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Shvidenko, A. and Nilsson, S.

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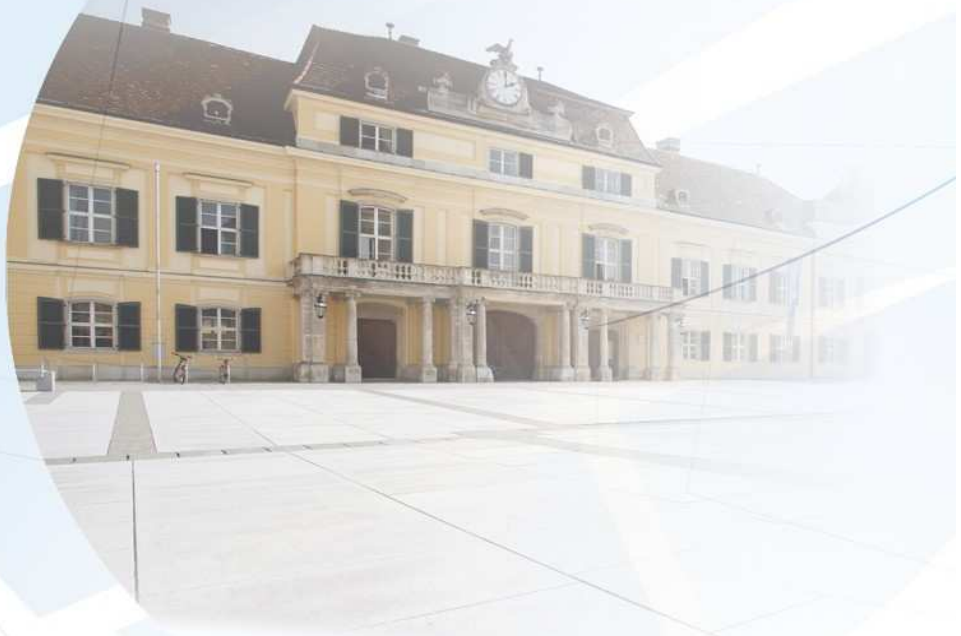

Working Paper

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IIASA International Institute for Applied Systems Analysis • A-2361 Laxenburg • Austria
Telephone: +43 2236 807 • Telefax: +43 2236 71313 • E-Mail: info@iiasa.ac.at

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Foreword

This is the time Siberia's forest sector has recently gained considerable international interest. IIASA, the Russian Academy of Sciences, and the Russian Federal Forest Service, in agreement with the Russian Ministry of theEnvironment and Natural Resources, signed agreements in 1992 and 1994 to carry out a large-scale study on the Siberian forest sector. The overall objective of the study is to focus on policy options that would encourage sustainable development of the sector. The goals are to assess Siberia's forest resources, forest industries, and infrastructure; to examine the forests' economic, social, and biospheric functions; with these functions in mind, to identify possible pathways for their sustainable development; and to translate these pathways into policy options for Russian and international agencies.

The first phase of the study concentrated on the generation of extensive and consistent databases for the total forest sector of Siberia and Russia. The study has now moved into its second phase, which encompasses assessment studies of the greenhouse gas balances, forest resources and forest utilization, biodiversity and landscapes, non-wood products and functions, environmental status, transportation infrastructure, forest industry and markets, and socio-economic problems. This report, by Professors Shvidenko and Nilsson from the study's core team, is a study with bearing on several of the above mentioned quantitative assessment studies.

Abstract

Analyses of aggregated data of the dynamics of Russian forests during the period from 1966 to 1993 have identified a rather stable development of Forested Areas (FA) and growing stock (an increase of 8% and 5%, respectively). Unforested Areas (UFA) have decreased significantly; for example, the total amount of unforested burned areas declined from 68.4 to 31.9 million ha over the period. Average growing stock by age groups increased for all main forest-forming species (excluding mature and overmature coniferous stands). Development in the growing stock in European Russia has been positive, but Asian Russia has experienced a rather severe decline. Studies of the 1983–1993 period show somewhat different results. Official data show that the total growing stock for Russia underwent a serious decline over this period. An adjustment for systematic inventory errors still shows that there has been a substantial decrease in the growing stock in Asian Russia. The decline identified during this latter period cannot be explained by the harvest carried out, but is probably due to disturbances such as forest fires, pest, insects, and anthropogenic activities.

From analyses, it can be concluded that the quality of the forests has been seriously impoverished in Russia during the 1966–1993 period. This impoverishment is due to severe local overharvesting in regions with developed infrastructure and to so-called creaming – namely, the harvesting of the best stands of specific species over huge areas.

There are still vast areas of unexploited and unmanaged forests in Russia. In spite of serious shortcomings in Russian forest management, the stability of Russian boreal forests and their capacity for natural regeneration seem to be extremely high. Therefore, it may to be premature to speak of "the disappearing Russian forests."

Key words: dynamics of forests, sustainable development, Russian forests

EXPANDING FORESTS BUT DECLINING MATURE CONIFEROUS FORESTS IN RUSSIA

Anatoly Shvidenko and Sten Nilsson

1. INTRODUCTION

In the public and the world scientific community the viewpoint is widely held that Russian forests are disappearing (Barr and Braden, 1988; Scott and Gordon, 1992; Golubchikov, 1992; Rosencrantz and Scott, 1992; Knight, 1992; Gusewelle, 1992; Cejka, 1992; Dudley, 1992; Greenpeace, 1993; Aksin, 1993; Luskotov, 1993; Dudley *et al.*, 1995; Stanners and Bourdeau, 1995). There are many significant shortcomings in the Russian forest sector; poor forest management, insufficient forest protection, and huge losses of wood at harvests and during wood processing have repeatedly been reported (e.g., Isaev, 1991a; Nilsson *et al.*, 1992; Shvidenko and Nilsson, 1994). Illustrations of the exhaustive nature of forest utilization in Russia in recent decades are plentiful (e.g., Petrenko, 1990; Sheingauz, 1989). However, explicit conclusions on the state and the dynamics of Russian forests can only be based on numerical analysis of changes in inventory data of forest areas over an extended period of time. In the case of Russia, we encounter several difficulties in comparisons of analyses over time: 1) different forest inventory methods are used in Russia and the methods have undergone several changes since the 1960s; 2) the availability of data is limited at the regional level because inventory data were not available to the scientific community before 1988; 3) vast areas of forests in northern Russia were inventoried many years ago using imprecise methods; 4) the quality and quantity of the information available on different categories of forest management vary – for example, the most detailed information is available on main forest-forming species (MFFS) in forests under state forest management, but limited and irregular data are available on kolkhosos forests or forests managed by other governmental agencies. In 1988 the distributions in the different categories were the following: the Forest Fund (FF) areas totaled 1182.6 million ha and Forested Areas (FA) totaled 771.1 million ha[1]. Approximately 94.4% of the FF and 92.5% of the FA were

[1] One of seven basic land-cover categories used in the former Soviet Union (and currently in Russia) is the Forest Fund (FF), which is, according to Russian legislation (1993), all forests and all land allocated for forest purposes. FF is divided into Forest Land (FL) and Nonforest Land (NFL). Forest Land is designated for forest growth and includes Forested Areas (FA), which are areas covered by forests with relative stocking of 0.4 or more for young stands and relative stocking of 0.3 and more for other stands, and Unforested Areas (UFA), which are regions that are temporarily forestless and include burned areas, dead stands, sparse forests, unregenerated harvesting areas, and grassy glades. NFL includes two land types: areas which are unacceptable for forest growth under current conditions (mires, rocks, tundra areas, sands, etc.) and lands set aside for special purposes (roads, hayfields, and so on). The latest Russian inventory manual further divides the FL into non-closed planted forests, forest plantations and nurseries, and natural sparse forests. The main forest-forming species includes three groups of tree species: coniferous (pine, larch, spruce, fir, and Russian cedar – *Pinus sibirica* and *P. koraiensis*), hard deciduous (oak, hornbeam, ash, stone birch, etc.), and soft deciduous species (basically birch and aspen).

managed by state forest authorities (of which 102.2 million ha or 8.6% of the FF and 37.4 million ha or 4.9% of the FA were transferred to long-term lease, mainly for agricultural purposes). Forests covered by MFFS and managed by state forest authorities totaled 652.9 million ha. Some 4.3% of the FF and 5.5% of the FA were managed by other agencies (Ministry of Defense, Ministry of Internal Affairs, sovkhosos forests, and so on); 1.3% of the FF and 2% of the FA were kolkhosos forests. Thus, about 85% of all FA were made up of the main forest-forming species, and between 94.7% (1966) and 92.4% (1993) of the total FF areas were under state forest management.

This paper pursues two main goals: first, to present a brief analysis of the consistency, accuracy, and reliability of Russian forest inventory methods; second, to discuss the dynamics, over time, of some important indicators such as FA, growing stock, and distribution of areas covered by dominant species. The basic statistical information was derived from data of the State Forest Account (Gosleshoz SSSR 1968, 1976, 1982, 1986; Goscomles SSSR 1990, 1991; Federal Forest Service of Russia, 1995) and from different Russian publications (see references). Because of a lack of compatible inventory data we limit our analysis to the 1966–1993 period.

2. REVIEW OF INVENTORY METHODS AND ACCURACY AND RELIABILITY OF DATA

There is one, major, source of information concerning all Russian forests: the State Forest Account (SFA). The SFA is regularly updated every five years; the first SFA was carried out in 1961, and over the past three decades revised SFAs of Russia were prepared in 1966, 1973, 1978, 1983, 1988, 1993. The SFA follows specific procedures for collecting data on the status of forests and for updating these data by a specific date (Gosleshoz SSSR, 1982).

Three basic methods have been used in Russian forest inventories: *lesoustroistvo* or forest inventory and planning (FIP), *aerotaxation* (aerial inventory methods), and *remote-sensing methods*. Basic requirements for forest inventory, procedures, and data handling were documented in special forest inventory instructions in 1951, 1964, 1986, and 1995.

The FIP is, and has been, the most common type of forest inventory method used in Russia, and it is carried out periodically in managed forests (every 10 to 15 years). The FIP presents a detailed description of each primary inventory and management unit; the areas of the units vary widely (between 3–5 and 30–50 ha), depending on the management regime. The principal inventory method is the ground ocular estimate, which is a measurement of the most important indicators in the forest stands under investigation. Aerial photographs are widely used for separating the primary inventory units and for mapping forests on different scales.

For the past several decades, the FIP has been conducted every year on 35–45 million ha of forest land.

The FIP's manuals must provide accurate estimates of the growing stock in each primary inventory unit (a deviation of ±10–15% is acceptable). Systematic errors are limited to ±5% at the forest enterprise level. There are about 1,990 forest enterprises in Russia, according to the 1993 inventory. Inventory teams rarely go beyond the restricted margin of error. Numerous control inventories, based on samplings of large territories (e.g., Antonaitis and Repshis, 1973; Fedosimov, 1986) and of individual primary inventory units in different regions of Russia (e.g., Pavlov and Demidov, 1971; Shvidenko, 1981), show that the FIP method underestimates the growing stock in mature and overmature stands by 5–15%, and sometimes more.

Vast areas in the north are unmanaged and unused FF territories (by 1956 only 19% of the forests in this region were classified as managed forests), so a special method of aerotaxation has been implemented to provide an overall inventory of Russian forests. Aerotaxation of never-before inventoried forests (basically in European North, Siberia , and the Far East) started in 1948. Two basic methods were applied using either small-scale aerial photographs (scale 1:50,000 or less) or topographic maps (scale 1:100,000). Aerotaxation was conducted using aerial photographs and photo schemes in which forest and non-forest polygons were separated by a method of contour deciphering. Inventoried areas were measured by aircraft over paths of distances between 2–4 and 4–8 (in the extreme north between 12 and 20) km. By the summer of 1956, about 200 forest enterprises with a total Forest Fund area of about 900 million ha had been inventoried by aerotaxation (Chilingarajan, 1959; Kostjuchenko *et al.*, 1967). Naturally, areas of primary inventory units varied widely and were large (from several hundreds to several thousands of hectares), and the accuracy of area and growing stock estimations was low. Subsequently, improved remote-sensing inventory methods showed that the aerotaxation in the vast Siberian territories significantly overestimated the growing stock by up to 20–25%, and sometimes even 30–50% (Danjulis *et al.*, 1989; Shvidenko *et al.*, 1996a).

Beginning in the 1960s, unexploited northern forests, measured earlier by aerotaxation, were inventoried by remote-sensing methods using aerial and satellite photographs (Gosleshoz SSSR, 1987). An average annual area of 10–25 million ha was inventoried with this method. A three-stage inventory method was usually used:

1. Mapping and stratification of all territories under inventory, based on satellite or small-scale stereoscopic aerial photographs.

2. Large-scale aerial photographs that decipher the basic indicators of selected and typical primary inventory units to evaluate specific features of the stratum.

3. Ground measurements of specifically selected sample plots in the form of stratified sampling.

For large areas, the level of accuracy using this three-stage method of inventory is high with a margin of error of ±3% (Sukhikh and Sinitsin, 1979).

Thus, the SFA data used in the analyses for the 1966–1993 period were obtained using these three methods, from which their accuracy and reliability are directly dependent upon the shares of the areas inventoried by each method for a specific year. By 1990, 665.8 million ha of the FF in Russia had been inventoried by the FIP process. Between 1967 and 1990, additional ground inventories were carried out on 376.3 million ha by the FIP. During this period some 380 million ha were inventoried using remote-sensing methods. The areas measured by new inventory methods between 1967 and 1990 mainly consisted of territories inventoried by aerotaxation between 1948 and 1956. By 1995, the areas that were initially inventoried solely by aerotaxation accounted for about 90 million ha in the extreme northern forest tundra and in pure tundra areas. The current state of forests in these territories is unknown, but the impact of these areas on aggregated data on Russian forests is negligible.

Other uncertainties in aggregated data of the SFA are due to the fact that inventories of individual regions were taken at wide and irregular intervals, and the methods used to update information at certain dates were not consistent during the 1966–1993 period and in some cases were very simple and imprecise (Sinitsin, 1990). In addition, inventory manuals have been modified since 1964. These changes produced artificial "improvements" in the inventory results that were due to changes in classifications and definitions, e.g., classification of mixed forests as forests dominated by coniferous, or weakening of technical requirements that regarded regenerated areas as forested areas. In spite of these shortcomings, the SFA data serve as a basis for analyzing the state and dynamics of Russian forests. Comparisons with inventory systems used in the Northern Hemisphere show that the aggregated Russian forest inventory data are, at least, of the same quality as those of the USA and Canada (Raile, 1994).

3. FOREST DYNAMICS

The dynamics of some selected forest indicators during 1966–1993 are given in *Tables 1–7*. Due to lack of information, there are difficulties in producing consistent tables with overlapping information.

Table 1. Dynamics of Russian forests between 1966 and 1993, in million ha and billion m^3.

	1966	1973	1978	1983	1988	1993	Relative change 1966 to 1993
FF, million ha	1161.9	1161.4	1186.2	1187.7	1182.6	1180.9	1.02
FL, million ha	863.0	862.1	872.3	880.5	884.1	886.5	1.03
FA in ER[a], million ha	161.3	158.8	163.5	164.4	166.0	166.6	1.03
FA in AR[b], million ha	544.3	570.8	586.0	602.2	606.1	597.0	1.10
FA in Russia, million ha	705.6	729.7	749.5	766.6	771.1	763.5	1.08
Allowable for harvesting	342.9	338.6	345.6	385.3	406.2	351.1	1.02
GS[c] in ER, billion m^3	17.0	17.4	18.7	19.3	20.3	21.1	1.24
GS in AR, billion m^3	60.0	61.3	62.0	62.6	61.4	59.6	0.99
GS in Russia, billion m^3	77.0	78.7	80.7	81.9	81.6	80.7	1.05
Coniferous FA, million ha	509.5	531.8	545.0	554.0	552.0	530.3	1.04
Coniferous GS, billion m^3	63.4	64.0	64.7	65.1	64.0	63.7	1.00
Mature stands, billion m^3	48.0	46.4	45.3	43.0	40.0	35.3	0.74
Percentage of forest cover in total land area	41.3	42.8	43.9	44.9	45.2	44.7	1.08

[a]European Russia.
[b]Asian Russia.
[c]Growing stock.

Table 2. Dynamics of forests under state forest management between 1966 and 1993, including long-term leases, in million ha and billion m^3.

	1966	1973	1978	1983	1988	1993	Relative change 1966 to 1993
FF, million ha	1105.6	1103.4	1123.0	1119.7	1115.8	1110.5	1.00
FA, million ha	657.5	678.9	694.3	708.5	713.5	705.8	1.07
Coniferous	488.2	508.3	519.2	526.5	526.0	507.7	1.04
GS, billion m^3	73.5	74.0	74.7	75.4	74.6	73.0	0.99
Coniferous	61.2	61.0	61.2	61.3	60.1	57.7	0.94
GS in mature forests, billion m^3	52.8	52.5	51.5	49.1	46.3	42.0	0.80
Coniferous	45.6	44.6	43.8	41.8	38.9	34.2	0.75
GS in mature forests allowable for harvesting[a]	27.3	27.9	27.4	28.3	29.1	25.7	0.94
UFA[b] million ha	144.2	124.8	116.1	106.7	106.1	115.5	0.80
Harvested areas	13.3	9.5	10.2	8.6	8.6	8.5	0.64
Burned areas	68.4	53.6	43.9	36.8	34.9	31.9	0.47
NFL, million ha incl. mires	300.8	296.8	309.0	300.5	292.2	285.3	0.95
Total average increment, million m^3	792.1	821.1	855.0	874.2	844.1	830.0	1.05
Accumulated area of plantations, million ha	5.9	9.7	11.7	14.5	16.5	17.3	2.91
AAC[c], million m^3	608.5	600.9	610.0	613.6	615.0	529.0	0.87
Actual harvest[c], million m^3	331.1	335.5	318.1	299.0	319.6	174.2	0.53
Thinnings[c], million m^3	15.4	24.0	24.8	25.9	26.9	19.9	1.29

[a]Without long-term leases of forests.

[b]Data for UFA include so-called sparse forests with a total area of about 60 million ha (e.g., 62.7 million ha in 1988). The 1993 inventory divided these forests into natural sparse forests (growing under severe climatic conditions, e.g., on the tree line in the north or in subalpine zones) with an area of 41.4 million ha and anthropogenic sparse forests which are subject to reforestation.

[a]AAC, actual harvest, and thinnings are given for commercial wood; the officially used conversion factor to convert commercial wood to growing stock is 1.12. For industrial harvest the average is 1.15–1.20. For thinning the factor depends on the structure of the thinned forests, e.g., in 1990 the conversion factor was 1.27 (Goscomles SSSR, 1991).

Table 3. Dynamics of Forested Areas by main forest-forming species under state forest management, in million ha.

	1966[a]	1973[a]	1978	1983	1988	1993	Relative change 1973 to 1993
Coniferous	479.24	492.99	519.24	526.46	526.10	507.71	0.98
• Pine	100.95	106.36	109.56	111.68	113.56	114.33	1.04
• Spruce	78.66	75.44	78.93	79.39	78.31	75.87	0.96
• Fir	11.03	13.65	14.74	15.22	15.67	14.37	0.97
• Larch	251.33	258.10	275.09	278.76	277.90	263.35	0.96
• Cedar	37.26	39.44	40.92	41.41	40.17	39.80	0.97
Hard deciduous	14.38	14.97	17.26	17.50	17.10	17.29	1.00
• Oak	7.08	7.32	7.20	7.11	6.96	6.78	0.94
• Beech	0.65	0.64	0.66	0.67	0.70	0.70	1.06
• Stone birch	4.97	5.28	7.80	8.36	7.97	8.34	1.07
Soft deciduous	107.31	106.35	109.94	110.90	109.68	113.21	1.03
• Birch	85.24	82.53	85.57	86.23	85.53	87.73	1.03
• Aspen	16.87	18.27	18.11	18.00	17.71	19.91	1.10
• Black alder	0.58	0.79	0.89	0.96	0.93	n.a.	n.a.
Total MFFS[b]	600.93	614.31	646.44	654.85	652.88	638.21	–

[a]MFFS data for 1966 and 1973 were published without areas under long-term lease. For the rest of the period the long-term leases were included. Forested areas and growing stock of the long-term leases increased constantly between 1966 and 1993 (FA, million ha/growing stock, billion m^3): 1966, 17.57/n.a.; 1973, 19.85/1.4; 1978, 23.85/1.75; 1983, 25.78/1.8; 1988, 31.80/1.9; 1993, 35.48/n.a.

[b]The structure of the FA covered by MFFS in European Russia differs somewhat from that of total Russia; in 1993 the ratio of coniferous:hard deciduous:soft deciduous was 64:4:32 for European Russia and 79:3:18 for total Russia.

Table 4. Dynamics of growing stock by main forest-forming species under state forest management, in billion m^3.

	1966[a]	1973[b]	1978	1983	1988	1993	Relative change 1978 to 1993
Coniferous	60.7	60.0	61.2	61.3	60.2	57.7	0.94
• Pine	13.6	13.6	13.6	14.0	14.3	14.6	1.07
• Spruce	11.9	11.2	11.3	11.1	10.7	10.1	0.89
• Fir	2.0	2.3	2.4	2.5	2.6	2.5	1.04
• Larch	26.6	25.9	26.6	26.2	25.2	22.9	0.86
• Cedar	6.7	7.0	7.2	7.4	7.4	7.6	1.04
Hard deciduous	1.45	1.55	1.77	1.80	1.82	1.86	1.05
• Oak	0.65	0.68	0.73	0.73	0.76	0.77	1.07
• Beech	0.15	0.15	0.15	0.16	0.18	0.18	1.13
• Stone birch	0.44	0.52	0.71	0.73	0.71	0.75	1.05
Soft deciduous	9.53	10.12	10.74	10.98	11.33	12.10	1.13
• Birch	6.90	7.09	7.51	7.70	7.94	8.52	1.13
• Aspen	2.11	2.45	2.54	2.52	2.60	2.74	1.08
• Black alder	0.06	0.07	0.09	0.09	0.09	n.a.	n.a.
Total Russia	71.7	71.7	73.7	74.1	73.2	71.6	0.97

[a]See footnote *a* to Table 3.

Table 5. Dynamics of average growing stock (m^3/ha) by economic regions and individual administrative regions for main forest-forming species under state forest management and without areas transferred to long-term leases.

	1966	1973	1978	1983	1988	1993
European Russia	114.4	114.4	117.8	118.4	122.3	126.0
North	104.9	105.2	103.1	99.4	99.5	103.6
• Arkhangelsk oblast	116.7	113.2	110.0	107.2	106.7	108.4
• Komi Republic	99.2	107.6	105.3	103.9	102.1	105.8
Northwest	118.4	126.8	150.9	154.1	167.2	164.4
Central	126.4	124.0	141.8	143.4	162.0	166.4
Volgo Vyatsky	124.2	122.0	128.6	126.2	134.6	135.0
C. Chernozyemny	100.3	113.3	112.9	127.0	131.0	153.7
Povolzhsky	107.0	114.0	118.7	128.5	130.9	136.5
North Caucasian	146.0	137.8	149.0	149.2	174.0	172.2
Ural	125.6	122.9	125.6	134.4	133.8	139.1
Asian Russia	131.8	117.2	114.5	114.1	111.4	117.4
West Siberia	120.1	127.7	127.9	127.1	125.4	125.7
• Tjumen oblast	109.5	120.8	120.0	118.2	113.7	109.2
East Siberia	134.3	130.2	127.0	129.1	130.7	133.3
• Krasnoyarsk kraj	134.2	125.8	123.7	124.5	124.1	126.6
• Irkutsk oblast	186.7	155.0	152.5	158.5	165.3	162.6
Far East	106.6	100.0	97.7	93.0	87.4	86.5
• Sakha Republic	93.3	85.5	81.4	76.2	70.4	70.5
• Sakhalin oblast	149.0	148.0	142.5	130.4	129.8	125.4
• Magadan oblast	60.9	54.1	51.3	50.4	38.3	38.5
Total Russia	119.3	116.6	115.5	114.7	113.7	114.3

Table 6. Dynamics of average growing stock (m^3/ha) by age group and species between 1956 and 1993 (forests of main forest-forming species under state forest management) for total Russia.

	1956	1961	1966	1973	1978	1983	1988	1993
				Coniferous species				
Young	26.4	27.3	32.9	28.7	27.9	29.1	30.9	31.4
Middle-aged	97.0	103.2	108.6	111.4	112.1	113.6	113.3	119.4
Immature	120.3	144.1	142.7	141.0	144.8	148.6	151.5	153.3
Mature and overmature	134.8	141.5	140.2	139.4	139.3	138.0	136.4	131.8
				Deciduous species				
Young	22.1	19.9	19.3	20.1	21.5	22.9	22.9	22.5
Middle-aged	66.3	70.7	74.0	84.4	90.2	93.3	95.1	96.7
Immature	92.9	100.9	104.4	112.7	119.0	123.9	131.0	140.6
Mature and overmature	109.4	120.2	128.1	143.0	147.8	149.0	152.6	152.5

Sources: 1956 to 1978 data are taken from Fedosimov, 1986; and 1983 to 1993 data are calculated from FSA.

Table 7. Dynamics of distribution of Forested Areas (in percent) by age groups[a] between 1966 and 1993 for forests under state forest management.

	1966	1973	1978	1983	1988	1993
	All forests under state forest management					
Young stands, age class I	5.4	8.2	9.1	9.2	8.8	18.0[b]
Young stands, age class II	5.5	6.0	6.7	7.4	8.5	
Middle-aged stands	15.7	17.2	18.8	21.1	23.5	24.1
Immature stands	10.2	9.8	9.6	9.9	10.0	9.7
Mature and overmature[c] stands	63.2	58.8	55.8	59.4	49.2	48.2
			Coniferous			
Young stands, age class I	4.4	7.4	8.9	9.1	9.1	17.4[b]
Young stands, age class II	4.4	5.0	5.5	6.3	7.6	
Middle-aged stands	13.8	15.0	15.8	17.2	19.1	22.0
Immature stands	9.6	9.0	8.6	9.3	9.5	9.5
Mature and overmature stands	67.8	63.6	61.2	58.1	54.7	51.1
			Average age			
All forest	104	100	103	103	95	n.a.
Coniferous	117	115	116	115	114	n.a.
Hard deciduous	93	79	85	85	92	n.a.
Soft deciduous	46	45	46	47	48	n.a.

[a]The length of age class used in Russia is 20 years for coniferous (cedar is an exception at 40 years) and for hard deciduous species of seed origin; for soft deciduous and hard deciduous species of vegetative origin the age class is 10 years. Age classes can be aggregated to age groups. There are four age groups in Russian classification: young, middle-aged, immature, and mature and overmature stands. The allocation of stands to these groups is based on the age of suitable harvest, which is defined in Gosleshoz SSSR, 1982.

[b]In 1993 data for young stands were reported in an aggregated form for both young age classes.

[c]Overmature stands are determined as three age classes older than the suitable final felling. Only in the 1966 inventory were mature and overmature stands identified separately and the overmature forests of main forest-forming species made up 28.7% of the Forested Areas and the growing stock equaled 25.02 billion m^3. The figures for coniferous forests were 31.3% and 21.89 billion m^3, respectively.

4. DISCUSSION

Based on the data presented in *Tables 1–7* and some additional sources, we can identify several basic features of the dynamics of Russian forests.

• From 1966 to 1993 the Forested Areas of Russian forests increased by 57.9 million ha (or 8.2%). This increase occurred mainly in forests under state forest management (48.3 million ha). There are two major reasons for this development: large areas were afforested, however survival rate was low (55–60%) because of poor planting techniques and bad management; and natural afforestation intensified owing to improvements in forest fire control.

Forested Areas covered by MFFS increased by 6.2% from 1966 to 1973. Areas covered by individual dominant species changed rather slowly. Nevertheless, from 1966 to 1993 the area

of spruce stands decreased by 2.8 million ha, and areas of deciduous species increased by 5.9 million ha. This is a consequence of a very intensive changes in the processes in forest species composition (deciduous species replaced indigenous coniferous stands) after concentrated clear cuts and forest fires.

It should be noted that reliable conclusions on the changes in FA and growing stock cannot be made based only on data of forests under state forest management because, over time, forests were redistributed among different ministries and land-use categories. For example, from 1988 to 1993 the FA under state forest management decreased by 21.2 million ha and the FA of MFFS decreased by 25.8 million ha. These decreases were not caused by poor forest management but rather by a transfer of forest management to different agencies. Over the past 10 years, the FA within all forests of Russia (not only state managed) decreased by 3.1 million ha. In European Russia the FA increased by 0.6 million ha over the same period.

• From 1966 to 1993 the total growing stock of all forests increased by 3.7 billion m^3, but growing stock of forests under state forest management slightly decreased by 0.45 billion m^3. No changes were identified for the growing stock of coniferous species (+0.3 billion m^3), but a decrease of more than 25% was identified in the growing stock of mature and overmature coniferous stands. A significant decrease in growing stock (by about 3 billion m^3) was observed in coniferous forests under state forest management. These forests are the primary source of industrial harvest. If the long-term leased forests are excluded from the comparison, the decrease is about 5.4 billion m^3.

Simultaneously, total growing stock development for all MFFS was rather stable (–0.05 billion m^3). The strongest increase took place in soft deciduous species (2.6 billion m^3).

However, a significant decrease in the growing stock of mature and overmature coniferous occurred between 1983 and 1993 (47.11 billion m^3 in 1983, 44.39 billion m^3 in 1988, and 39.43 billion m^3 in 1993). This corresponds to a total decrease of 7.68 billion m^3 and provides strong evidence of a qualitative decline of mainly Asian forests.

• Unfortunately, the Russian inventory does not directly give any indicators on current growth (increment). The official average increment (which increased from 792 million m^3 in 1966 to 830 million m^3 in 1993) is defined as a weighted ratio (by area) between growing stock and average age of stands, and is an accumulated indicator for the total life span of the forests; it does not characterize the current productivity of the forests. Official data on gross and net growth for all Russian forests have never been reported. Some expert estimates (MFMRF, 1968; Shvidenko *et al.*, 1996b) report about 0.9–1.0 billion m^3 for net annual growth and 1.8–2.1 billion m^3 for gross annual growth. Thus, the mortality is estimated to

be some 0.9–1.0 billion m^3 per year[2]. If these assumptions are correct, simple calculations show that the total net growth from 1966 to 1993 ranged from 24 to 27 billion m^3. The wood removed from forests (final harvest and thinning) did not exceed 0.42–0.45 billion m^3 of stemwood annually during this period. This means that total losses caused by forest-replacing disturbances such as forest fire, insects and diseases, and industrial pollution can be estimated to be between 9 and 12 billion m^3 for the period considered and to be between 0.30 and 0.45 billion m^3 per year. This is in addition to about 1.0 billion m^3 of annual natural mortality.

• We obtain a somewhat different picture if we attempt to consider the systematic errors of the inventory data. Based on available data on accuracy and dynamics of areas inventoried by different inventory methods, we developed a simplified expert system to recalculate the dynamics of growing stock from 1966 to 1993. The correction factor for the FIP was assumed to vary from +15% (1966) to +8% (1993) in Asian Russia and from +12% to +6% in European Russia. The correction factor for aerotaxation data was assumed to vary from –25% to –10% in Asian Russia and from –18% to –6% in European Russia during the same period. No systematic errors were assumed for remote-sensing methods. The results of the reconstruction of the dynamics are given in *Table 8*.

Table 8. Reconstructed dynamics of total growing stock in Russian forests from 1966 to 1993.

	1966	1973	1978	1983	1988	1993
Percentage of ground inventory in ER[a]	41	44	56	75	88	94
Percentage of ground inventory in AR[b]	22	30	38	52	59	60
Growing stock in ER, billion m^3	16.5	17.3	18.3	19.9	21.4	22.2
Growing stock in AR, billion m^3	59.2	60.2	62.1	64.6	64.2	62.6
Total Russia, billion m^3	75.7[c]	77.5[c]	80.4	84.5	85.6	84.8
Percentage of derivation from official data of FSA	–1.7	–1.5	–0.4	+3.2	+4.9	+5.1

[a]European Russia.
[b]Asian Russia.
[c]Growing stock in 1966 was inventoried without long-term forests. In addition, the inventories of the growing stock were not updated in either 1966 or 1973. Under the reconstruction of the dynamics, we took these factors into account.

The main conclusion is that such reconstruction of the dynamics does not significantly change official data on total growing stock development: the difference varies from –1.69 to +5.08%. However, in both "official" and "reconstructed" versions severe losses in growing stock have been observed over the past 10 years. A stable increase of growing stock in European Russia cannot compensate for the losses in Asia.

[2] The term "mortality" is used as an aggregated measure of natural mortality caused by 1) competition of trees (natural mortality in a narrow sense), 2) death of overmature trees and by all types of non-forest-replacing disturbances.

From 1983 to 1993 the total accumulated harvest (adjusted for unmonitored harvest according to Backman, 1995) was some 1.36 billion m^3 in Asian Russia, with a 2 billion m^3 decline in the growing stock. Over the same period, the harvest in European Russia was 40% higher than that in Asian Russia, and the growing stock increased by 2.3 billion m^3 in European Russia. Thus, factors other than harvests have been driving the growing stock decline in Asian Russia.

• The indicator which is probably moderately free from different disturbances (e.g., changes in areas and land-use categories) is the average growing stock by age group (see *Table 6*). There is a significant increase in growing stock (ranging from 20 to 50%) observed for all age groups and species with two exceptions: mature coniferous species (due to forestry policy during the past decade to harvest the best and most productive forests) and young deciduous stands (mainly young stands from natural post-fire and post-harvest regeneration). In our opinion, the increase in growing stock is due to the decrease in frequency and severity of non-stand-replacing disturbances.

• In European Russia, the average growing stock was identified to have increased from 114.4 to 126.0 m^3 per ha for MFFS and from 105.4 to 126.7m^3 per ha for all forests from 1966 to 1993. All of the European Russian economic regions, except the Northern region, have experienced a significant increase in growing stock (see *Table 5*) of up to 38.8% in the Northwestern region and 53.7% in the Central Chernozyemny region. This development cannot be completely explained by changes in the average age of the forests. For example, the average age of all forests in the Central region increased from 37 to 47 years between 1966 and 1988; in Central Chernozyemny from 32 to 39 years; and in the Northwestern region from 55 to 59 years (for coniferous species 49 to 51, 34 to 38, and 64 to 65 years, respectively). The decrease in growing stock in the Northern region mainly resulted from overharvesting (growing stock decreased in the Arkangelsk oblast by 8.6% and in the Karelia Republic by 9.6%). In the Murmanskaja oblast region, which was subject to years of intensive industrial exploitation, in addition to severe air pollution, growing stock decreased by 13.5%.

In Asian Russia development declined during the 1966–1993 period. Average growing stock decreased from 110.2 to 99.8 m^3 per ha for all forests and from 131.8 to 117.4 m^3 per ha for MFFS. Numerous regions have experienced a significant decrease in growing stock because of insufficient fire protection (Sakha Republic by 24.4% and Magadan oblast by 36.8%). In the Sakhalin region where a combination of insufficient fire protection and intensive harvesting occurred, there was a decrease of 15.7%. If we take into consideration systematic errors, we find that growing stock declined by 25–50%. An adjustment for systematic errors is supported by analyses of the distribution dynamics of FA by site indexes and relative stocking. From 1966 to 1993 the average site index for all forests covered by MFFS increased from IV.29 to IV.12, and for coniferous from IV.55 to IV.37. Such changes cannot be explained either by changes in forest inventory standards or by the uncertainty of

aggregated calculations. The stocking changes have a similar character; the average stocking changed from 0.56 to 0.59 for all forests and from 0.53 to 0.57 for coniferous forests.

• The qualitative impoverishment of forests in regions with industrial harvest can be illustrated by two typical regions: the European North and the Russian Far East. The depletion in the European North is mainly due to local overharvesting. In this region, about 82% of the total annual allowable cut was harvested during the 1970–1990 period, and roughly 84–101% of the annual allowable cut of coniferous species was harvested in administrative units (there are five oblasts and autonomous republics in the region). Karelia had a total overharvest in coniferous species of 119% over the 1987–1989 period. The overharvest was significant for separate enterprises with a developed infrastructure and transportation network and for individual species. In the Murmansk region the actual harvest in pine stands varied from 102 to 223% of the annual allowable cut, and many enterprises overharvested coniferous species by a factor of 1.5–2. During the 1966–1988 period about 700 million m^3 of coniferous wood were locally overharvested in the European North and Ural regions. At the same time, deciduous species (20–30% of the total growing stock) were left unutilized in harvested areas. By 1990, mature coniferous forests had a growing stock that would provide sustainable harvest levels (1990 level) for an additional 25 years in the Vologda oblast, for 36 years in Karelia, and for 40–45 years in the Murmansk oblast (Isaev, 1991b).

The situation is different in the Far East. Only large logs were harvested, and the removal from harvested areas was roughly 1.5–2.5 times less than the average growing stock of mixed stands dominated by coniferous species. This resulted in a significant decrease in areas dominated by cedar (*Pinus koraiensis*). Forested Areas decreased by 17.2% (from 3.97 million ha to 3.29 million ha) in Far Eastern forests under state management between 1966 and 1993, but the cedar forests in Khabarovsk kraj decreased by 2.5 times (from 1.46 million ha to 0.56 million ha). The exhaustive character of logging is evident. Between 1965 and 1988, about 8 million ha of the most productive stands were harvested in the Far East. The 1988 inventory identified 34% of the harvested areas as unregenerated harvesting areas.

• A rough aggregated estimate of the dynamics of the biospheric role of the Russian forests can be made based on the indicator of productivity. If we use the results from the reconstruction of the dynamics of the growing stock and the average ratio between the carbon content of forest vegetation and the green growing stock of 0.4 Mg C per m^3 (Alexeev and Birdsey, 1994; Isaev *et al.*, 1995; Lakida *et al.*, 1995), we can conclude that the total carbon content in vegetation from the Russian forest ecosystems has increased by 11.9% (from 30.3 to 33.9 Pg C) during the period studied. By using the same approach, the increase of needles and leaves (the "photosynthetic capacity") was estimated to be 12.3%. Thus, there is no evidence of decline in the productivity of the Russian forests over the period.

• The distribution of Russian forests into utilization groups has constantly changed over time, resulting in an increase of forests with restricted industrial utilization. A method for classifying forests into three groups was approved in 1943: Group I includes protected forests with very strong limitations on the industrial harvest; Group II consists of mainly protected forests with restricted industrial use; and Group III is made up of forests for industrial use and unused forests. In 1956, 2.9% of all FA were classified as belonging to Group I; 9.2% were part of Group II; and 87.9% were considered part of Group III. In 1961 the distribution was 12.0%, 4.8%, and 83.2%, respectively, and in 1993 it was 16.7%, 7.7%, and 75.6%, respectively. For forests in European Russia it was 28.6%, 24.6%, and 46.8%, respectively.

The distribution of forests into groups is a crucial factor in determining acceptable and available areas for harvest. In 1956 harvestable (or exploitable) forests accounted for 43.5% of the FA in Russia (Group I forests were completely excluded from exploitation, but this situation changed in 1962 when severely restricted final felling was permitted in subgroups of Group I forests). Currently, Group I forests are divided into 27 categories of protection; final harvest is completely prohibited in 13 of them.

In 1988, exploitable forests in the FA totaled 388.5 million ha of which 116.9 million ha were located in European Russia. In 1993 the corresponding figures were 351.1 and 115.6 million ha, respectively. Three basic types of forests are unavailable for exploitation: 1) parts of the protected forests in Group I; 2) specially protected forests in all three forest groups that require local protection; 3) low-productive stands with a growing stock of mature stands that is less than 50 m^3 per ha in Asian Russia and 40 m^3 per ha in European Russia. The last two categories include roughly 75% of all nonexploitable Forest Areas and about 60% of the growing stock in total Russia. In European Russia the corresponding figures are 50% and 45%, respectively.

5. CONCLUSION

In this paper we have identified three basic features of Russian forest dynamics that have occurred between 1966 and 1993.

First, for total forests in Russia during the 1966–1993 period only the growing stock indicator for mature coniferous forests shows a significant decline. All other indicators show a stable or an increased development. However, forests under state forest management show a substantial decline over the same period in the following indicators: growing stock of mature forests, growing stock of coniferous forests, and growing stock of mature coniferous forests. All other indicators show positive development. Thus, it is likely that the decline in growing stock has been more severe in forests under state forest management than in other forests. The reason for this is that a dominant part of industrial harvest takes place in state-managed

forests. It should be noted, however, that the forests under state forest management are better inventoried than other forests.

With regard to individual dominant tree species under state forest management, all coniferous species except pine have experienced a decline in Forested Areas, although the growing stock development for these species shows a decline only for spruce and larch.

At the aggregate (regional) level there has been a stable or an increased development of the growing stock per ha in European Russian forests, but a rather severe decline in Asian Russian forests; this latter situation is mainly driven by a dramatic decline in the Far East. Also, several subregions in both European Russia and Asian Russia have undergone severe declines during the 1966–1993 period.

Studies of the 1983–1993 period show somewhat different results. Development during this period can be measured by studying the development of the growing stock listed in *Table 9*. Official figures (not adjusted for systematic inventory errors) indicate that there has been a serious decline in the total growing stock. This development is driven by a decrease in the total growing stock of coniferous species, especially in mature coniferous forests. For European Russia, however, the data show that there has been a substantial increase in the total growing stock. Thus, the decline in the growing stock for total Russia is caused by a severe decline in Asian Russia. The decline is most serious in those forests under state forest management.

Table 9. Growing stock development between 1983 and 1993 and the difference from 1983 to 1993, in billion m^3.

Growing stock/Region	1966	1983	1993	Difference 1983–1993
		All forests in Russia		
European Russia	17.0	19.3	21.1	+1.8
Asian Russia	60.0	62.6	59.6	–3.0
Russia	77.0	81.9	80.7	–1.2
Coniferous, Russia	63.4	65.1	63.7	–1.4
Mature coniferous, Russia	48.0	43.0	35.3	–7.7
		Forests under state management		
Russia	73.5	75.4	73.0	–2.4
Coniferous, Russia	61.2	61.3	57.7	–3.6
Mature coniferous	45.6	41.8	34.2	–7.6
		Reconstructed dynamics of all Russian forests		
European Russia	16.5	19.9	22.2	+2.3
Asian Russia	59.2	64.6	62.6	–2.0
Russia	75.7	84.5	84.8	+0.3

The reconstructed dynamics show that there has been a serious decline in the growing stock in Asian Russia and that there have been large increases in the growing stock in European Russia. The increases evident in the reconstructed dynamics are even larger than those indicated by official figures.

The strong decrease in growing stock in Asian Russia between 1983 and 1993 is not due to harvesting. This decline seems to be mainly due to other disturbances such as forest fire, pests, insects, and anthropogenic activities. To some extent the severe decline can also be due to lag effects in inventory methods, which would mean that the decreases in Asia started in the late 1970s and early 1980s but were not identified until after the 1983 inventory.

Evidence shows that the productivity of the Russian forests, which is an indicator of the forests' biospheric role, has not decreased but has increased during the 1966–1993 period.

The second feature of recent Russian forest dynamics is that the quality of Russian forests has been seriously impoverished between 1966 and 1993. Regions with a developed infrastructure have been substantially overharvested (especially in European Russia). In addition, the harvest has been carried out through so-called creaming processes over vast areas containing large trees and special species; this has seriously decreased the quality of the forests (especially in the Far East).

Third, there are still huge areas of unused, unexploited, and unmanaged forests in Russia; this situation makes it difficult to justify the premise that Russian forests are disappearing from a global perspective. In spite of the existing shortcomings in Russian forest management, the stability and the capacity of natural regeneration of Russian boreal forests seem to be extremely high.

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