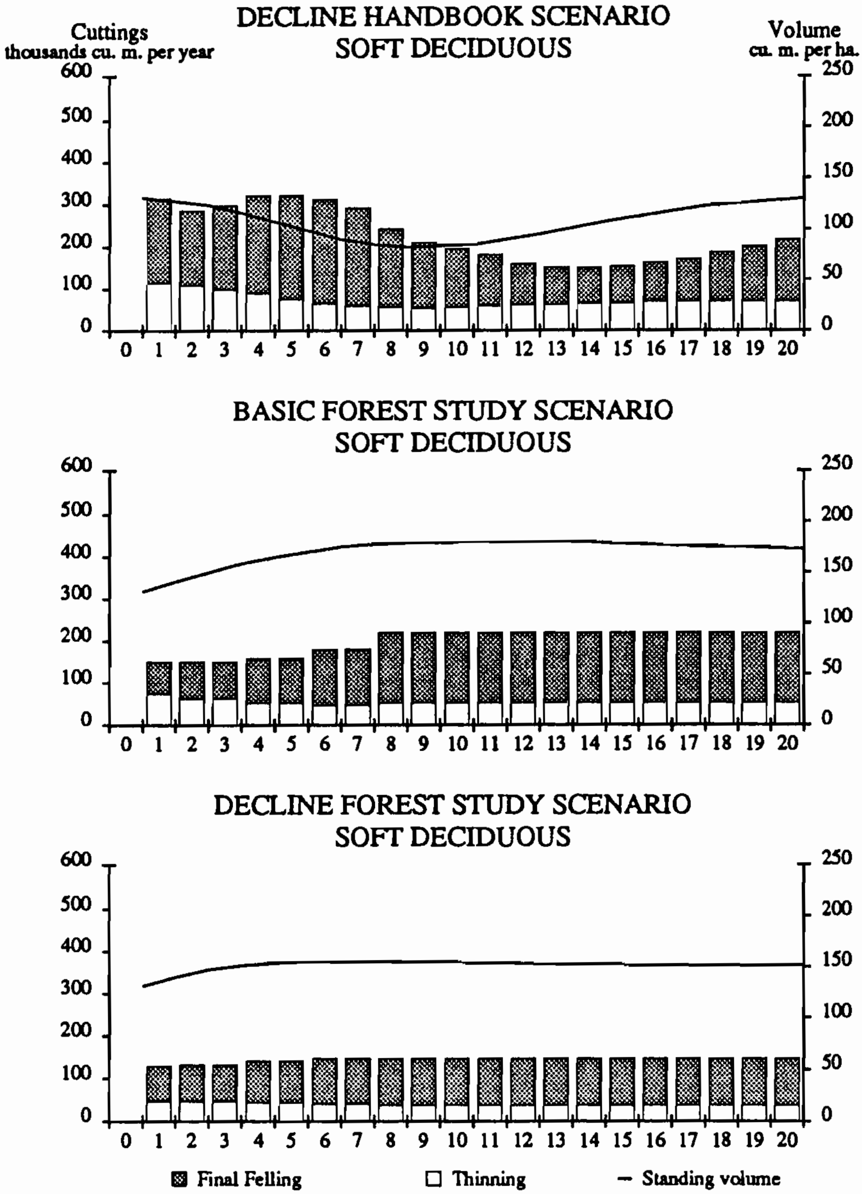

Figure A.30. Projections of potential harvest and growing stock of soft deciduous species in the Pre-Baltic region under the decline scenarios. Current soft deciduous fellings are 0.2 million cubic meters o.b.

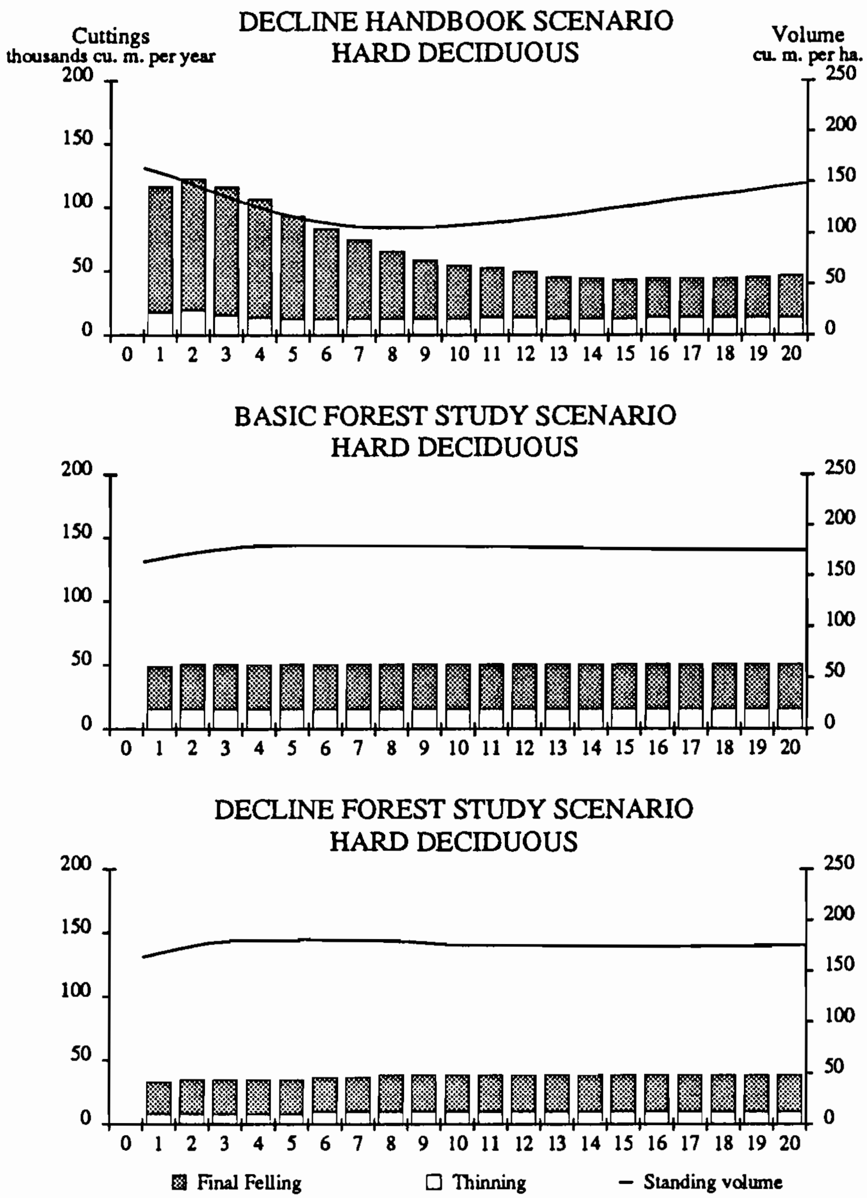

Figure A.31. Projections of potential harvest and growing stock of hard deciduous species in the Pre-Baltic region under the decline scenarios. Current hard deciduous fellings are 0.1 million cubic meters o.b.

Volgo-Vyatsky Region (Table A.6 and Figures A.32 to A.39)

Basic Scenarios

The Basic Handbook Scenario gives a strong harvest pulse during the first period of the simulation for all species groups. This indicates a rather strong imbalance between existing forest structure and a fully implemented handbook silviculture. One significant feature is the current high standing volumes of spruce, aspen, and oak and corresponding low growth rates. Upon the implementation of handbook silviculture these stands are liquidated and replaced by new stands. The Basic Forest Study Scenario gives even harvesting potentials and increasing standing volumes for all species groups throughout the entire simulation period.

The average growth rate is slightly lower in the Basic Forest Study Scenario in comparison with the Basic Handbook Scenario.

Decline Scenarios

The impacts of air-pollution effects are rather modest on both harvesting potential and growing stock in the Volgo-Vyatsky region. The effect is a decline in the total average harvesting potential by about 2 million cubic meters per year, evenly distributed between coniferous and deciduous species. The average growth rate is slightly lower under the decline conditions.

Summary

The Basic Handbook Scenario indicates a strong imbalance between current forest structure and a fully implemented handbook silviculture. The Basic Forest Study Scenario generates an even total harvesting potential and increasing growing stocks throughout the entire simulation period for all species groups.

The dominating part of the total harvesting potential is in deciduous species (about 60 percent). About 25 percent of the total average harvesting potential should be harvested in the form of thinnings.

The impact of air pollutants is modest in the Volgo-Vyatsky region. With the current deposition of air pollutants, the total average harvesting potential will be reduced by about 2 million cubic meters per year throughout the entire simulation period.

Table A.6. Volgo-Vyatsky region.

Variable	Basic Handbook	Basic Forest Study	Handbook Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	135–152	135–172	135–139	135–175
Fellings[b]				
Year 1	76.6	31.5	82.2	30.6
Year 40	33.3	33.7	34.3	31.3
Year 80	36.8	33.9	35.5	31.3
Coniferous				
Growing stock[a]	144–152	144–177	144–136	144–186
Fellings[b]				
Year 1	45.5	12.5	50.4	12.3
Year 40	13.5	13.8	14.6	12.6
Year 80	16.5	13.8	15.7	12.6
Soft deciduous				
Growing stock[a]	126–154	126–169	126–144	126–164
Fellings[b]				
Year 1	30.3	18.6	30.8	18.0
Year 40	19.3	19.5	19.2	18.4
Year 80	19.8	19.7	19.4	18.4
Hard deciduous				
Growing stock[a]	123–102	123–149	123–89	123–156
Fellings[b]				
Year 1	0.8	0.4	1.0	0.3
Year 40	0.5	0.4	0.5	0.3
Year 80	0.5	0.4	0.4	0.3
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	36.2	33.2	36.9	31.1
Coniferous	16.3	13.5	17.0	12.5
Soft deciduous	19.4	19.3	19.4	18.3
Hard deciduous	0.5	0.4	0.5	0.3
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	3.9	3.8	3.9	3.6
Coniferous	3.4	3.1	3.4	3.0
Soft deciduous	4.6	4.7	4.5	4.5
Hard deciduous	2.1	1.9	2.1	1.8
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	135–152	135–172	135–139	135–175
Coniferous	144–152	144–177	144–136	144–186
Soft deciduous	126–154	126–169	126–144	126–164
Hard deciduous	123–102	123–149	123–89	123–156

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

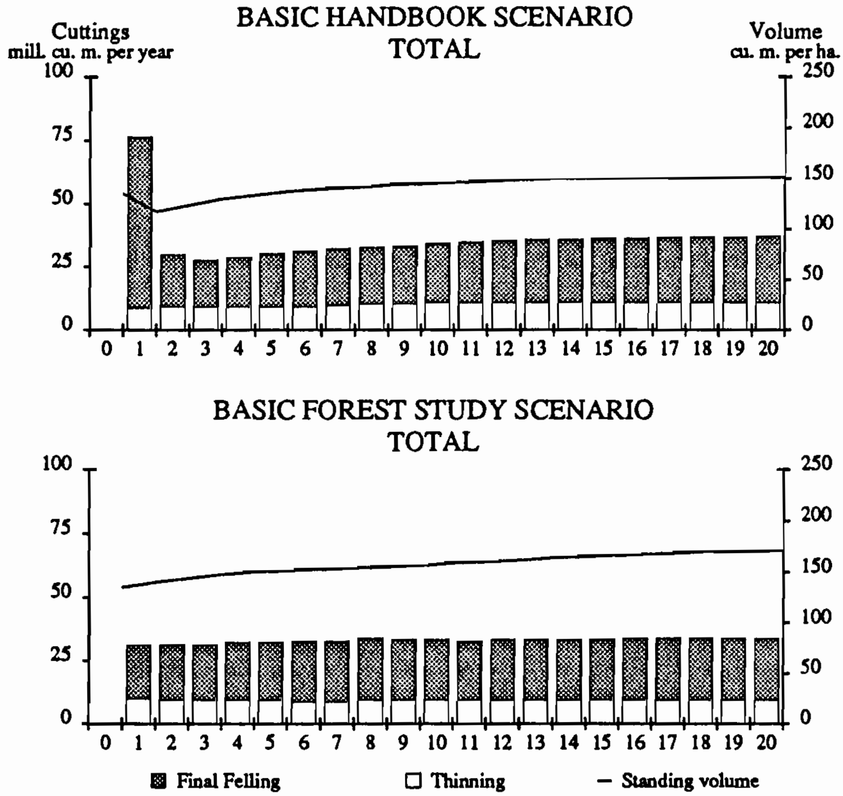

Figure A.32. Projections of total potential harvest and growing stock in the Volgo-Vyatsky region under the basic scenarios. Current total fellings are 27.1 million cubic meters o.b.

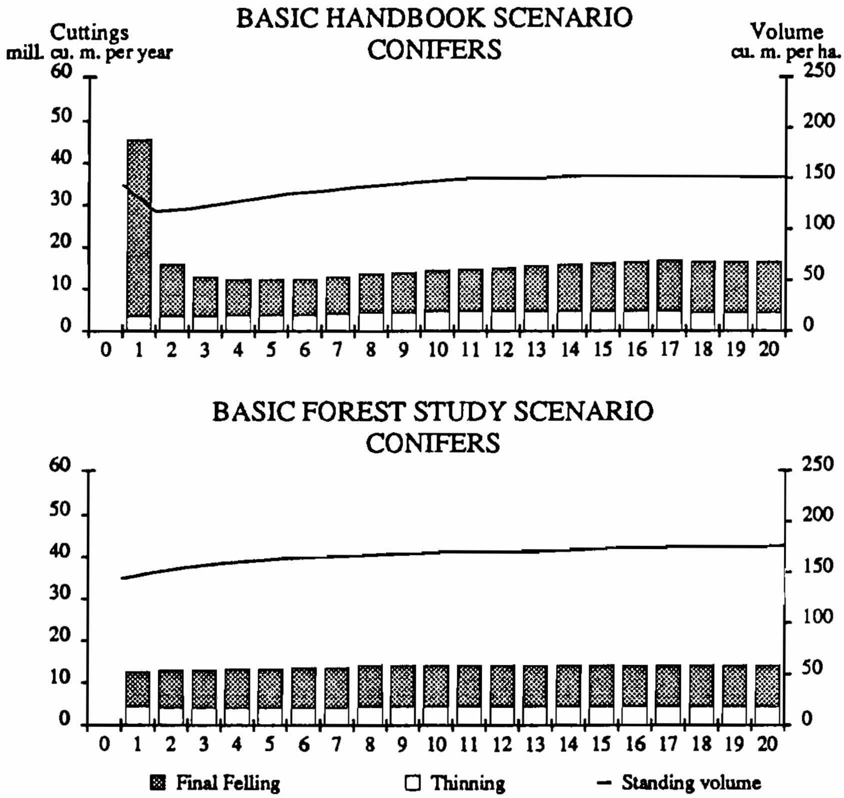

Figure A.33. Projections of potential harvest and growing stock of coniferous species in the Volgo-Vyatsky region under the basic scenarios. Current coniferous fellings are 11.6 million cubic meters o.b.

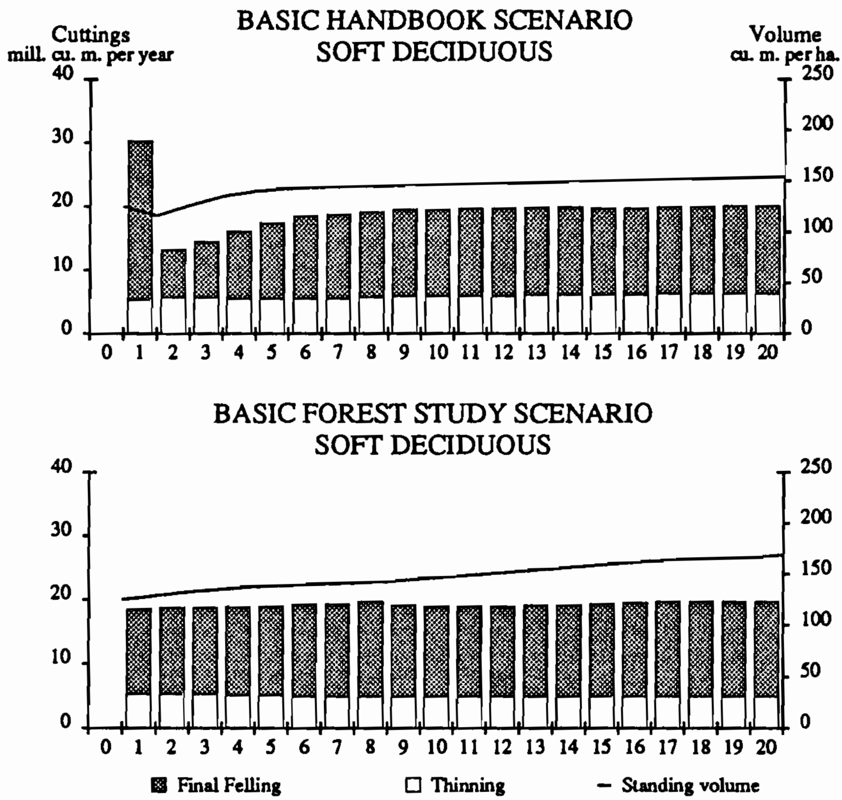

Figure A.34. Projections of potential harvest and growing stock of soft deciduous species in the Volgo-Vyatsky region under the basic scenarios. Current soft deciduous fellings are 15.2 million cubic meters o.b.

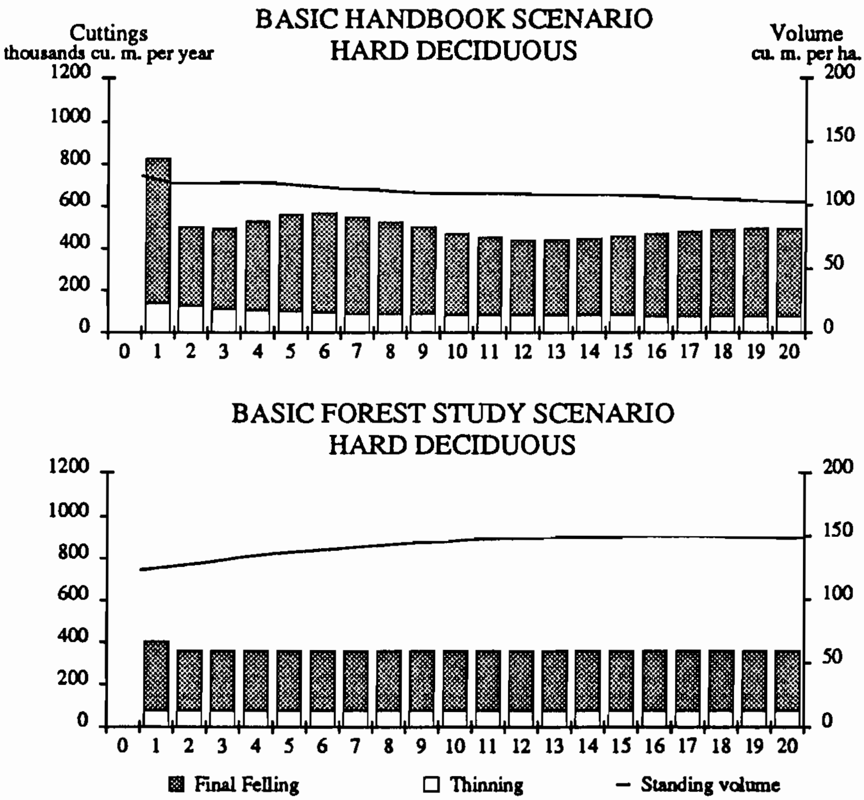

Figure A.35. Projections of potential harvest and growing stock of hard deciduous species in the Volgo-Vyatsky region under the basic scenarios. Current hard deciduous fellings are 0.3 million cubic meters o.b.

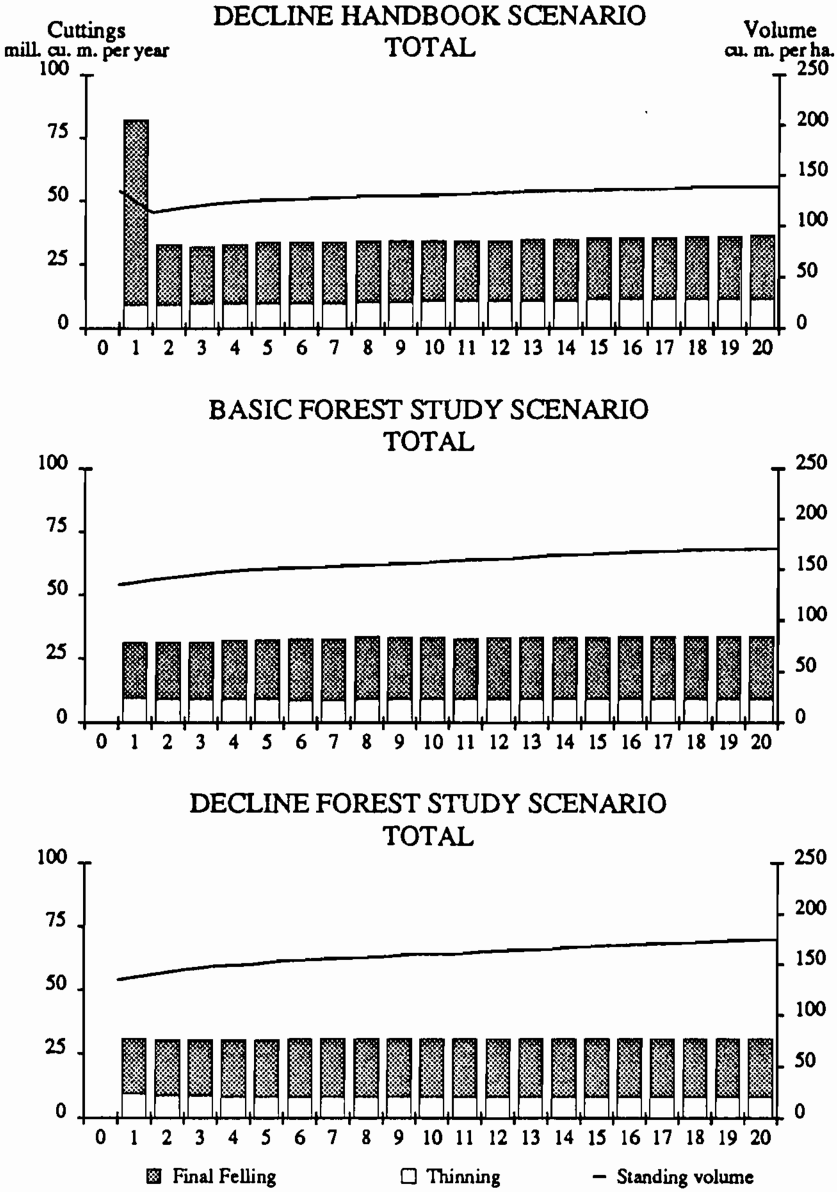

Figure A.36. Projections of total potential harvest and growing stock in the Volgo-Vyatsky region under the decline scenarios. Current total fellings are 27.1 million cubic meters o.b.

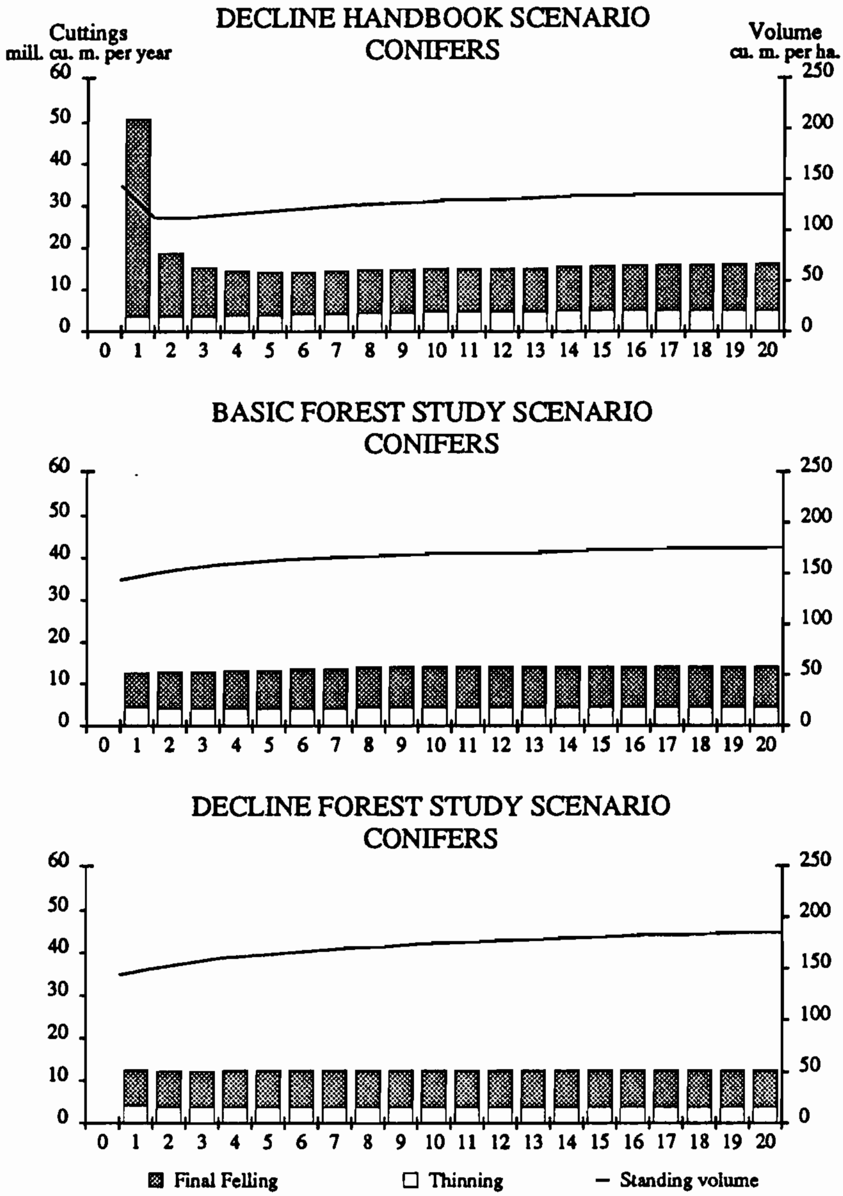

Figure A.37. Projections of potential harvest and growing stock of coniferous species in the Volgo-Vyatsky region under the decline scenarios. Current coniferous fellings are 11.6 million cubic meters o.b.

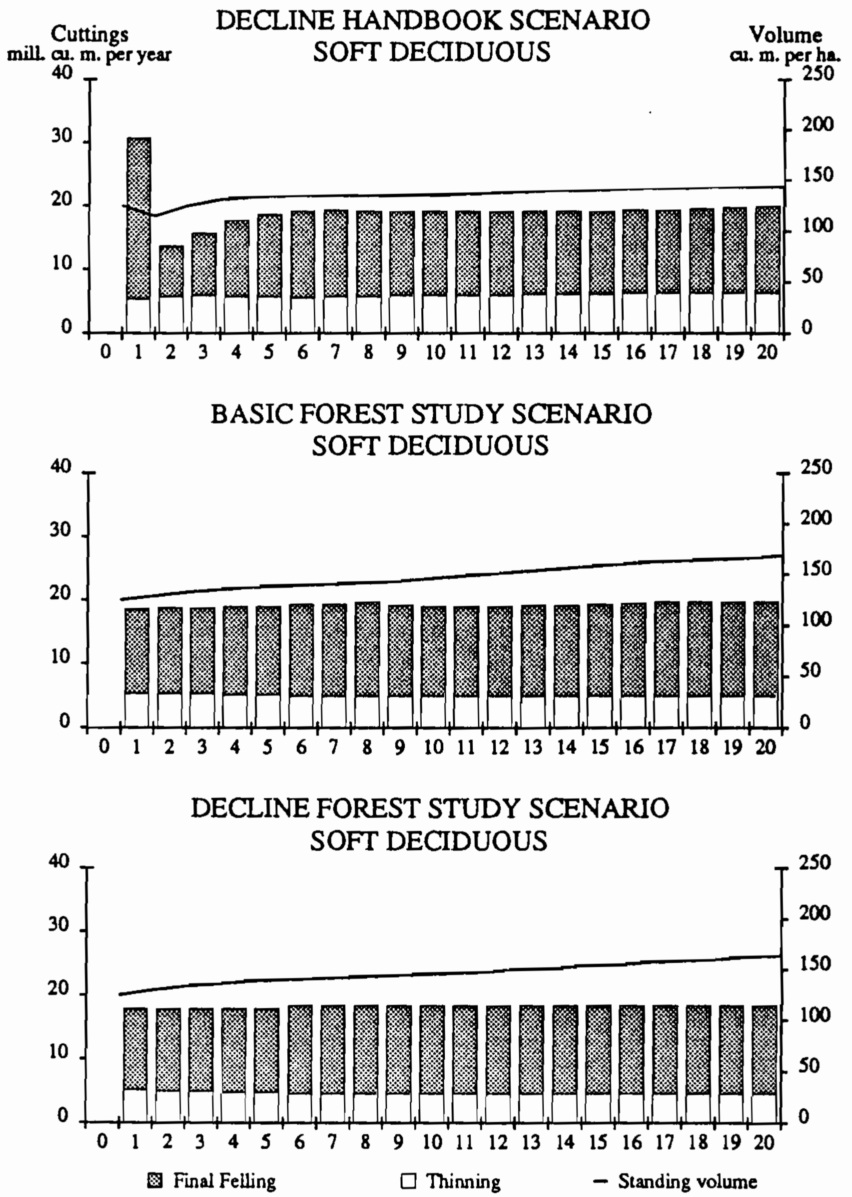

Figure A.38. Projections of potential harvest and growing stock of soft deciduous species in the Volgo-Vyatsky region under the decline scenarios. Current soft deciduous fellings are 15.2 million cubic meters o.b.

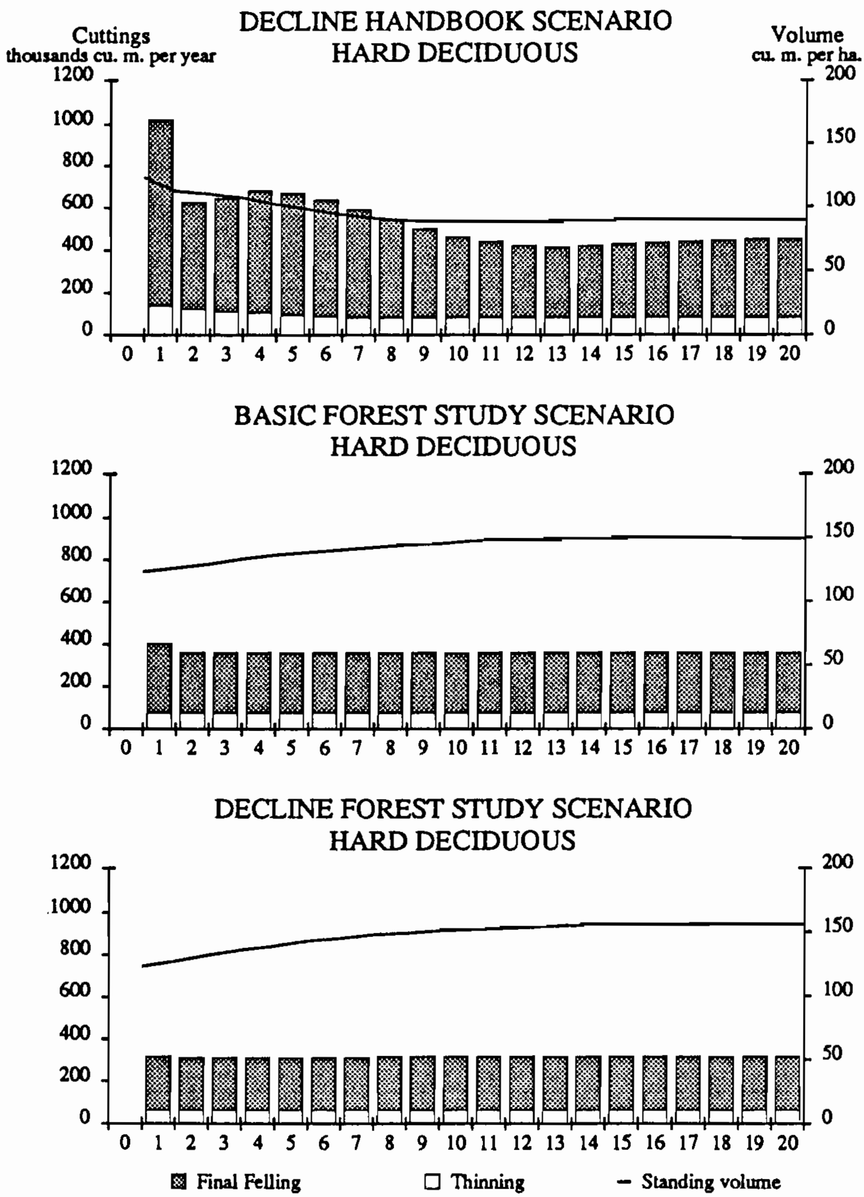

Figure A.39. Projections of potential harvest and growing stock of hard deciduous species in the Volgo-Vyatsky region under the decline scenarios. Current hard deciduous fellings are 0.3 million cubic meters o.b.

Central Chernozyomny Region (Table A.7 and Figures A.40 to A.47)

The area of commercial forests is small in comparison with most of the regions analyzed in the European USSR. The current total area is 885,000 hectares, which is distributed over many individual species. Nearly 75 percent of the forested area belongs to the protected Forest Group I.

Basic Scenarios

The two basic scenarios give nearly identical results for total harvesting potential and development of growing stock of total species groups (*Figure A.40*). For coniferous species the harvesting potential is more uneven in the Basic Handbook Scenario in comparison with the Basic Forest Study Scenario. The patterns of harvesting potential and development of growing stock in the deciduous groups are similar in the two basic scenarios. Thus, there is also a very good match between the current structure of the commercial forests and a fully implemented handbook silviculture.

Decline Scenarios

The impact of air-pollution effects is most pronounced in the hard deciduous species group, with a decline in the harvesting potential and slight decline over time in the growing stock. The strongest effects of air pollutants on the growth rate also occur in this species group.

The decline of the total harvest potential due to air pollutants is only about 10 percent or 0.3 million cubic meters per year.

Summary

There is a very good correspondence between the current structure of the forest resources and a fully implemented handbook silviculture. The major part of the harvest potential is in the deciduous species (nearly 70 percent), mainly hard deciduous. About 30 percent of the harvesting potential should be taken out as thinnings.

The decline effects on the total harvesting potential by air pollutants are about 10 percent or 0.3 million cubic meters per year.

Table A.7. Central Chernozyomny region.

Variable	Basic Hand-book	Basic Forest Study	Hand-book Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	142–148	142–155	142–132	142–159
Fellings[b]				
Year 1	2.9	2.8	3.7	2.4
Year 40	3.2	3.2	3.0	2.8
Year 80	3.3	3.2	2.8	2.8
Coniferous				
Growing stock[a]	166–185	166–192	166–167	166–201
Fellings[b]				
Year 1	1.0	1.0	1.2	0.9
Year 40	1.1	1.1	1.1	1.0
Year 80	1.1	1.1	1.0	1.0
Soft deciduous				
Growing stock[a]	104–142	104–144	104–131	104–154
Fellings[b]				
Year 1	0.5	0.6	0.6	0.5
Year 40	0.7	0.7	0.6	0.6
Year 80	0.7	0.7	0.7	0.6
Hard deciduous				
Growing stock[a]	141–129	141–138	141–111	141–136
Fellings[b]				
Year 1	1.4	1.2	1.9	1.0
Year 40	1.4	1.4	1.3	1.2
Year 80	1.5	1.4	1.1	1.2
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	3.2	3.1	3.2	2.8
Coniferous	1.1	1.0	1.1	1.0
Soft deciduous	0.7	0.7	0.7	0.6
Hard deciduous	1.4	1.4	1.4	1.2
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	3.7	3.6	3.5	3.2
Coniferous	4.2	4.1	4.1	3.9
Soft deciduous	4.5	4.4	4.2	3.9
Hard deciduous	3.0	3.0	2.8	2.6
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	142–148	142–155	142–132	142–159
Coniferous	166–185	166–192	166–167	166–201
Soft deciduous	104–142	104–144	104–131	104–154
Hard deciduous	141–129	141–138	141–111	141–136

[a] In m^3 o.b. ha^{-1}; yr0–yr100. [b] In mill. m^3 o.b. yr^{-1}. [c] Average for the simulations over 100 years.

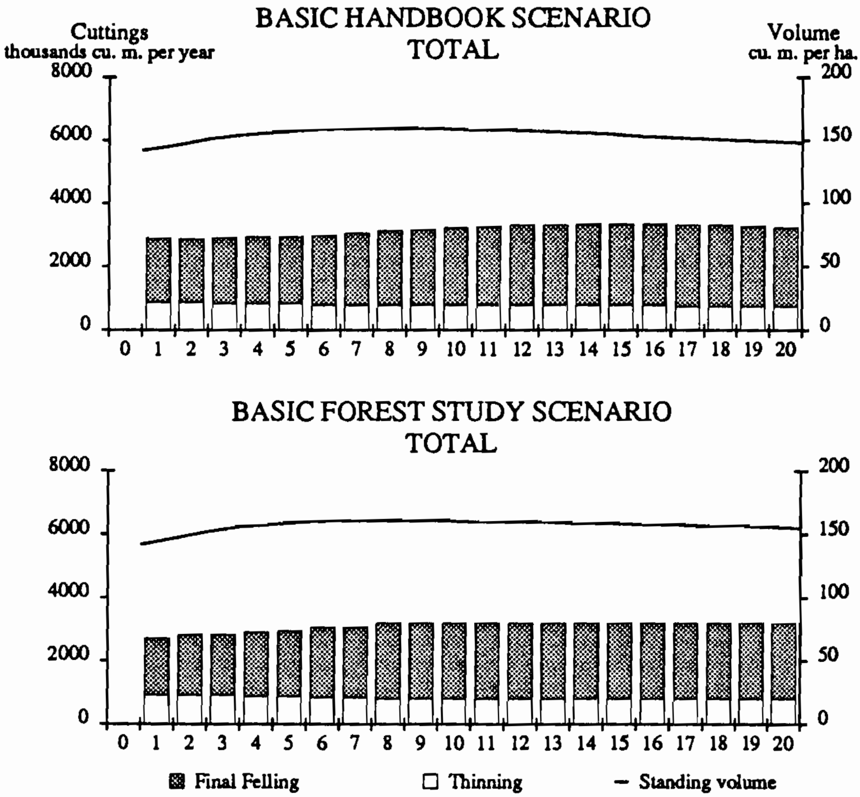

Figure A.40. Projections of total potential harvest and growing stock in the Central Chernozyomny region under the basic scenarios. Current total fellings are 2.4 million cubic meters o.b.

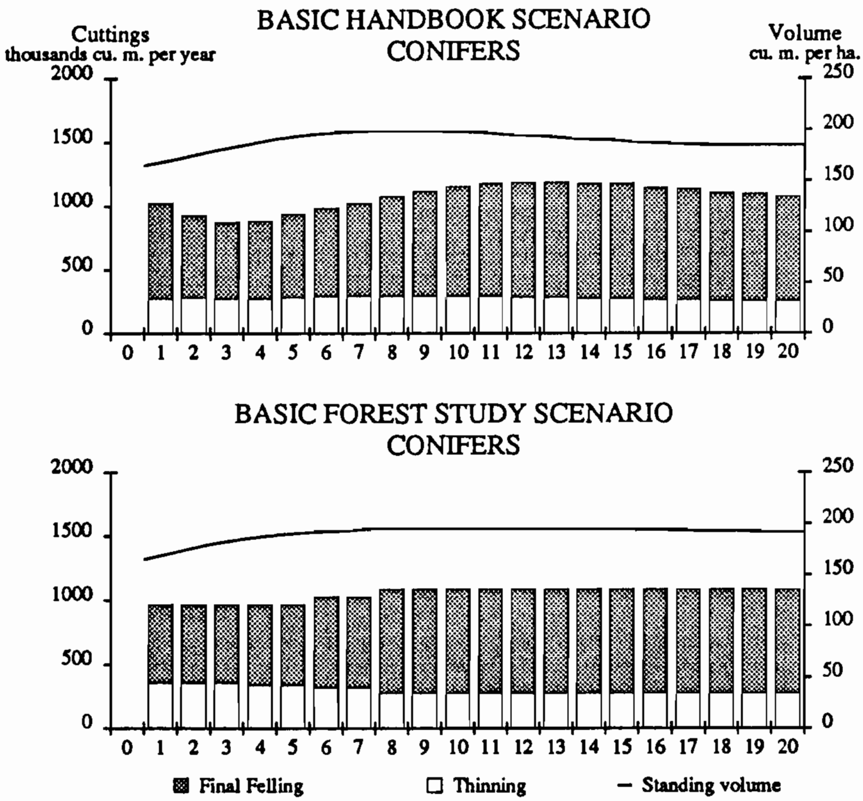

Figure A.41. Projections of potential harvest and growing stock of coniferous species in the Central Chernozyomny region under the basic scenarios. Current coniferous fellings are 1.8 million cubic meters o.b.

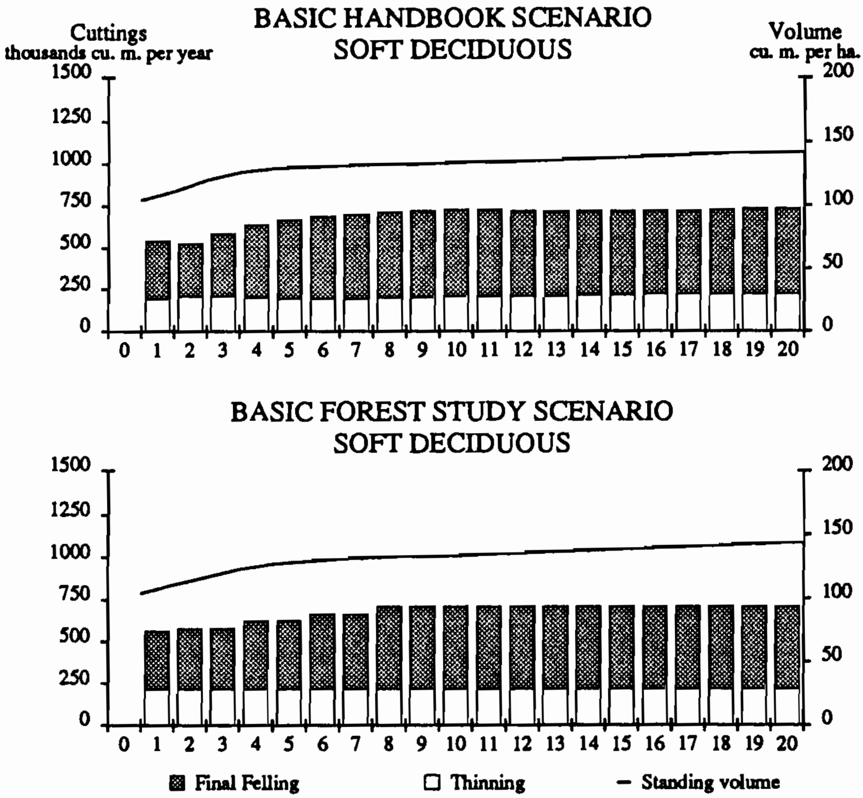

Figure A.42. Projections of potential harvest and growing stock of soft deciduous species in the Central Chernozyomny region under the basic scenarios. Current soft deciduous fellings are 0.25 million cubic meters o.b.

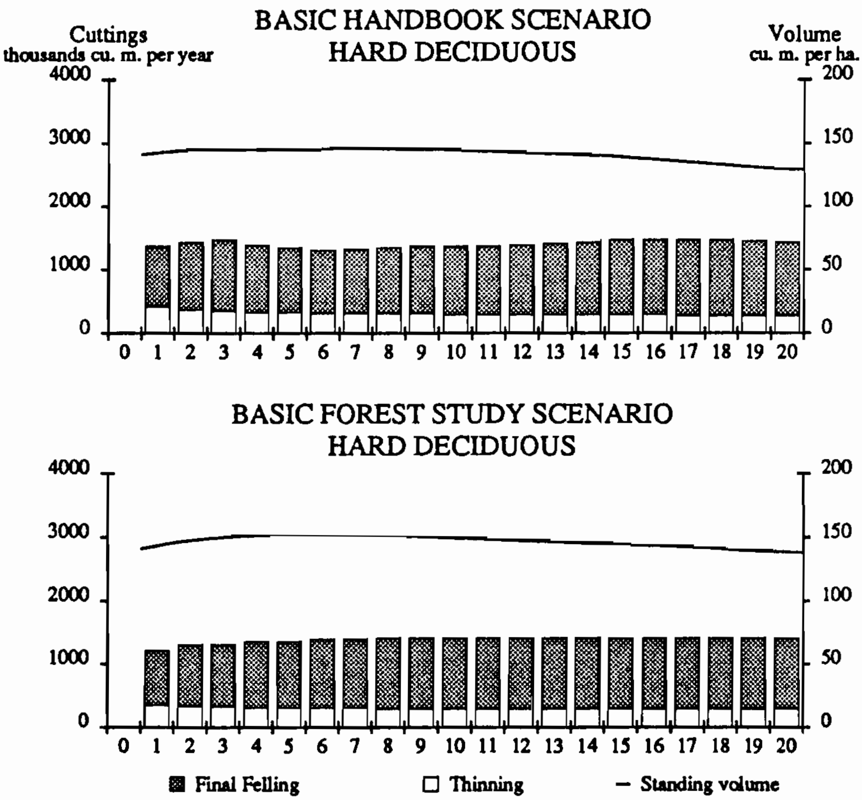

Figure A.43. Projections of potential harvest and growing stock of hard deciduous species in the Central Chernozyomny region under the basic scenarios. Current hard deciduous fellings are 0.35 million cubic meters o.b.

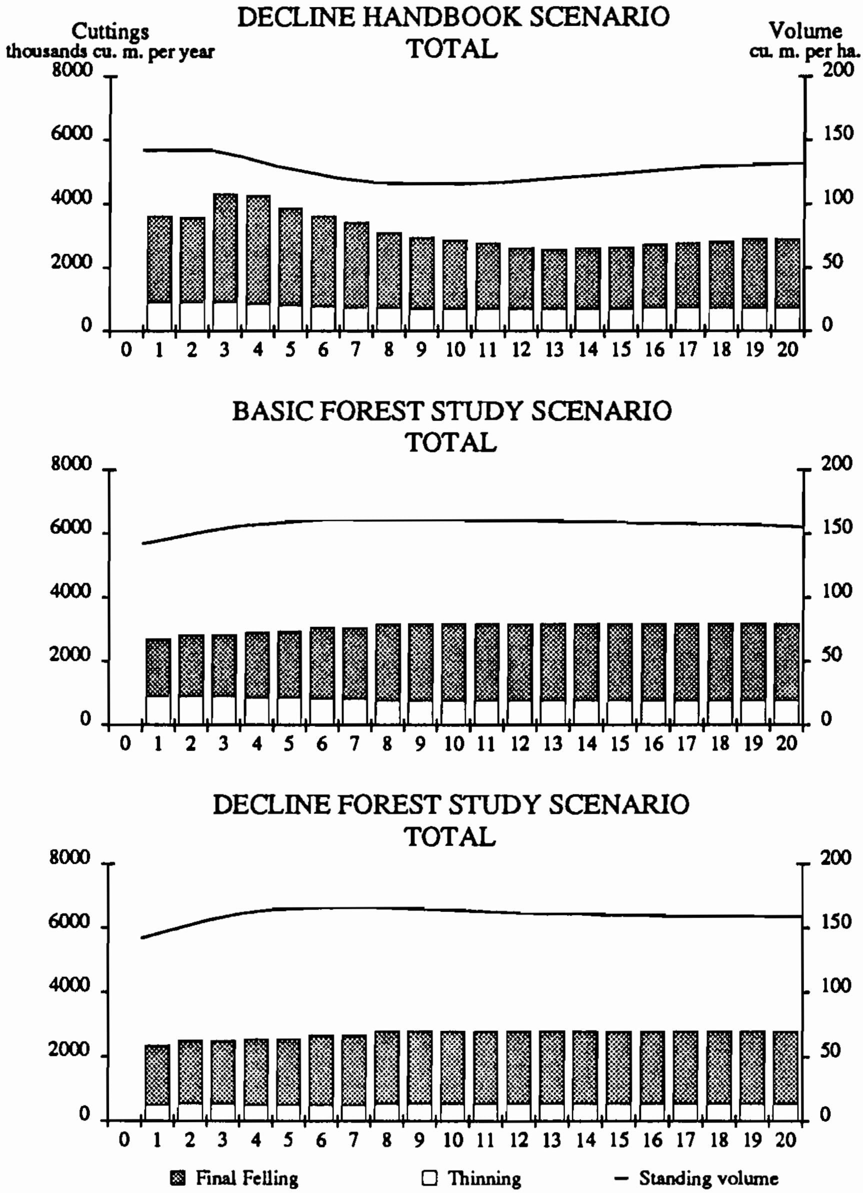

Figure A.44. Projections of total potential harvest and growing stock in the Central Chernozyomny region under the decline scenarios. Current total fellings are 2.4 million cubic meters o.b.

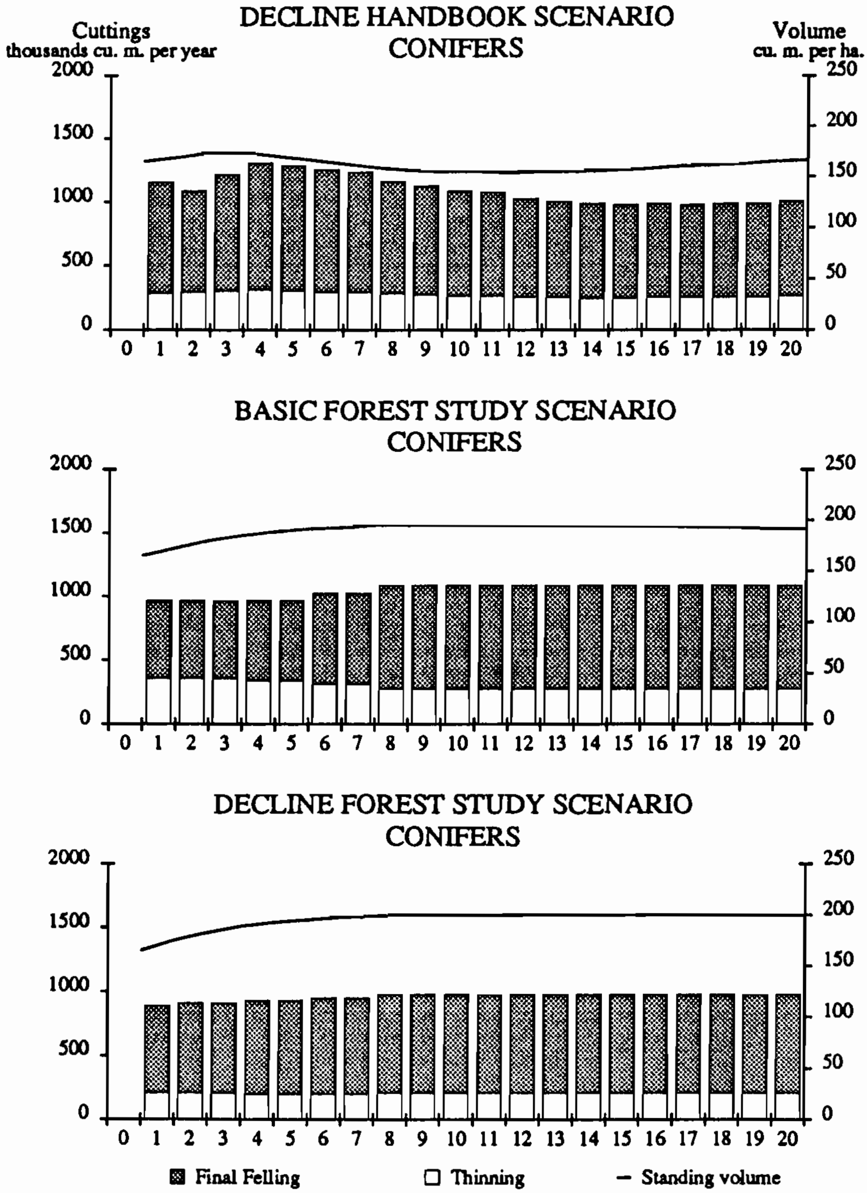

Figure A.45. Projections of potential harvest and growing stock of coniferous species in the Central Chernozyomny region under the decline scenarios. Current coniferous fellings are 1.8 million cubic meters o.b.

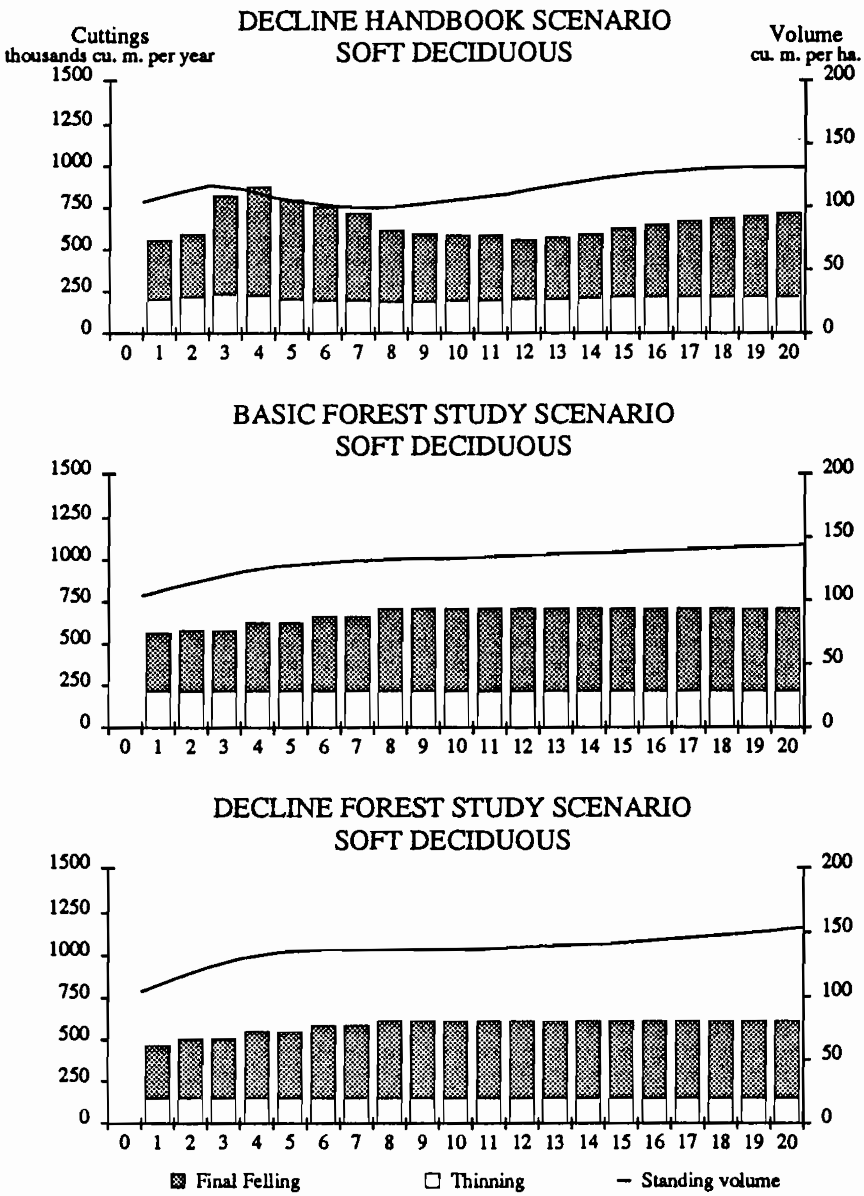

Figure A.46. Projections of potential harvest and growing stock of soft deciduous species in the Central Chernozyomny region under the decline scenarios. Current soft deciduous fellings are 0.25 million cubic meters o.b.

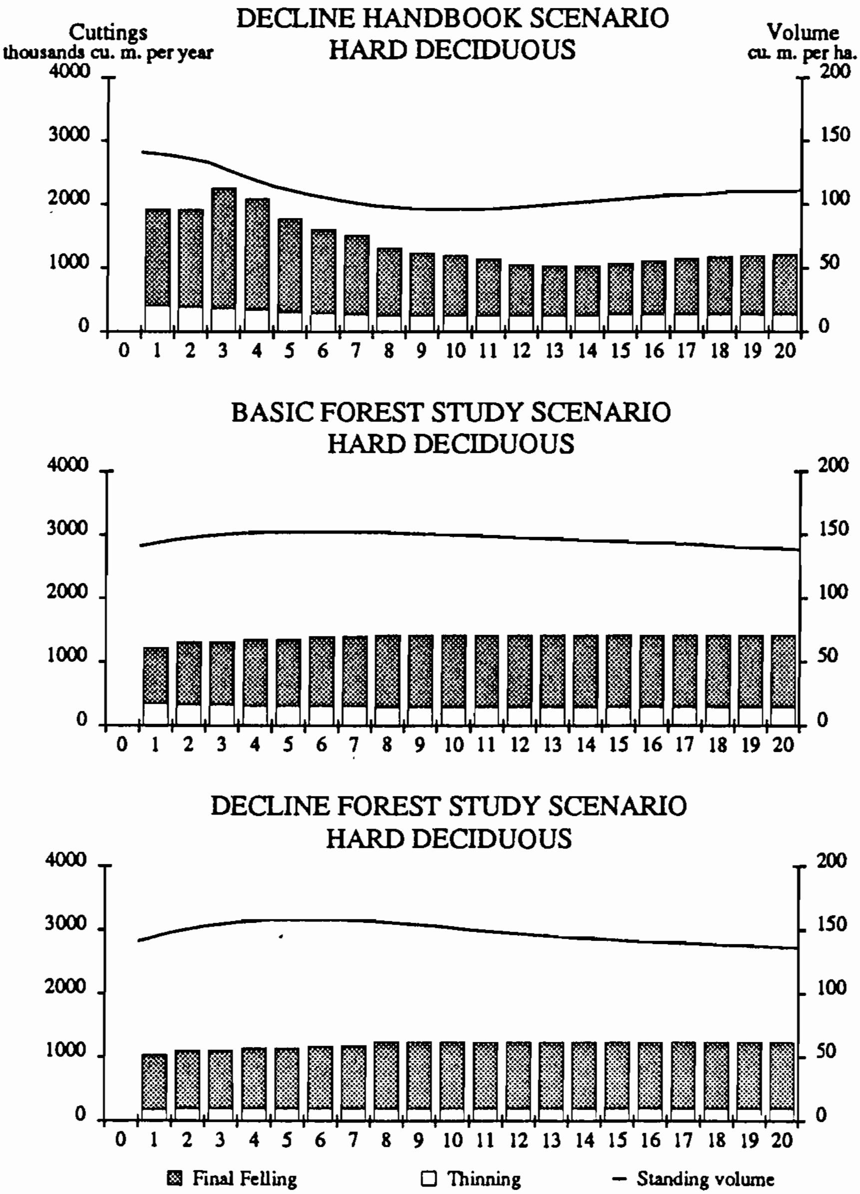

Figure A.47. Projections of potential harvest and growing stock of hard deciduous species in the Central Chernozyomny region under the decline scenarios. Current hard deciduous fellings are 0.35 million cubic meters o.b.

Povolzhsky Region (Table A.8 and Figures A.48 to A.55)

About 75 percent of the commercial forest area is deciduous forest, and nearly 50 percent of the forests are in the protected Forest Group I.

Basic Scenarios

In total, there is a rather good balance between the existing structure of the forest resources and a fully implemented handbook silviculture. The harvesting pulses in the first period for coniferous and soft deciduous species in the Basic Handbook Scenario are not pronounced. The Basic Forest Study Scenario gives slightly increasing harvesting and growing-stock potentials for total species, coniferous species, and soft deciduous species. The difference in total harvesting potential between the two basic scenarios is minor (about 6 percent lower in the Basic Forest Study Scenario).

Decline Scenarios

The decline impact of air pollutants does not change the potential harvesting profiles and development paths of the growing stock of total species, coniferous species, and soft deciduous species. Hard deciduous species are affected by air pollutants, both in the Handbook Decline Scenario and in the Forest Study Decline Scenario. In the Handbook Decline Scenario, the harvesting profile is much more uneven and the growing stock has a lower average level than in the Basic Handbook Scenario. In the Forest Study Decline Scenario, the harvesting potential is significantly lower in the last two-thirds of the simulation period for this species group in comparison with the Basic Forest Study Scenario. The growth rate is reduced by between 0.2 and 0.3 cubic meters over bark per hectare per year in the different species groups by decline from air pollutants. The decline in the total harvesting potential is estimated to be 0.8 million cubic meters per year or about 8 percent.

Summary

There is a rather good balance in the Povolzhsky region between existing forest structure and a structure imposed by handbook silviculture. The dominating harvest potential is in deciduous species (more than 70 percent). About 30 percent of the total harvesting potential is harvested in the form of thinnings. The impact of air pollutants is rather modest (about 8 percent on the total potential average harvest).

Table A.8. Povolzhsky region.

Variable	Basic Hand-book	Basic Forest Study	Hand-book Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	125–140	125–146	125–130	125–147
Fellings[b]				
Year 1	11.6	9.5	12.1	8.9
Year 40	10.7	10.1	10.6	9.2
Year 80	10.9	10.1	10.6	9.2
Coniferous				
Growing stock[a]	139–173	139–192	139–159	139–195
Fellings[b]				
Year 1	2.7	2.2	2.8	2.2
Year 40	2.9	2.9	3.0	2.7
Year 80	3.1	2.9	3.0	2.7
Soft deciduous				
Growing stock[a]	129–140	129–150	129–130	129–153
Fellings[b]				
Year 1	6.4	4.6	6.5	4.3
Year 40	5.7	4.9	5.5	4.5
Year 80	5.2	4.9	5.1	4.5
Hard deciduous				
Growing stock[a]	106–113	106–101	106–105	106–98
Fellings[b]				
Year 1	2.5	2.7	2.8	2.4
Year 40	2.1	2.3	2.1	2.0
Year 80	2.6	2.3	2.5	2.0
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	10.6	9.9	10.7	9.2
Coniferous	2.9	2.7	2.9	2.6
Soft deciduous	5.3	4.8	5.3	4.4
Hard deciduous	2.4	2.4	2.5	2.2
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	3.9	3.8	3.9	3.5
Coniferous	4.2	4.2	4.2	4.0
Soft deciduous	4.5	4.2	4.4	3.9
Hard deciduous	2.9	2.8	2.9	2.5
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	125–140	125–146	125–130	125–147
Coniferous	139–173	139–192	139–159	139–195
Soft deciduous	129–140	129–150	129–130	129–153
Hard deciduous	106–113	106–101	106–105	106–98

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

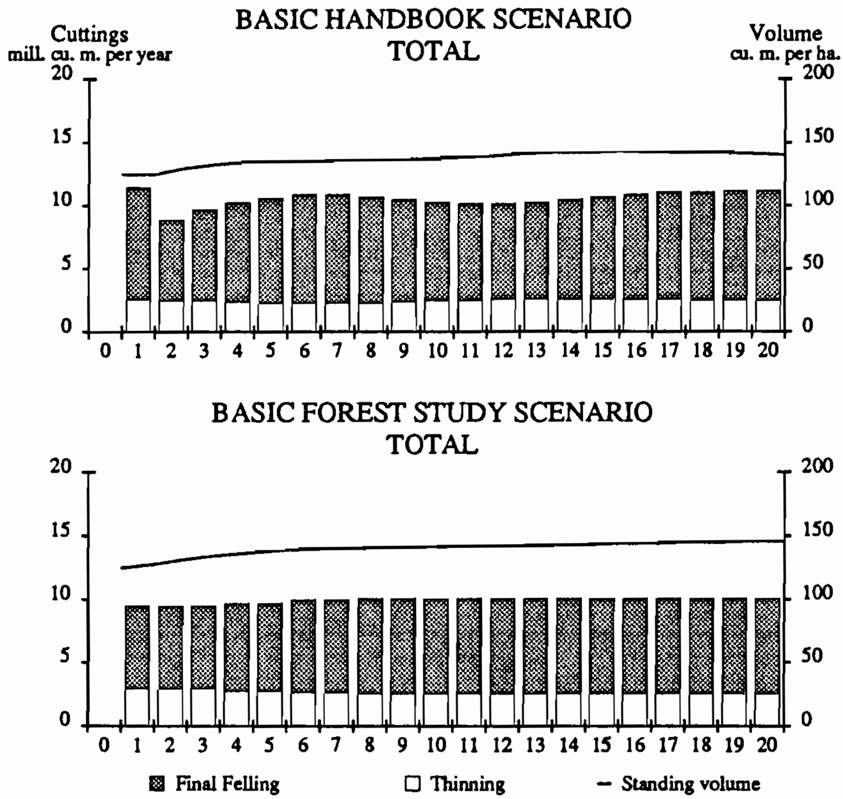

Figure A.48. Projections of total potential harvest and growing stock in the Povolzhsky region under the basic scenarios. Current total fellings are 9.2 million cubic meters o.b.

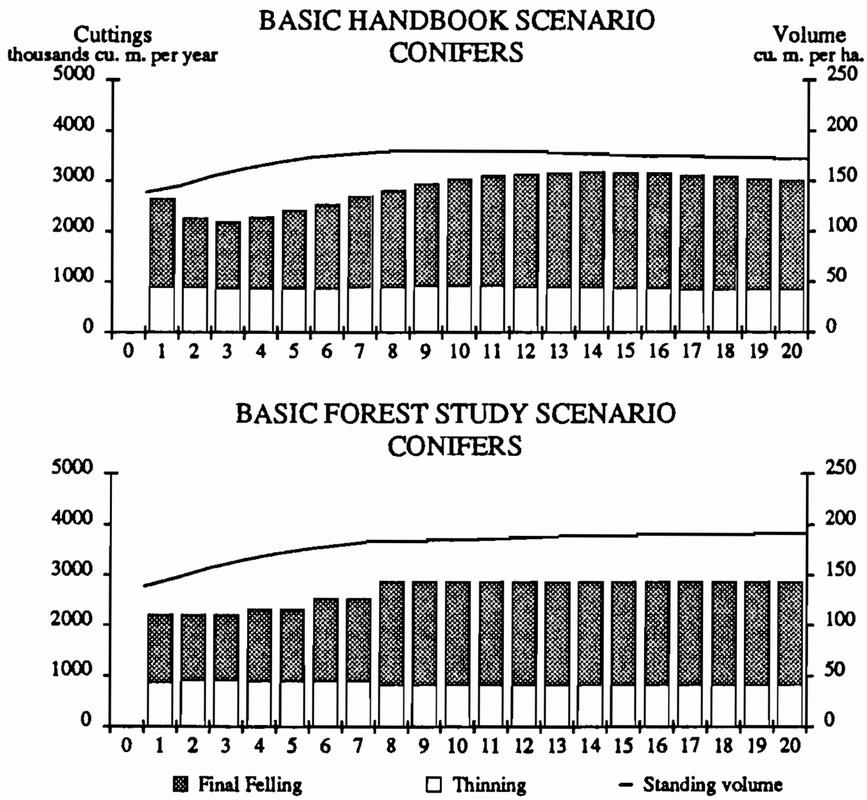

Figure A.49. Projections of potential harvest and growing stock of coniferous species in the Povolzhsky region under the basic scenarios. Current coniferous fellings are 0.4 million cubic meters o.b.

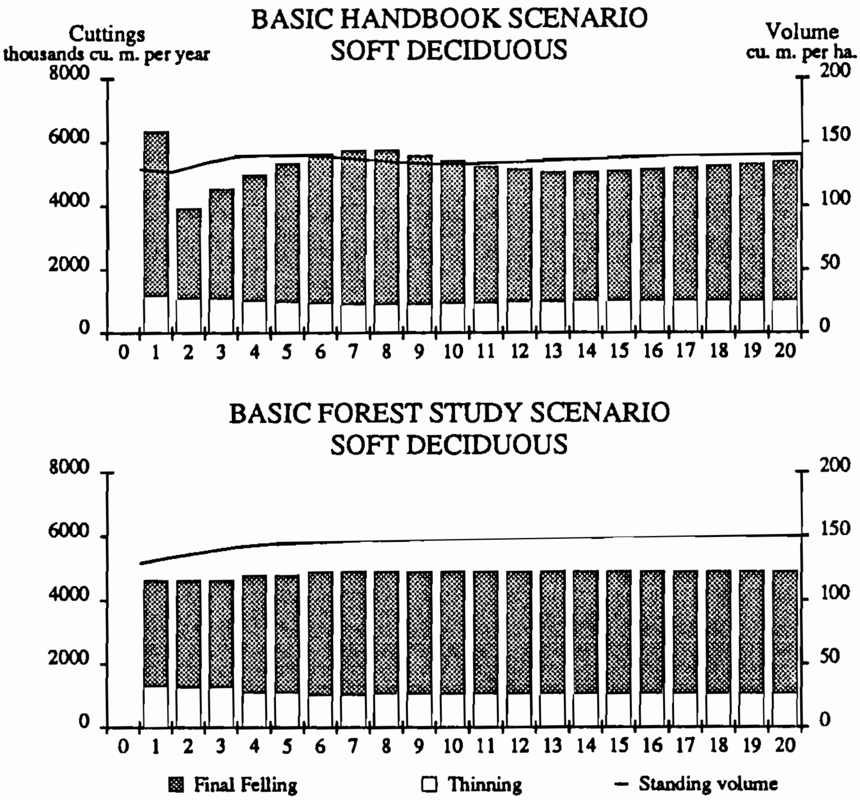

Figure A.50. Projections of potential harvest and growing stock of soft deciduous species in the Povolzhsky region under the basic scenarios. Current soft deciduous fellings are 6.1 million cubic meters o.b.

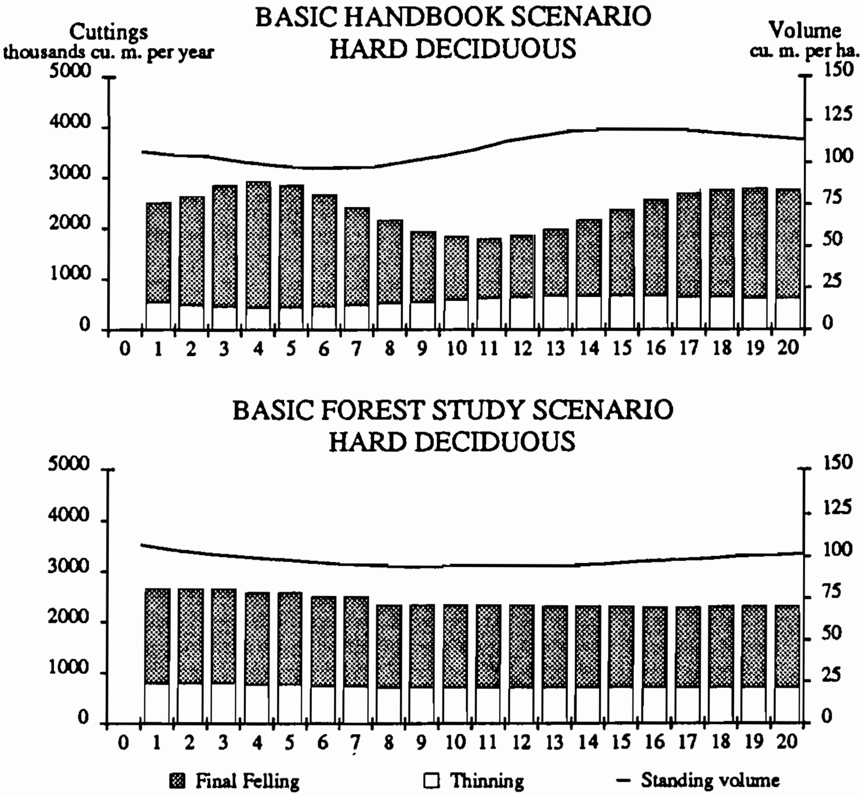

Figure A.51. Projections of potential harvest and growing stock of hard deciduous species in the Povolzhsky region under the basic scenarios. Current hard deciduous fellings are 2.7 million cubic meters o.b.

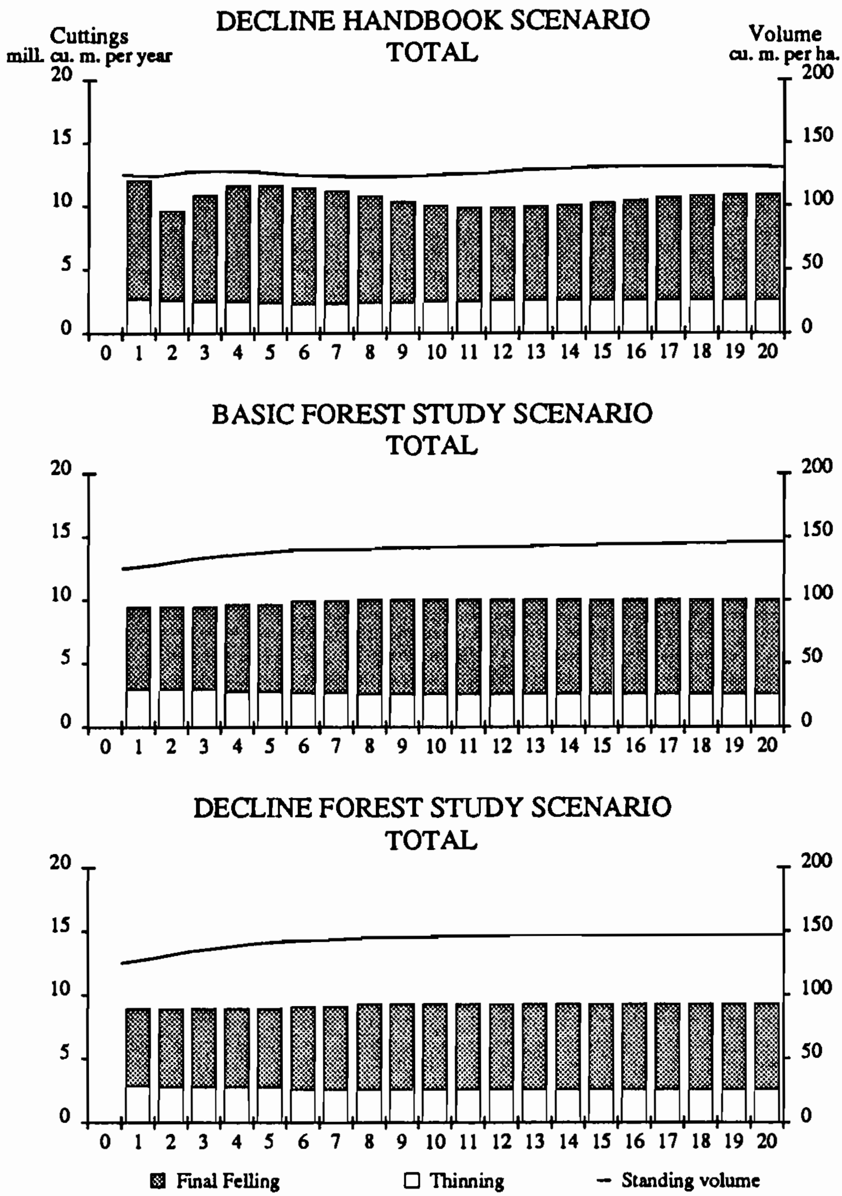

Figure A.52. Projections of total potential harvest and growing stock in the Povolzhsky region under the decline scenarios. Current total fellings are 9.2 million cubic meters o.b.

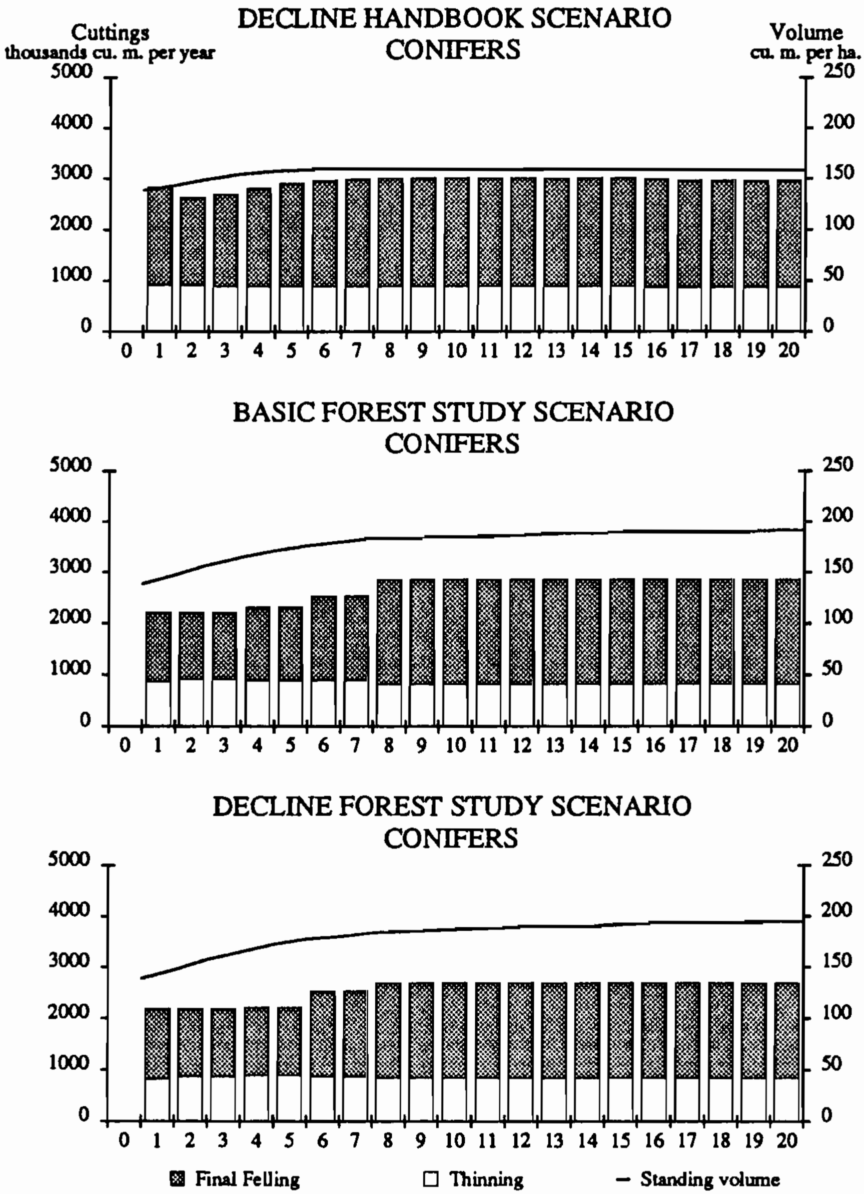

Figure A.53. Projections of potential harvest and growing stock of coniferous species in the Povolzhsky region under the decline scenarios. Current coniferous fellings are 0.4 million cubic meters o.b.

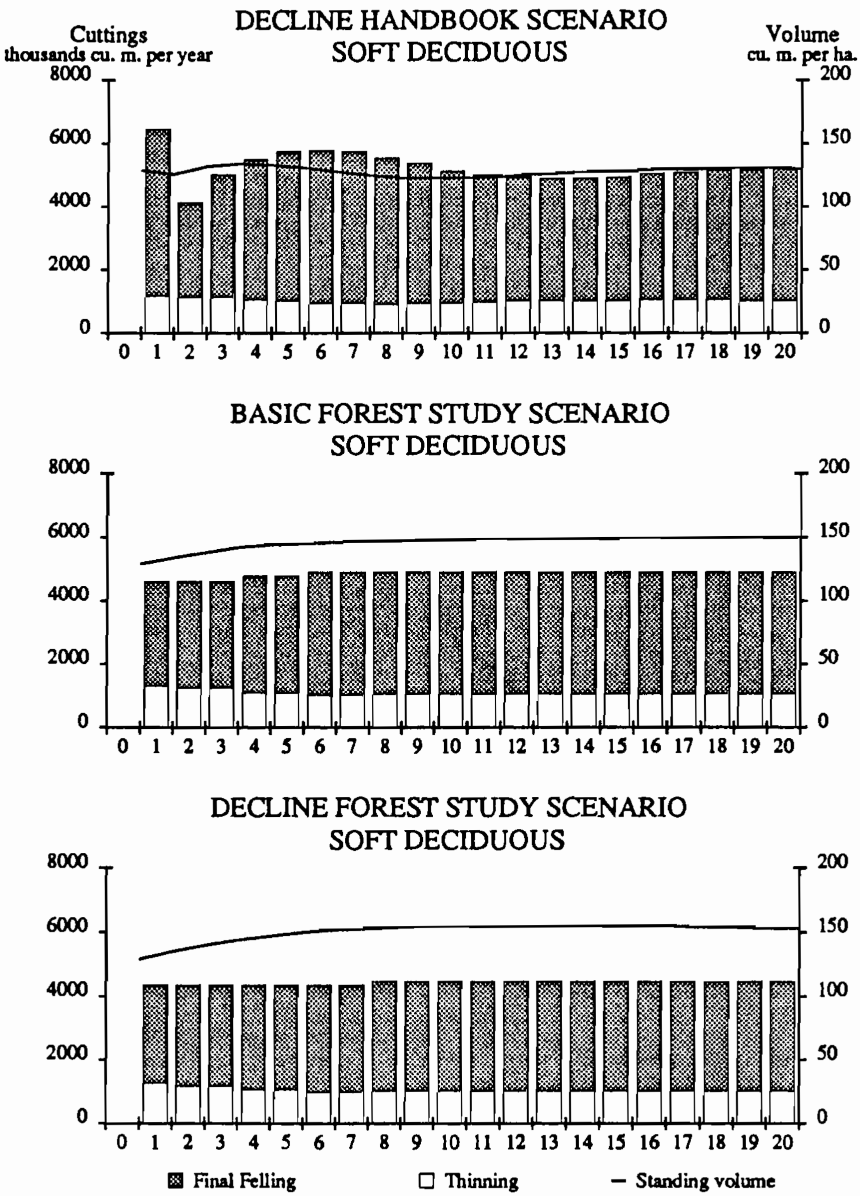

Figure A.54. Projections of potential harvest and growing stock of soft deciduous species in the Povolzhsky region under the decline scenarios. Current soft deciduous fellings are 6.1 million cubic meters o.b.

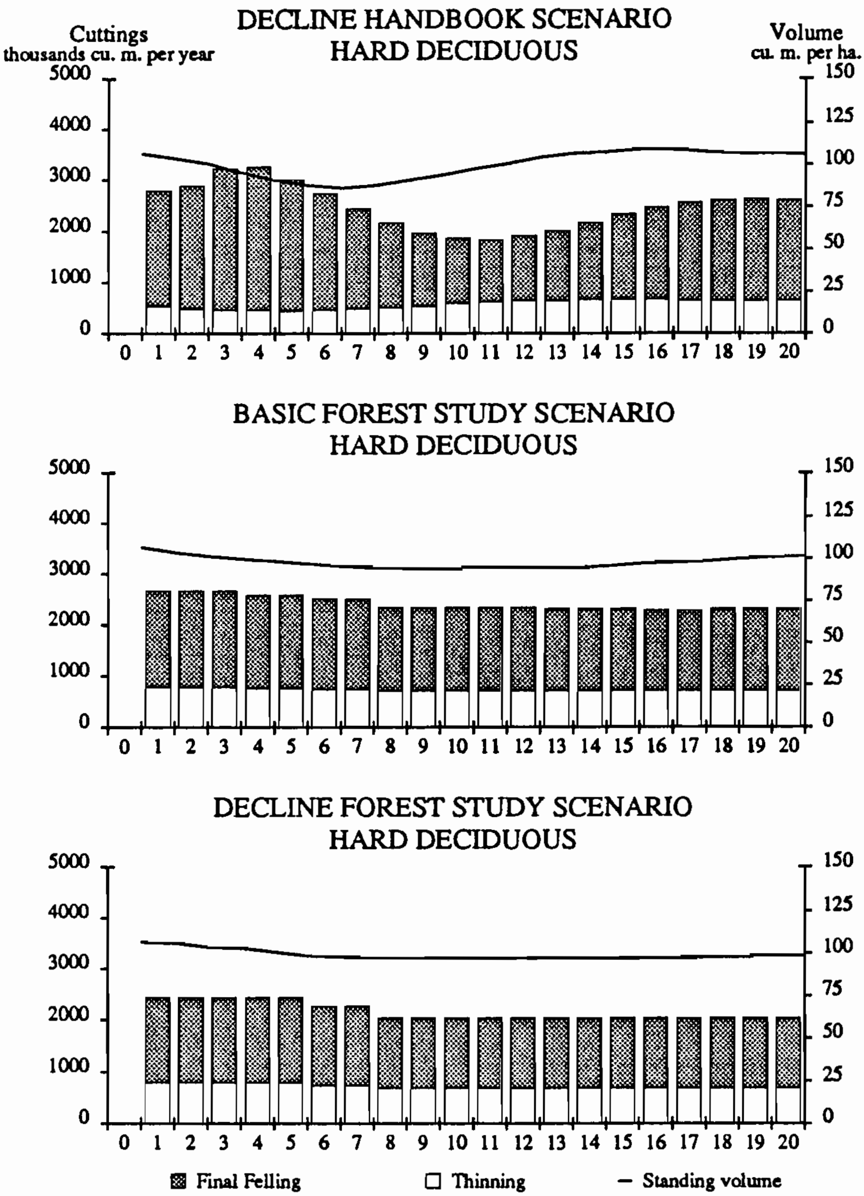

Figure A.55. Projections of potential harvest and growing stock of hard deciduous species in the Povolzhsky region under the decline scenarios. Current hard deciduous fellings are 2.7 million cubic meters o.b.

Ural Region (Tables A.9 and A.10 and Figures A.56 to A.67)

The Ural region has a basic problem that is similar to the problem in the Northern region with a concentration of coniferous forests in age classes above 120 years. The current age-class distribution for coniferous species is presented in *Table A.9*. Thus, there is a balancing problem concerning the rate of liquidation of the overmature coniferous forests. The soft deciduous group has a relatively good age-class distribution, but, even here, overmature forests exist. The hard deciduous group has an uneven age-class distribution, which causes some structural management problems. The growth rates are low in the Ural region, especially of spruce and fir. The average standing volume is normal. The region has many unutilized aspen forest resources.

Table A.9. Age-class distribution for coniferous forests in the Ural region.

Age class	Area (1,000 ha)	Standing volume (m^3 ha^{-1})	Growth rate (m^3 ha^{-1} yr^{-1})
0–19	3,560	32	2.04
20–39	2,123	55	3.20
40–59	1,058	105	3.51
60–79	945	157	3.10
80–99	1,160	202	2.37
100–119	1,416	231	1.77
120–139	1,486	246	1.07
140–299	2,152	257	0.55

Basic Scenarios

Like in the Northern region, there are many different possible time profiles available for the liquidation of the overmature coniferous forests in the Ural region. Therefore for this region, we also present three alternative basic scenarios in addition to the Basic Handbook Scenario and the Basic Forest Study Scenario, with the objective of illustrating the range of opportunities for different liquidation paths better. The definitions of these additional scenarios (USSR Path, Rapid Liquidation, and Increased Harvesting) have been presented in the discussion on the Northern region in this appendix.

From the Basic Handbook Scenario, it can be seen that the forest structure in this region is not in line with the implementation of handbook silviculture. This is valid for all three aggregated species groups (coniferous, soft deciduous, and hard deciduous). This results from a large area of coniferous forest with an age class of more than 120 years and overmature residual stands of soft and hard deciduous species. With the conditions employed in the Basic Forest Study Scenario, there is a possibility of achieving an even level of the harvesting potential throughout the entire simulation period for all species groups, but with declining standing volume over time.

The USSR Path Scenario generates a total harvest pattern that is similar to the Basic Forest Study Scenario, but at a higher potential average harvesting level in the beginning of the simulation period. If the individual species groups are studied it can be concluded that the USSR Path Scenario will cause a collapse of the hard deciduous group after about 35 years.

The Rapid Liquidation Scenario gives a high potential harvesting level in the coniferous group during the first 50 years. In the soft deciduous group, there are limited possibilities of a strong increase in the harvesting potential during the first half of the simulation period. For hard deciduous species there is a better possibility of following the conditions with a rapid liquidation of the residual stands in the beginning of the simulation period.

In the Increased Harvesting Scenario there is a possibility of following the conditions for the scenario with a strongly increased successive harvest during the first 40 to 50 years, with a following decrease to harvest levels currently suggested by the Soviet agencies for the coniferous species group. There are limited possibilities of following this pattern for the soft and hard deciduous species groups.

All five basic scenarios give a similar level for the total average potential harvest (between 75 and 78 million cubic meters over bark per year). This conclusion is also valid for the development of the growing stock, with one exception. The USSR Path Scenario concludes with a higher growing-stock level at the end of the simulation period in comparison with the other basic scenarios.

The total growth rates are lower in the Basic Forest Study Scenario, Rapid Liquidation Scenario, and Increased Harvesting Scenario in comparison with the Basic Handbook Scenario and USSR Path Scenario (about 0.1 to 0.2 cubic meters over bark per hectare per year lower). Compared with other regions of Europe, the growth rates are lower in the Ural region, but much higher in comparison with the Northern region.

Decline Scenarios

The decline effects are rather strong in the Ural region (about 10 million cubic meters per year on average). This is a result of rather difficult regional pollution problems in the Ural region. The decline affects soft deciduous species by decreasing harvest potential by some 6 million cubic meters per year, and coniferous species by decreasing potentials by about 4 million cubic meters per year. The average total growth rate declines by 0.4 cubic meters over bark per hectare per year in the decline scenario. The strongest growth-rate effects are achieved in soft deciduous species. The decline in the growth rate is between 0.3 and 0.5 cubic meters per hectare per year for the different species groups.

The decline effects of air pollutants increase the need for restructuring the forest resources in the Ural region. This is illustrated by the Handbook Decline Scenario. The harvest peak in this scenario is even more dramatic than in the Basic Handbook Scenario. This is valid for all the aggregated species groups.

Summary

The overall problem in the Ural region is balancing the liquidation of overmature forests. Different alternatives exist from a sustainability point of view. Therefore, the choice for future harvesting profile is more a question of how fast one will liquidate the overmature forest and the availability of resources for harvesting and regeneration. The estimate of the total potential harvest (average for the simulation period) seems to be 76 million cubic meters over bark per year, with roughly half of the potential in coniferous species and half in the soft deciduous group. About 20 percent of the harvesting potential should be harvested in the form of thinnings. The recommended physical harvesting potential exceeds the current total harvest by nearly 20 million cubic meters over bark per year.

The effects of air pollutants are significant in the Ural region. The total yearly loss of the harvesting potential is estimated to be about 10 million cubic meters over bark or 13 percent.

Table A.10. Ural region.

Variable	Basic Hand-book	Basic Forest Study	Hand-book Decline	Forest Study Decline	USSR Path	Rapid Liqui-dation	Increased Harvesting
Selected data on harvests and growing stock							
Total							
Growing stock[a]	129–114	129–113	129–98	129–113	129–133	129–113	129–112
Fellings[b]							
Year 1	277.0	74.2	304.4	64.0	87.0	103.4	70.8
Year 40	60.6	76.8	60.8	65.8	72.8	72.5	81.8
Year 80	74.4	75.5	65.4	66.4	70.6	69.7	68.0
Coniferous							
Growing stock[a]	141–117	141–113	141–94	141–114	141–127	141–115	141–114
Fellings[b]							
Year 1	178.8	37.0	204.0	32.9	40.3	60.0	34.0
Year 40	25.1	37.0	29.4	32.9	39.2	34.5	43.0
Year 80	35.5	37.0	31.3	33.4	32.7	32.5	30.9
Soft deciduous							
Growing stock[a]	114–111	114–114	114–103	114–112	114–144	114–112	114–110
Fellings[b]							
Year 1	92.7	36.0	94.8	30.2	44.5	41.2	35.6
Year 40	34.5	38.5	30.4	31.8	32.9	36.7	37.3
Year 80	37.3	37.2	32.8	31.8	36.2	35.8	35.8
Hard deciduous							
Growing stock[a]	120–95	120–91	120–90	120–92	120–96	120–96	120–94
Fellings[b]							
Year 1	5.5	1.2	5.6	0.9	2.2	2.2	1.2
Year 40	1.0	1.3	1.0	1.1	0.7	1.3	1.5
Year 80	1.6	1.3	1.3	1.2	1.7	1.4	1.3
Summary of results							
Potential harvest (mill. m^3 o.b. yr^{-1})[c]							
Total	78.5	76.0	78.7	65.7	74.8	76.5	75.4
Coniferous	39.1	37.0	41.1	33.1	37.0	38.0	37.4
Soft deciduous	37.8	37.7	36.1	31.6	36.3	37.0	36.6
Hard deciduous	1.6	1.3	1.5	1.1	1.6	1.5	1.4
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]							
Total	3.0	2.9	2.8	2.5	3.0	2.9	2.8
Coniferous	2.6	2.4	2.5	2.1	2.5	2.5	2.4
Soft deciduous	3.5	3.5	3.3	3.0	3.7	3.5	3.4
Hard deciduous	2.8	2.2	2.7	1.9	2.9	2.7	2.5
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)							
Total	129–114	129–113	129–98	129–113	129–133	129–113	129–112
Coniferous	141–117	141–113	141–94	141–114	141–127	141–115	141–114
Soft deciduous	114–111	114–114	114–103	114–112	114–144	114–112	114–110
Hard deciduous	120–95	120–91	120–90	120–92	120–96	120–96	120–94

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

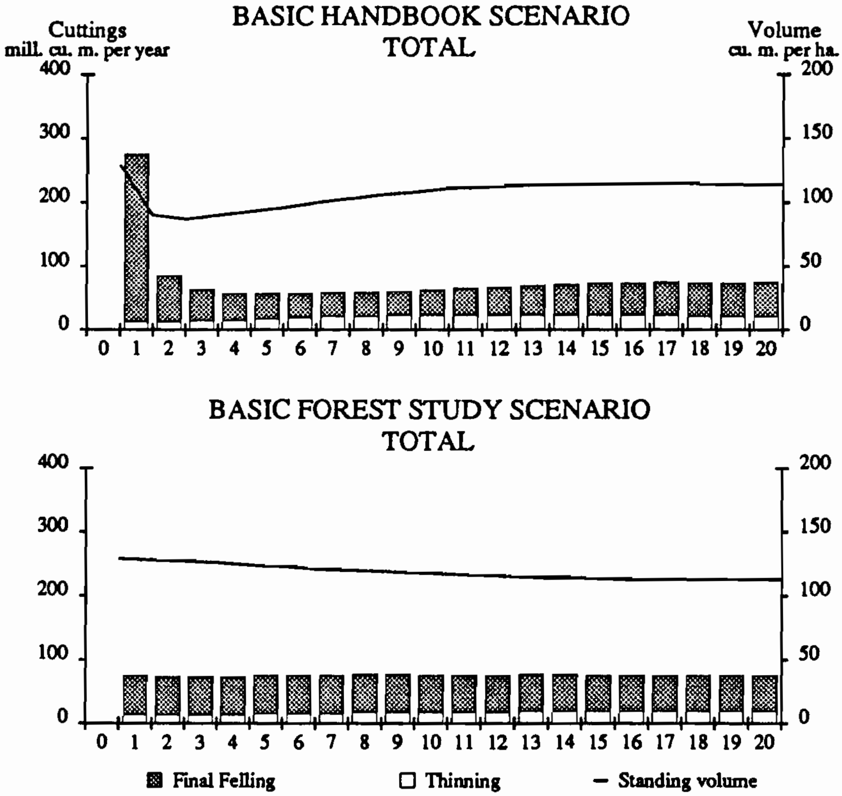

Figure A.56. Projections of total potential harvest and growing stock in the Ural region under the basic scenarios. Current total fellings are 56.3 million cubic meters o.b.

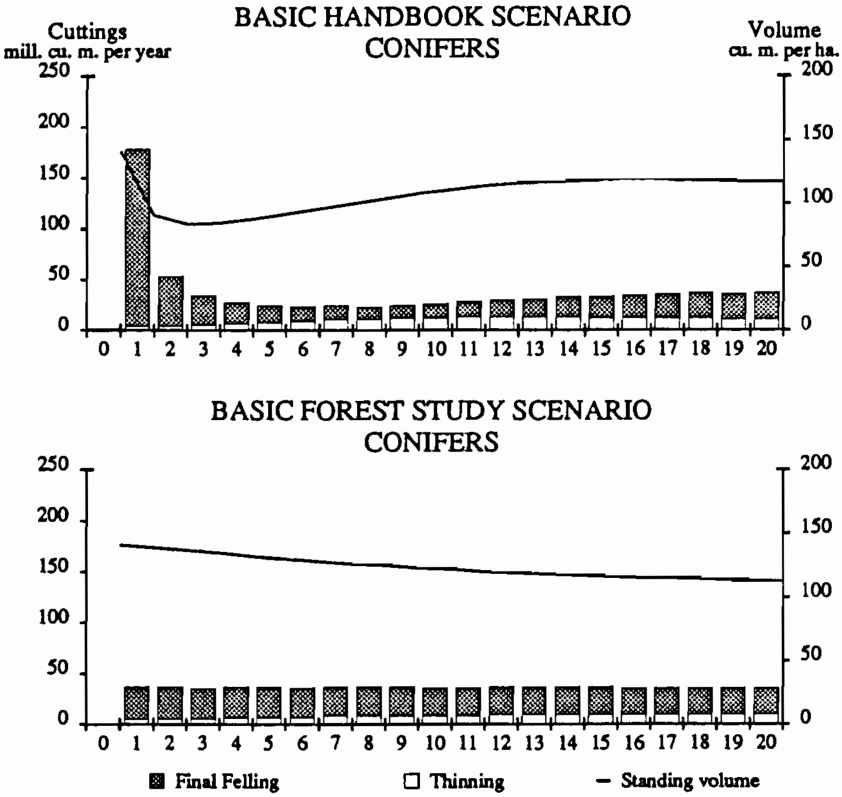

Figure A.57. Projections of potential harvest and growing stock of coniferous species in the Ural region under the basic scenarios. Current coniferous fellings are 33 million cubic meters o.b.

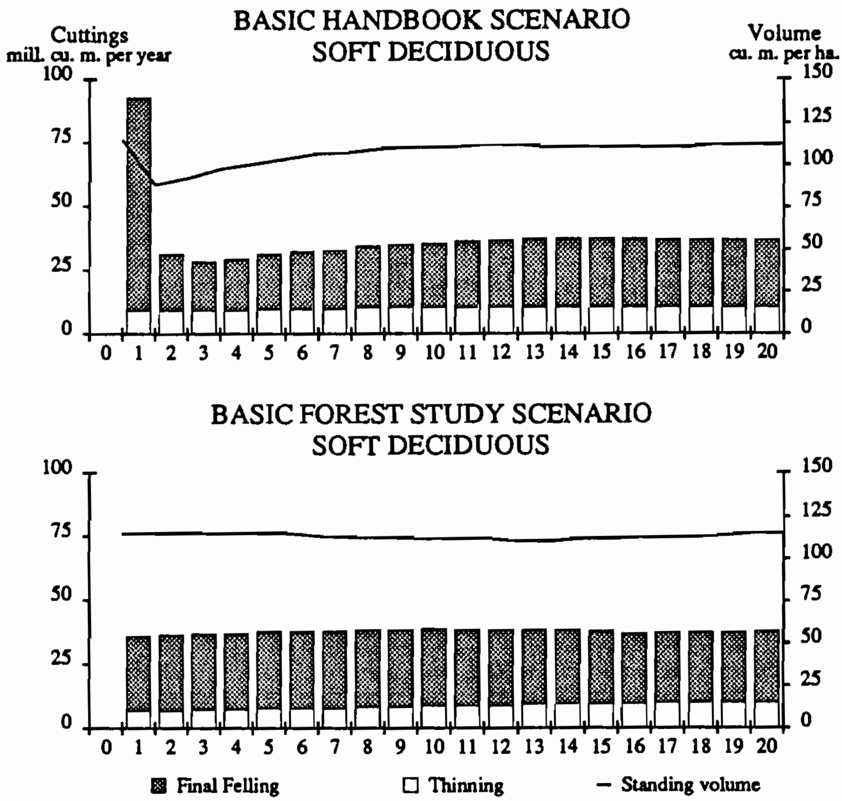

Figure A.58. Projections of potential harvest and growing stock of soft deciduous species in the Ural region under the basic scenarios. Current soft deciduous fellings are 22.5 million cubic meters o.b.

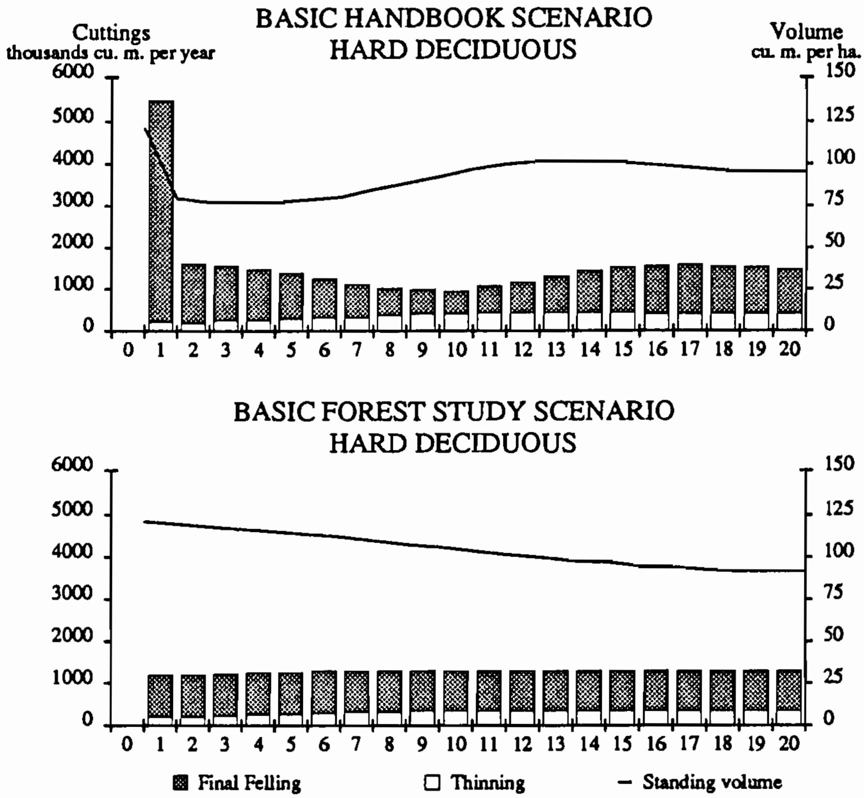

Figure A.59. Projections of potential harvest and growing stock of hard deciduous species in the Ural region under the basic scenarios. Current hard deciduous fellings are 0.8 million cubic meters o.b.

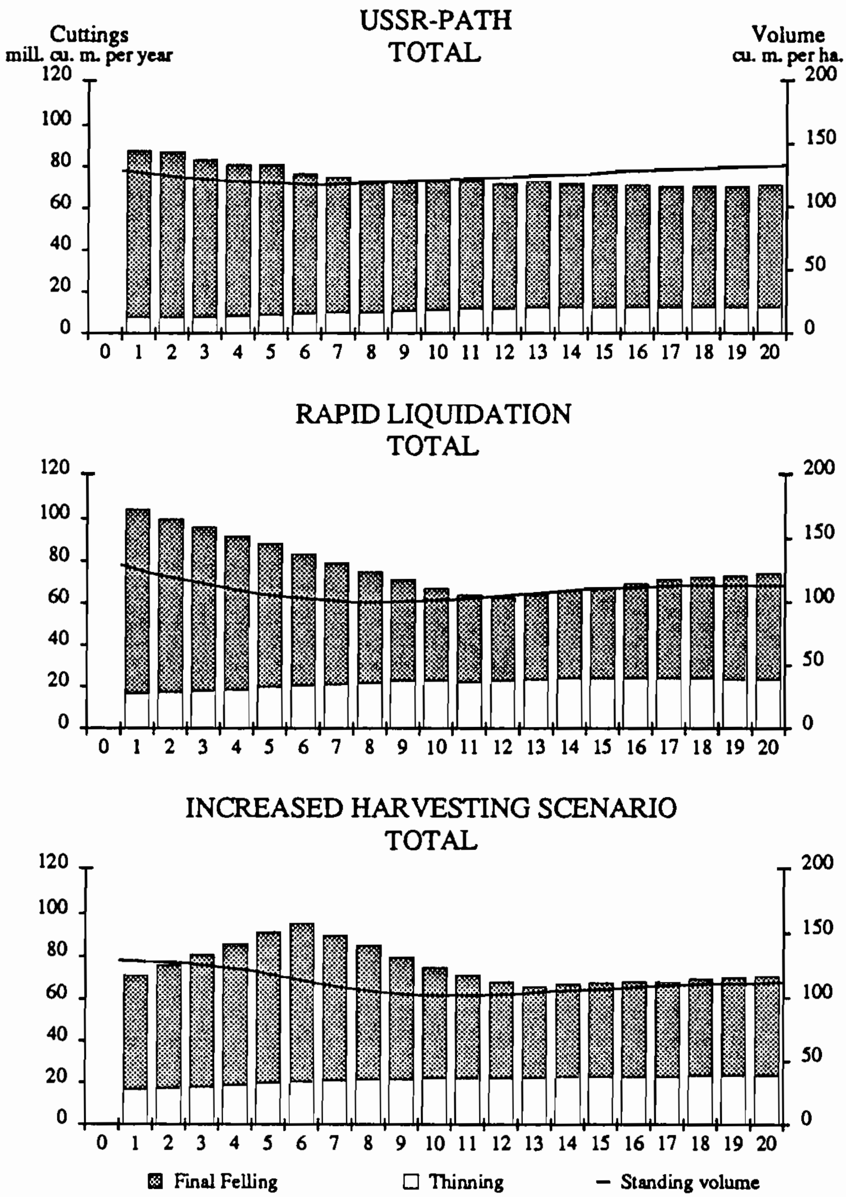

Figure A.60. Projections of total potential harvest and growing stock in the Ural region under the USSR Path Scenario, Rapid Liquidation Scenario, and Increased Harvesting Scenario. Current total fellings are 56.3 million cubic meters o.b.

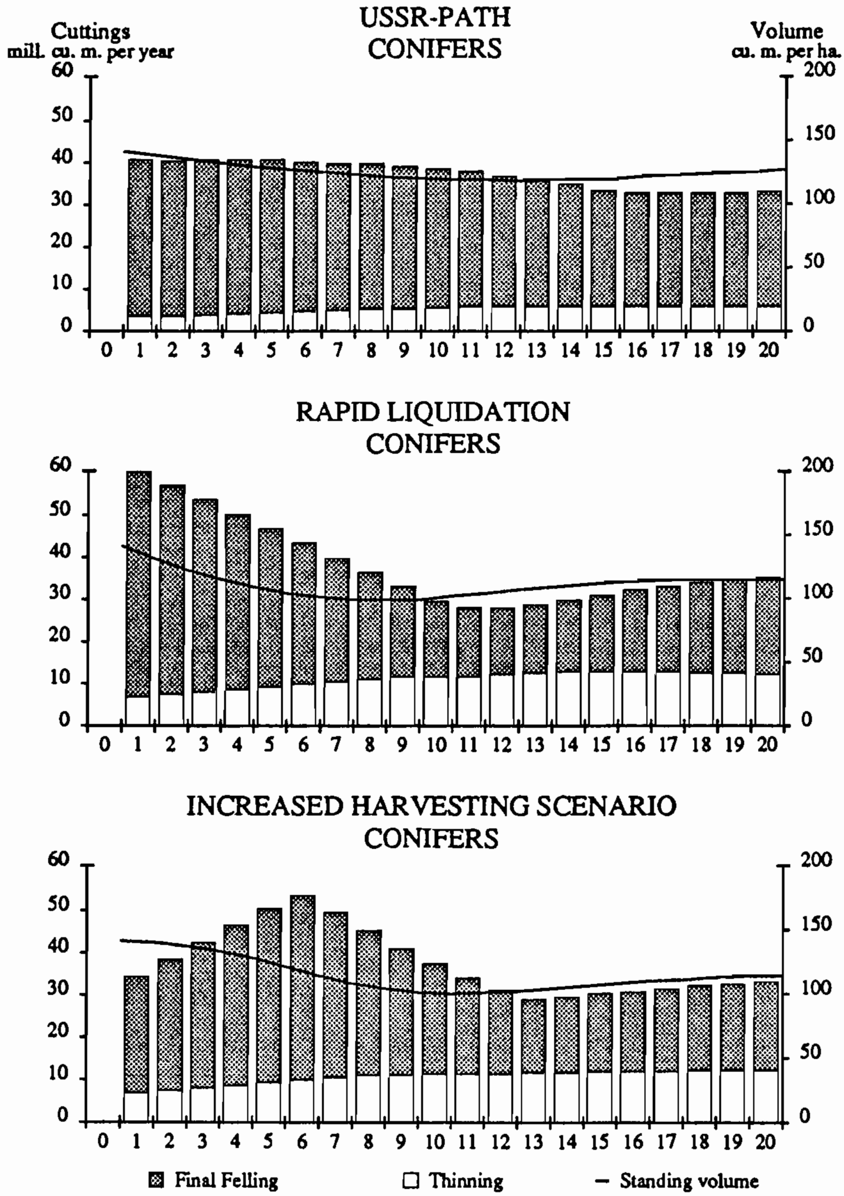

Figure A.61. Projections of potential harvest and growing stock of coniferous species in the Ural region under the USSR Path Scenario, Rapid Liquidation Scenario, and Increased Harvesting Scenario. Current coniferous fellings are 33 million cubic meters o.b.

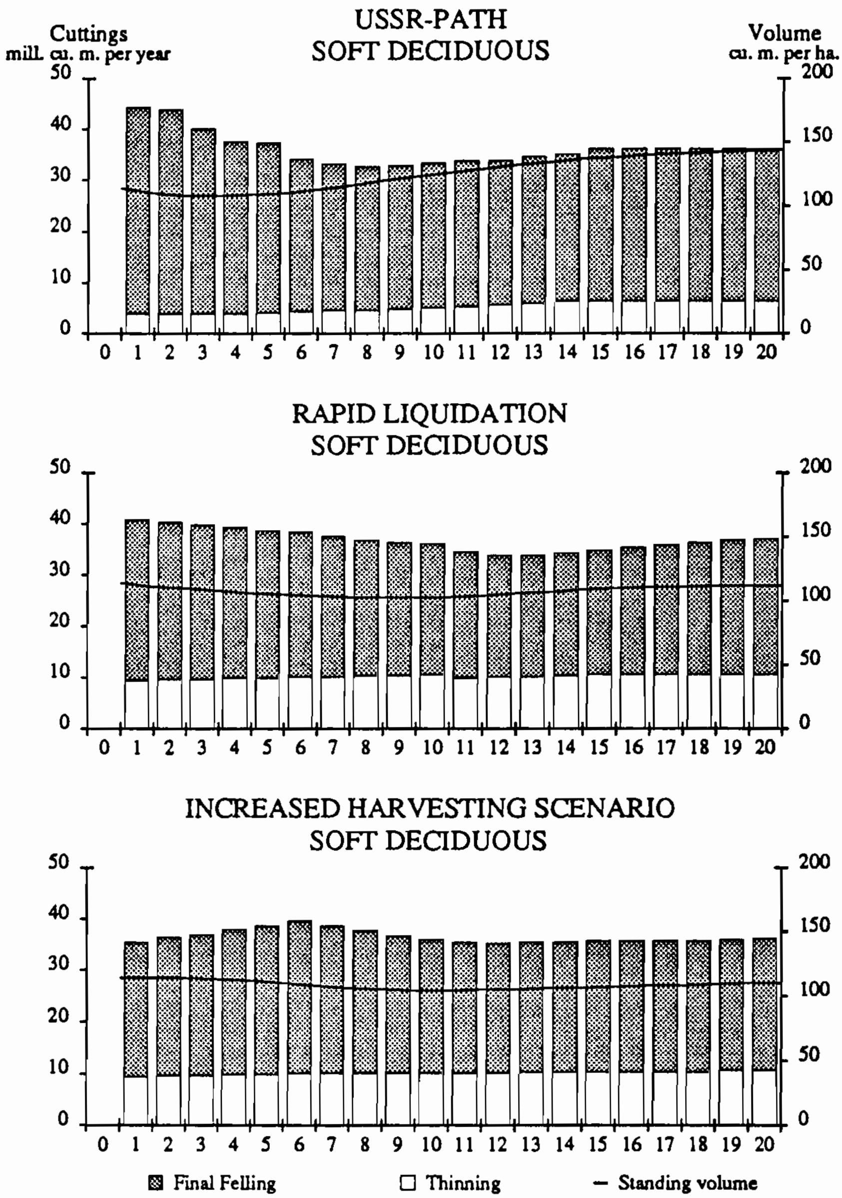

Figure A.62. Projections of potential harvest and growing stock of soft deciduous species in the Ural region under the USSR Path Scenario, Rapid Liquidation Scenario, and Increased Harvesting Scenario. Current soft deciduous fellings are 22.5 million cubic meters o.b.

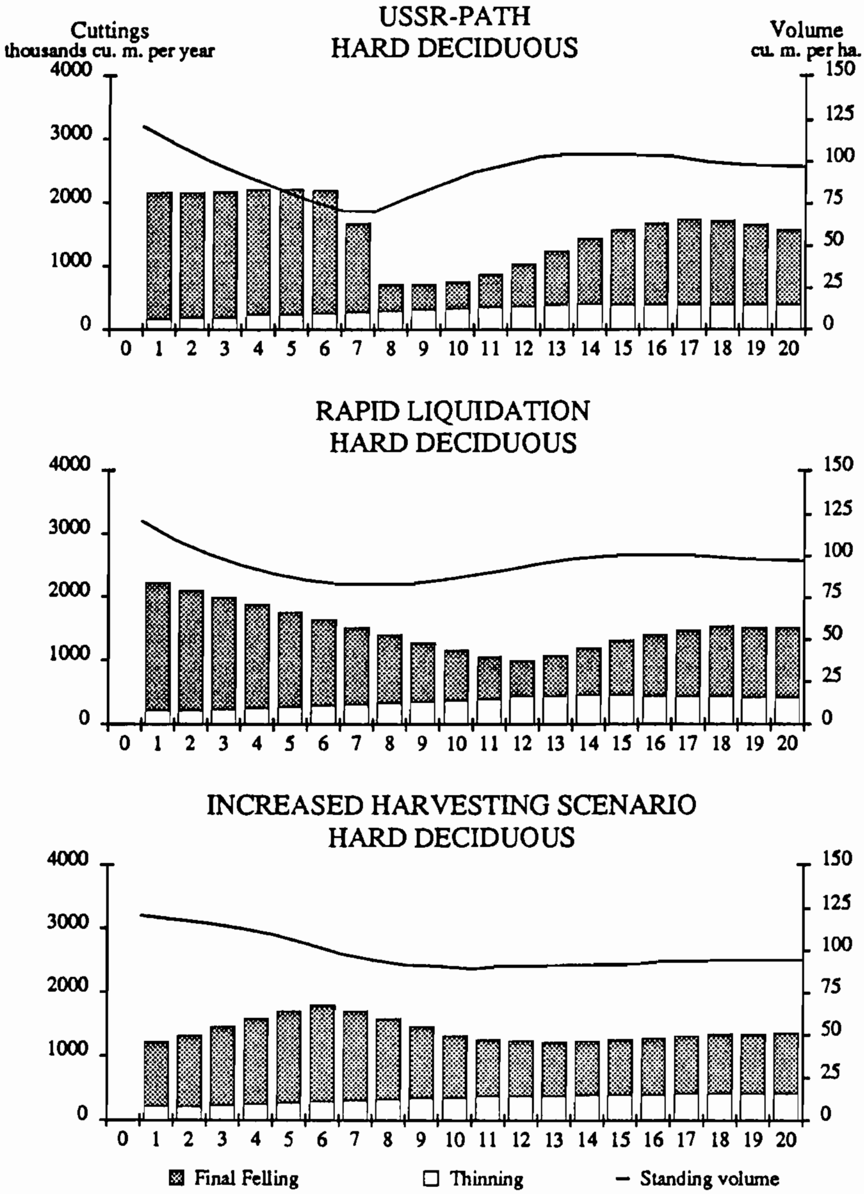

Figure A.63. Projections of potential harvest and growing stock of hard deciduous species in the Ural region under the USSR Path Scenario, Rapid Liquidation Scenario, and Increased Harvesting Scenario. Current hard deciduous fellings are 0.8 million cubic meters o.b.

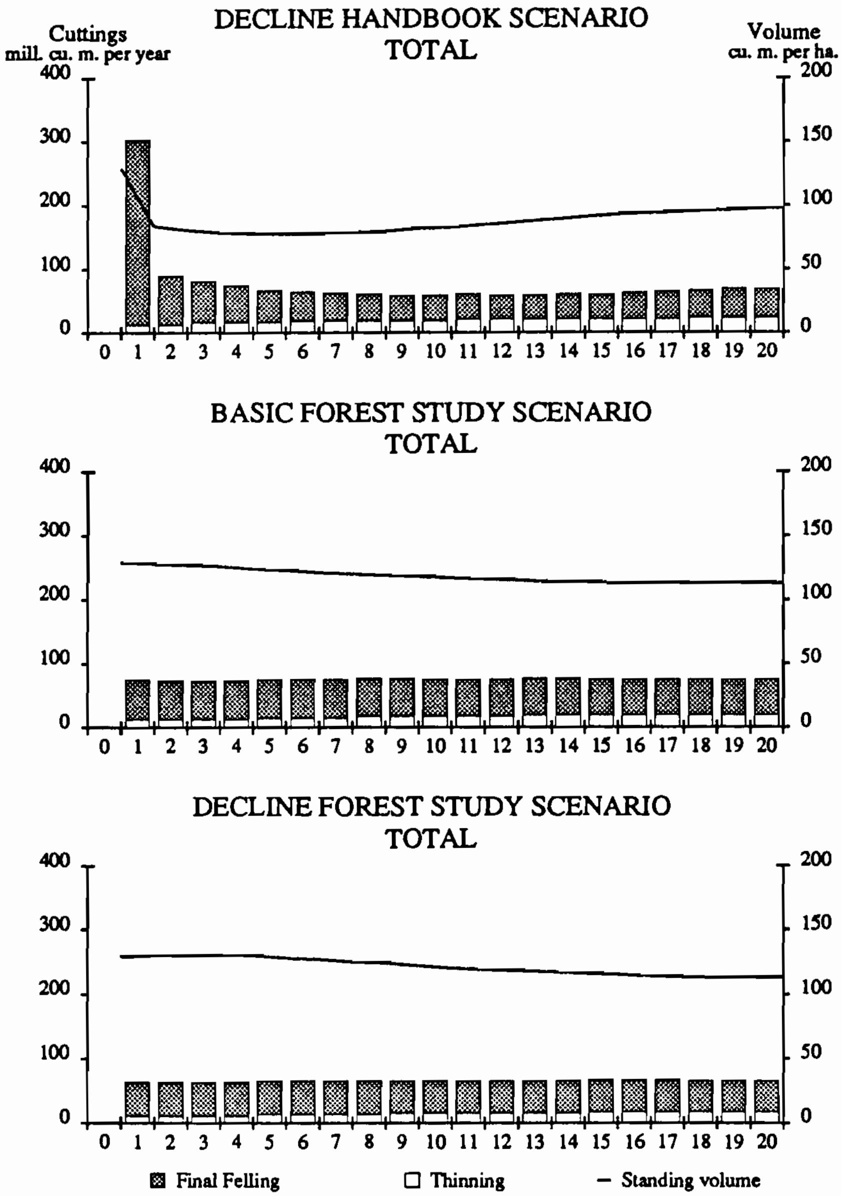

Figure A.64. Projections of total potential harvest and growing stock in the Ural region under the decline scenarios. Current total fellings are 56.3 million cubic meters o.b.

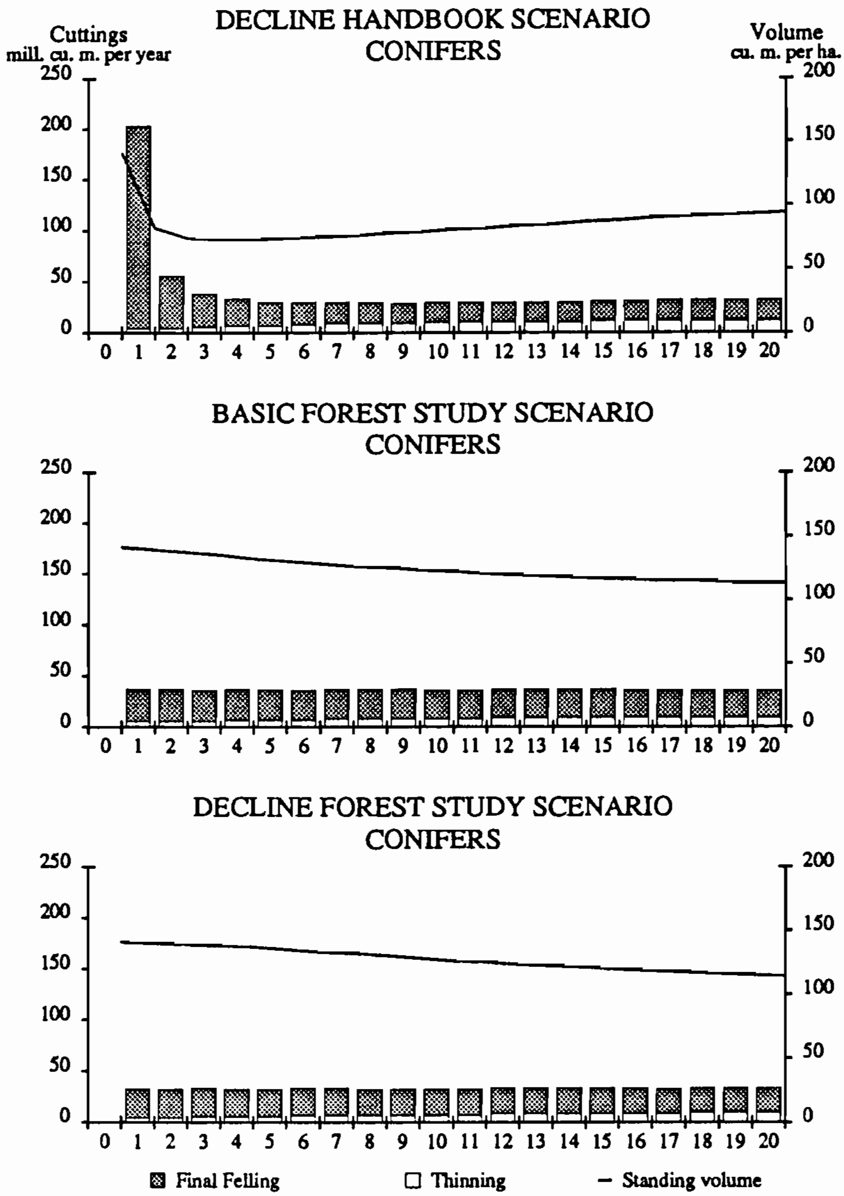

Figure A.65. Projections of potential harvest and growing stock of coniferous species in the Ural region under the decline scenarios. Current coniferous fellings are 33 million cubic meters o.b.

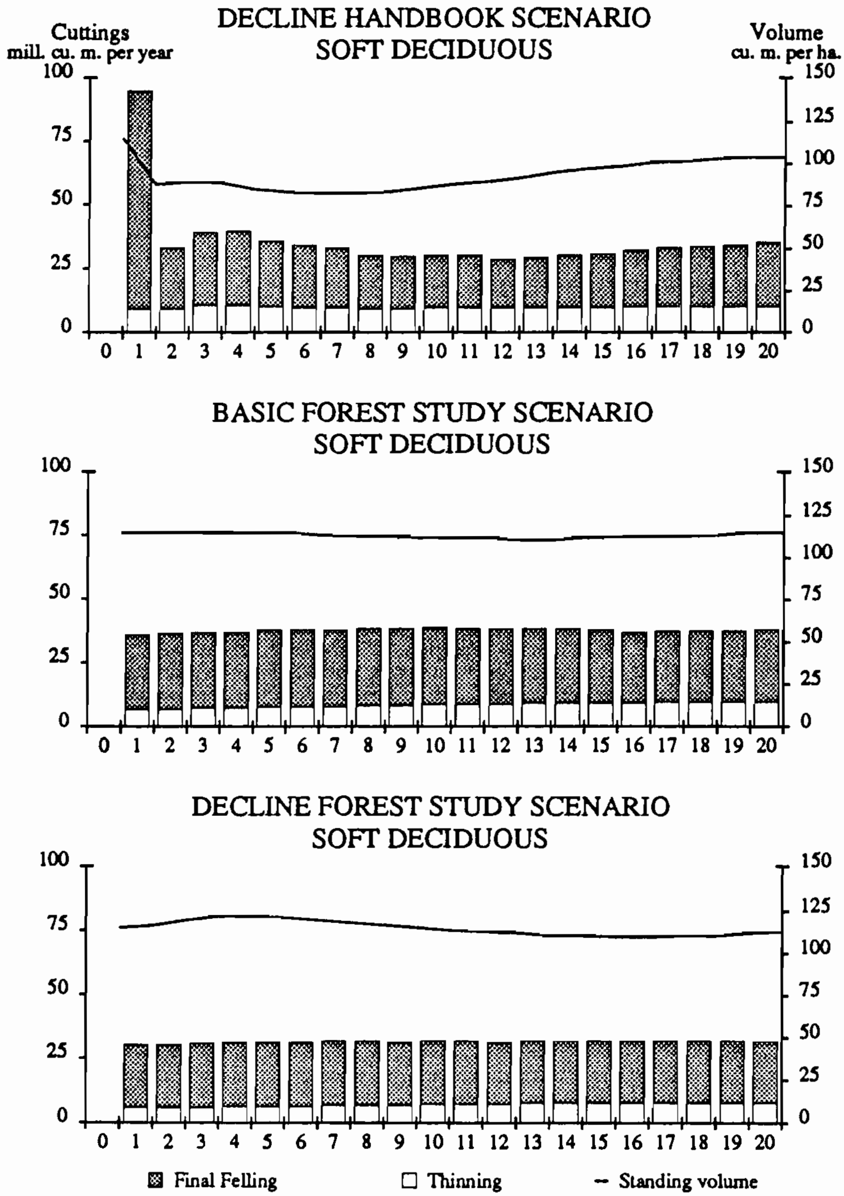

Figure A.66. Projections of potential harvest and growing stock of soft deciduous species in the Ural region under the decline scenarios. Current soft deciduous fellings are 22.5 million cubic meters o.b.

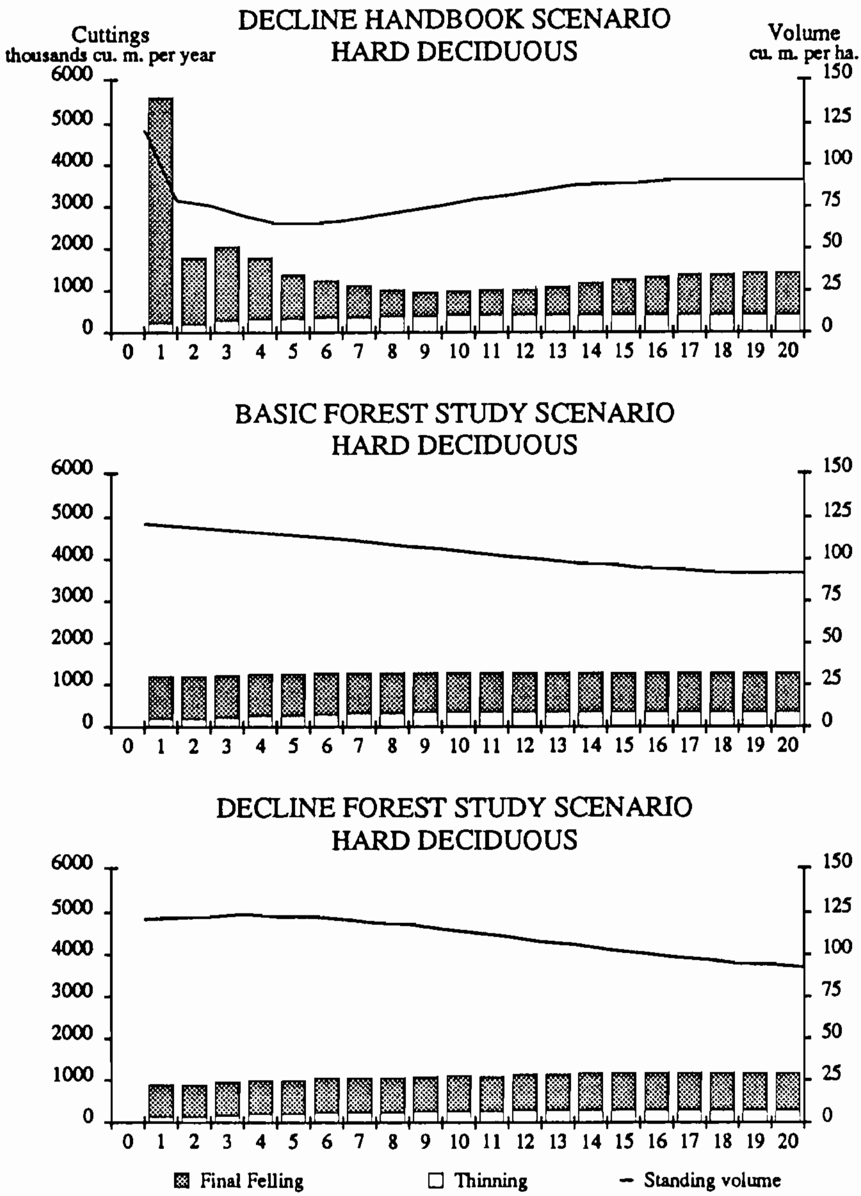

Figure A.67. Projections of potential harvest and growing stock of hard deciduous species in the Ural region under the decline scenarios. Current hard deciduous fellings are 0.8 million cubic meters o.b.

North Caucasian Region (Table A.11 and Figures A.68 to A.75)

The majority of commercial forests are in Forest Group I (the most protected group), with the dominating species group being hard deciduous. There are very large variations in the forest resources of the North Caucasian region. This can be explained by the diversity of ecological zones in the region, which vary from desert to mountain forests. The growing-stock figures are extremely high for most species (an exception is pine which consists of mainly young forests). This is an indication that the resources are underutilized and that most of the forests have functions other than production of commercial wood. The age-class distribution of coniferous species is very uneven. Hard deciduous species show a concentration of forests over 130 years old, and soft deciduous species with a concentration of middle-aged forests.

Basic Scenarios

There is a strong imbalance between the existing structure of the forest resources and a structure generated by full implementation of the handbook silviculture. This is valid for all species groups, but is most evident for coniferous and hard deciduous species.

Under the conditions in the Basic Forest Study Scenario, it is possible to get an even harvesting potential for all species groups. This scenario also gives a stable development of the growing stock throughout the entire simulation period. This scenario's growing stock is much higher in comparison with the Basic Handbook Scenario due to slower liquidation of the overmature forest. The same is valid for the growth rates.

The Basic Forest Study Scenario gives an average total harvest potential of 4.5 million cubic meters over bark per year. The major part comes from the hard deciduous species group (3.4 million cubic meters over bark).

Decline Scenarios

The effects of air pollutants have a moderate impact on the total potential future wood supply in the North Caucasian region. The decline in the total potential is about 0.4 million cubic meters over bark per year (some 8 percent). The potential harvesting patterns and developments of growing stock in the decline scenarios do not deviate much from the basic scenarios. However, the growing-stock level at the end of the simulation period is lower in the Handbook Decline Scenario in comparison with the Basic Handbook Scenario. This is a result of a faster liquidation in the case of decline effects of air pollutants. In the decline situation the total growth rate is reduced by 0.3 cubic meters per hectare per year. The decline in the growth rate is most pronounced in deciduous species.

Summary

As in most of the regions of the European USSR, the North Caucasian region has an imbalance between the current structure of the forest resources and a structure achieved by implementing the handbook silviculture. There is the possibility of shaping an even total harvest potential of 4.5 million cubic meters over bark per year in the North Caucasian region. About 75 percent of the harvesting potential is found in hard deciduous species. About 20 percent of this potential should be harvested as thinnings. The potential harvest level suggested exceeds the current harvest by some 45 percent.

The effects of air pollutants are moderate and cause a decline of the total potential harvest by 0.4 million cubic meters over bark.

Table A.11. North Caucasian region.

Variable	Basic Hand-book	Basic Forest Study	Hand-book Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	228–186	228–248	228–160	228–253
Fellings[b]				
Year 1	18.4	4.6	19.9	4.1
Year 40	4.6	4.5	4.8	4.1
Year 80	5.0	4.5	4.8	4.1
Coniferous				
Growing stock[a]	363–204	363–453	363–142	363–463
Fellings[b]				
Year 1	3.5	0.2	3.5	0.2
Year 40	0.2	0.2	0.2	0.2
Year 80	0.2	0.2	0.2	0.2
Soft deciduous				
Growing stock[a]	135–117	135–138	136–109	136–154
Fellings[b]				
Year 1	2.3	1.0	2.4	0.8
Year 40	1.1	0.9	1.1	0.8
Year 80	1.0	0.9	1.0	0.8
Hard deciduous				
Growing stock[a]	245–206	245–264	245–178	245–266
Fellings[b]				
Year 1	12.6	3.4	14.0	3.1
Year 40	3.3	3.4	3.5	3.1
Year 80	3.8	3.4	3.6	3.1
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	5.9	4.5	6.0	4.1
Coniferous	0.4	0.2	0.4	0.2
Soft deciduous	1.2	0.9	1.1	0.8
Hard deciduous	4.3	3.4	4.5	3.1
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	3.8	3.5	3.7	3.2
Coniferous	3.4	3.5	3.2	3.4
Soft deciduous	3.5	3.0	3.4	2.7
Hard deciduous	3.9	3.6	3.8	3.3
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	228–186	228–248	228–160	228–253
Coniferous	363–204	363–453	363–142	363–463
Soft deciduous	135–117	135–138	136–109	136–154
Hard deciduous	245–206	245–264	245–178	245–266

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

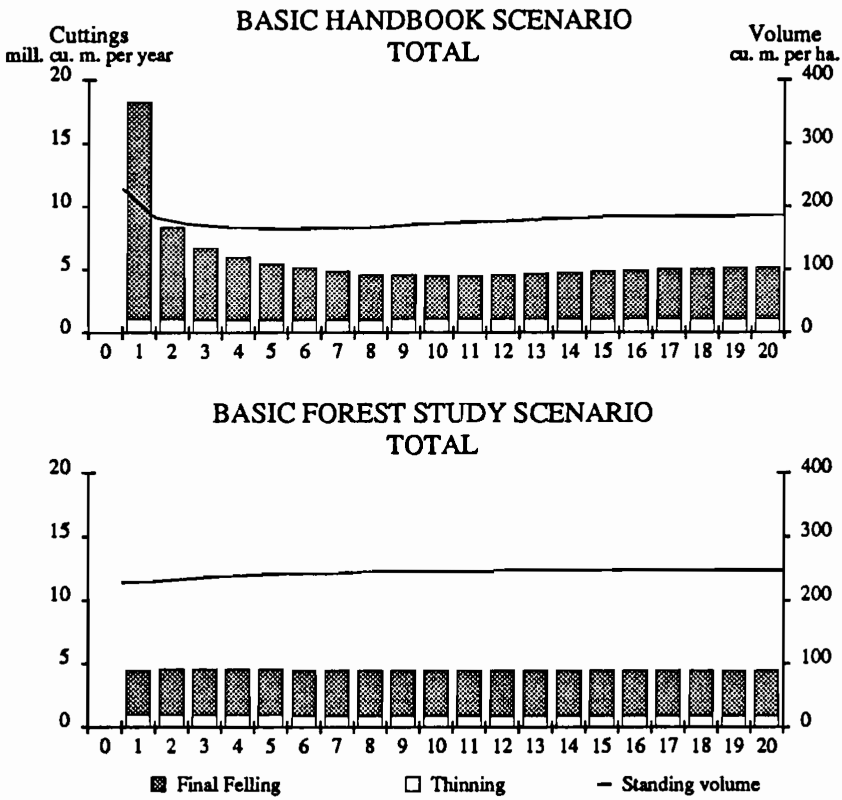

Figure A.68. Projections of total potential harvest and growing stock in the North Caucasian region under the basic scenarios. Current total fellings are 3.1 million cubic meters o.b.

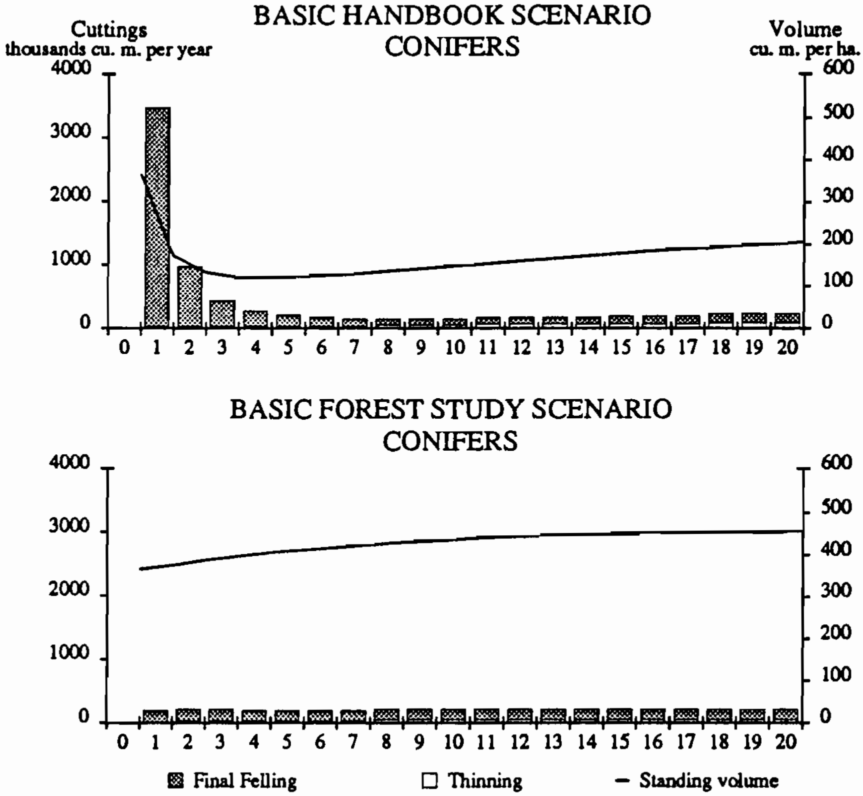

Figure A.69. Projections of potential harvest and growing stock of coniferous species in the North Caucasian region under the basic scenarios. Current coniferous fellings are 0.2 million cubic meters o.b.

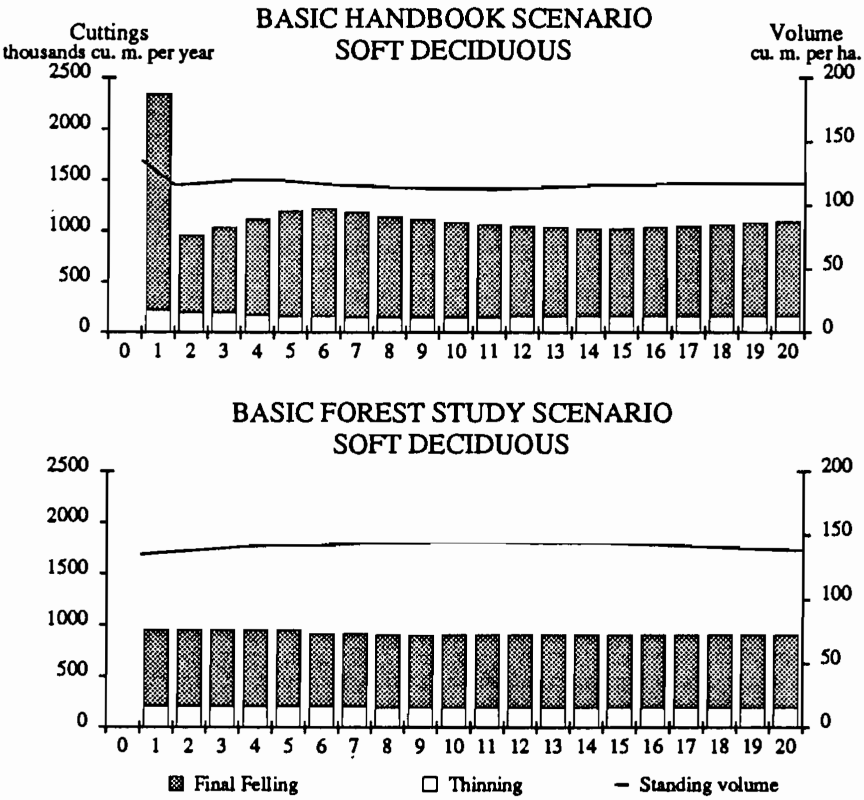

Figure A.70. Projections of potential harvest and growing stock of soft deciduous species in the North Caucasian region under the basic scenarios. Current soft deciduous fellings are 0.8 million cubic meters o.b.

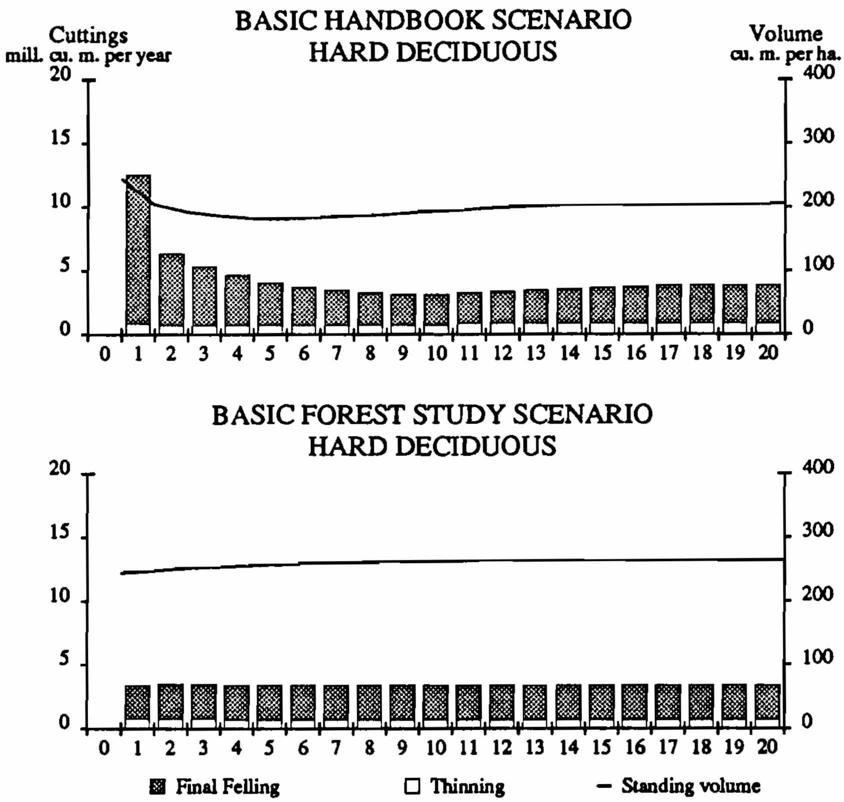

Figure A.71. Projections of potential harvest and growing stock of hard deciduous species in the North Caucasian region under the basic scenarios. Current hard deciduous fellings are 2.1 million cubic meters o.b.

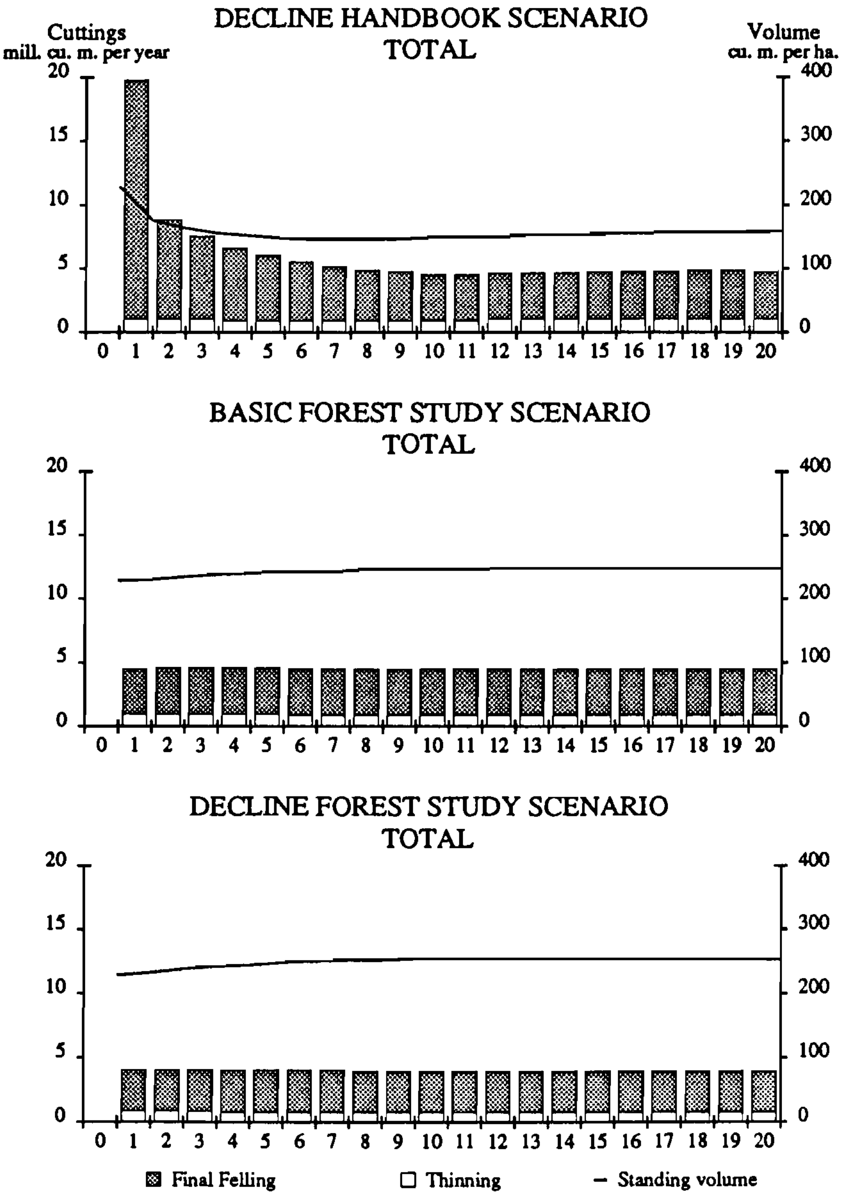

Figure A.72. Projections of total potential harvest and growing stock in the North Caucasian region under the decline scenarios. Current total fellings are 3.1 million cubic meters o.b.

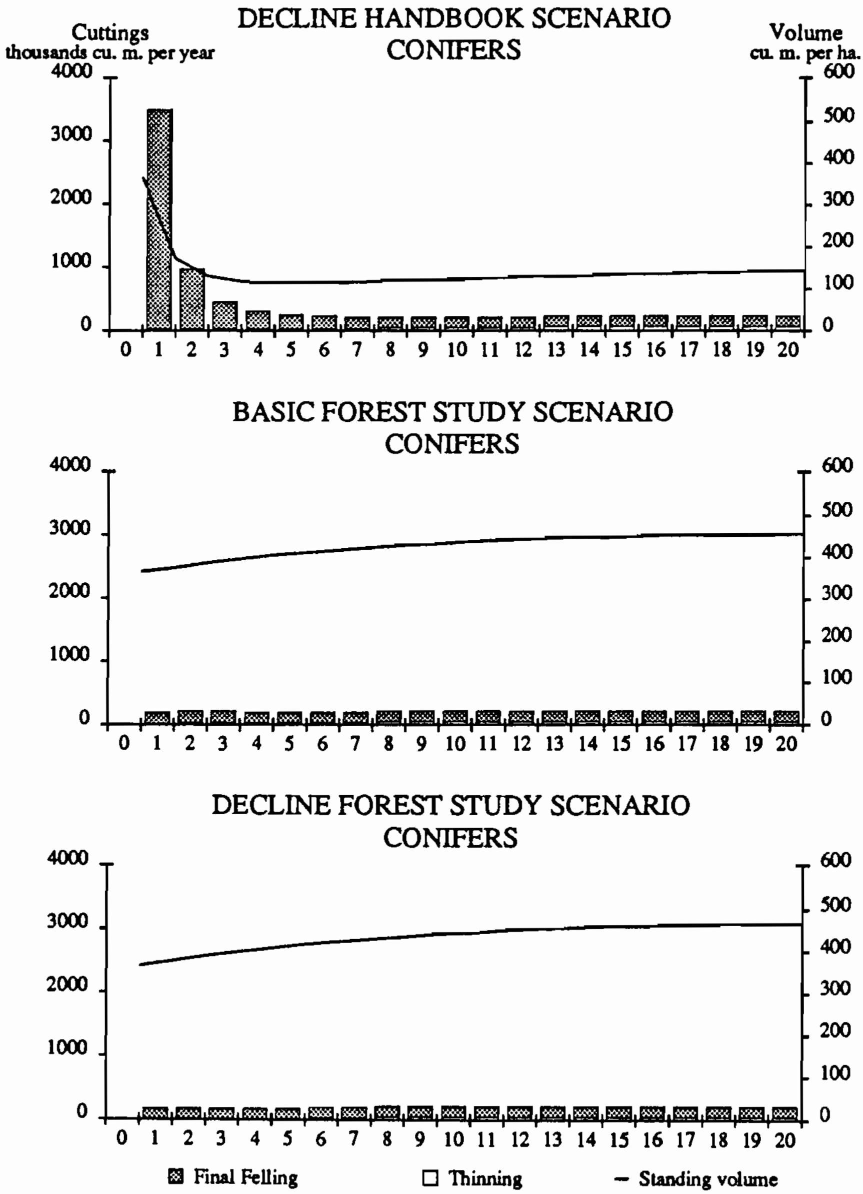

Figure A.73. Projections of potential harvest and growing stock of coniferous species in the North Caucasian region under the decline scenarios. Current coniferous fellings are 0.2 million cubic meters o.b.

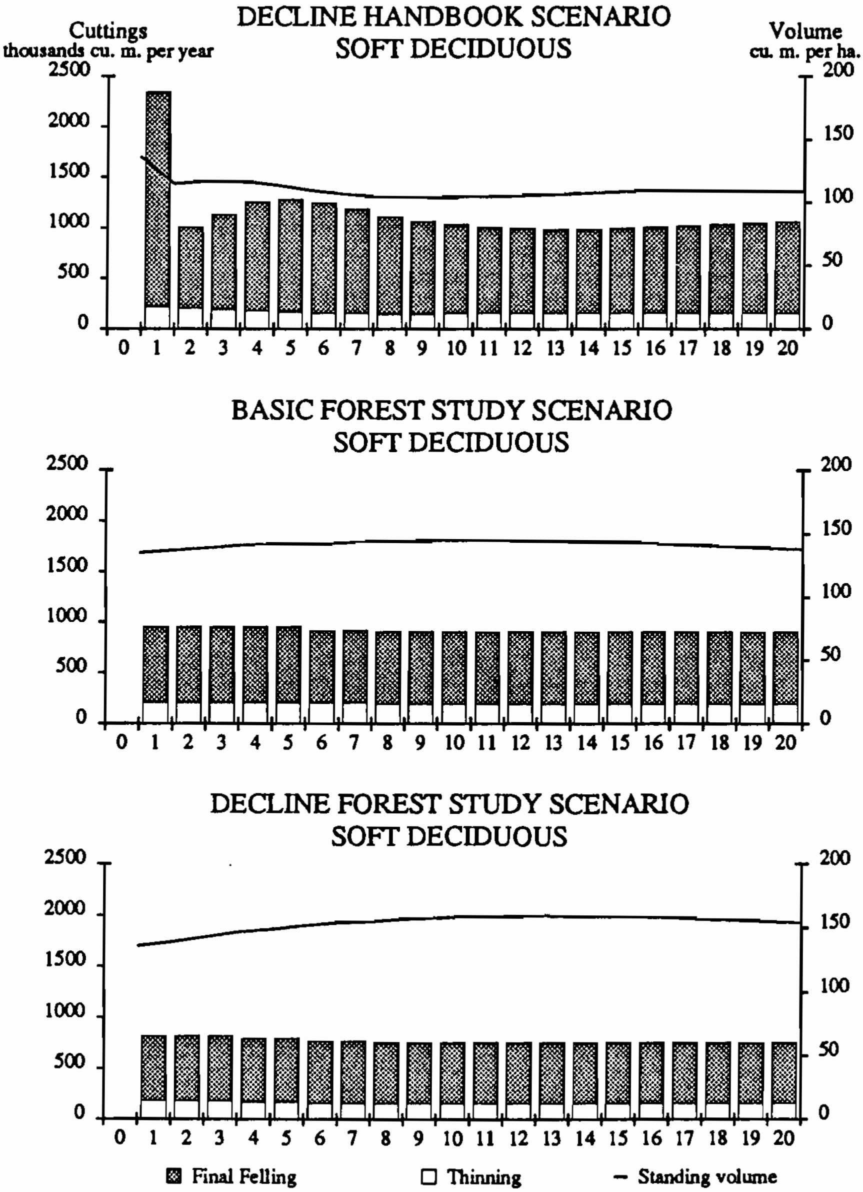

Figure A.74. Projections of potential harvest and growing stock of soft deciduous species in the North Caucasian region under the decline scenarios. Current soft deciduous fellings are 0.8 million cubic meters o.b.

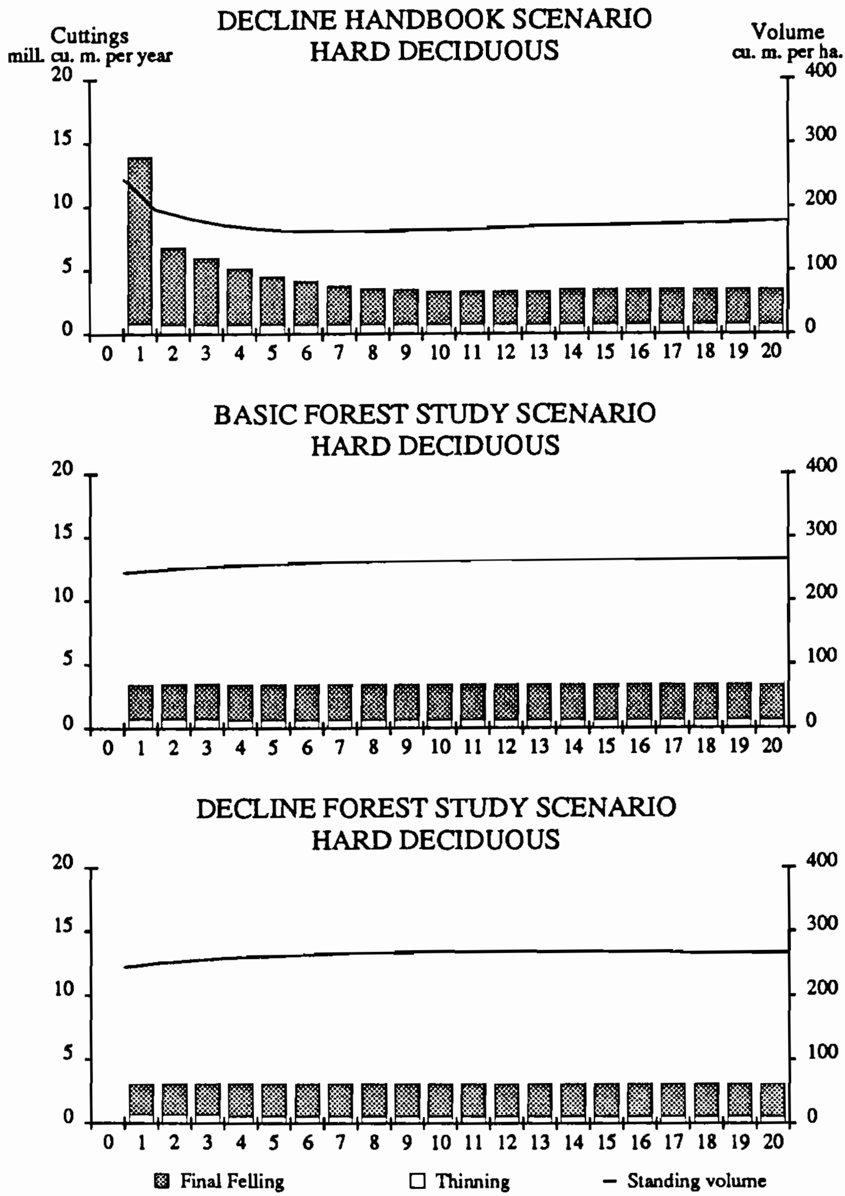

Figure A.75. Projections of potential harvest and growing stock of hard deciduous species in the North Caucasian region under the decline scenarios. Current hard deciduous fellings are 2.1 million cubic meters o.b.

Carpathian Region (Table A.12 and Figures A.76 to A.83)

The Carpathian region is characterized by rather high standing-volume figures and growth rates. Thus, the characteristics of these forest resources are similar to Central European mountainous forests. Most of the commercial forests belong to Forest Group II. Hard deciduous species dominate in this region, followed by coniferous species. The distributions of coniferous forests and hard deciduous species have a concentration of the age classes of 20 to 30 years, but also a large amount of residual overmature stands. The soft deciduous species has the most even age-class distribution of the three groups.

Basic Scenarios

The most evident imbalance between the existing forest structure and a structure derived from a fully implemented handbook silviculture is for hard deciduous species. The other two species groups have a better balance. The Basic Handbook Scenario results in declining growing stocks over the simulation period for all species. This is a result of fast liquidation of overmature forests.

The Basic Forest Study Scenario generates even potential harvesting patterns for the entire simulation period and increasing growing stocks over time. The latter is most pronounced for coniferous species and soft deciduous species. The two basic scenarios give similar growth rates.

The total average potential harvest level is estimated to be 3.1 million cubic meters over bark, with 1.5 million in coniferous species and 1.5 million in hard deciduous species. This is 0.8 million cubic meters less than the current harvest. The largest discrepancy between the current harvest and potential harvest is found in coniferous species. The negative balance is 0.9 million cubic meters per year.

Decline Scenarios

The decline effects of air pollutants are strong in the Carpathian region. This region has one of the highest deposition rates in the European USSR. The decline effects cause a strong imbalance between the existing structure and the handbook structure. This imbalance is not seen in the basic scenarios. In the Forest Study Decline Scenario there are still possibilities of achieving an even potential harvesting level and development of the growing stock of all species groups, although the potential harvesting level is dramatically lower in comparison with the Basic Forest Study Scenario. The air-pollution effects cause a strong decline in the total average harvesting potential: from

3.1 to 1.8 million cubic meters over bark per year. This corresponds to a 40 percent drop in the total harvesting potential. The species groups most affected by the decline are hard deciduous and coniferous species. There also is a corresponding decline in the annual growth rates under decline conditions.

Summary

Under the basic conditions, there is a moderate imbalance between existing forest structure and a structure resulting from a fully implemented handbook silviculture. But the effects of air pollutants cause a strong imbalance between the existing structure and the structure according to handbook silviculture.

Under the basic conditions, the Basic Forest Study Scenario results in a total average harvest potential of 3.1 million cubic meters over bark per year. This is 0.8 million cubic meters less than the current harvest. This indicates an existing overharvesting of the forest resources in the Carpathian region. The largest imbalance between current harvest and the potentially sustainable harvesting levels is evident in coniferous species. About 30 percent of the total harvest potential should be removed in the form of thinnings. The imbalance between current harvest and potential average harvest is further accentuated by the decline caused by air pollutants. In the decline situation the total harvest potential will decline to 1.8 million cubic meters over bark per year. Thus, there is a strong negative air-pollution impact on the future wood supply in the Carpathian region. Under decline conditions, a difference between the current total harvest and potential average sustainable harvest could be more than 2 million cubic meters over bark per year.

Table A.12. Carpathian region.

Variable	Basic Hand-book	Basic Forest Study	Hand-book Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	257–231	257–294	257–154	257–296
Fellings[b]				
Year 1	4.4	2.9	6.8	1.5
Year 40	3.5	3.2	2.8	1.9
Year 80	3.6	3.2	1.5	1.9
Coniferous				
Growing stock[a]	276–273	276–362	276–20	276–363
Fellings[b]				
Year 1	1.6	1.4	2.9	0.9
Year 40	1.8	1.6	1.3	1.0
Year 80	1.8	1.6	0.8	1.0
Soft deciduous				
Growing stock[a]	155–126	155–170	155–103	155–159
Fellings[b]				
Year 1	0.1	0.0	0.2	0.0
Year 40	0.0	0.1	0.0	0.0
Year 80	0.1	0.1	0.0	0.0
Hard deciduous				
Growing stock[a]	247–205	247–251	247–125	247–255
Fellings[b]				
Year 1	2.7	1.5	3.7	0.6
Year 40	1.7	1.5	1.5	0.9
Year 80	1.7	1.5	0.7	0.9
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	3.4	3.1	2.8	1.8
Coniferous	1.7	1.5	1.3	1.0
Soft deciduous	0.1	0.1	0.1	0.0
Hard deciduous	1.6	1.5	1.4	0.8
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	5.5	5.6	3.6	3.4
Coniferous	7.2	7.3	4.9	5.0
Soft deciduous	4.2	4.3	3.0	2.4
Hard deciduous	4.4	4.4	2.8	2.4
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	257–231	257–294	257–154	257–296
Coniferous	276–273	276–362	276–20	276–363
Soft deciduous	155–126	155–170	155–103	155–159
Hard deciduous	247–205	247–251	247–125	247–255

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

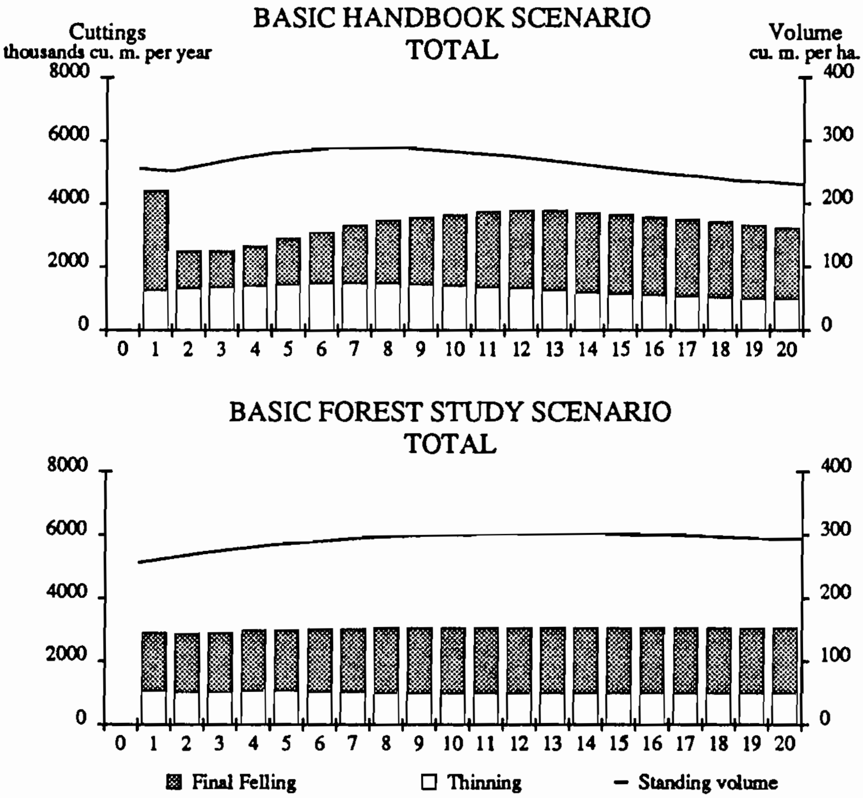

Figure A.76. Projections of total potential harvest and growing stock in the Carpathian region under the basic scenarios. Current total fellings are 4.0 million cubic meters o.b.

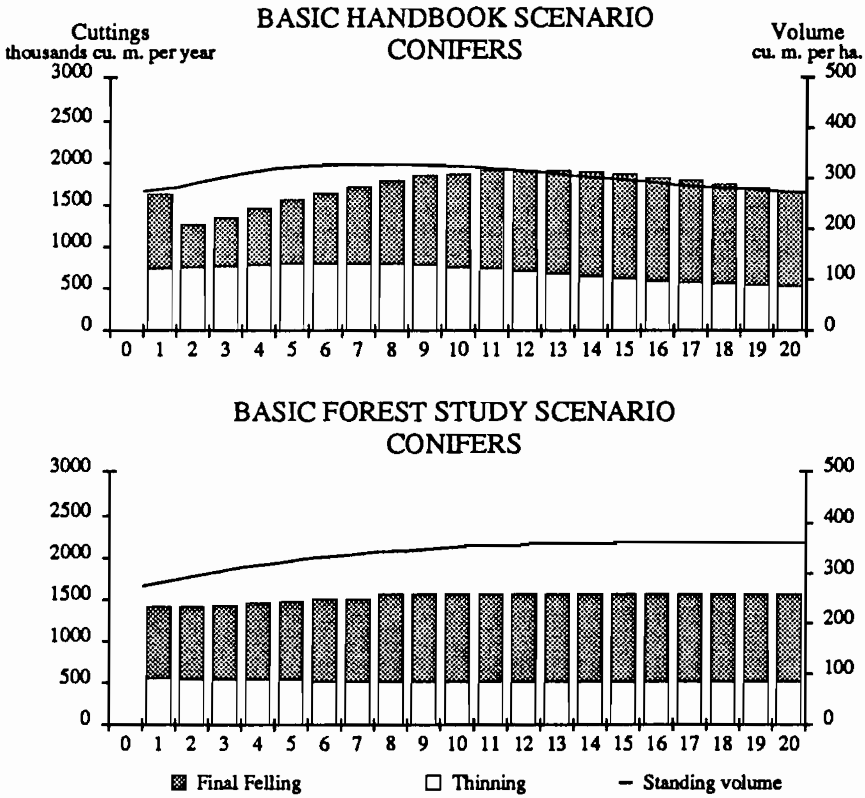

Figure A.77. Projections of potential harvest and growing stock of coniferous species in the Carpathian region under the basic scenarios. Current coniferous fellings are 2.4 million cubic meters o.b.

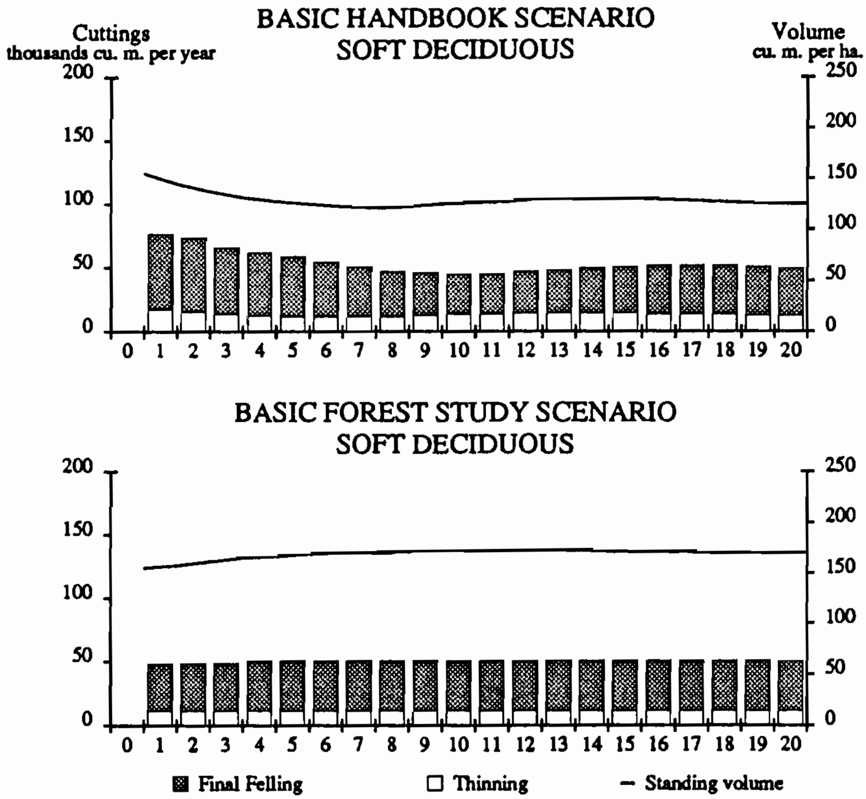

Figure A.78. Projections of potential harvest and growing stock of soft deciduous species in the Carpathian region under the basic scenarios. Current soft deciduous fellings are 0.1 million cubic meters o.b.

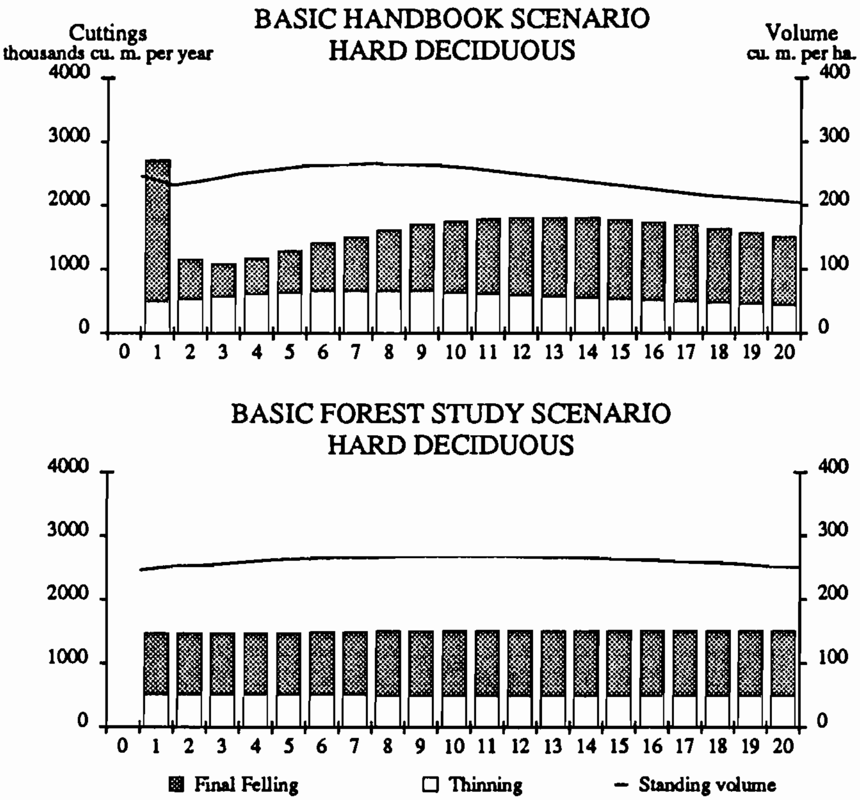

Figure A.79. Projections of potential harvest and growing stock of hard deciduous species in the Carpathian region under the basic scenarios. Current hard deciduous fellings are 1.5 million cubic meters o.b.

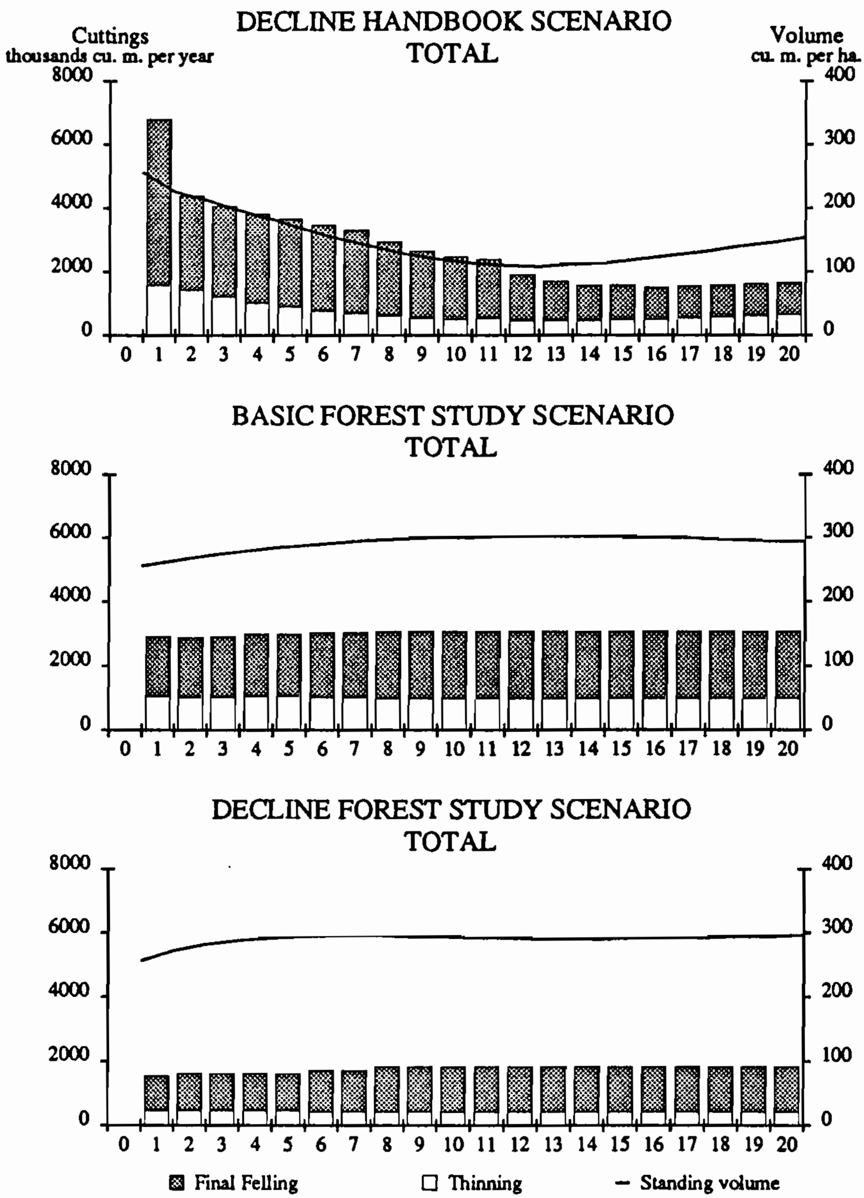

Figure A.80. Projections of total potential harvest and growing stock in the Carpathian region under the decline scenarios. Current total fellings are 4.0 million cubic meters o.b.

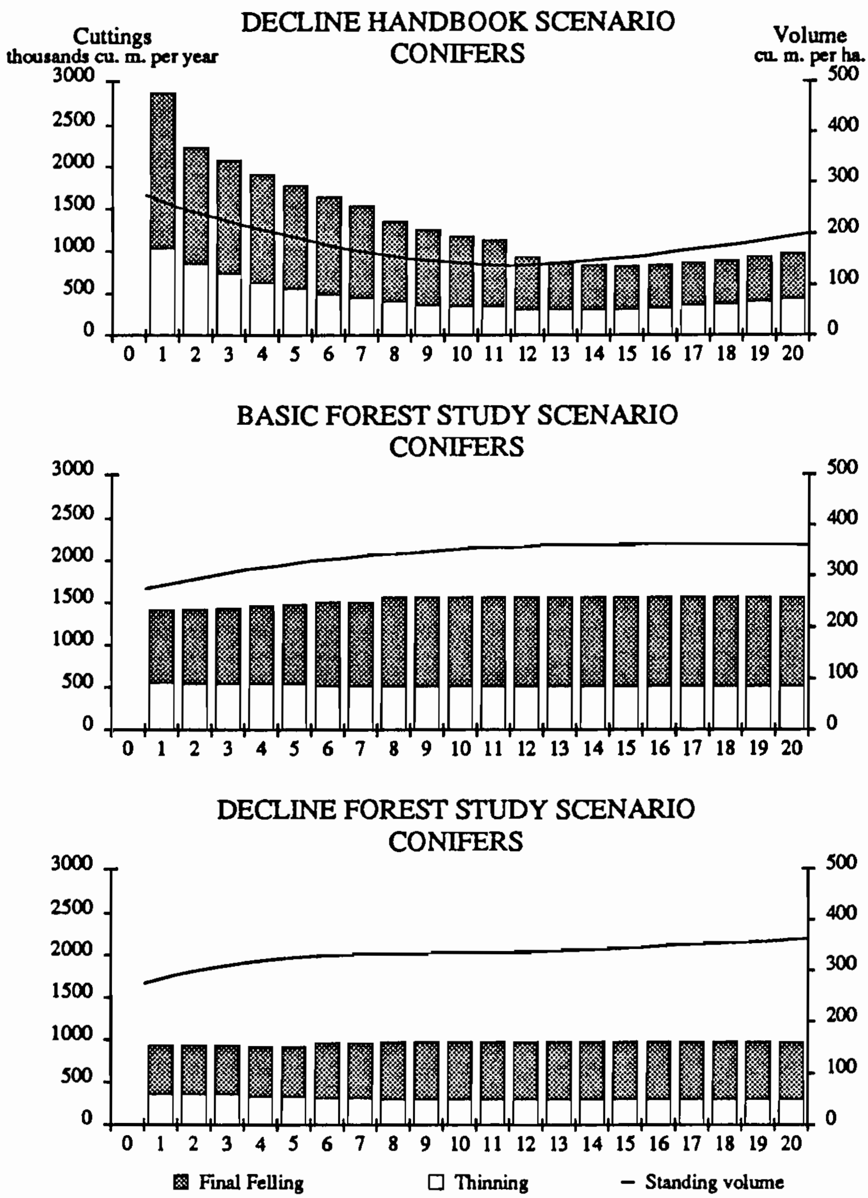

Figure A.81. Projections of potential harvest and growing stock of coniferous species in the Carpathian region under the decline scenarios. Current coniferous fellings are 2.4 million cubic meters o.b.

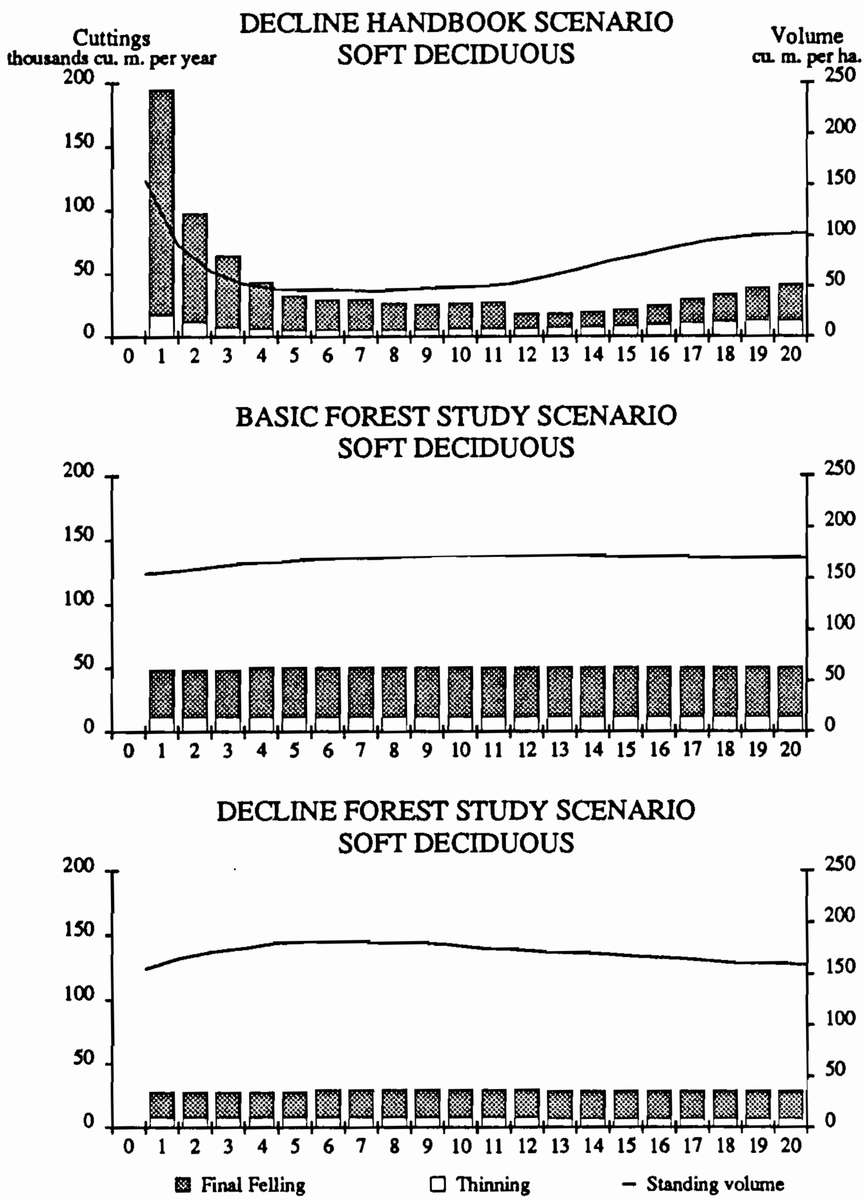

Figure A.82. Projections of potential harvest and growing stock of soft deciduous species in the Carpathian region under the decline scenarios. Current soft deciduous fellings are 0.1 million cubic meters o.b.

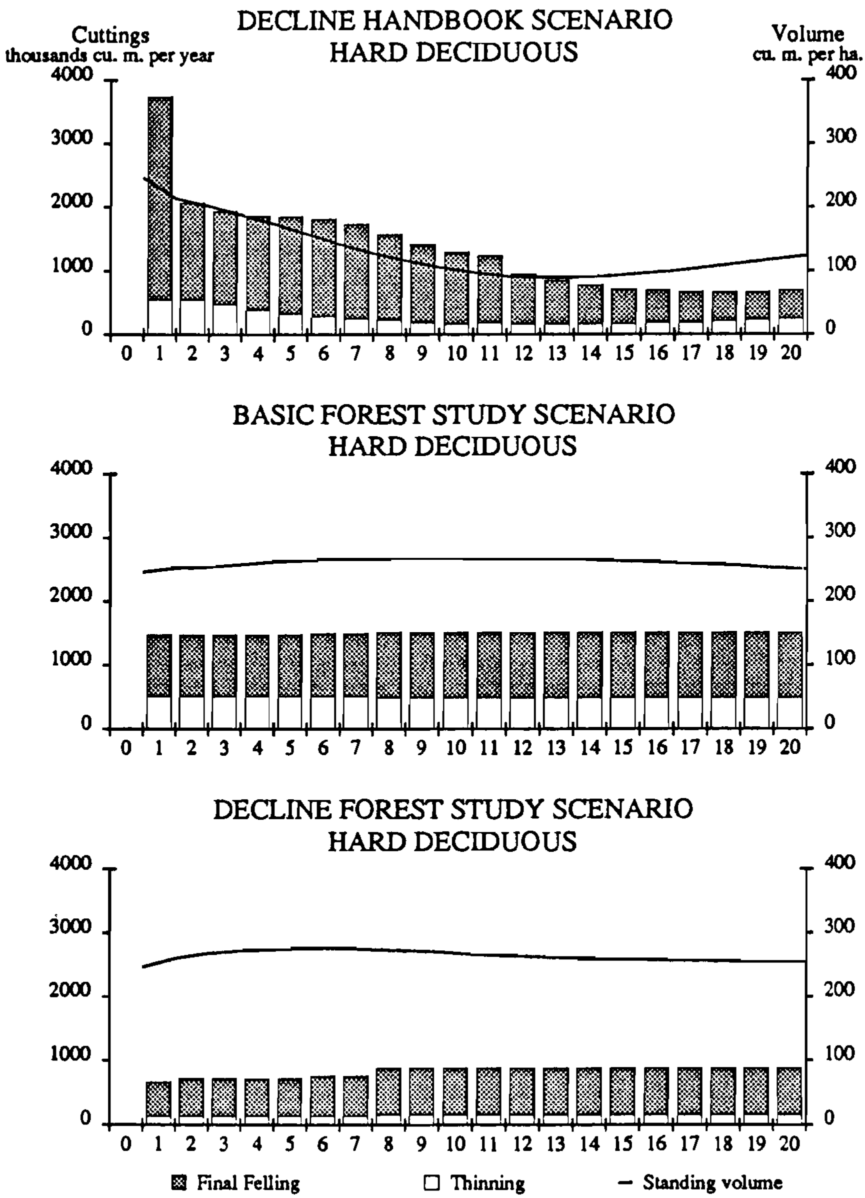

Figure A.83. Projections of potential harvest and growing stock of hard deciduous species in the Carpathian region under the decline scenarios. Current hard deciduous fellings are 1.5 million cubic meters o.b.

Polesye Region (Table A.13 and Figures A.84 to A.91)

The Polesye region is dominated by coniferous forests (about 65 percent of the commercial forest area). The remaining forests are roughly made up of equal parts of soft and hard deciduous species. The majority of the forest resources are within Forest Group II (about 80 percent).

The existing age-class distribution is primarily in the middle-aged classes for all species groups. The current growing stock and growth rates show normal and expected levels in this region.

Basic Scenarios

The two basic scenarios show similar development concerning the potential harvesting level for all species groups. During the first 40 years of the simulation period, there is a steady increase in the harvesting potential over time. In the Basic Forest Study Scenario the harvesting potential is stabilized, and levels out after 40 years. After the same period of time in the Basic Handbook Scenario, the potential harvesting level starts to decline for coniferous and soft deciduous species. In the Basic Handbook Scenario, there is an increase in the harvesting potential of hard deciduous species throughout the entire simulation period.

In the Basic Handbook Scenario there is a slight decline over time in the growing stock for all species groups. The growing stock is slightly increasing over time in the Basic Forest Study Scenario for all species groups. The growth rates are very similar in the two basic scenarios.

The increased harvesting potential over time in the basic scenarios (with no harvest peaks in the beginning of the simulation) is a result of the current lack of mature and overmature forests in the Polesye region.

Decline Scenarios

There are significant air-pollution effects in the Polesye region. Because of these decline effects there are no possibilities of increasing the harvesting potential over time to the same extent as in the basic scenarios. The total average harvesting potential will decrease by 1 million cubic meters per year under these pollution conditions. That corresponds to a 15 percent decline of the total average harvesting potential.

With regard to the wood supply, all species groups are affected by air pollutants to the same extent. The total growth rate is reduced by 0.5 million cubic meters per hectare per year by the decline.

Summary

The lack of mature and overmature species characterizes the forests of the Polesye region. Under the basic conditions, this results in an increased harvesting potential over time. Thus, there are no harvesting peaks indicating an imbalance between the existing structure and a structure imposed by the handbook silviculture. The total average harvesting potential is 7.7 million cubic meters over bark per year under the basic conditions. About 25 percent of this potential should be harvested as thinnings. The majority of the potential harvest is coniferous (5.1 million cubic meters or 65 percent). There is rather a good balance between the total potential harvest and the current harvest. The total current felling is 6.3 million cubic meters over bark per year. However, the potential harvest in coniferous species is 5.1 million cubic meters over bark and the current harvest is 3.5 million. This indicates slight expansion possibilities. Most of this expansion is removed in the form of thinnings.

The decline effects of air pollutants are significant in the Polesye region. The total average harvesting potential is reduced by 15 percent or 1 million cubic meters over bark per year due to air-pollution decline.

Table A.13. Polesye region.

Variable	Basic Handbook	Basic Forest Study	Handbook Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	152–157	152–205	152–146	152–208
Fellings[b]				
Year 1	4.7	5.1	5.3	4.8
Year 40	10.3	8.3	9.8	7.0
Year 80	8.6	8.3	6.8	7.0
Coniferous				
Growing stock[a]	166–159	166–224	166–151	166–232
Fellings[b]				
Year 1	3.3	3.8	3.6	3.5
Year 40	7.1	5.5	7.1	4.8
Year 80	5.8	5.5	4.7	4.8
Soft deciduous				
Growing stock[a]	111–153	111–166	111–138	111–153
Fellings[b]				
Year 1	0.7	0.7	0.8	0.7
Year 40	2.2	1.8	1.6	1.4
Year 80	1.6	1.8	1.3	1.4
Hard deciduous				
Growing stock[a]	147–152	147–178	147–136	147–183
Fellings[b]				
Year 1	0.7	0.6	0.9	0.6
Year 40	1.0	1.0	1.1	0.8
Year 80	1.2	1.0	0.8	0.8
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	8.6	7.7	8.2	6.7
Coniferous	5.9	5.1	5.6	4.6
Soft deciduous	1.7	1.6	1.6	1.3
Hard deciduous	1.0	1.0	1.0	0.8
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	4.4	4.4	4.1	3.9
Coniferous	4.6	4.6	4.3	4.2
Soft deciduous	4.7	4.6	4.2	3.7
Hard deciduous	3.3	3.4	3.1	3.0
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	152–157	152–205	152–146	152–208
Coniferous	166–159	166–224	166–151	166–232
Soft deciduous	111–153	111–166	111–138	111–153
Hard deciduous	147–152	147–178	147–136	147–183

[a] In m^3 o.b. ha^{-1}; yr0–yr100. [b] In mill. m^3 o.b. yr^{-1}. [c] Average for the simulations over 100 years.

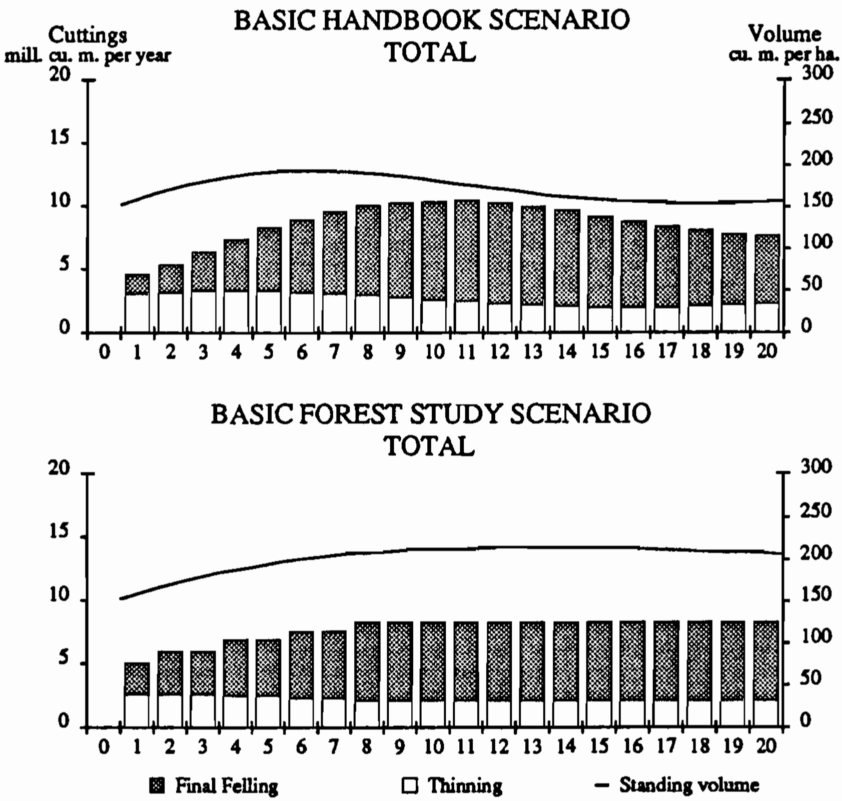

Figure A.84. Projections of total potential harvest and growing stock in the Polesye region under the basic scenarios. Current total fellings are 6.3 million cubic meters o.b.

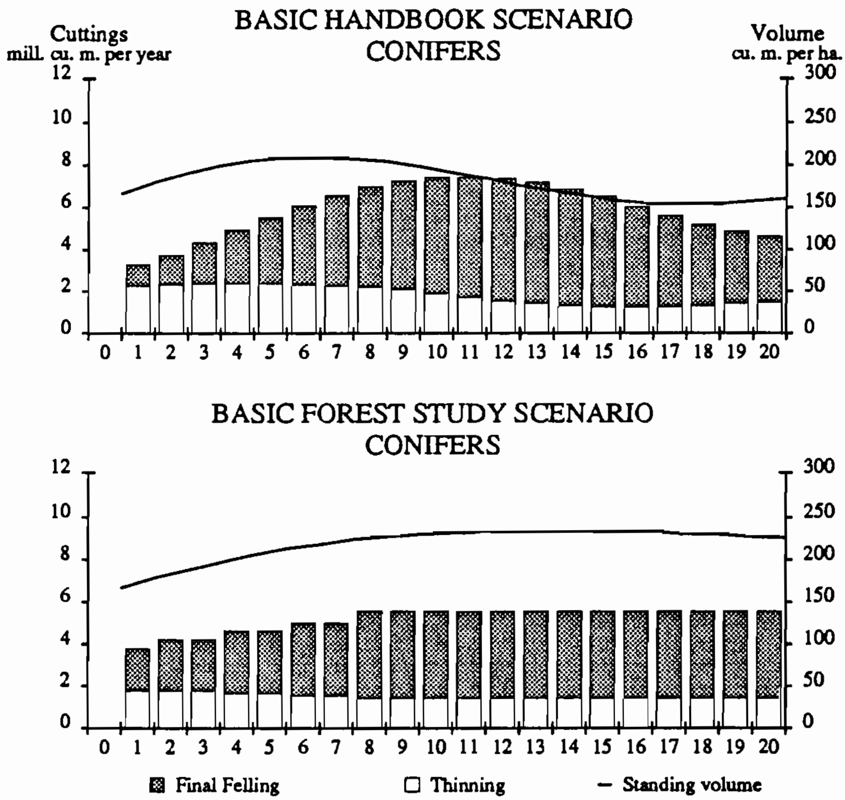

Figure A.85. Projections of potential harvest and growing stock of coniferous species in the Polesye region under the basic scenarios. Current coniferous fellings are 3.5 million cubic meters o.b.

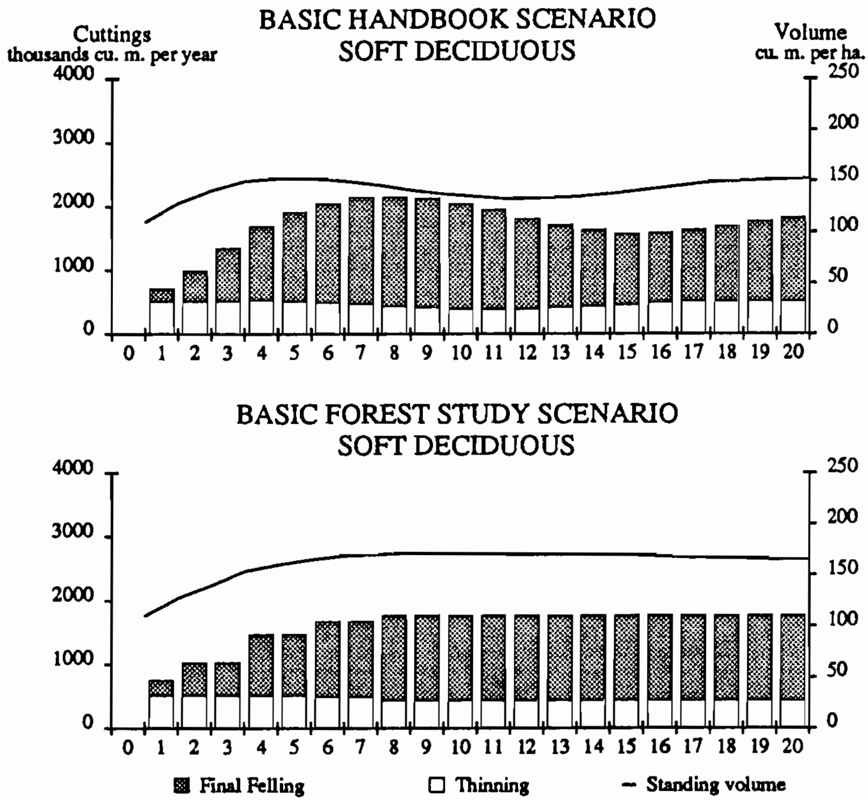

Figure A.86. Projections of potential harvest and growing stock of soft deciduous species in the Polesye region under the basic scenarios. Current soft deciduous fellings are 1.7 million cubic meters o.b.

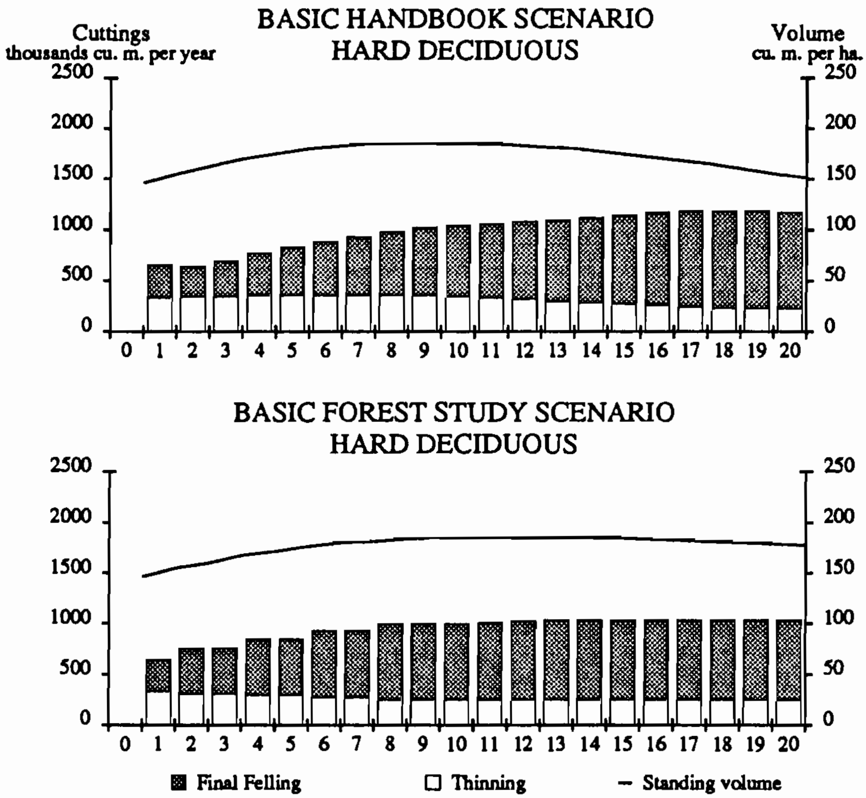

Figure A.87. Projections of potential harvest and growing stock of hard deciduous species in the Polesye region under the basic scenarios. Current hard deciduous fellings are 1.1 million cubic meters o.b.

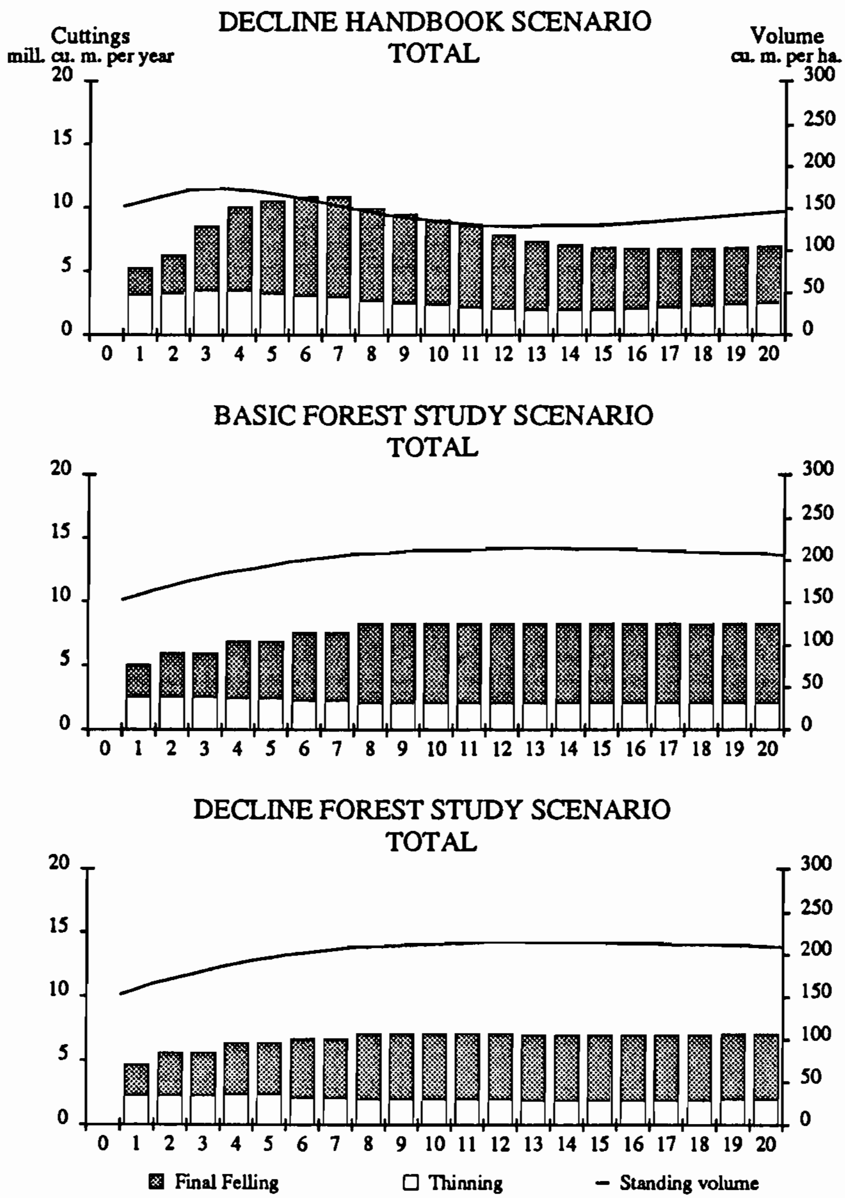

Figure A.88. Projections of total potential harvest and growing stock in the Polesye region under the decline scenarios. Current total fellings are 6.3 million cubic meters o.b.

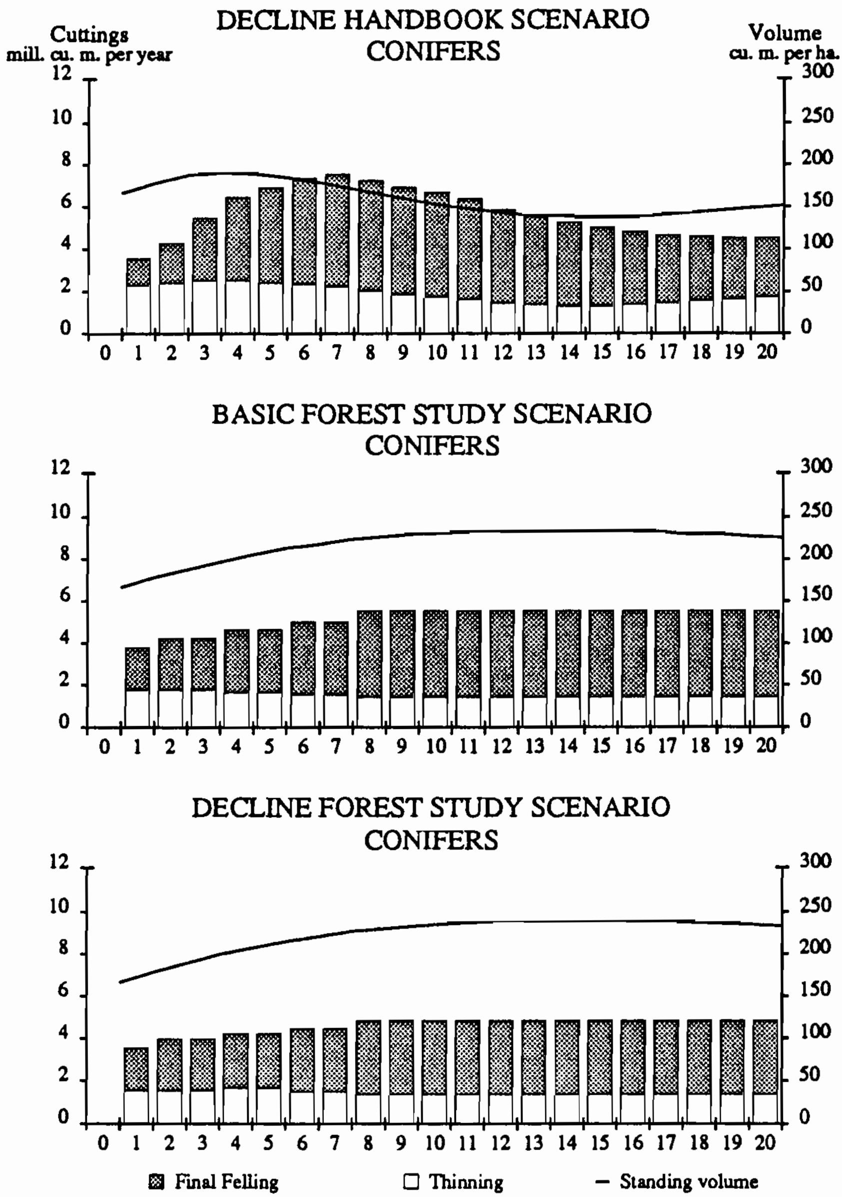

Figure A.89. Projections of potential harvest and growing stock of coniferous species in the Polesye region under the decline scenarios. Current coniferous fellings are 3.5 million cubic meters o.b.

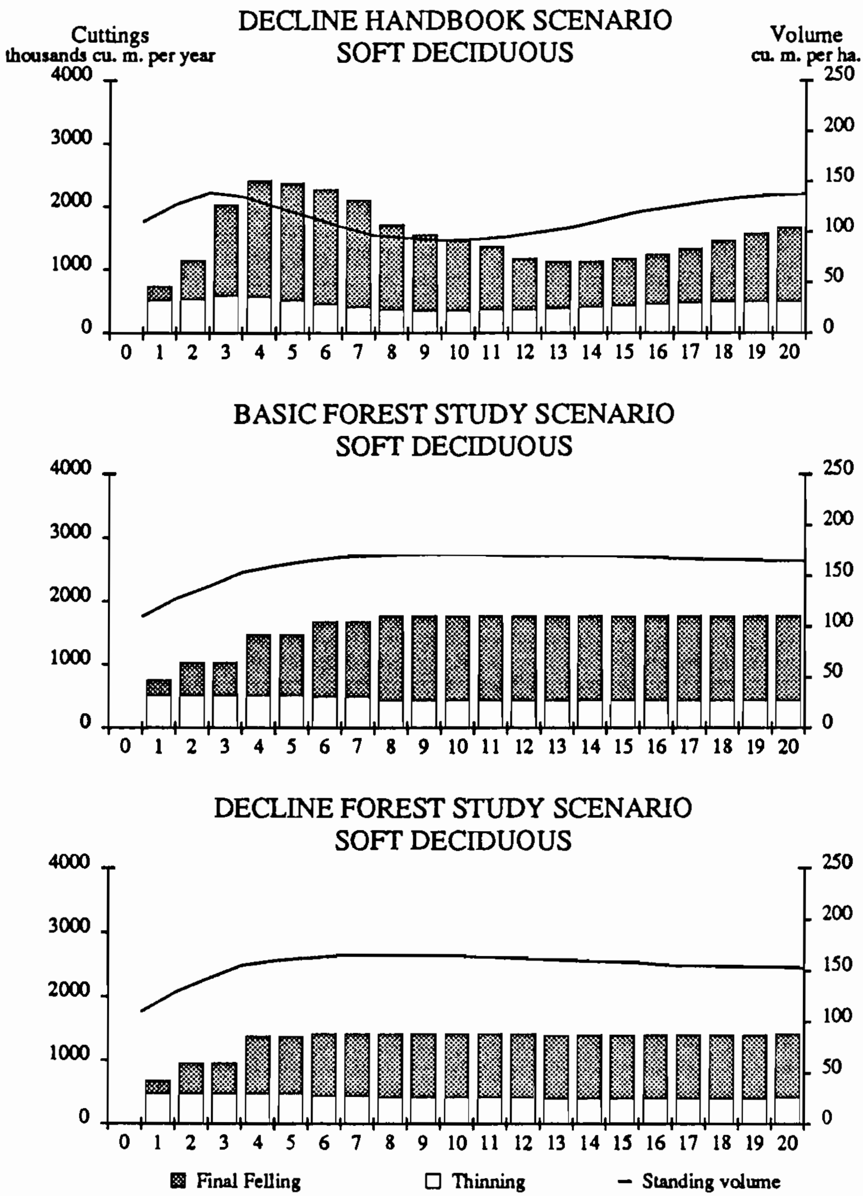

Figure A.90. Projections of potential harvest and growing stock of soft deciduous species in the Polesye region under the decline scenarios. Current soft deciduous fellings are 1.7 million cubic meters o.b.

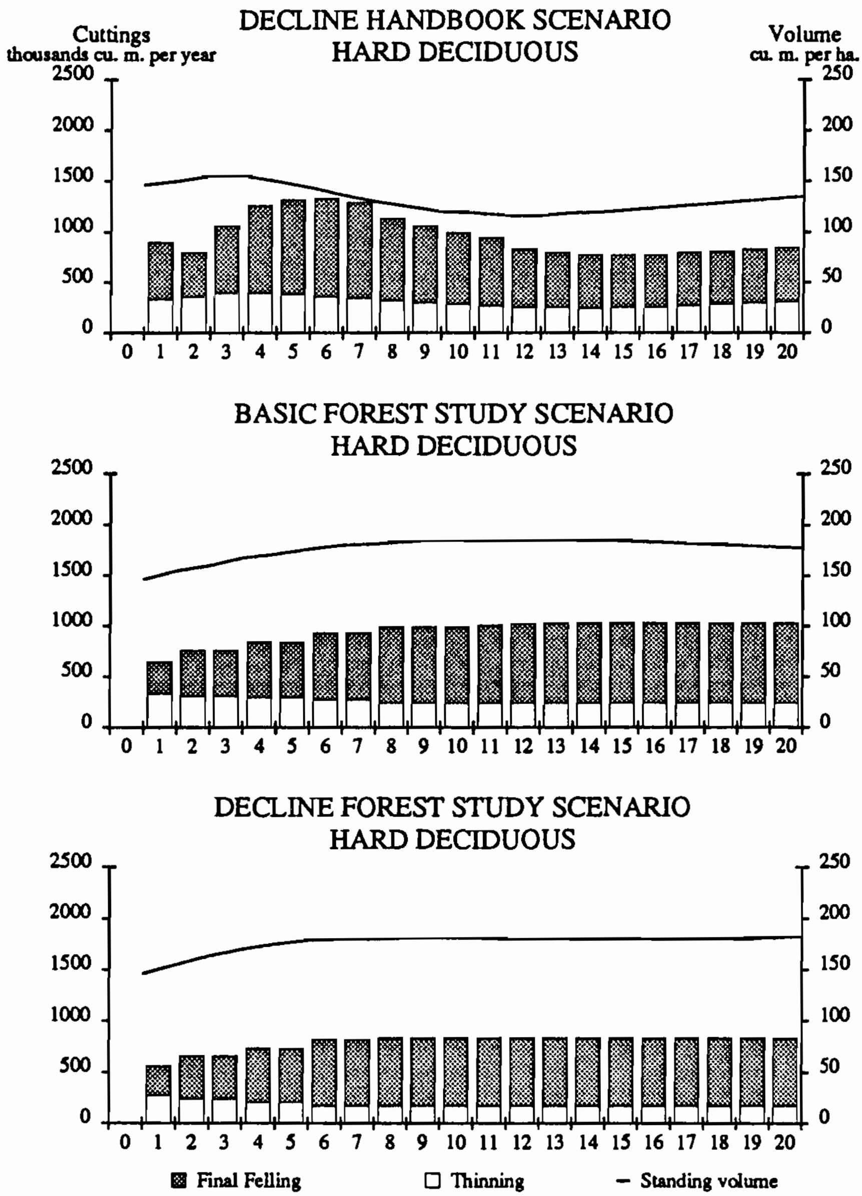

Figure A.91. Projections of potential harvest and growing stock of hard deciduous species in the Polesye region under the decline scenarios. Current hard deciduous fellings are 1.1 million cubic meters o.b.

Forest Steppe Region (Table A.14 and Figures A.92 to A.99)

Hard deciduous species constitute about 47 percent of the commercial forests in the Forest Steppe region; coniferous forests make up about 38 percent. About 55 percent of the commercial forests are part of the protected Forest Group I.

The forests have relatively high growing stock with moderate growth rates. There is a concentration in the age-class distribution toward middle-aged forests.

Basic Scenarios

Due to the lack of overmature and mature forests in the Forest Steppe region there are no initial harvesting peaks identified in the basic scenarios. In contrast, a slight increase in the harvesting potential over time during the first half of the simulation period can be seen. This is valid for coniferous and hard deciduous species. In the soft deciduous group, there is a decline in the harvesting potential in the Basic Handbook Scenario, but an even level is found in the Basic Forest Study Scenario throughout the entire simulation period. These results indicate that some residual soft deciduous stands exist in the region.

The Basic Forest Study Scenario gives higher growing-stock levels than the Basic Handbook Scenario. The difference is about 50 cubic meters per hectare. The growth rates are about the same in the two scenarios.

The Basic Forest Study Scenario generates a total average potential harvest level of 5.3 million cubic meters over bark per year. About 30 percent of this potential should be harvested as thinnings. The biggest potential is in coniferous species (2.4 million cubic meters over bark or about 45 percent).

Decline Scenarios

There are significant effects of air pollutants on the sustainability and future wood supply possibilities in the Forest Steppe region. Under the Forest Study Decline Scenario conditions, the decline of the total average harvesting potential is estimated to be about 1.6 million cubic meters over bark per year. The effects are of similar magnitude for all species groups.

In the Handbook Decline Scenario, the air-pollution effects generate an increased harvest during the first 30 to 40 years of the simulation period, with subsequent declining harvest levels for all species groups. The air-pollution effects cause a more rapid liquidation of affected stands than under the basic conditions. The growth rates are strongly influenced by air pollutants. This is especially true for the deciduous species; for these species the decline in the growth rate is about one cubic meter over bark per hectare per year.

Summary

There is no excess of overmature and mature forests in the Forest Steppe region. This results in a rather good balance between the existing forest structure and the structure suggested by a fully implemented handbook silviculture.

Under basic conditions the total average harvest potential is estimated to be 5.3 million cubic meters over bark per year. This corresponds quite well with the current total harvest level which is 4.2 million cubic meters. However, there is a discrepancy in the distribution of the potential harvest and current fellings of species groups. Current coniferous fellings are 0.5 million cubic meters, and potential harvest under basic conditions is 2.4 million cubic meters. In contrast, current fellings of deciduous species are 3.7 million, although the potential is only 2.9 million cubic meters per year.

The decline effects caused by air pollutants are significant in the Forest Steppe region. The total average harvesting potential is reduced by 1.6 million cubic meters over bark per year under decline conditions. It corresponds to 30 percent of the total average potential under basic conditions.

Table A.14. Forest Steppe region.

Variable	Basic Hand-book	Basic Forest Study	Hand-book Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	184–145	184–216	184–136	184–212
Fellings[b]				
Year 1	5.9	4.6	10.4	3.6
Year 40	6.4	5.4	4.6	3.7
Year 80	6.0	5.4	3.6	3.7
Coniferous				
Growing stock[a]	189–171	189–231	189–164	189–228
Fellings[b]				
Year 1	1.9	1.9	3.8	1.8
Year 40	3.1	2.5	2.1	1.8
Year 80	2.5	2.5	1.6	1.8
Soft deciduous				
Growing stock[a]	202–160	202–193	202–142	202–205
Fellings[b]				
Year 1	1.7	1.0	2.7	0.6
Year 40	1.0	1.0	0.6	0.6
Year 80	1.1	1.0	0.7	0.6
Hard deciduous				
Growing stock[a]	175–118	175–212	175–112	175–201
Fellings[b]				
Year 1	2.3	1.7	3.9	1.2
Year 40	2.3	1.9	1.9	1.3
Year 80	2.4	1.9	1.3	1.3
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	6.1	5.3	5.2	3.7
Coniferous	2.6	2.4	2.2	1.8
Soft deciduous	1.2	1.0	1.0	0.6
Hard deciduous	2.3	1.9	2.0	1.3
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	4.3	4.4	3.6	3.1
Coniferous	5.1	5.4	4.3	4.1
Soft deciduous	5.6	5.1	4.4	3.1
Hard deciduous	3.3	3.5	2.7	2.4
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	184–145	184–216	184–136	184–212
Coniferous	189–171	189–231	189–164	189–228
Soft deciduous	202–160	202–193	202–142	202–205
Hard deciduous	175–118	175–212	175–112	175–201

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

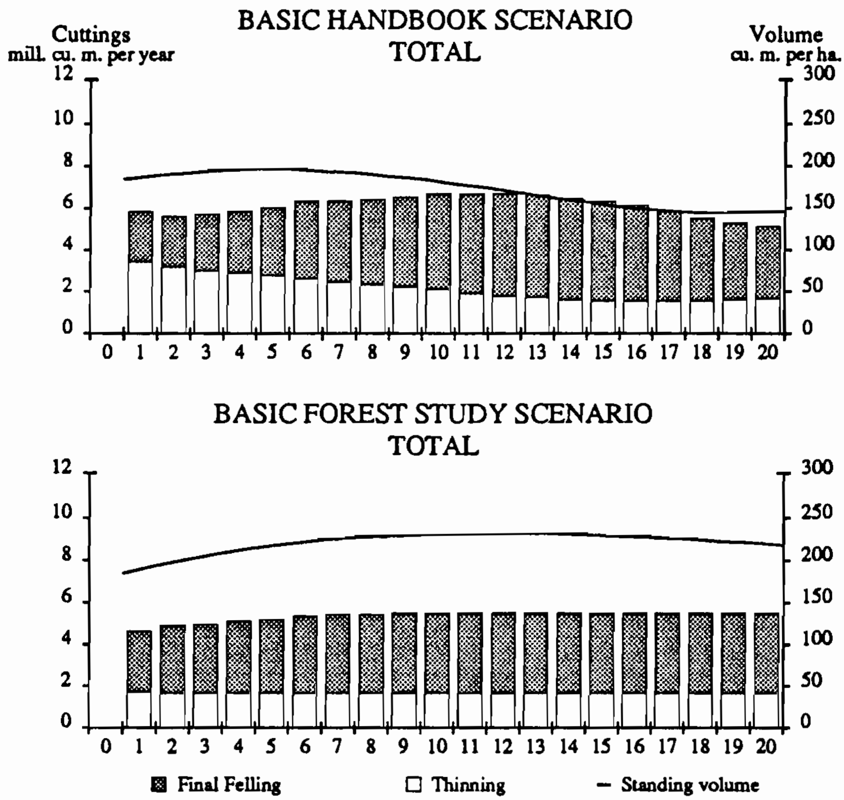

Figure A.92. Projections of total potential harvest and growing stock in the Forest Steppe region under the basic scenarios. Current total fellings are 4.2 million cubic meters o.b.

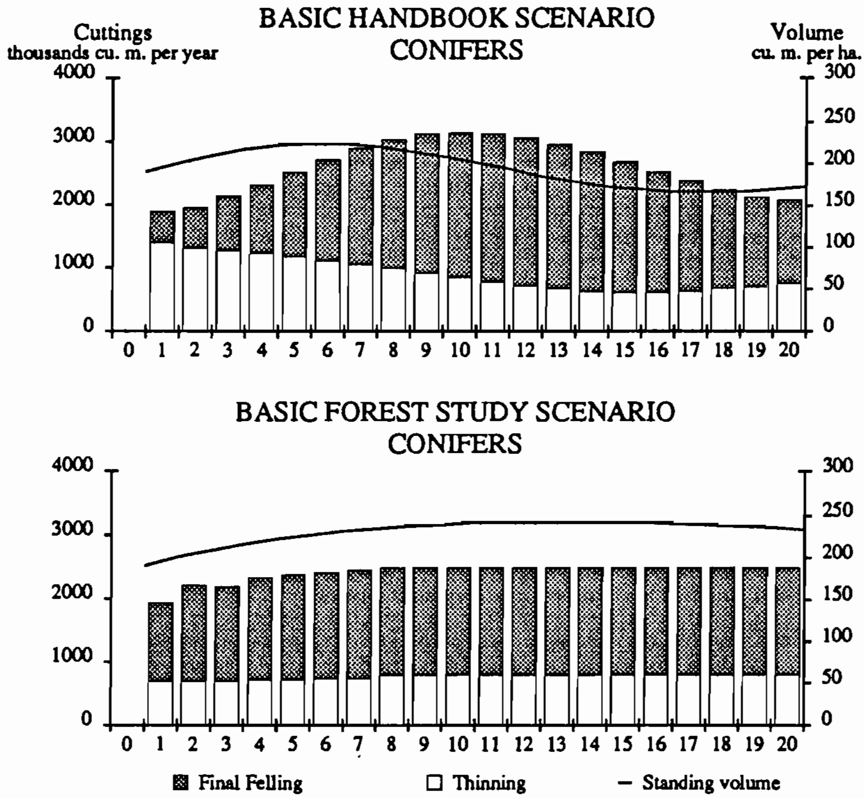

Figure A.93. Projections of potential harvest and growing stock of coniferous species in the Forest Steppe region under the basic scenarios. Current coniferous fellings are 0.5 million cubic meters o.b.

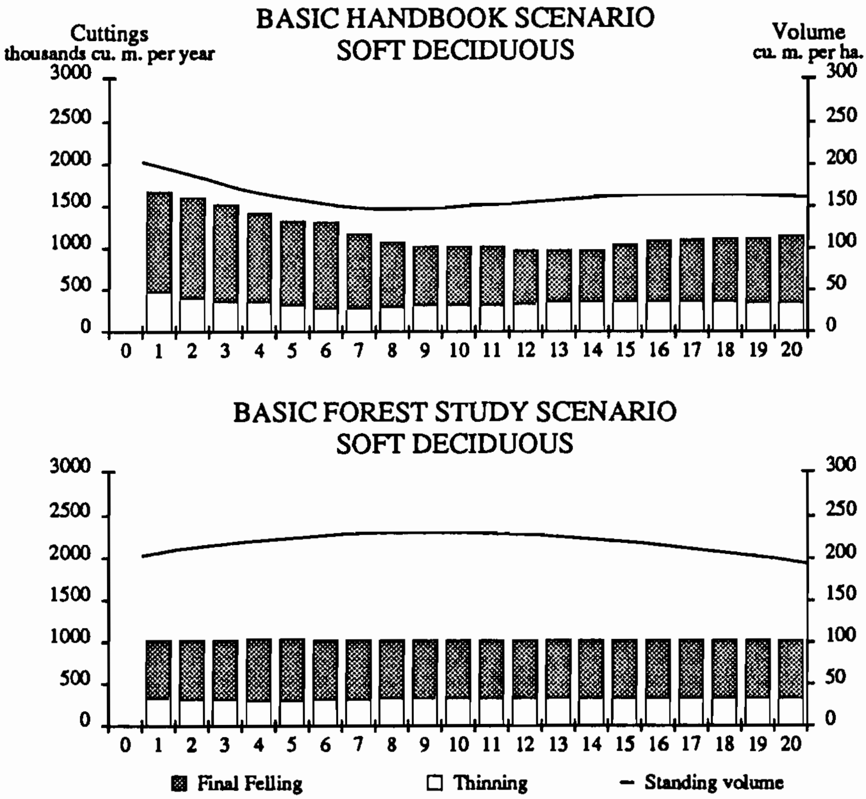

Figure A.94. Projections of potential harvest and growing stock of soft deciduous species in the Forest Steppe region under the basic scenarios. Current soft deciduous fellings are 1.3 million cubic meters o.b.

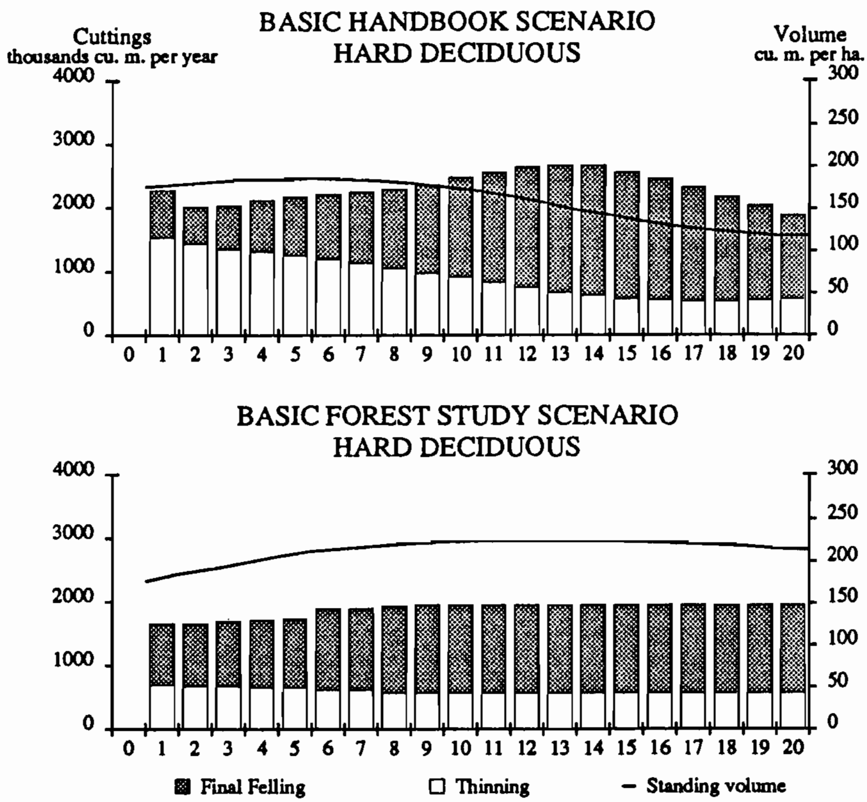

Figure A.95. Projections of potential harvest and growing stock of hard deciduous species in the Forest Steppe region under the basic scenarios. Current hard deciduous fellings are 2.4 million cubic meters o.b.

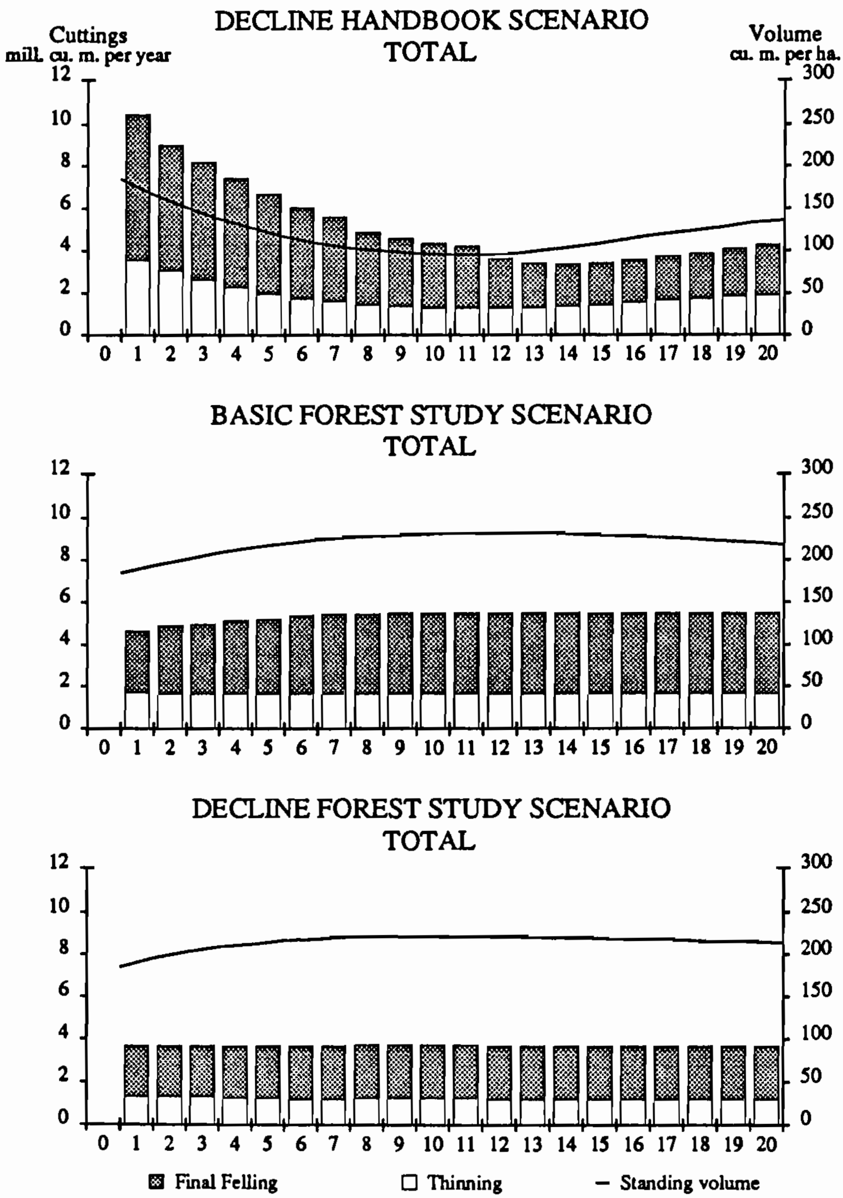

Figure A.96. Projections of total potential harvest and growing stock in the Forest Steppe region under the decline scenarios. Current total fellings are 4.2 million cubic meters o.b.

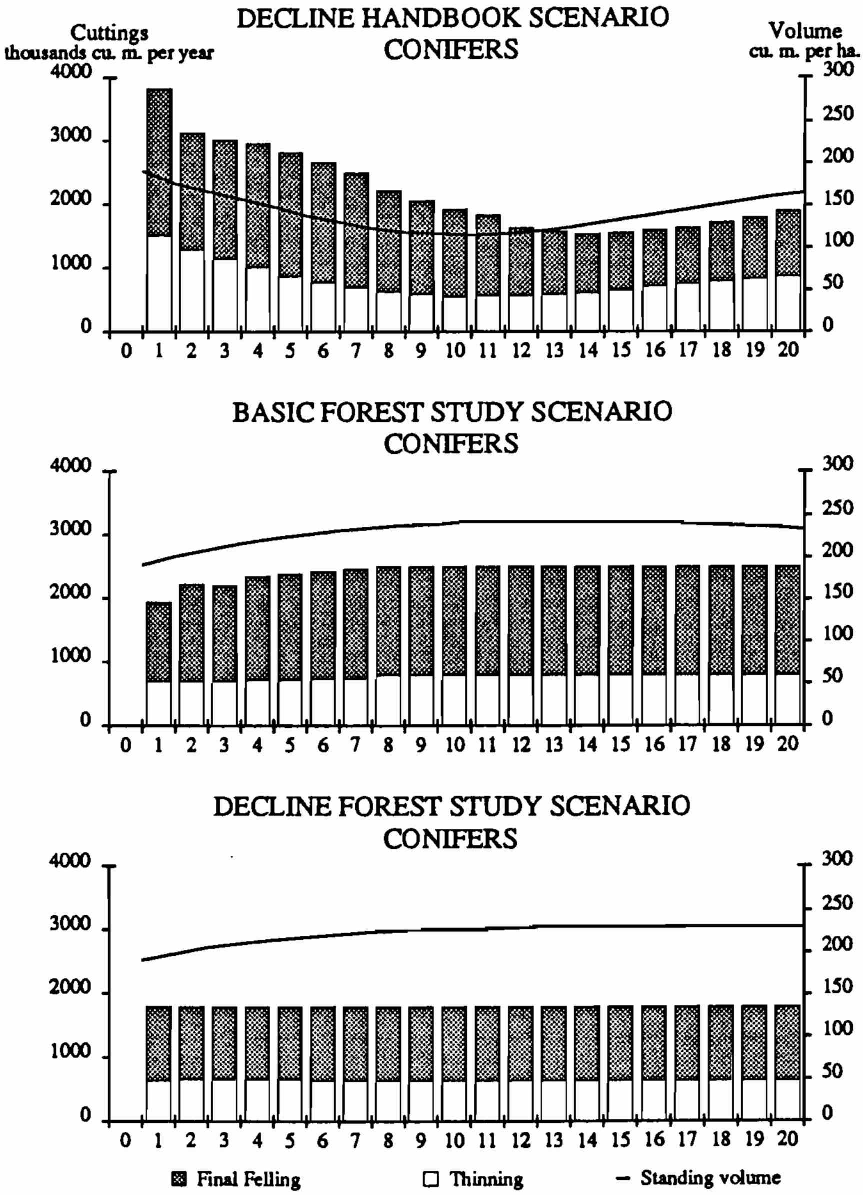

Figure A.97. Projections of potential harvest and growing stock of coniferous species in the Forest Steppe region under the decline scenarios. Current coniferous fellings are 0.5 million cubic meters o.b.

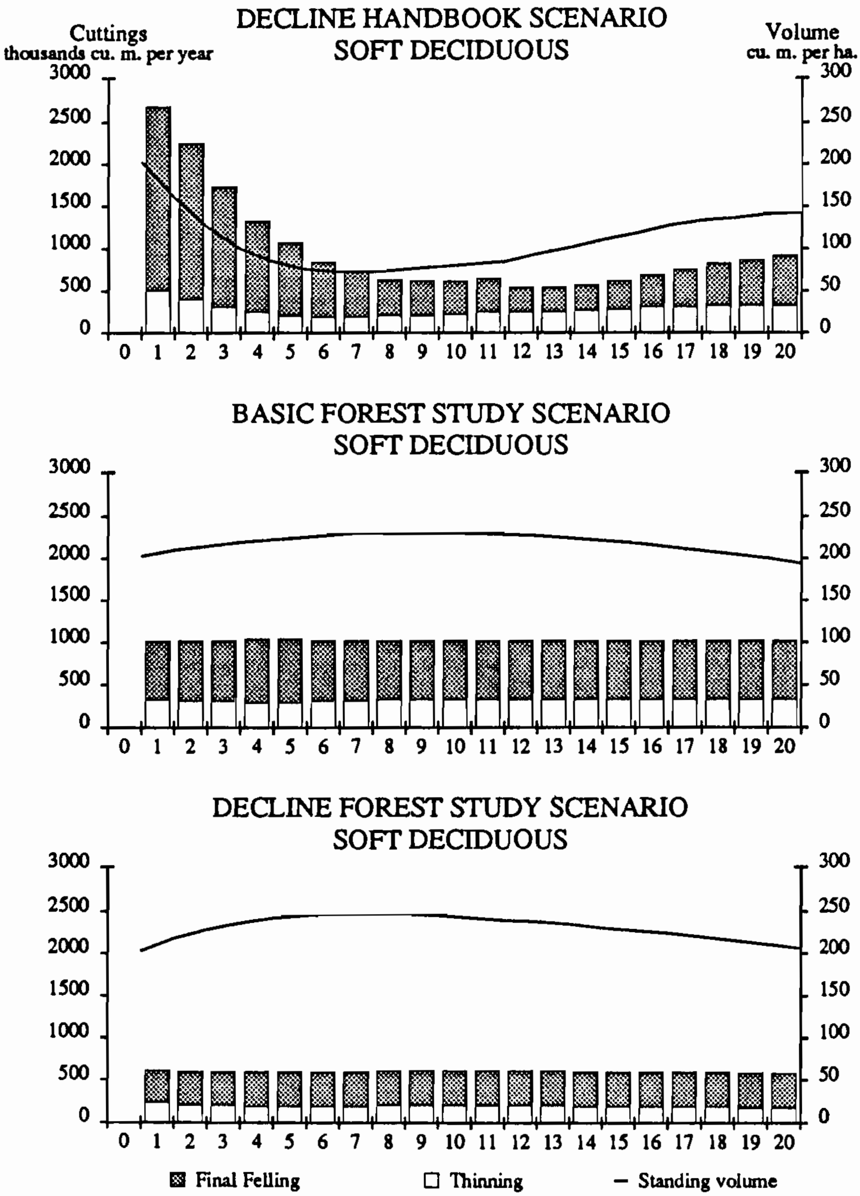

Figure A.98. Projections of potential harvest and growing stock of soft deciduous species in the Forest Steppe region under the decline scenarios. Current soft deciduous fellings are 1.3 million cubic meters o.b.

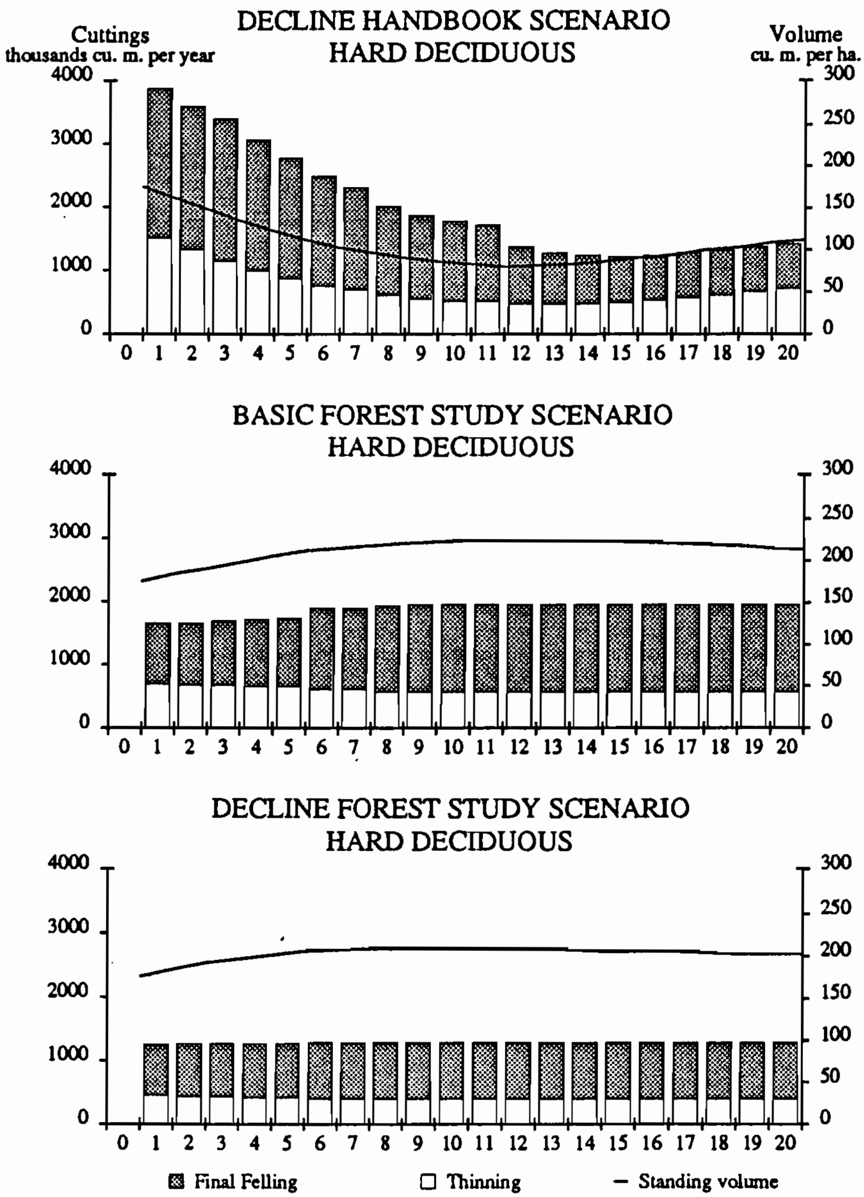

Figure A.99. Projections of potential harvest and growing stock of hard deciduous species in the Forest Steppe region under the decline scenarios. Current hard deciduous fellings are 2.4 million cubic meters o.b.

Moldavian Region (Table A.15 and Figures A.100 to A.105)

The commercial forest area of Moldavia is small, only 151,000 hectares with 98 percent being classified as hard deciduous forests. Furthermore, over 90 percent of the commercial forest belongs to the group that is protected. For most species the existing growing stock and growth rates show normal levels. However, pine and spruce stands have very low growing-stock levels. This can be explained by the fact that most of these forests are made up of young plantations. The dominating species group, hard deciduous, shows a rather even age-class distribution.

There also are soft deciduous species in Moldavia (about 300 hectares), but they have been excluded in the analyses due to the small extent of this forest.

Basic Scenarios

The Basic Handbook Scenario shows an oscillating development for the potential harvesting level and growing stock of all species groups. In the Basic Forest Study Scenario the dominating species group, hard deciduous, shows a slight increase in the harvesting potential in the beginning of the simulation period. The growing-stock level has a slight increase over the simulation period in this scenario.

The existing coniferous forests are young plantations. These young forests will generate an increased harvesting potential and growing stock over the simulation period, even if the amount is negligible with regard to the total wood supply.

The total average potential harvest for the Moldavian region, according to the basic scenarios, is 0.6 million cubic meters per year. Nearly 100 percent of the harvest stems from hard deciduous species. About 25 percent of the harvesting potential should be harvested in the form of thinnings.

Decline Scenarios

There are strong decline effects caused by air pollutants in Moldavia. The decline of the total potential harvest is estimated to be more than 30 percent. The total growth rate will decline by 1 cubic meter over bark per hectare per year. The air-pollution effects also cause a harvest pulse in the Handbook Decline Scenario, which is not seen in the Basic Handbook Scenario. The handbook silviculture pushes for a rapid replacement of the declining forests, which results in the harvest pulse.

Summary

The commercial forest resources are very small in Moldavia and totally dominated by hard deciduous species. The total average harvesting potential is only 0.6 million cubic meters per year. The existing structure of the hard deciduous species is in very good balance with the structure generated by the handbook silviculture. The coniferous forests (only 3 percent of the commercial forestland area) are young plantations, and will increase harvesting potential and growing stock.

Table A.15. Moldavian region.

Variable	Basic Hand- book	Basic Forest Study	Hand- book Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	116–127	116–138	116–115	116–134
Fellings[b]				
Year 1	0.5	0.5	1.3	0.4
Year 40	0.5	0.6	0.5	0.4
Year 80	0.6	0.6	0.6	0.4
Coniferous				
Growing stock[a]	23–117	23–117	23–123	23–122
Fellings[b]				
Year 1	0.0	0.0	0.0	0.0
Year 40	0.0	0.0	0.0	0.0
Year 80	0.0	0.0	0.0	0.0
Soft deciduous				
Growing stock[a]	0–0	0–0	0–0	0–0
Fellings[b]				
Year 1	0.0	0.0	0.0	0.0
Year 40	0.0	0.0	0.0	0.0
Year 80	0.0	0.0	0.0	0.0
Hard deciduous				
Growing stock[a]	118–127	118–138	118–115	118–135
Fellings[b]				
Year 1	0.5	0.5	1.3	0.4
Year 40	0.5	0.6	0.5	0.4
Year 80	0.6	0.6	0.6	0.4
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	0.6	0.6	0.6	0.4
Coniferous	0.0	0.0	0.0	0.0
Soft deciduous	0.0	0.0	0.0	0.0
Hard deciduous	0.6	0.6	0.6	0.4
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	4.2	4.1	4.0	3.1
Coniferous	4.0	4.0	3.3	3.3
Soft deciduous	0.0	0.0	0.0	0.0
Hard deciduous	4.2	4.1	4.0	3.1
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	116–127	116–138	116–115	116–134
Coniferous	23–117	23–117	23–123	23–122
Soft deciduous	0–0	0–0	0–0	0–0
Hard deciduous	118–127	118–138	118–115	118–135

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

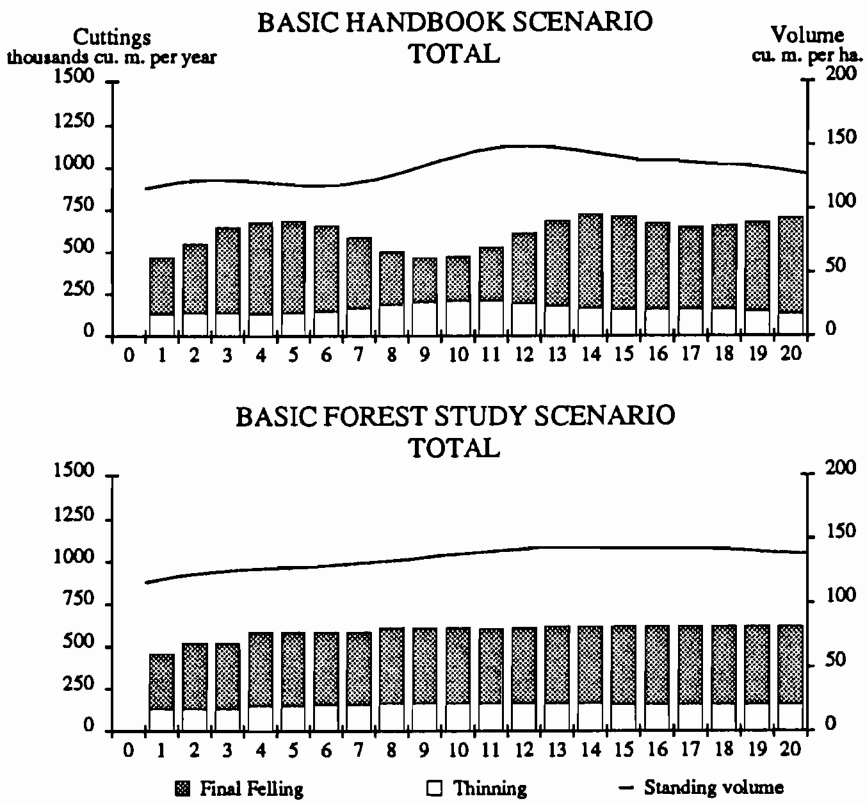

Figure A.100. Projections of total potential harvest and growing stock in the Moldavian region under the basic scenarios. Current total fellings are 0.4 million cubic meters o.b.

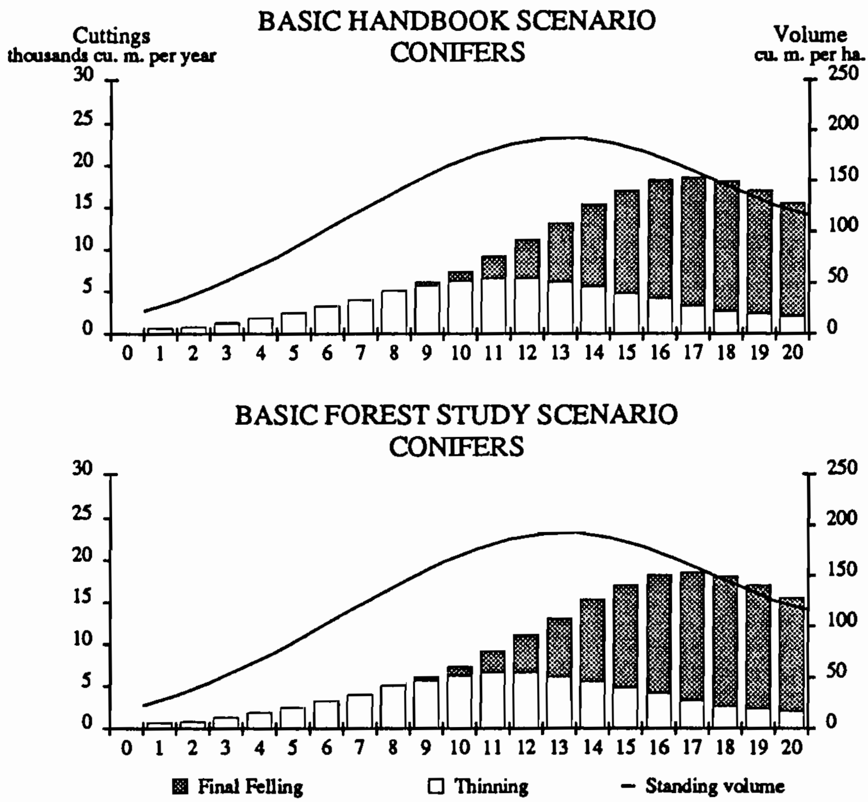

Figure A.101. Projections of potential harvest and growing stock of coniferous species in the Moldavian region under the basic scenarios. Current coniferous fellings are 0 cubic meters o.b.

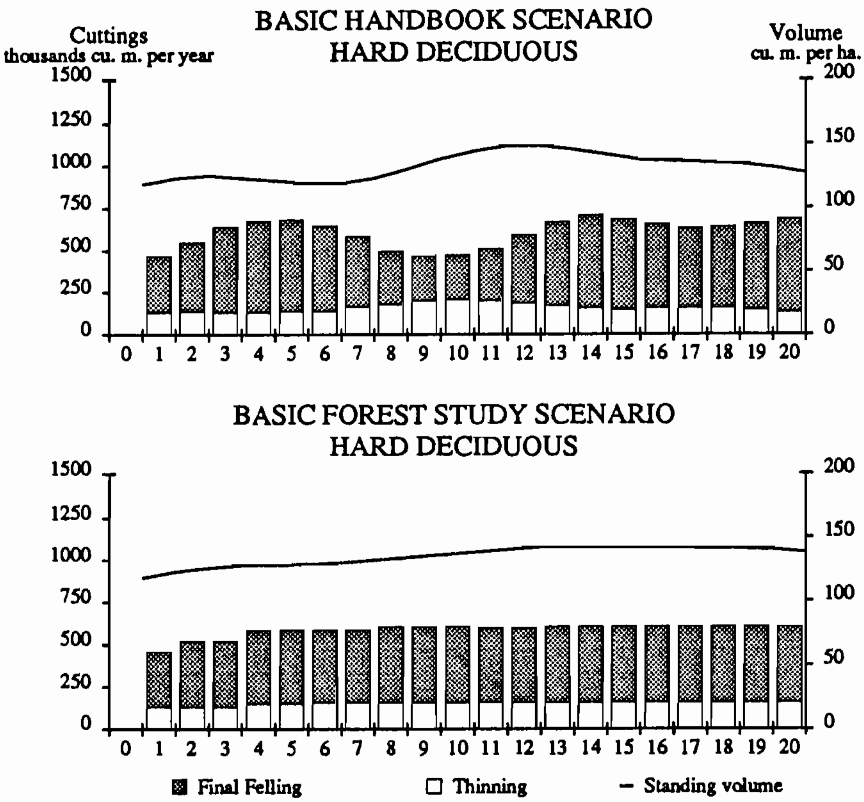

Figure A.102. Projections of potential harvest and growing stock of hard deciduous species in the Moldavian region under the basic scenarios. Current hard deciduous fellings are 0.4 million cubic meters o.b.

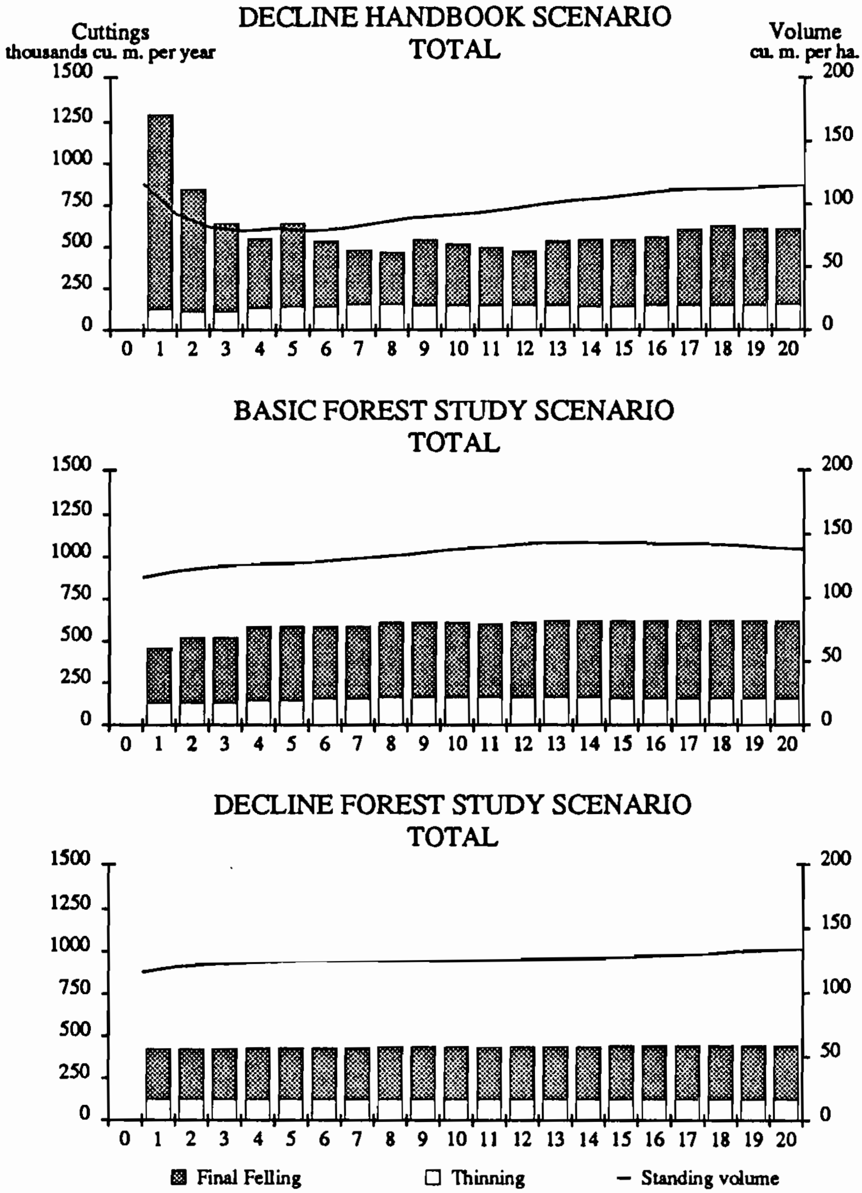

Figure A.103. Projections of total potential harvest and growing stock in the Moldavian region under the decline scenarios. Current total fellings are 0.4 million cubic meters o.b.

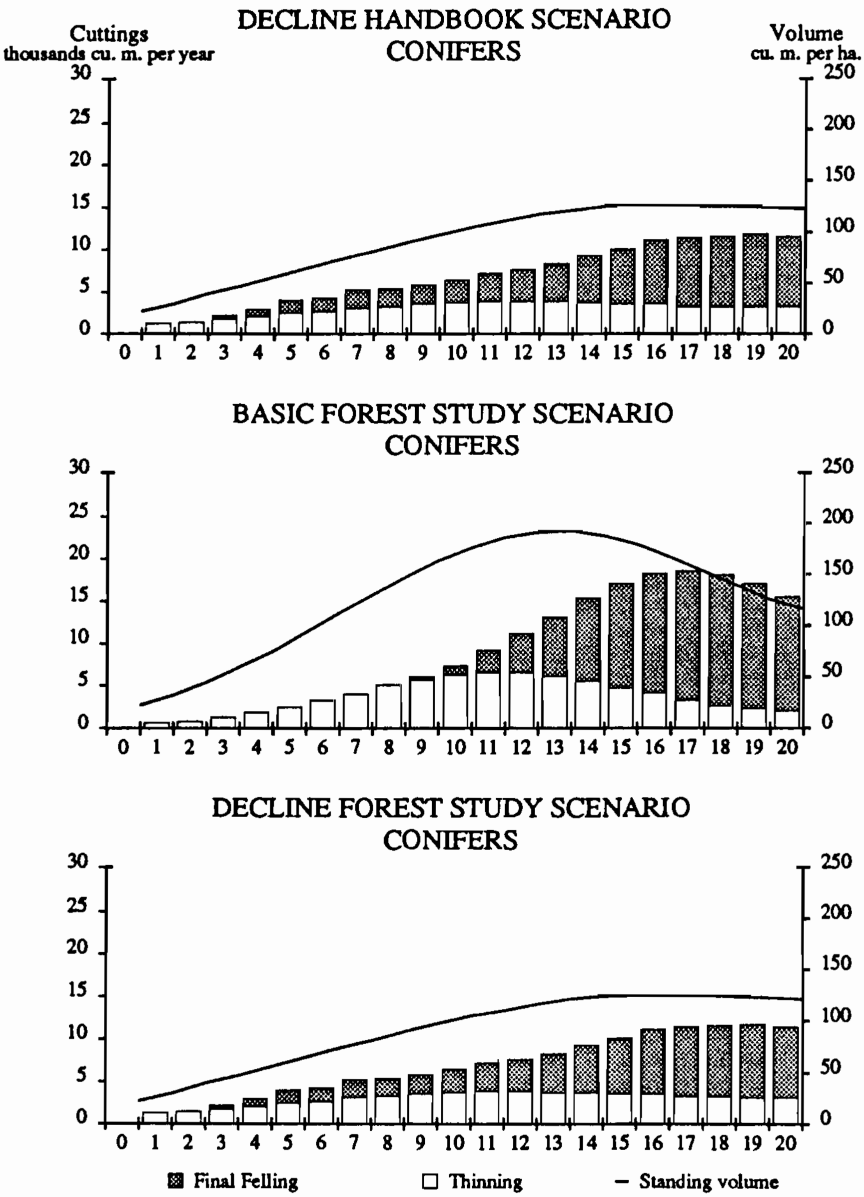

Figure A.104. Projections of potential harvest and growing stock of coniferous species in the Moldavian region under the decline scenarios. Current coniferous fellings are 0 cubic meters o.b.

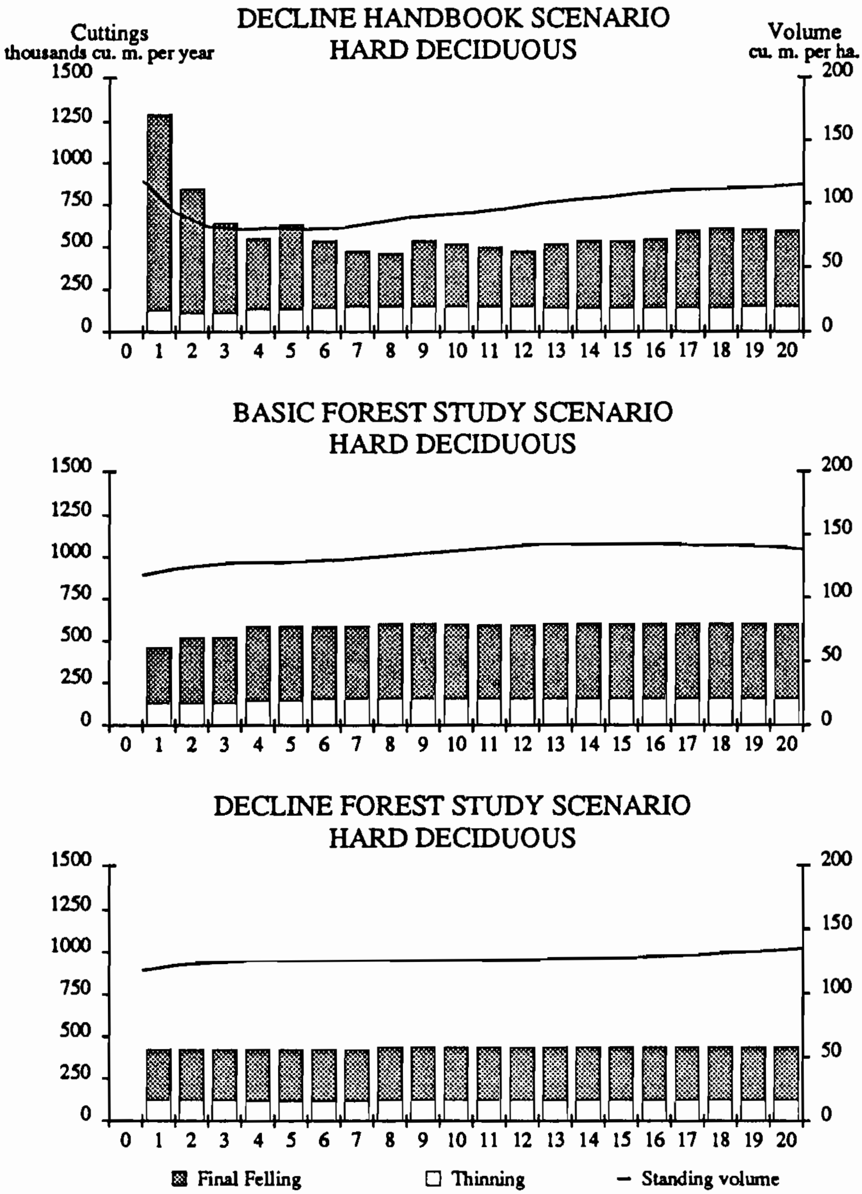

Figure A.105. Projections of potential harvest and growing stock of hard deciduous species in the Moldavian region under the decline scenarios. Current hard deciduous fellings are 0.4 million cubic meters o.b.

Byelorussian Region (Table A.16 and Figures A.106 to A.113)

The Byelorussian region is dominated by coniferous species (nearly 70 percent of the commercial forestland area), followed by soft deciduous species (28 percent of the commercial area). The major parts of the forests are in Forest Group II (about 65 percent). The age-class distribution is concentrated in young and middle-aged stands for all species groups. In addition, the hard deciduous species group peaks at 100 years. Thus, there is a lack of mature and overmature forests in all species groups (however, less pronounced in hard deciduous species).

Basic Scenarios

Due to the concentration of the existing forests in young and middle-aged forests, the Basic Handbook Scenario generates an increasing harvesting potential during the first 30 to 40 years of the simulation period for all species groups. Correlated to the increased harvesting potential is a decreased level of growing stock over the simulation period.

The Basic Forest Study Scenario gives a rather stable and even harvesting potential throughout the entire simulation period. During the first 15 to 20 years of the simulation, there is a slight increase in the harvesting potential for all species groups. There is also a slight increase during the simulation period in this scenario's growing stock. The total growth rates are similar in the two basic scenarios.

Under the basic conditions, the total average potential is estimated to be 15.9 million cubic meters over bark per year. About 65 percent of the harvesting potential is in coniferous species. The thinning proportion of the total harvest potential is estimated to be 25 percent. The current fellings are only 8.9 million cubic meters per year, with 4.5 million cubic meters in coniferous species. Thus, there seems to be a possibility of an increased harvest in the coniferous species.

Decline Scenarios

The decline effects of air pollutants are significant in all species groups. The air pollutants also cause harvesting pulses in the Handbook Decline Scenario for coniferous and hard deciduous species. This is a result of striving for replacement of declining forests by the handbook silviculture programs. In the Forest Study Decline Scenario there are still possibilities of having even harvesting and growing-stock levels throughout the entire simulation period. However, the potential harvest level is much lower under the decline conditions in comparison with the Basic Forest Study Scenario.

The total decline in the potential harvesting caused by air pollutants is estimated to be 4.4 million cubic meters over bark per year or 28 percent of the total potential (Basic Forest Study Scenario). The biggest effects of the decline are achieved in the coniferous species. The total growth rate is reduced by 0.9 cubic meters over bark per hectare per year.

Summary

There is a lack of mature and overmature forests in the Byelorussian region, which results in a slightly increased harvesting potential and growing stock over time. There seems to be a good possibility of increasing the harvests of coniferous species under the basic conditions. The difference between average potential and current fellings for this species group is 5.9 million cubic meters. The major part of this difference probably stems from increased thinnings.

The decline effects of air pollutants are estimated to be considerable. The decline in the total harvest potential is 4.4 million cubic meters over bark per year or 28 percent of the total average potential under basic conditions.

Table A.16. Byelorussian region.

Variable	Basic Handbook	Basic Forest Study	Handbook Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	142–131	142–164	142–111	142–160
Fellings[b]				
Year 1	10.2	13.0	32.1	11.2
Year 40	22.0	16.4	14.6	11.6
Year 80	17.1	16.4	12.5	11.6
Coniferous				
Growing stock[a]	147–125	147–163	147–104	147–160
Fellings[b]				
Year 1	6.8	8.6	24.7	7.6
Year 40	13.7	10.7	9.4	7.8
Year 80	11.6	10.7	7.8	7.8
Soft deciduous				
Growing stock[a]	134–140	134–164	134–126	134–159
Fellings[b]				
Year 1	3.0	3.8	6.3	3.2
Year 40	7.7	5.0	4.6	3.4
Year 80	4.8	5.0	4.2	3.4
Hard deciduous				
Growing stock[a]	126–157	126–172	126–133	126–170
Fellings[b]				
Year 1	0.4	0.6	1.1	0.4
Year 40	0.6	0.7	0.6	0.4
Year 80	0.7	0.7	0.5	0.4
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	17.8	15.9	16.6	11.5
Coniferous	11.6	10.4	10.8	7.7
Soft deciduous	5.6	4.9	5.2	3.4
Hard deciduous	0.6	0.6	0.6	0.4
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	3.2	3.2	2.8	2.3
Coniferous	3.0	3.0	2.5	2.3
Soft deciduous	3.9	3.6	3.4	2.5
Hard deciduous	3.2	3.4	2.9	2.3
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	142–131	142–164	142–111	142–160
Coniferous	147–125	147–163	147–104	147–160
Soft deciduous	134–140	134–164	134–126	134–159
Hard deciduous	126–157	126–172	126–133	126–170

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

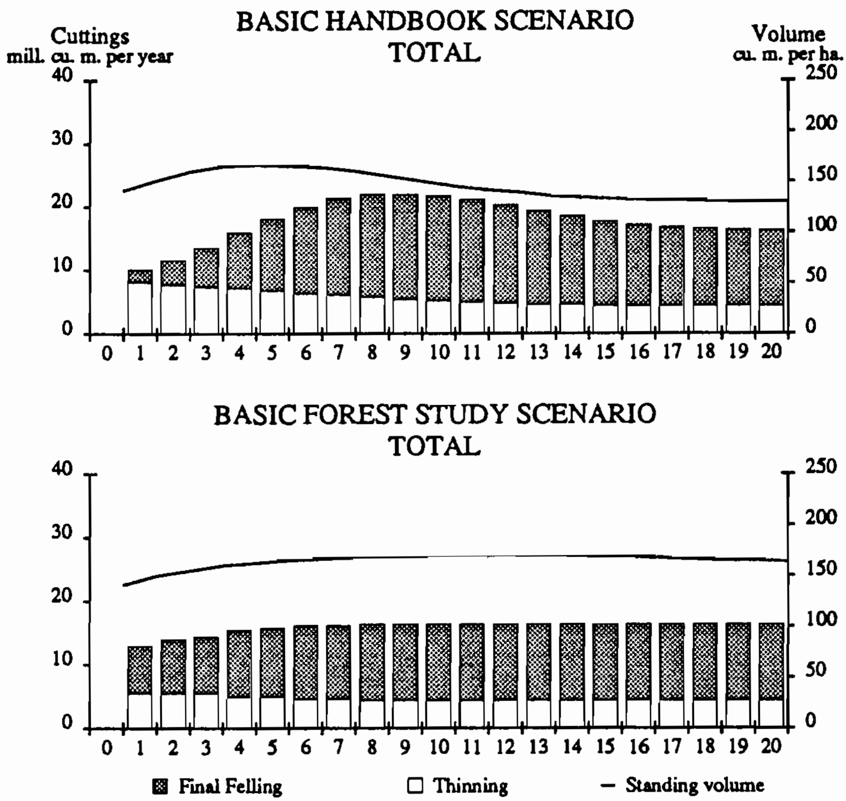

Figure A.106. Projections of total potential harvest and growing stock in the Byelorussian region under the basic scenarios. Current total fellings are 8.9 million cubic meters o.b.

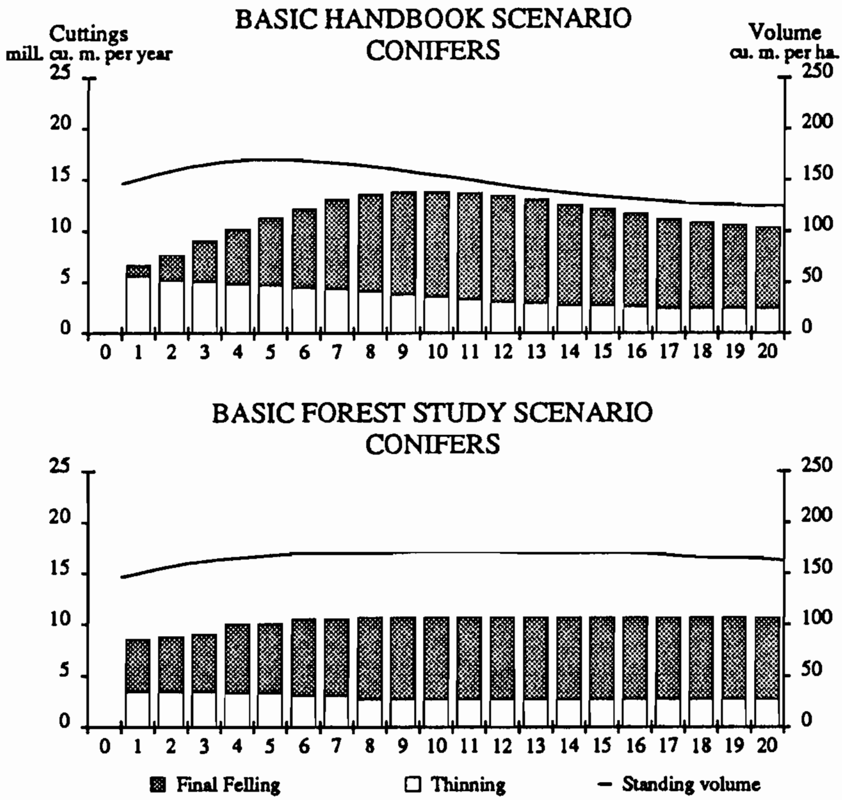

Figure A.107. Projections of potential harvest and growing stock of coniferous species in the Byelorussian region under the basic scenarios. Current coniferous fellings are 4.5 million cubic meters o.b.

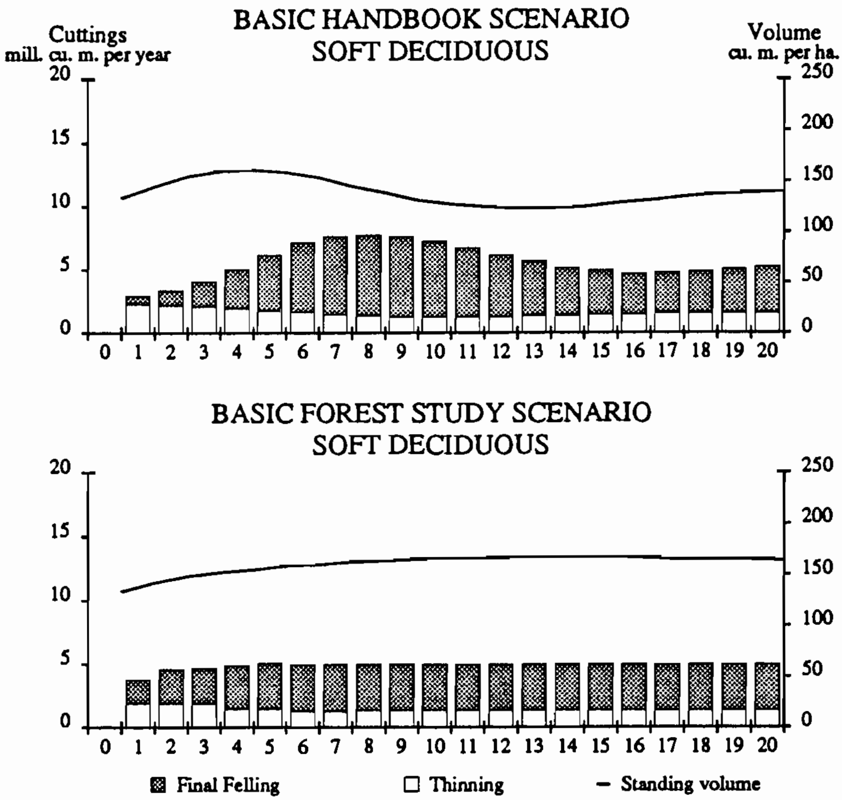

Figure A.108. Projections of potential harvest and growing stock of soft deciduous species in the Byelorussian region under the basic scenarios. Current soft deciduous fellings are 3.9 million cubic meters o.b.

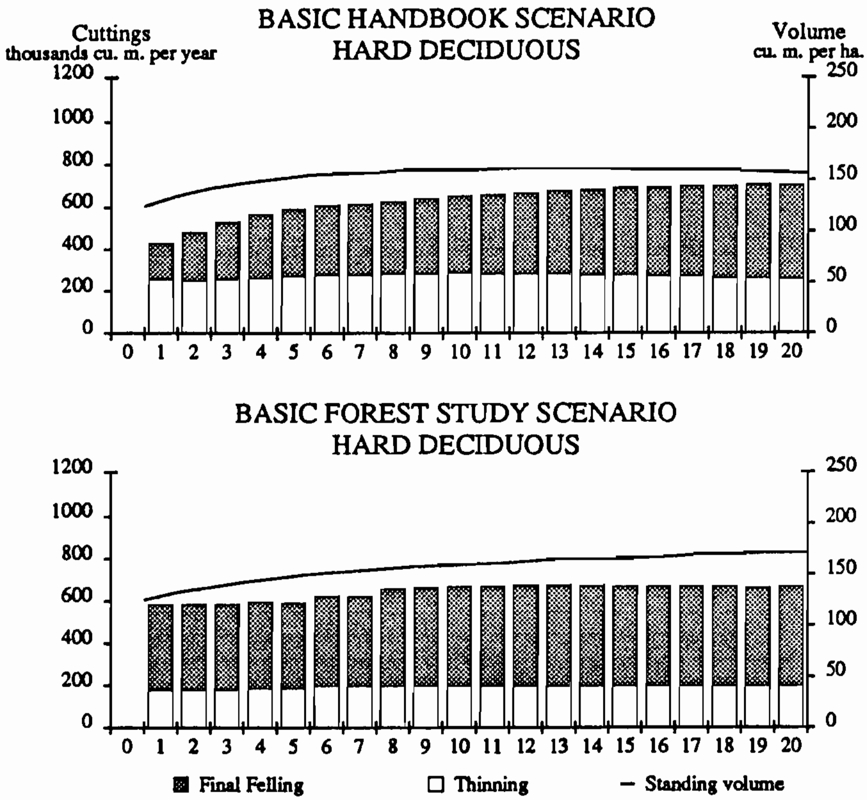

Figure A.109. Projections of potential harvest and growing stock of hard deciduous species in the Byelorussian region under the basic scenarios. Current hard deciduous fellings are 0.5 million cubic meters o.b.

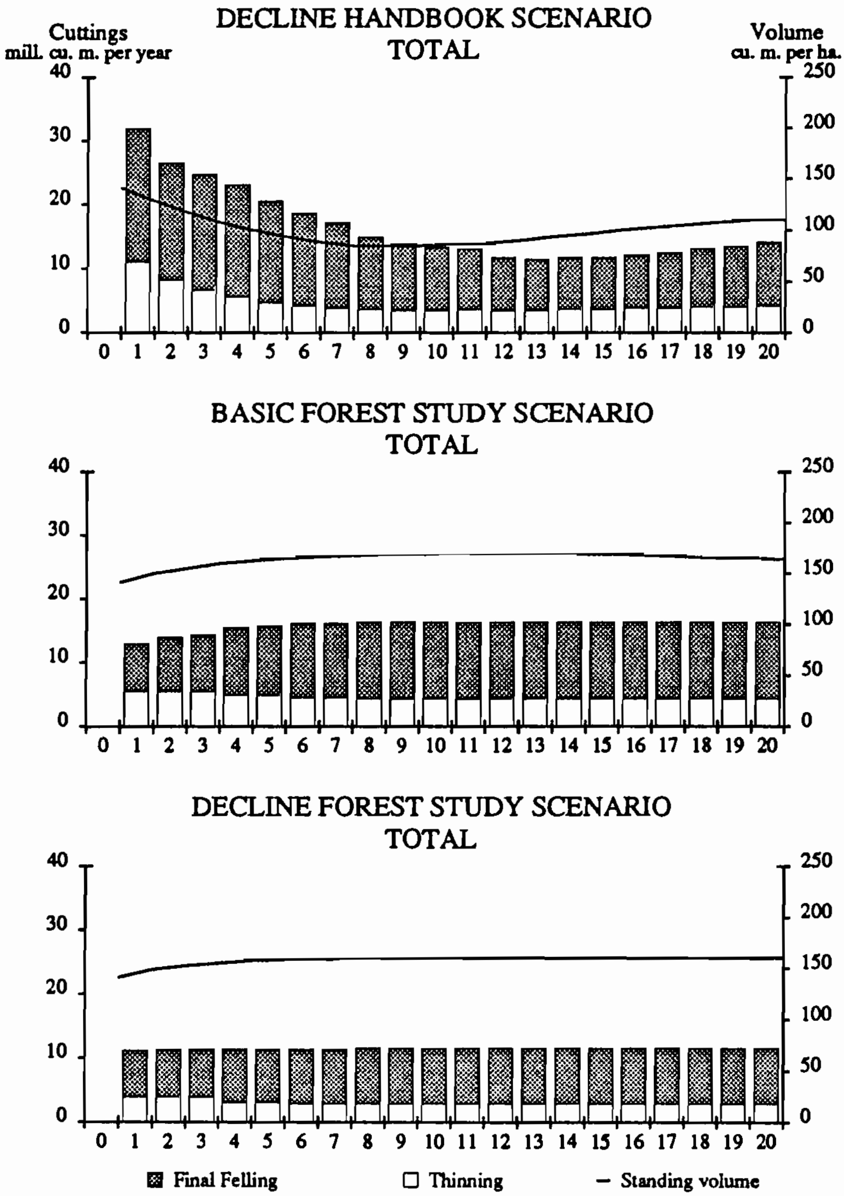

Figure A.110. Projections of total potential harvest and growing stock in the Byelorussian region under the decline scenarios. Current total fellings are 8.9 million cubic meters o.b.

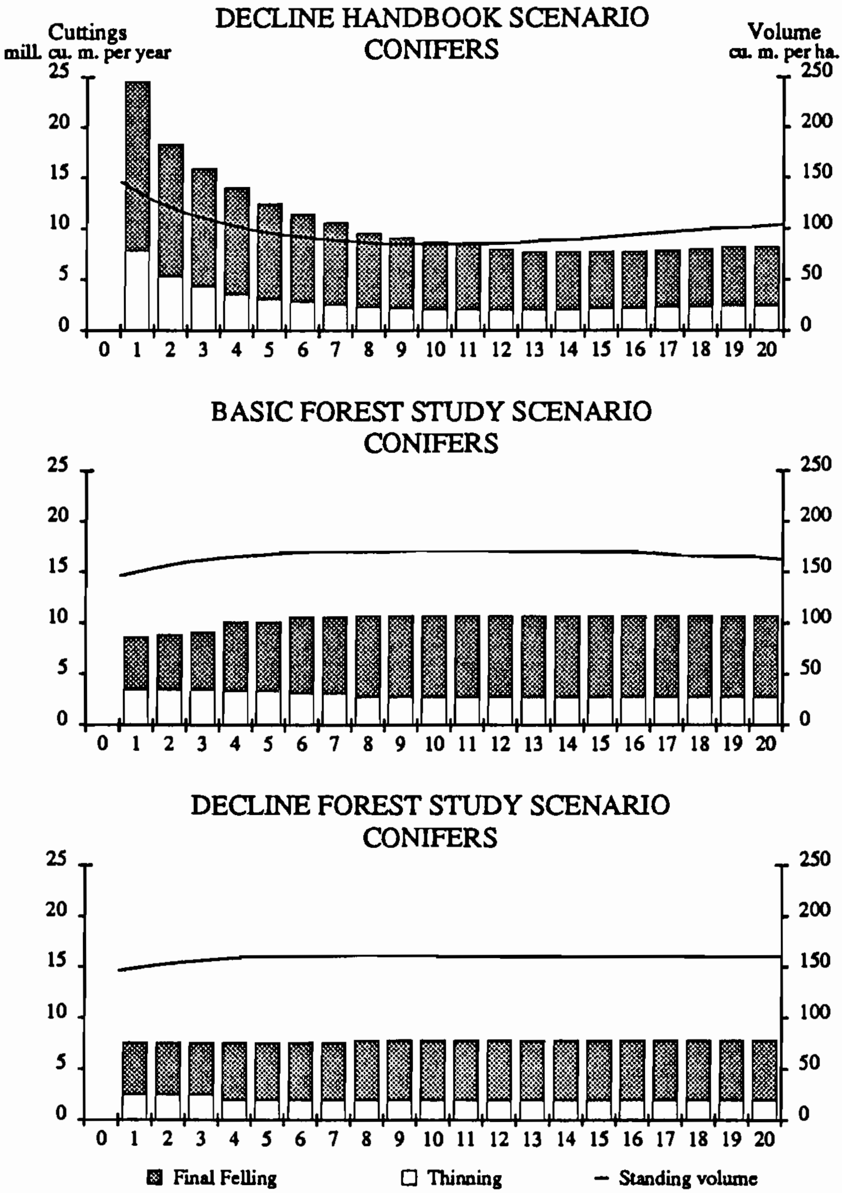

Figure A.111. Projections of potential harvest and growing stock of coniferous species in the Byelorussian region under the decline scenarios. Current coniferous fellings are 4.5 million cubic meters o.b.

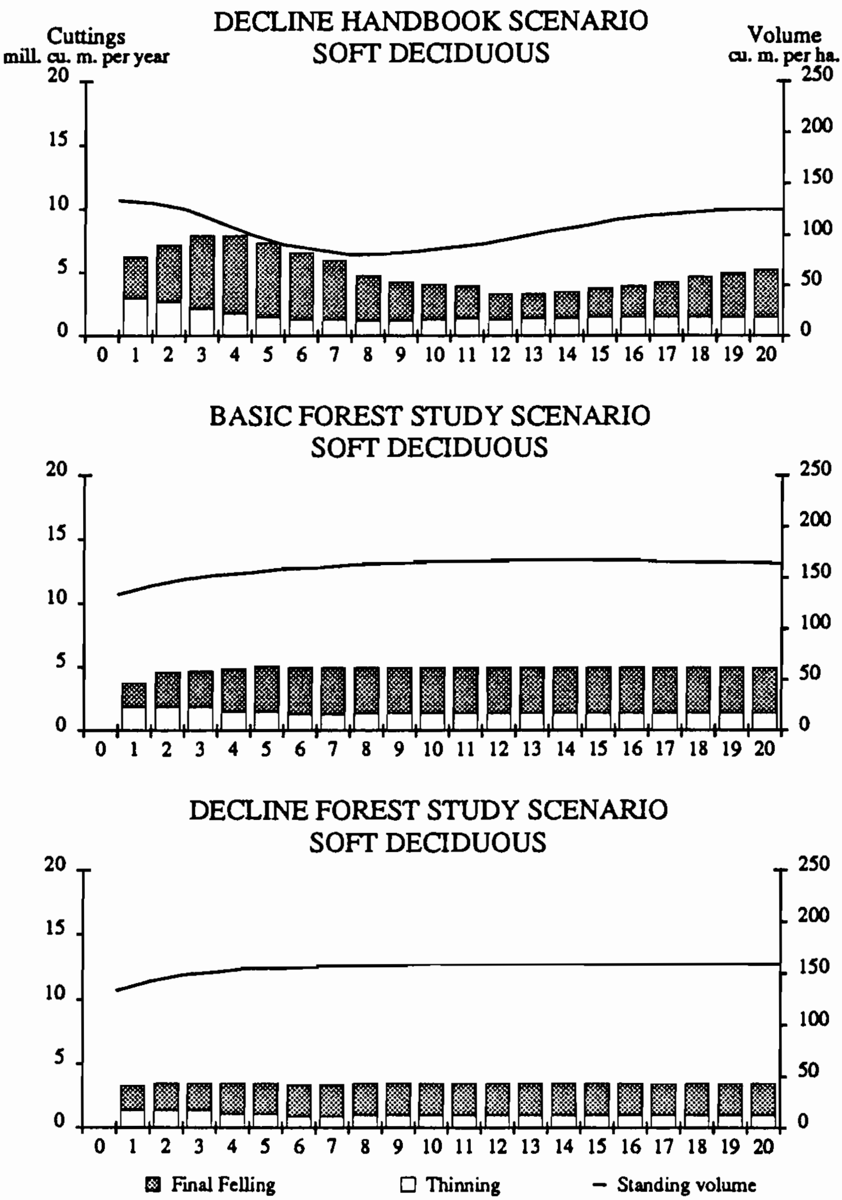

Figure A.112. Projections of potential harvest and growing stock of soft deciduous species in the Byelorussian region under the decline scenarios. Current soft deciduous fellings are 3.9 million cubic meters o.b.

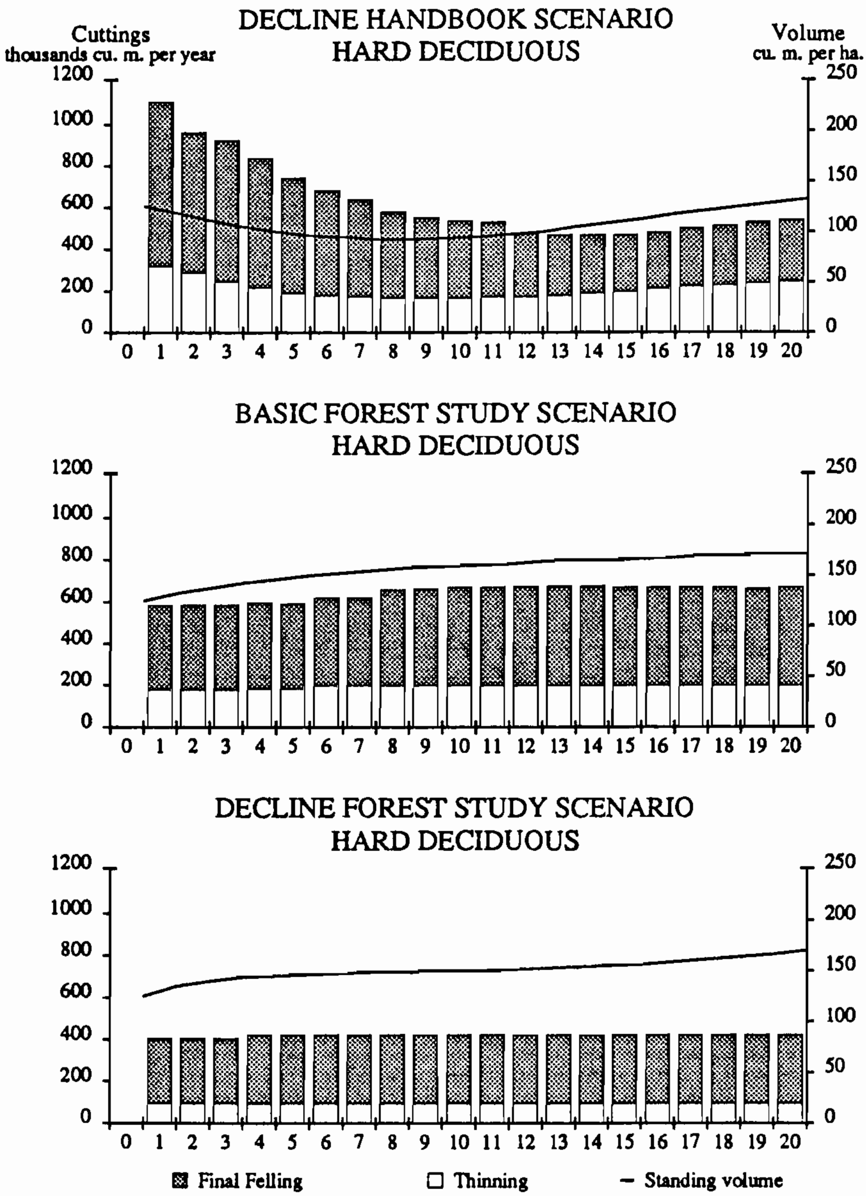

Figure A.113. Projections of potential harvest and growing stock of hard deciduous species in the Byelorussian region under the decline scenarios. Current hard deciduous fellings are 0.5 million cubic meters o.b.

Estonian Region (Table A.17 and Figures A.114 to A.121)

The commercial forest area of Estonia is rather small (about 835,000 hectares). The major species group is coniferous species constituting some 65 percent of the commercial forestland area. The soft deciduous species group covers about 34 percent of the forestland area. The major forest resources (some 85 percent) are classified as Forest Group II.

Coniferous species have an even age-class distribution. The deciduous species have a concentration in the upper middle-aged classes.

Basic Scenarios

The Basic Handbook Scenario and the Basic Forest Study Scenario give a rather even potential level and development of growing stock of total species, coniferous species, and soft deciduous species. Thus, there is a good balance between the existing structure of the forests and a structure generated by the handbook silviculture. Hard deciduous species show a more irregular pattern, but they constitute a harvesting potential of only some 5,000 cubic meters over bark per year. The growth rates for the different species groups are similar in the two basic scenarios.

Under the basic conditions, the total average harvesting potential is estimated to be 2.0 million cubic meters over bark per year. The current total harvest is 2.6 million cubic meters. Thus, there seems to be an overharvesting taking place in Estonia. The size of the overharvest for coniferous species is similar to the size for deciduous species.

At a sustainable average harvesting level of 2 million cubic meters over bark per year, about 27 percent of the volume should be harvested as thinnings.

Decline Scenarios

The decline effects of air pollutants in Estonia are strong. In the Handbook Decline Scenario strong harvesting pulses are achieved for all species groups in the beginning of the simulation period. The handbook silviculture programs aim at rapidly replacing the declining forests, which will result in harvest peaks.

In the Forest Study Decline Scenario there are still possibilities of achieving an even harvesting level for all species groups throughout the entire simulation period. However, the harvesting level is lower in comparison with the Basic Forest Study Scenario. The decline effects are estimated to decrease the average total harvesting potential by 0.4 million cubic meters over bark per year or by 20 percent.

The same development of the growing stock can be achieved in the Forest Study Decline Scenario as in the Basic Forest Study Scenario.

Summary

The overall problem in Estonia seems to be current overharvesting of the forest resources. The current harvest level cannot continue. The forest resources are especially stressed if the effects of air pollutants are considered. The current harvest level is 2.6 million cubic meters, which will be reduced to 1.6 million if decline from air pollutants is taken into account.

Table A.17. Estonian region.

Variable	Basic Hand-book	Basic Forest Study	Hand-book Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	107–119	107–134	107–104	107–140
Fellings[b]				
Year 1	2.2	1.8	5.2	1.4
Year 40	2.3	2.0	1.7	1.6
Year 80	2.1	2.0	1.9	1.6
Coniferous				
Growing stock[a]	106–116	106–134	106–98	106–144
Fellings[b]				
Year 1	1.5	1.2	4.1	0.9
Year 40	1.4	1.3	1.1	1.0
Year 80	1.4	1.3	1.2	1.0
Soft deciduous				
Growing stock[a]	108–125	108–134	108–114	108–133
Fellings[b]				
Year 1	0.7	0.6	1.1	0.5
Year 40	0.9	0.7	0.6	0.6
Year 80	0.7	0.7	0.7	0.6
Hard deciduous				
Growing stock[a]	139–159	139–143	139–153	139–138
Fellings[b]				
Year 1	0.0	0.0	0.0	0.0
Year 40	0.0	0.0	0.0	0.0
Year 80	0.0	0.0	0.0	0.0
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	2.2	2.0	2.2	1.6
Coniferous	1.4	1.3	1.4	1.0
Soft deciduous	0.8	0.7	0.8	0.6
Hard deciduous	0.0	0.0	0.0	0.0
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	2.7	2.7	2.6	2.2
Coniferous	2.6	2.6	2.5	2.2
Soft deciduous	3.0	2.8	2.9	2.3
Hard deciduous	2.0	1.9	2.5	2.0
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	107–119	107–134	107–104	107–140
Coniferous	106–116	106–134	106–98	106–144
Soft deciduous	108–125	108–134	108–114	108–133
Hard deciduous	139–159	139–143	139–153	139–138

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

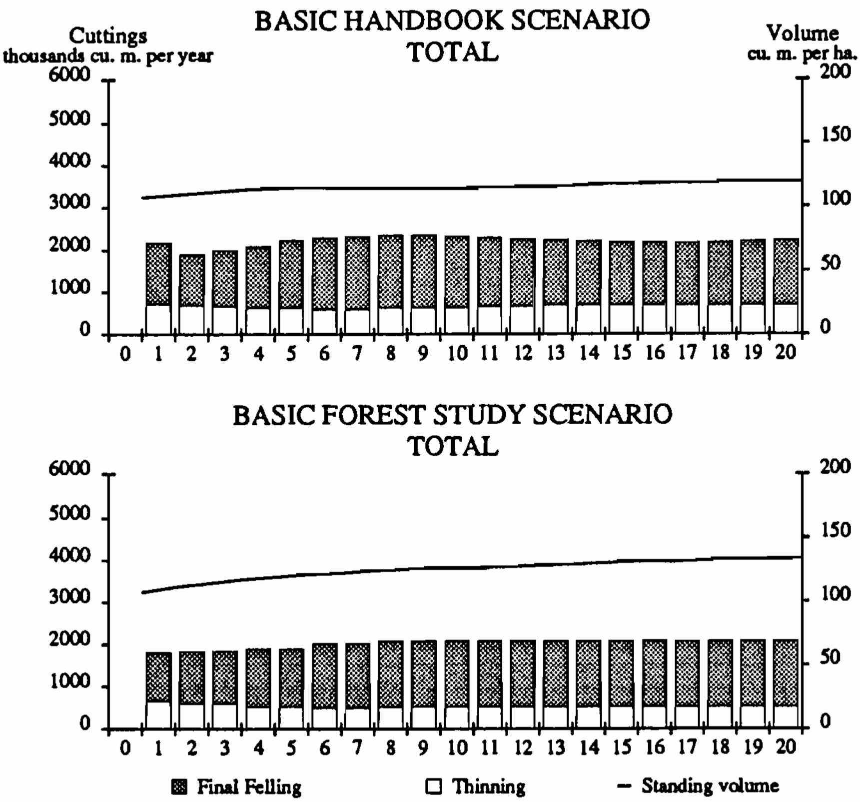

Figure A.114. Projections of total potential harvest and growing stock in the Estonian region under the basic scenarios. Current total fellings are 2.6 million cubic meters o.b.

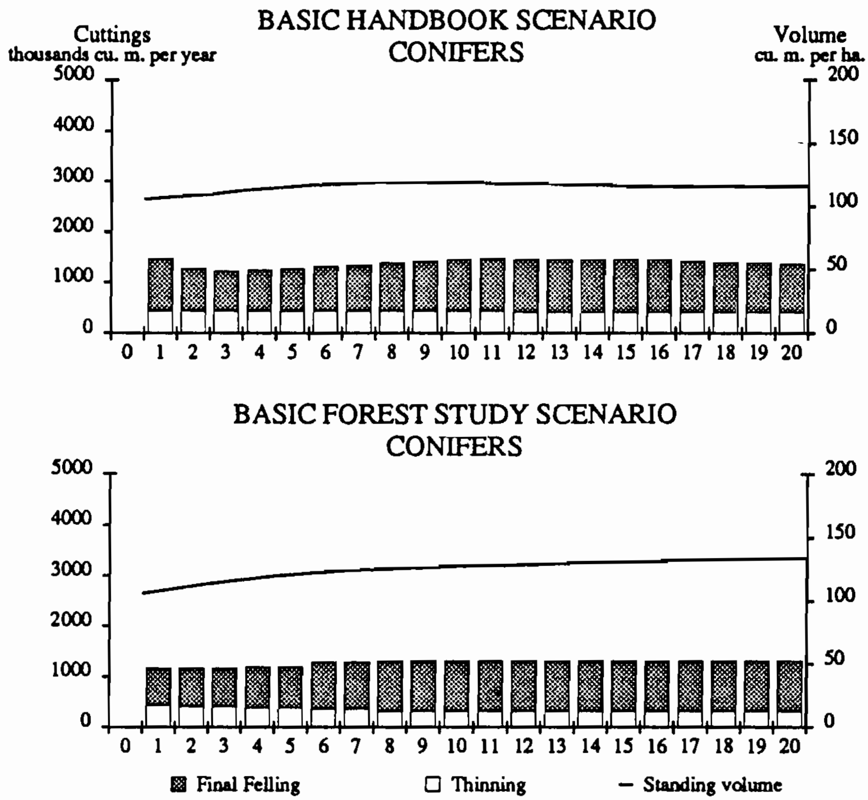

Figure A.115. Projections of potential harvest and growing stock of coniferous species in the Estonian region under the basic scenarios. Current coniferous fellings are 1.5 million cubic meters o.b.

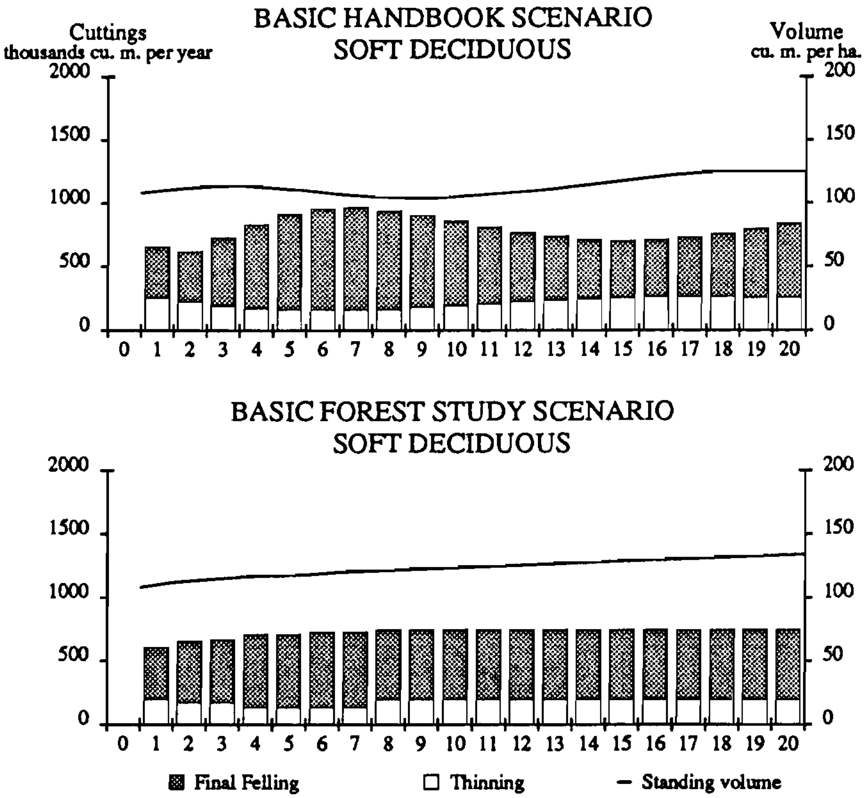

Figure A.116. Projections of potential harvest and growing stock of soft deciduous species in the Estonian region under the basic scenarios. Current soft deciduous fellings are 1.1 million cubic meters o.b.

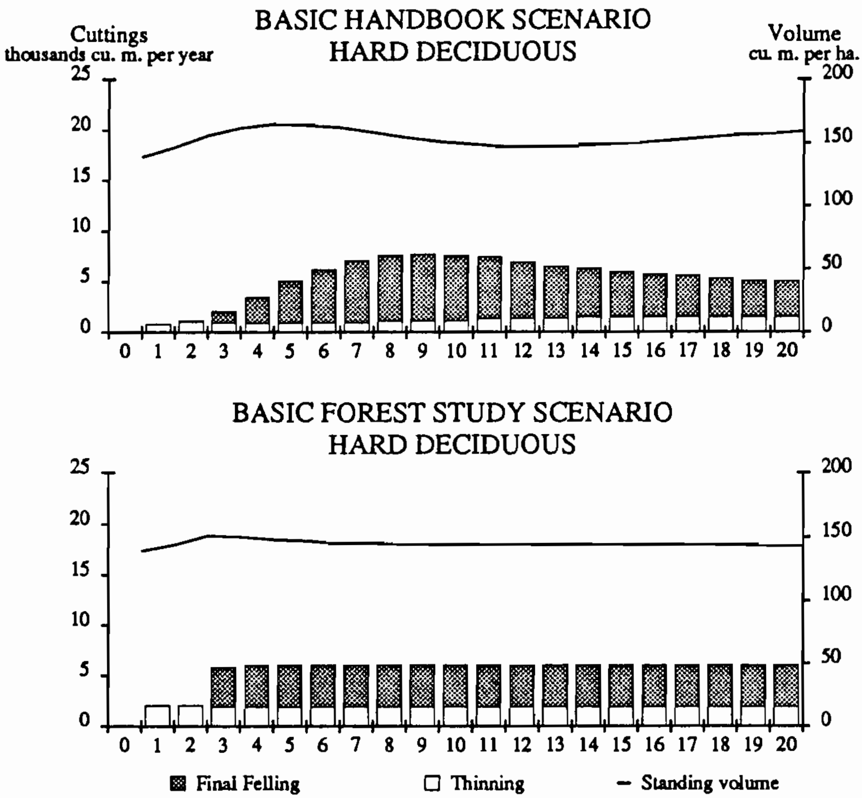

Figure A.117. Projections of potential harvest and growing stock of hard deciduous species in the Estonian region under the basic scenarios. Current hard deciduous fellings are 0.01 million cubic meters o.b.

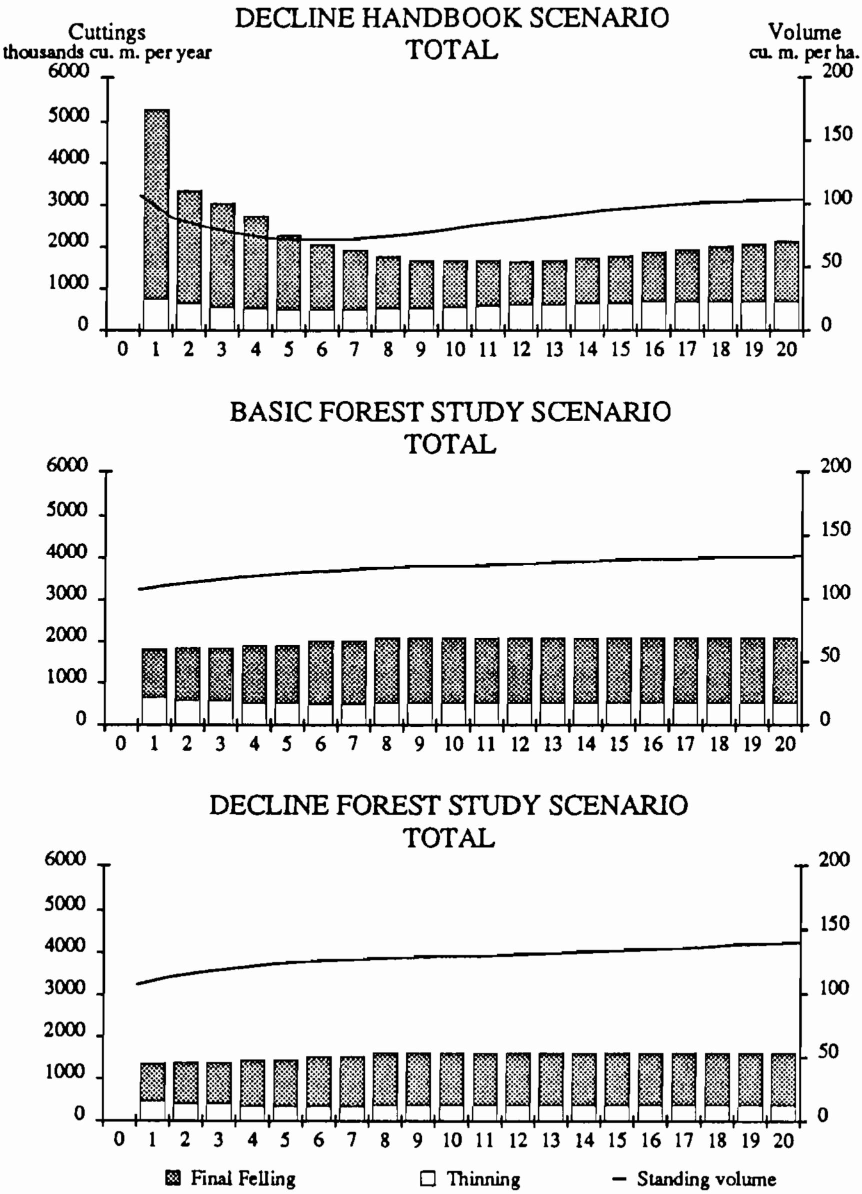

Figure A.118. Projections of total potential harvest and growing stock in the Estonian region under the decline scenarios. Current total fellings are 2.6 million cubic meters o.b.

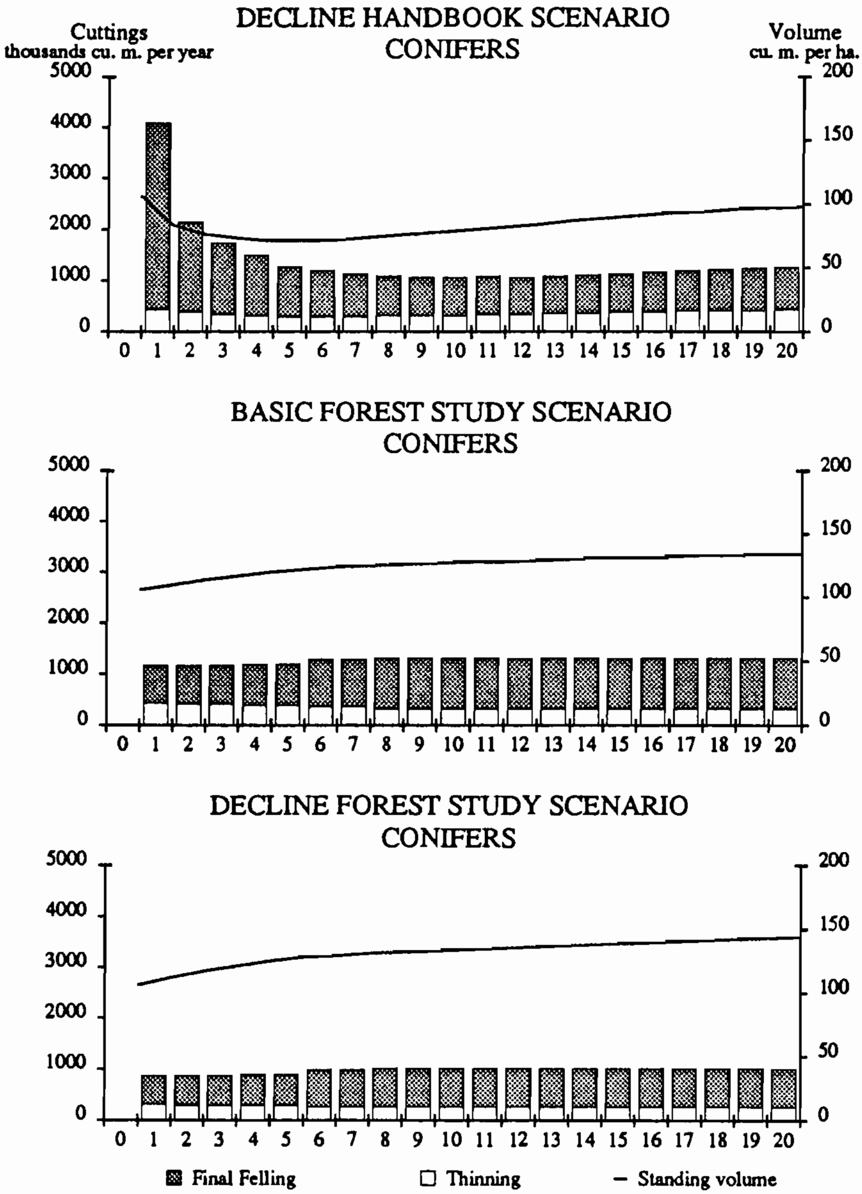

Figure A.119. Projections of potential harvest and growing stock of coniferous species in the Estonian region under the decline scenarios. Current coniferous fellings are 1.5 million cubic meters o.b.

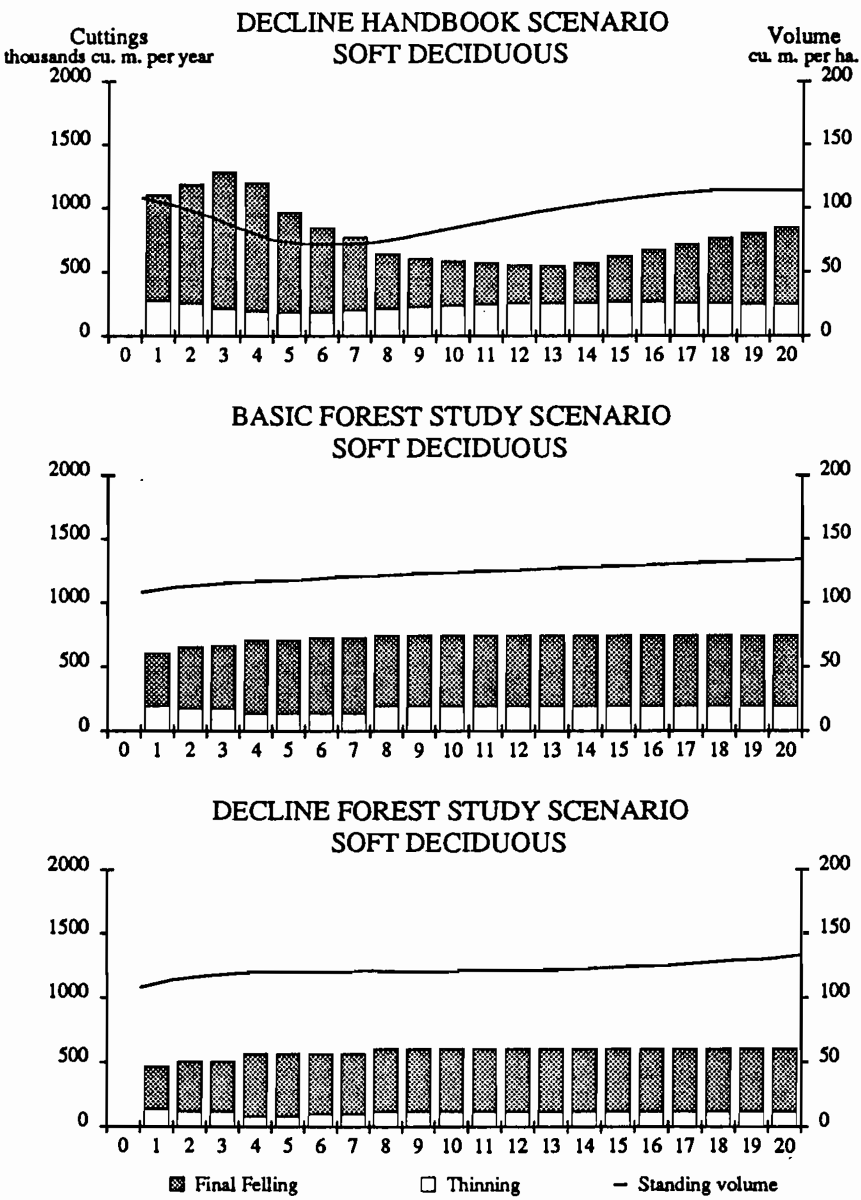

Figure A.120. Projections of potential harvest and growing stock of soft deciduous species in the Estonian region under the decline scenarios. Current soft deciduous fellings are 1.1 million cubic meters o.b.

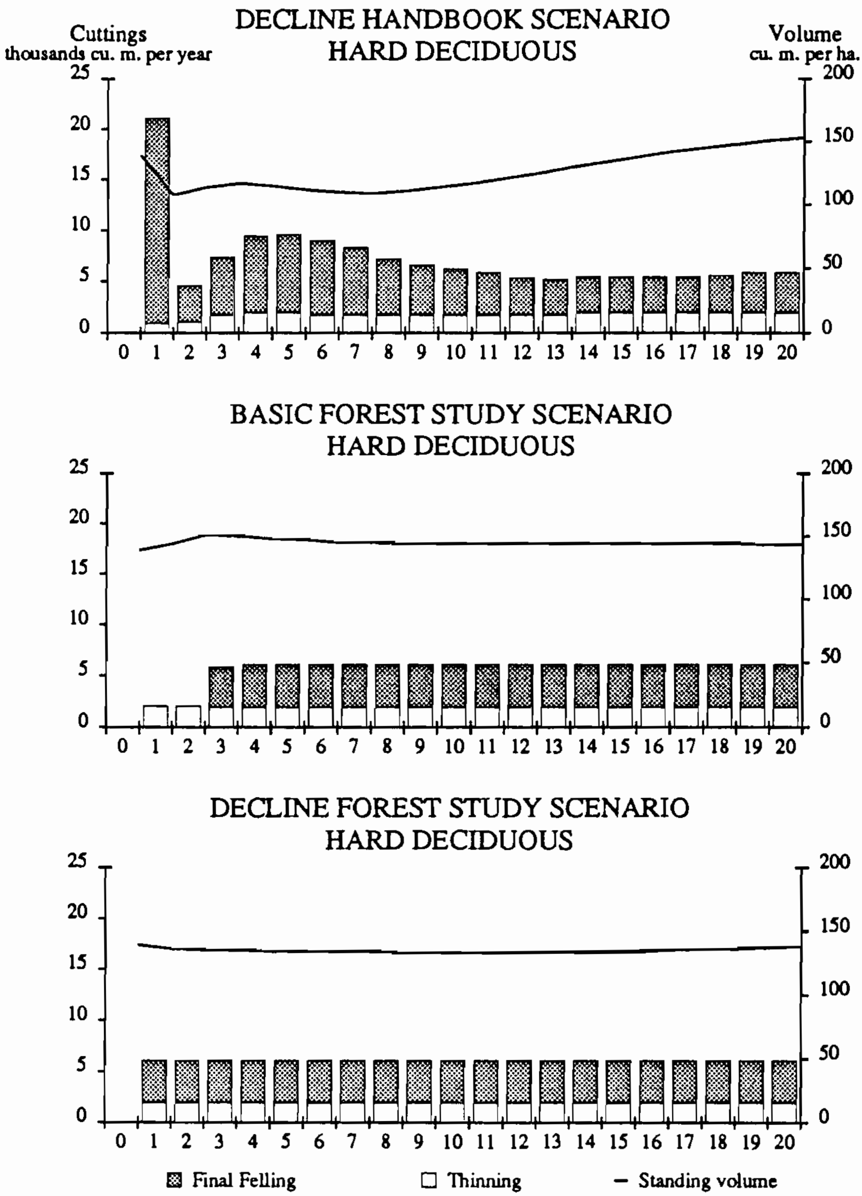

Figure A.121. Projections of potential harvest and growing stock of hard deciduous species in the Estonian region under the decline scenarios. Current hard deciduous fellings are 0.01 million cubic meters o.b.

Latvian Region (Table A.18 and Figures A.122 to A.127)

The Latvian commercial forests are dominated by coniferous species (68 percent) and soft deciduous species (32 percent). About 55 percent of the commercial forest area belongs to Forest Group II, and the rest to Forest Group I.

The existing age-class distribution is rather even for coniferous species. In soft deciduous species, there is a concentration in age classes of 30 to 50 years.

Basic Scenarios

The Basic Handbook Scenario generates a slight harvest pulse in the beginning of the simulation period for all species groups. This indicates a nearly complete correspondence between the existing structure of the forest resources and one which is generated by implementing the handbook silviculture.

In the Basic Forest Study Scenario there is a possibility of achieving even harvesting potentials and growing-stock development for all species groups during the entire simulation period.

Under the basic conditions, the estimated total average harvesting level is 4.4 million cubic meters over bark. This corresponds quite well with the current total fellings of 3.9 million cubic meters over bark. However, there is an imbalance between the current harvest level and potential levels if individual species groups are studied. The average potential coniferous harvest is estimated to be 3.0 million cubic meters over bark, but the current harvest is only 1.8 million cubic meters. The corresponding figures for soft deciduous species are 1.5 million cubic meters and 2.1 million cubic meters. This indicates a current overharvest of this species group.

Of the total average potential of 4.4 million cubic meters over bark per year, nearly 25 percent should be harvested as thinnings.

The growth rates are quite similar in the two basic scenarios. This is a result of the good balance between the existing structure of the forest and a structure generated by the handbook silviculture.

Decline Scenarios

The effects of air pollutants are significant in Latvia. The decline causes considerable harvesting peaks in the beginning of the simulation period in the Handbook Decline Scenario for all species groups. The developments of the growing stocks also are more unstable in this scenario than in the Basic Handbook Scenario.

In the Forest Study Decline Scenario there are still possibilities of achieving even harvesting levels and developments of the growing stocks for all species groups during the entire simulation period. The sustainable total average harvesting level under decline conditions is estimated to be 3.7 million cubic meters over bark per year. This corresponds to about a 15 percent decline of the total potential under basic conditions.

The total growth rate declines by 0.4 cubic meters over bark per hectare per year as an effect of the air pollutants.

Summary

There is a rather good balance between the existing structure of forest resources in Latvia and a structure generated by a fully implemented handbook silviculture. However, this balance is disturbed by the effects of air pollutants. There is also a good balance, under basic conditions, between current total harvest and the estimated total average harvesting potential. On the other hand, there are imbalances for the individual species groups concerning current harvest and sustainable potential harvest level. These imbalances suggest increased coniferous harvests and decreased soft deciduous fellings in the future in maintaining a sustainable forest resource in Latvia.

The decline caused by air pollutants generates a decrease of the total average harvesting potential by about 15 percent or 0.7 million cubic meters over bark per year.

Table A.18. Latvian region.

Variable	Basic Hand-book	Basic Forest Study	Hand-book Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	164–151	164–174	164–132	164–184
Fellings[b]				
Year 1	6.4	4.5	8.1	3.8
Year 40	4.9	4.5	4.6	3.8
Year 80	4.5	4.5	3.8	3.8
Coniferous				
Growing stock[a]	168–152	168–184	168–129	168–198
Fellings[b]				
Year 1	4.5	3.0	6.0	2.6
Year 40	3.2	3.0	3.2	2.6
Year 80	3.2	3.0	2.6	2.6
Soft deciduous				
Growing stock[a]	155–148	155–151	155–136	155–155
Fellings[b]				
Year 1	1.9	1.5	2.1	1.2
Year 40	1.7	1.5	1.4	1.2
Year 80	1.3	1.5	1.2	1.2
Hard deciduous				
Growing stock[a]	0–0	0–0	0–0	0–0
Fellings[b]				
Year 1	0.0	0.0	0.0	0.0
Year 40	0.0	0.0	0.0	0.0
Year 80	0.0	0.0	0.0	0.0
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	4.8	4.5	4.8	3.8
Coniferous	3.3	3.0	3.3	2.6
Soft deciduous	1.5	1.5	1.5	1.2
Hard deciduous	0.0	0.0	0.0	0.0
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	3.6	3.5	3.4	3.1
Coniferous	3.5	3.5	3.3	3.2
Soft deciduous	3.6	3.4	3.4	2.8
Hard deciduous	0.0	0.0	0.0	0.0
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	164–151	164–174	164–132	164–184
Coniferous	168–152	168–184	168–129	168–198
Soft deciduous	155–148	155–151	155–136	155–155
Hard deciduous	0–0	0–0	0–0	0–0

[a]In m^3 o.b. ha^{-1}; yr0–yr100. [b]In mill. m^3 o.b. yr^{-1}. [c]Average for the simulations over 100 years.

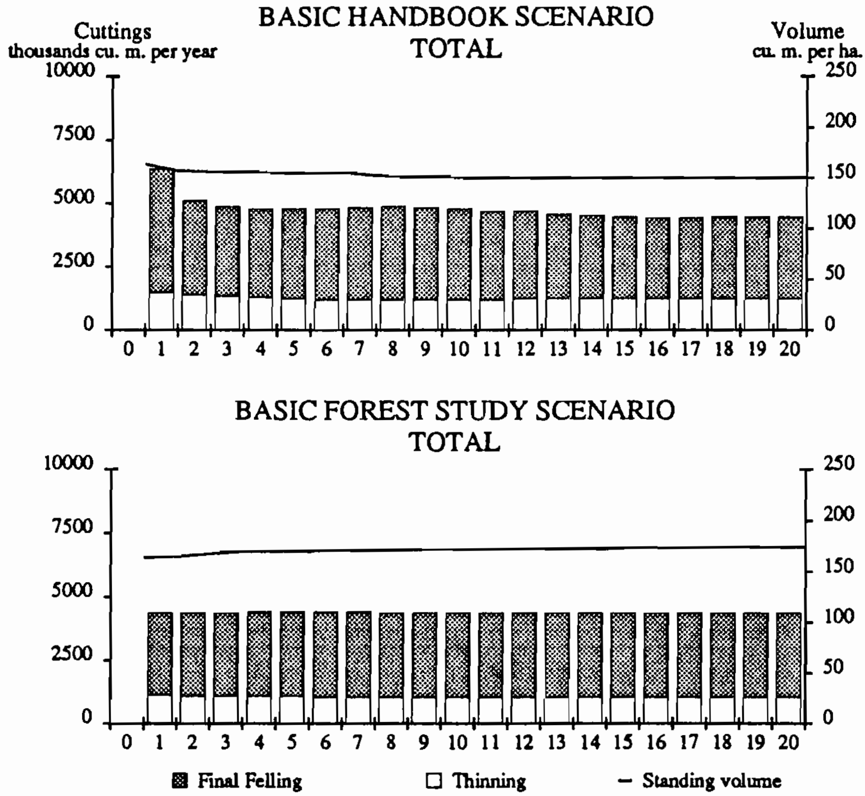

Figure A.122. Projections of total potential harvest and growing stock in the Latvian region under the basic scenarios. Current total fellings are 3.9 million cubic meters o.b.

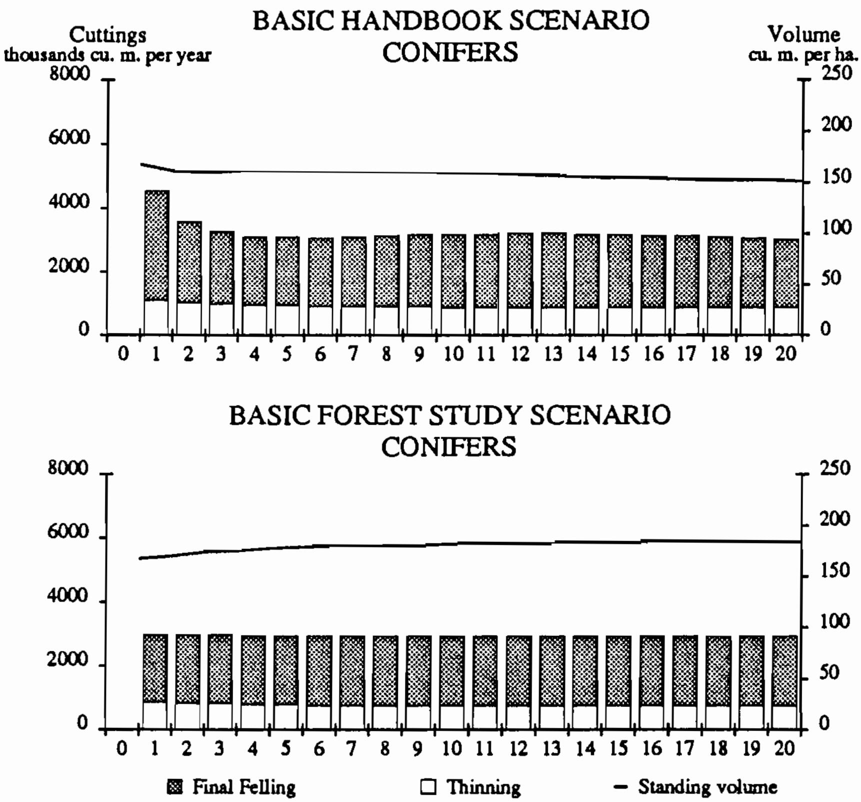

Figure A.123. Projections of potential harvest and growing stock of coniferous species in the Latvian region under the basic scenarios. Current coniferous fellings are 1.8 million cubic meters o.b.

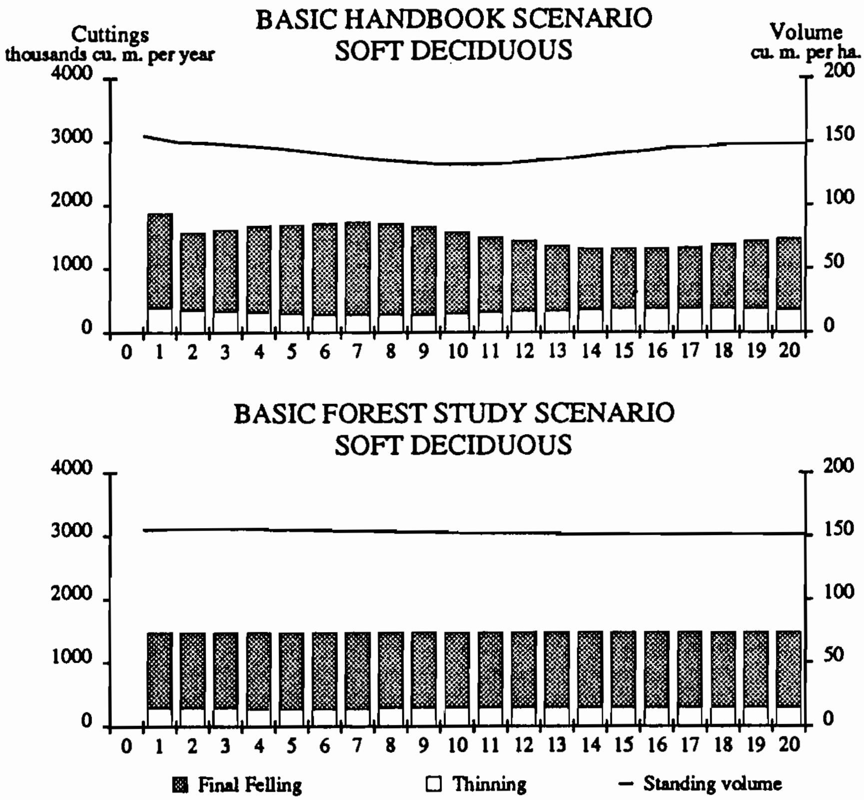

Figure A.124. Projections of potential harvest and growing stock of soft deciduous species in the Latvian region under the basic scenarios. Current soft deciduous fellings are 2.1 million cubic meters o.b.

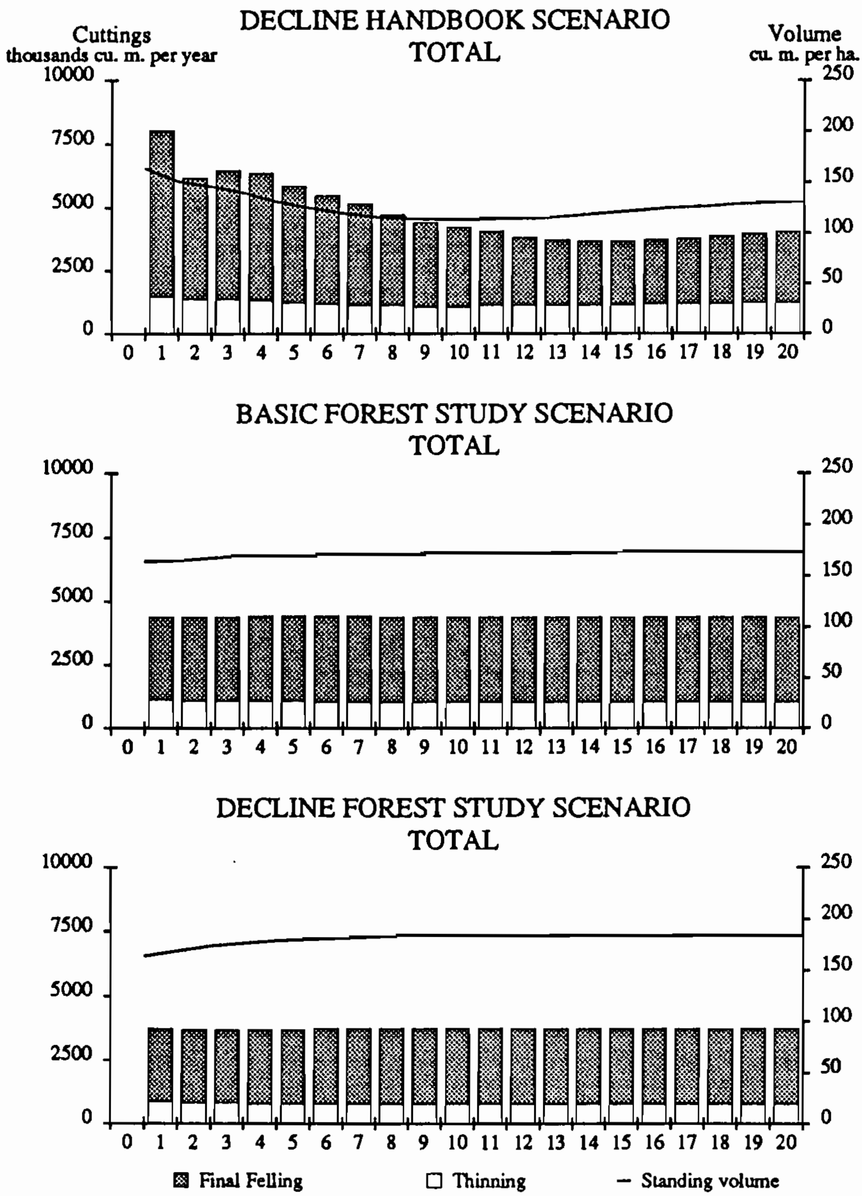

Figure A.125. Projections of total potential harvest and growing stock in the Latvian region under the decline scenarios. Current total fellings are 3.9 million cubic meters o.b.

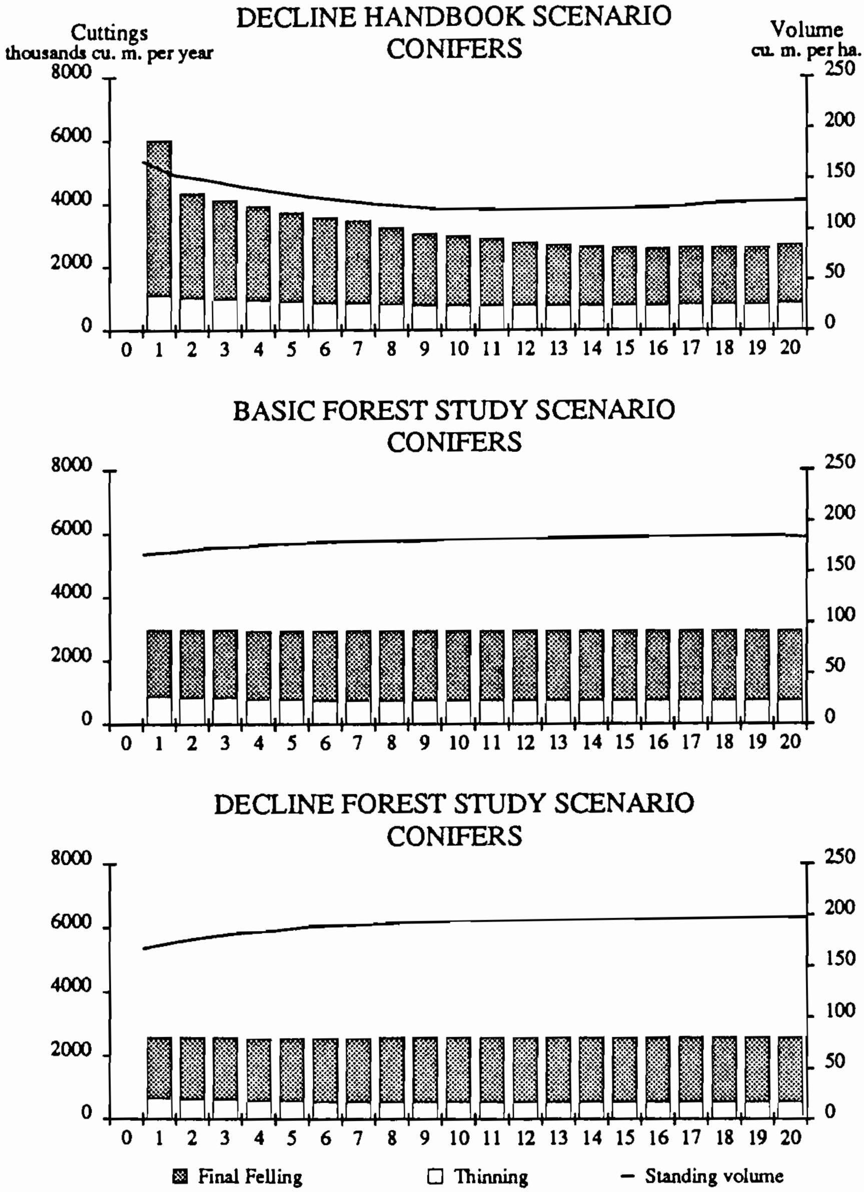

Figure A.126. Projections of potential harvest and growing stock of coniferous species in the Latvian region under the decline scenarios. Current coniferous fellings are 1.8 million cubic meters o.b.

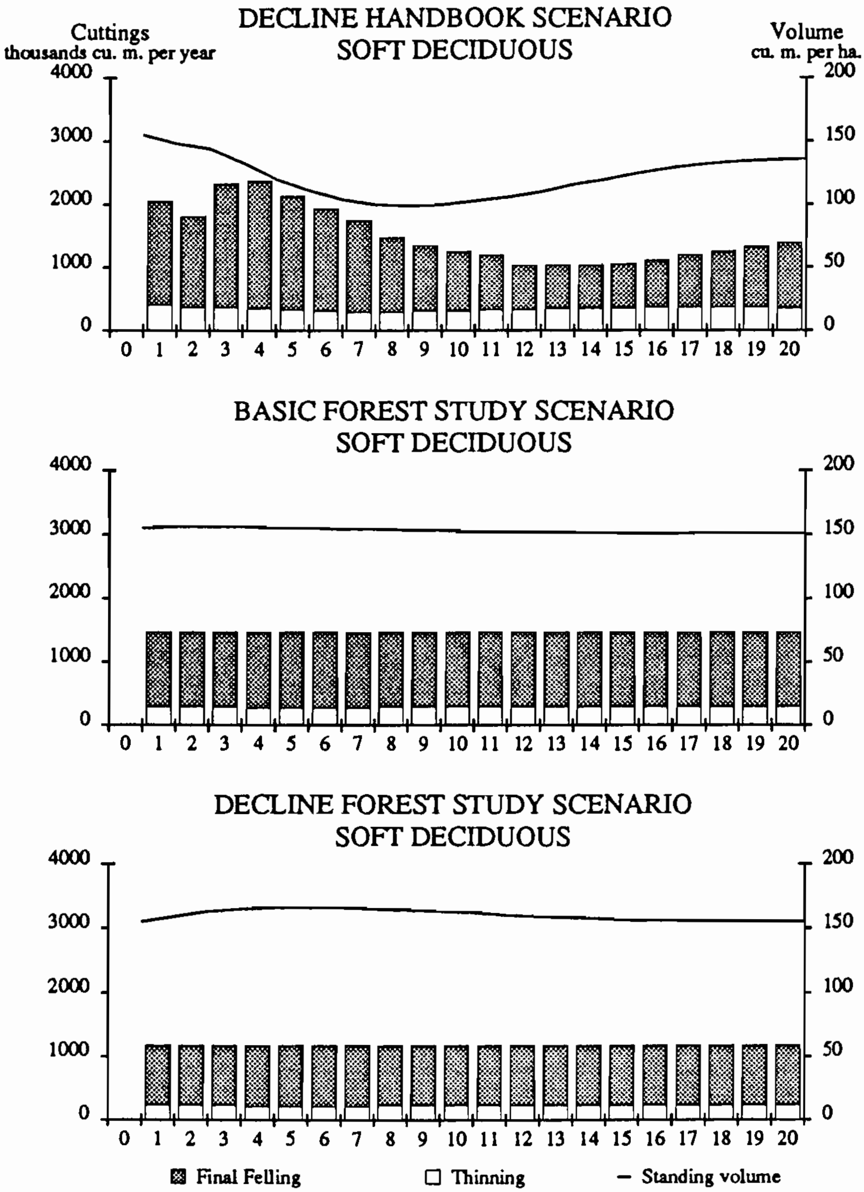

Figure A.127. Projections of potential harvest and growing stock of soft deciduous species in the Latvian region under the decline scenarios. Current soft deciduous fellings are 2.1 million cubic meters o.b.

Lithuanian Region (Table A.19 and Figures A.128 to A.135)

The commercial forests of Lithuania are dominated by coniferous species (some 65 percent) and soft deciduous species (32 percent). The major part of the commercial forest area belongs to Forest Group II (about 65 percent) and the rest to Forest Group I.

Most of the forests are young or middle-aged. Hence, there is a lack of mature and overmature forests for final fellings in the Lithuanian region. In soft deciduous species there is an accumulation in the age classes of 30 to 50 years.

Basic Scenarios

Due to the lack of overmature forests and a concentration of the existing resources in young and middle-aged forests, the Basic Handbook Scenario generates an increasing harvesting potential for all species groups during the first 40 years of the simulation period. Coupled with the increased harvest is a slight decline in the growing stocks.

In the Basic Forest Study Scenario there is a possibility of keeping an even harvesting level throughout the entire simulation period with exception of hard deciduous species. For this species group, the harvesting potential is more uneven over time. In addition to the even potential harvesting level is an even and stable development of the growing stocks in this scenario. However, there is an exception to this rule. In soft deciduous species, it is necessary to decrease the growing-stock level to maintain the even harvesting level.

There is a difference in the growth rates between the two basic scenarios. The Basic Forest Study Scenario gives a lower total growth rate than the Basic Handbook Scenario (0.2 cubic meters over bark per hectare per year lower).

The total average harvesting potential under basic conditions is estimated to be 3.8 million cubic meters over bark per year. The total current harvest is 3.0 million cubic meters. The average harvesting potential for coniferous species is 2.4 million cubic meters, although the current harvest is only 1.2 million cubic meters. In contrast, the conditions for deciduous species are the opposite, with an average potential of 1.5 million cubic meters and a current harvest of 1.8 million cubic meters over bark per year. About 30 percent of the total average harvesting potential should be harvested as thinnings.

Decline Scenarios

The decline effects caused by air pollutants are significant in Lithuania. The total average harvesting potential decreases by 0.6 million cubic meters per year or by 16 percent due to air pollutants. The Handbook Decline Scenario does not change the principal structure of the forests.

In the Forest Study Decline Scenario there are possibilities of keeping even potential harvesting patterns throughout the entire simulation period. The group most affected by the decline is the coniferous species. The decline in this group is estimated to be 0.4 million cubic meters over bark per year. The total growth rate is decreased by 0.5 cubic meters per hectare per year.

Summary

Most of the forests in Lithuania are young or middle-aged. This results in an increasing harvesting potential in the beginning of the simulation period in the Basic Handbook Scenario. In the Basic Forest Study Scenario more or less even harvesting levels are achieved. The total average harvest potential is in balance with the current harvest. However, there are imbalances between potentials and current harvests for individual species groups, which indicates that changes in harvesting policy are required in the future.

The decline effects from air pollutants are estimated to be significant in Lithuania. The decrease in the total average harvesting potential is calculated to be 16 percent of the potential under basic conditions.

Table A.19. Lithuanian region.

Variable	Basic Hand-book	Basic Forest Study	Hand-book Decline	Forest Study Decline
Selected data on harvests and growing stock				
Total				
Growing stock[a]	182–164	182–195	182–150	182–195
Fellings[b]				
Year 1	2.7	3.5	4.6	3.1
Year 40	5.3	3.9	4.6	3.3
Year 80	4.2	3.9	3.3	3.2
Coniferous				
Growing stock[a]	194–171	194–235	194–158	194–236
Fellings[b]				
Year 1	1.7	2.1	3.0	2.0
Year 40	3.3	2.4	3.2	2.0
Year 80	2.9	2.4	2.2	2.0
Soft deciduous				
Growing stock[a]	163–148	163–116	163–131	163–109
Fellings[b]				
Year 1	0.9	1.2	1.5	1.0
Year 40	1.8	1.3	1.2	1.1
Year 80	1.1	1.3	0.9	1.1
Hard deciduous				
Growing stock[a]	130–180	130–193	130–175	130–220
Fellings[b]				
Year 1	0.1	0.2	0.1	0.1
Year 40	0.2	0.2	0.2	0.2
Year 80	0.2	0.2	0.2	0.1
Summary of results				
Potential harvest (mill. m^3 o.b. yr^{-1})[c]				
Total	4.4	3.9	4.2	3.2
Coniferous	2.8	2.4	2.7	2.0
Soft deciduous	1.4	1.3	1.3	1.1
Hard deciduous	0.2	0.2	0.2	0.1
Growth (m^3 o.b. ha^{-1} yr^{-1})[c]				
Total	3.8	3.6	3.5	3.1
Coniferous	3.8	3.8	3.5	3.3
Soft deciduous	3.8	3.2	3.4	2.6
Hard deciduous	5.0	5.5	4.7	4.9
Development of growing stock (m^3 o.b. ha^{-1}; yr0–yr100)				
Total	182–164	182–195	182–150	182–195
Coniferous	194–171	194–235	194–158	194–236
Soft deciduous	163–148	163–116	163–131	163–109
Hard deciduous	130–180	130–193	130–175	130–220

[a] In m^3 o.b. ha^{-1}; yr0–yr100. [b] In mill. m^3 o.b. yr^{-1}. [c] Average for the simulations over 100 years.

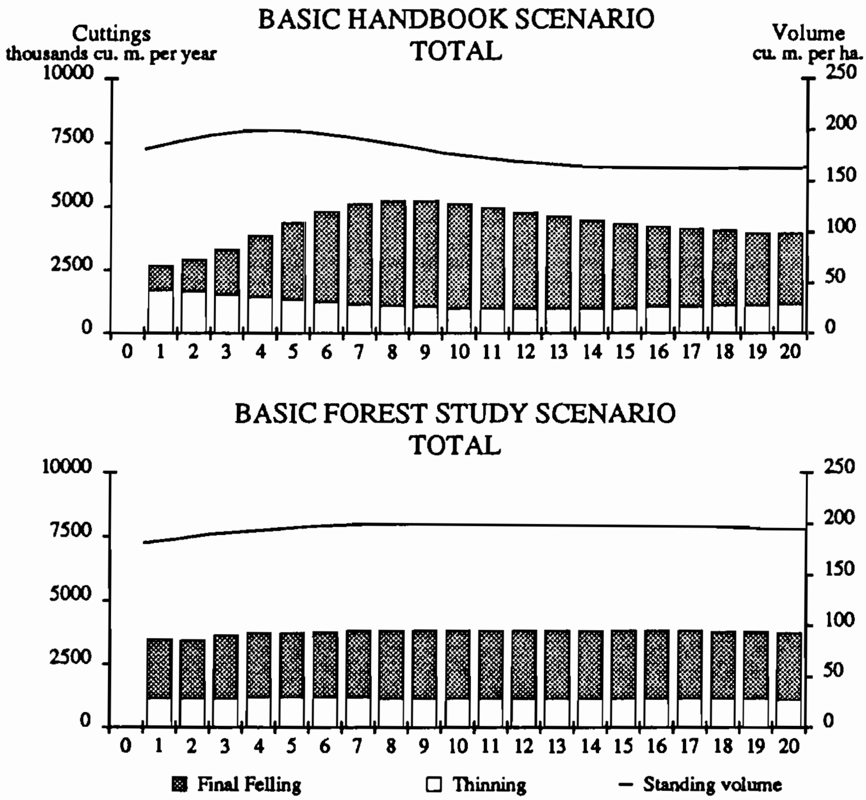

Figure A.128. Projections of total potential harvest and growing stock in the Lithuanian region under the basic scenarios. Current total fellings are 3 million cubic meters o.b.

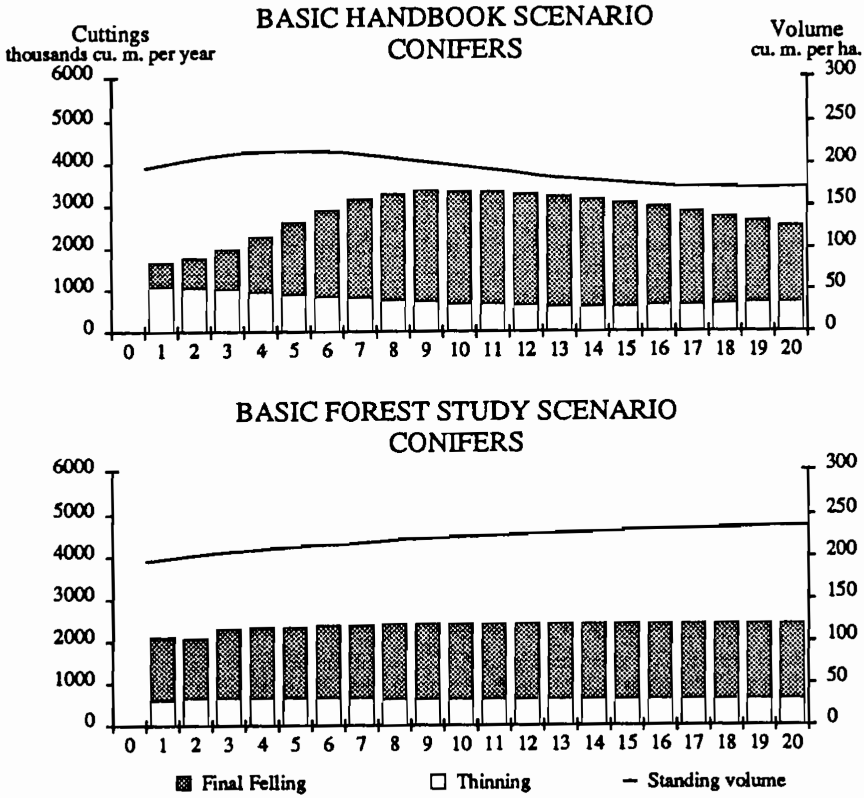

Figure A.129. Projections of potential harvest and growing stock of coniferous species in the Lithuanian region under the basic scenarios. Current coniferous fellings are 1.2 million cubic meters o.b.

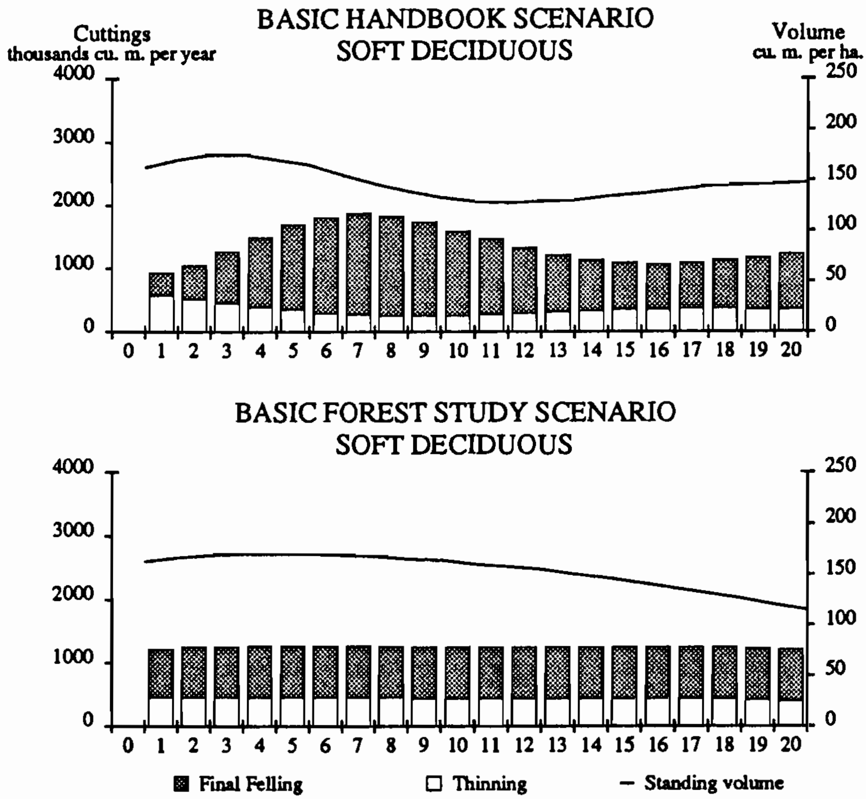

Figure A.130. Projections of potential harvest and growing stock of soft deciduous species in the Lithuanian region under the basic scenarios. Current soft deciduous fellings are 1.6 million cubic meters o.b.

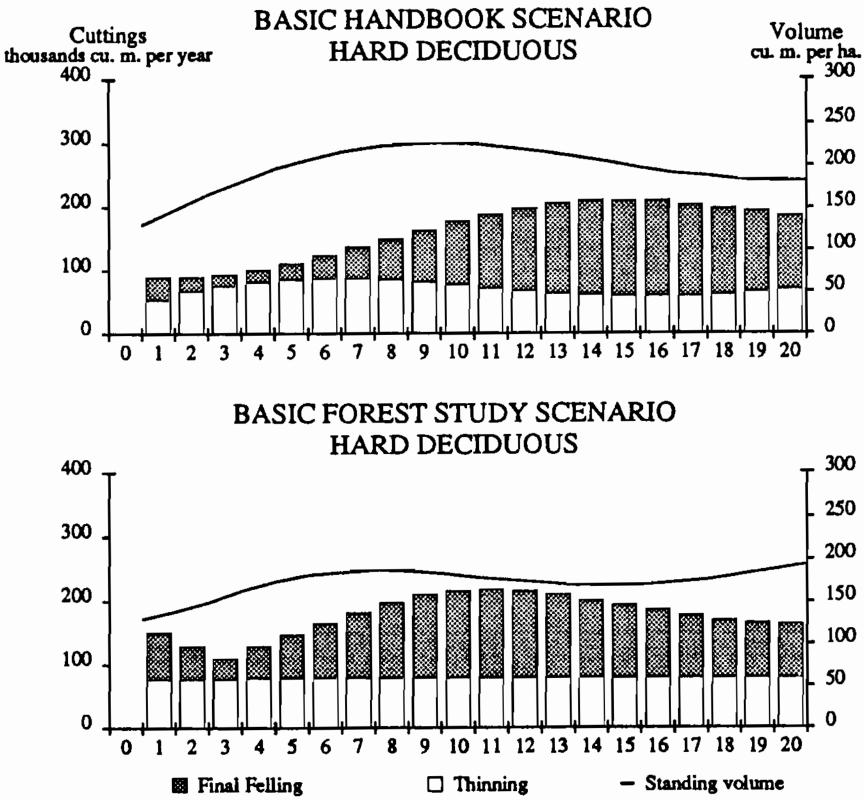

Figure A.131. Projections of potential harvest and growing stock of hard deciduous species in the Lithuanian region under the basic scenarios. Current hard deciduous fellings are 0.2 million cubic meters o.b.

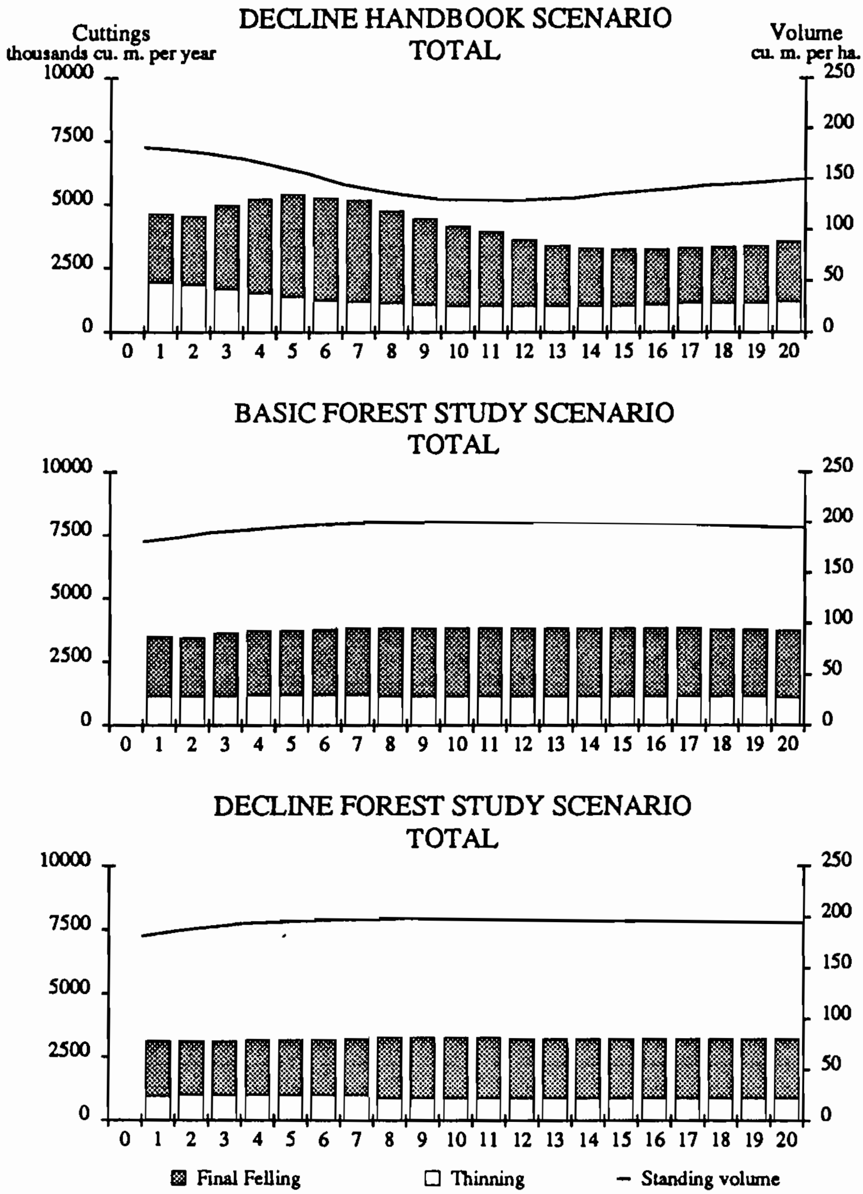

Figure A.132. Projections of total potential harvest and growing stock in the Lithuanian region under the decline scenarios. Current total fellings are 3 million cubic meters o.b.

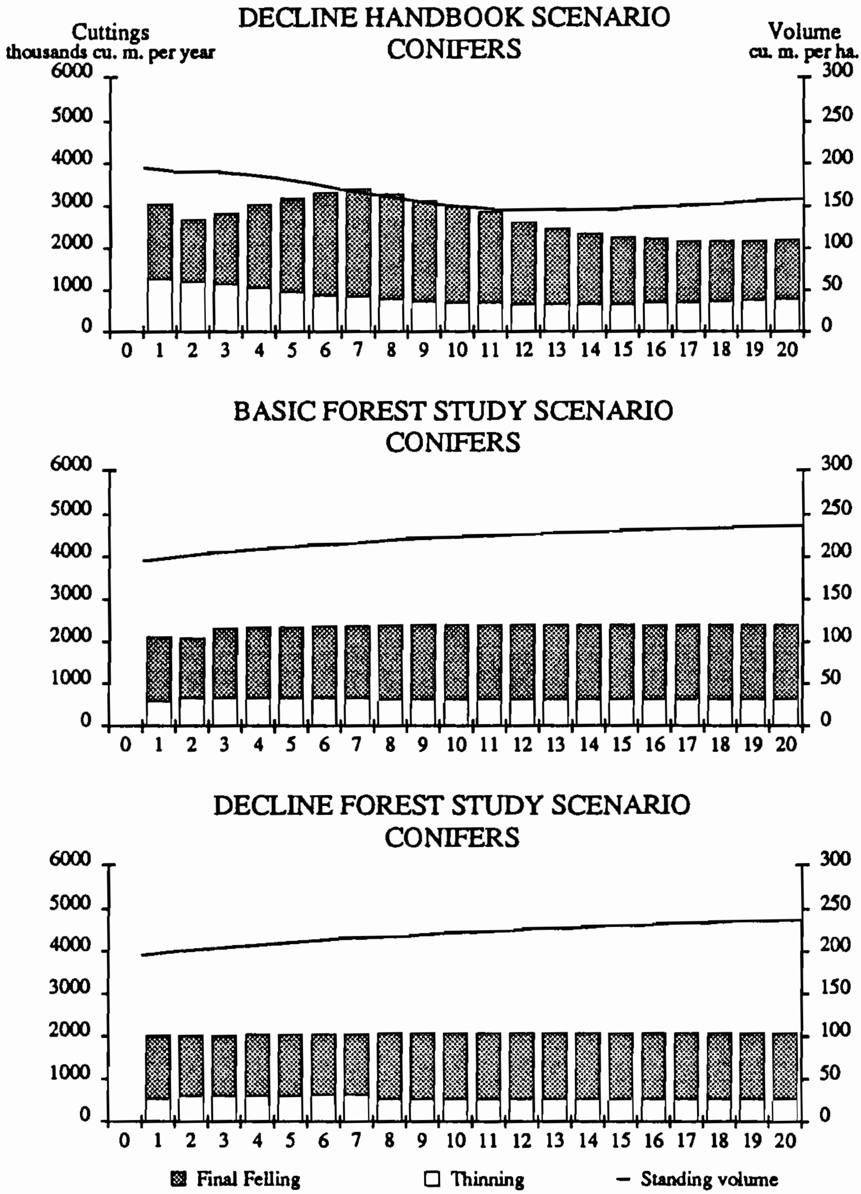

Figure A.133. Projections of potential harvest and growing stock of coniferous species in the Lithuanian region under the decline scenarios. Current coniferous fellings are 1.2 million cubic meters o.b.

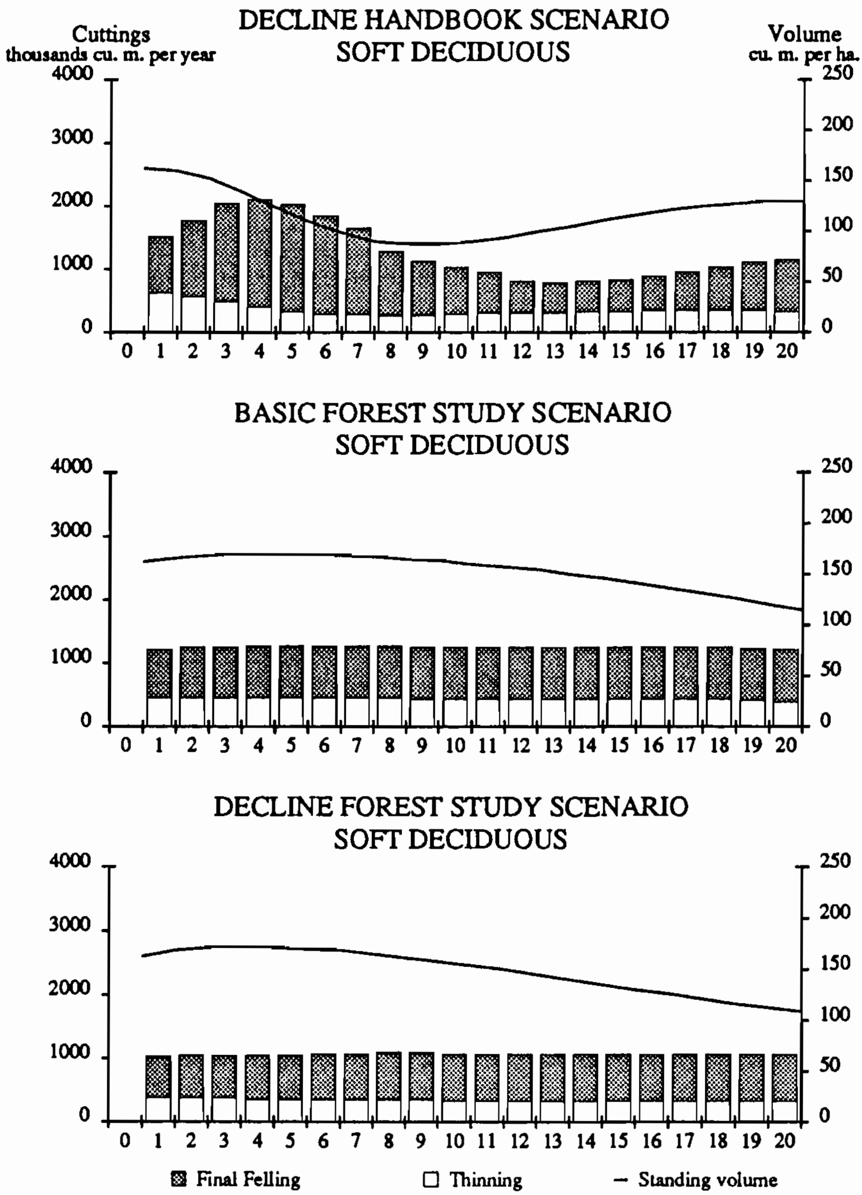

Figure A.134. Projections of potential harvest and growing stock of soft deciduous species in the Lithuanian region under the decline scenarios. Current soft deciduous fellings are 1.6 million cubic meters o.b.

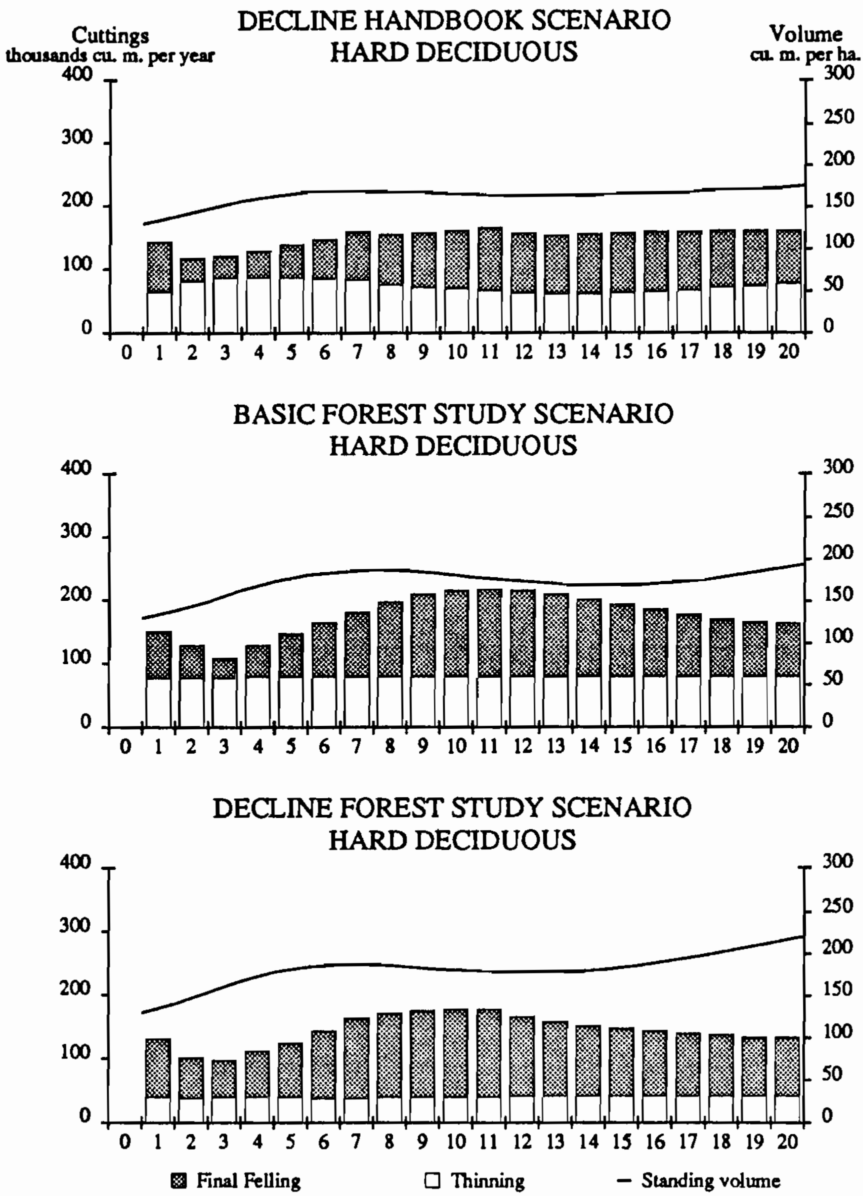

Figure A.135. Projections of potential harvest and growing stock of hard deciduous species in the Lithuanian region under the decline scenarios. Current hard deciduous fellings are 0.2 million cubic meters o.b.

Appendix B

Definitions of Soviet Forestry Terms

The Forest Fund is made up of areas of the USSR covered by forests and areas not covered by forests but which could be used for future forestry production under certain conditions. These latter areas include water reservoirs, bogs, and steep slopes.

Forest land is divided into forested areas, which are covered by trees forming closed stands and by shrubs in the cases where high forest establishment is impossible due to ecological conditions, and non-forested areas. The non-forested areas can be harvested areas without satisfactory regeneration, burned areas with no regeneration, etc.

Non-forest land includes agricultural land such as pastures, hayfields, bogs, gullies, steep slopes, and farmsteads. The forested area is divided into noncommercial and commercial land. The Forest Fund is composed of forests belonging to the state and managed by state forestry organizations (94 percent), forests belonging to other ministries and departments (2 percent), and the collective farm forests (4 percent). These last forests were given to the collective farms for unlimited use. The links between the different forest areas are illustrated in *Figure B.1*. The data for different forest areas in *Figure B.1* encompass official statistics from the State Forest Account of January 1, 1988, and the data employed in this study. As discussed in the book, some areas of the European USSR are not included in this study, namely, the forests of Armenia, Azerbaijan, Georgia, and the pure steppe part of the Ukraine. But as seen in *Figure B.1* the excluded area constitutes only 0.9 million hectares or about 0.6 percent of the commercial forests of the European USSR.

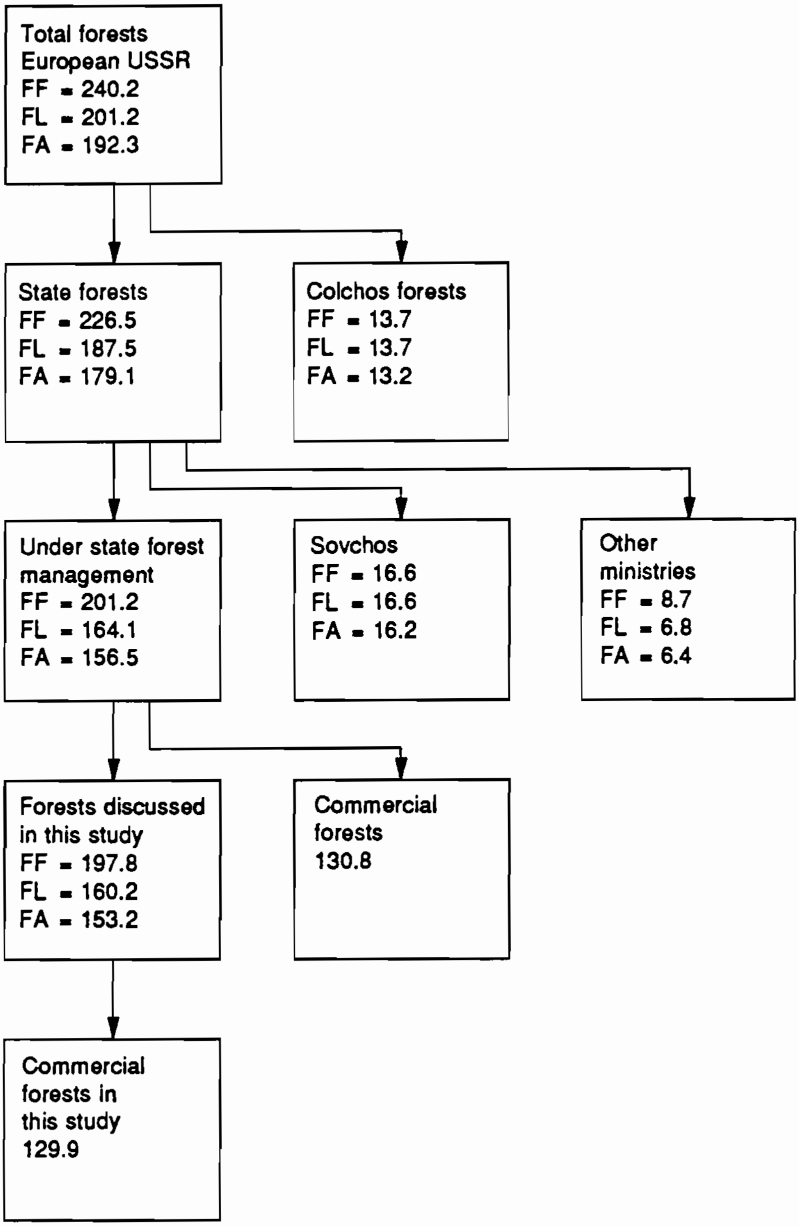

Figure B.1. Links between different forest types in the European USSR: FF = Forest Fund; FL = forest land; and FA = forested area. Data are expressed in million hectares.

The forest resources are also classified into three groups (different social purposes):

- Group I includes forests that mainly fulfill environmental functions such as water preservation and recreational functions.
- Group II is made up of forests growing in scarcely forested areas and forests with a limited exploitable value.
- Group III includes forests with several functions; the major function of these forests is the production of industrial wood.

Parts of the forests belonging to Group I are mainly reserves, nature parks, green belts, and sensitive area and constitute noncommercial forests. However, small areas of sensitive forests also exist in Groups II and III and are included in the noncommercial forests. Final felling is not allowed in these forests, so these forests are not considered when calculating the annual allowable cut (AAC). Forest cover is the percentage of forest in the ratio between forested area and the total area of a region.

Standing volume, which is presented in the basic forest inventory, is the volume of solid wood in cubic meters over bark per hectare. The commercial wood of standing volume includes wood for industrial production (industrial wood), wood for fuel, and wood for use in the chemical industry. The last two categories are called fuel wood or fire wood.

The volume of industrial wood is given as solid volume under bark (stem wood). The volume of fuel wood is given as solid volume over bark. For the conversion of commercial wood to standing volume, a standard factor of 1.12 is used.

Age class is classified by the average age of the major species in a forest. For coniferous and deciduous species of seedling origin, 20-year age classes are normally employed in the USSR (except for the Ukraine, which has a 10-year age class for these species). For other species, 10-year age classes are employed (except for the Ukraine and other smaller regions where five-year age classes are used).

Site indexes (productivity classes) are determined by the mean height at a certain age. Two different indexes are employed: one for coniferous and deciduous species with seedling origin and one for all other species and origin.

Density is determined as the ratio between the sum of the basal areas of the actual stand at breast height and the sum of basal areas of a *normal* stand according to yield tables. The density is graded from 1.0 to 0.4 for young forests and from 1.0 to 0.3 for all other stands. Stands with less density are classified as non-forested areas.

Mean annual increment (MAI) is determined by the ratio between the standing volume and the average age of the major species. MAI according to this definition is given in most forest inventories.

The aggregation into species groups includes coniferous species, hard deciduous species (oak, beech, ash, hornbeam, maple, and hard birches), and soft deciduous species (poplar, aspen, and soft birches).

Thinnings are defined as repeated cuttings of the stands starting at the formation of the stand and ending at one age class before the time for final felling. Thinnings are carried out to produce a sound composition and structure of the stand and to improve the production of high-quality timber. In the USSR three major types of thinnings can be identified:

- Tending and pre-commercial thinnings of young stands (normally done before a stand age of 20 years).
- Thinning to stimulate forest growth.
- Commercial thinning for production of high-quality timber.

Sanitation harvests are carried out for trees infested with insects and fungi and for windfallen trees. Sanitation harvests are carried out as both selective harvest and final cut. Other harvests include harvesting to clear areas for construction, powerlines, roads, pipelines, and so on.

Final felling is carried out in mature stands in the form of final or reproduction harvest. Final harvest is done in Groups II and III and aims at an efficient exploitation of the forest. Reproduction harvest is carried out in Group I and aims at improving environmental and protective functions of the forests, in combination with a rational production of commercial timber. Reproduction harvest normally takes place between 20 and 40 years after the optimal age of final harvest in the commercial forests according to yield tables.

Forest legislation on forest management in the USSR is driven by the principle of nonexhaustible and sustainable production. But to a large extent, this principle has only been established on paper. In recent years several models have been employed for analysis of sustainable forests, but these analyses have not been used by policy makers.

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