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Carbon Storage in Forests and Peatlands of Russia

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Abstract

Contains information about carbon storage in the vegetation, soils, and peatlands of Russia. Estimates of carbon storage in forests are derived from statistical data from the 1988 national forest inventory of Russia and from other sources. Methods are presented for converting data on timber stock into phytomass of tree stands, and for estimating carbon storage in forest soils and peatlands in Russia's administrative territories and natural ecoregions. Also included is information on the timber stock of Russia's primary tree species and phytomass of forest vegetation, mortmass, and peat.

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CARBON STORAGE IN FORESTS AND PEATLANDS OF RUSSIA

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Preface

This report is the result of the joint Russian-American research project 23-817, Carbon Budget in Boreal Forests, sponsored by the V.N. Sukachev Institute of Forest, Siberian Branch of the Russian Academy of Sciences, and the USDA Forest Service's Global Change Research Program. This research was initiated to evaluate contemporary carbon storage in the forests of Russia and other countries of the Earth's boreal belt, and to assess past and future dynamics of carbon. The initial research results in this report include detailed statistical estimates of carbon storage in the forests and peatlands of Russia. More extensive results were published by the editors in a 1994 monograph entitled "Carbon in Ecosystems of Forests and Peatlands of Russia" (in Russian). Ongoing research addresses past and future carbon dynamics.

The authors thank the USDA Forest Service's Northeastern Research Station, the Krasnoyarsk Science Foundation, and the Russian Fund of Fundamental Investigations (Project 96-04-48344) for the financial support that made this research possible. The forest-inventory database of Krasnoyarsk Kray and the Republic of Yakutia (Sakha) was made available with the help of A. P. Vitaliev, former head of the Krasnoyarsk Forestry Administration, and A. P. Isayev, senior researcher at the Institute of Biology (Russian Academy of Sciences, Yakutsk Research Center). Assistance in the gathering of published data was provided V. D. Perevoznikova, E. A. Kaderov, T.K. Murina, A.V. Voloikitina, M.A. Sofronov, and L. V. Verevochkina. Preliminary artwork was supplied by I. A. Mikhailova. The authors also thank I. V. Semechkin, V.N. Gorbachev, O.G. Chertov, Daniel Kucera, John Hom, Tom Stone, and Elon Verry for their reviews of the manuscript, Rosemary Mullen for processing data in the tables, and Kelly O'Brian for supervising the translation of this report from Russian to English.

Chapter 1. Introduction

V. A. Alexeyev

Increasing carbon dioxide in the atmosphere and expected climate changes have generated great interest in quantifying the content and dynamics of carbon in terrestrial and aquatic ecosystems (Keeling et al. 1976; Woodwell and Houghton 1977; Kobak 1988; Apps and Kurz 1993; Dixon et al. 1994). Should the amount of carbon dioxide in the atmosphere double in the next 50 to 70 years, the average yearly temperature could rise by 3º to 5ºC (Budyko 1972; Schneider 1990; Budyko et al. 1991). This warming would affect primarily the northern latitudes, with the strongest effects in winter (Budyko et al. 1991).

Climate warming to this extent could result in large-scale global phenomena, for example, melting of polar ice and flooding of lowlands (Houghton and Woodwell 1989), more frequent fires, and droughts in many forest and agricultural areas (Manabe and Wetherald 1987; Gleick 1988; Budyko et al. 1991).

Because the vegetation of forests contains more than 75 percent of all carbon accumulated in the vegetation of terrestrial ecosystems (Olson et al. 1983), the role of forests in global climate change is critical. Of particular interest to researchers are the vast boreal forests of the Northern Hemisphere. Models have been developed for expected transformations of boreal forests and their impact on changes in the carbon balance of forest ecosystems and the atmosphere (Apps and Kurz 1993; Emmanual et al. 1985; Bonan et al. 1992; Price and Apps 1993). For example, Bonan et al. (1992) showed how future redistributions of boreal forest and tundra vegetation could initiate climate feedbacks that affect lower latitudes.

Because we lack reliable and detailed data on the storage and dynamics of carbon in Russia, which contains 22 percent of the world's forest area, it is difficult to measure the global carbon budget and resulting impacts of global change. A recent summary of the global carbon budget by Schimel (1995) showed that the missing carbon sink could be as high as 2 billion tons per year (Gt/yr), and highlighted the uncertainty in various estimates of Russian forest and peatland sinks.

1.1 Estimating Carbon Storage in Forest and Peatland Ecosystems

To calculate the storage of carbon in forest ecosystems and peatlands, it is necessary to have diverse and reliable data about the stock of: (1) vegetation mass in forest ecosystems, (2) organic matter in forest soils, and (3) phytomass, peat, and their organic matter in peatland ecosystems.

Stock of Phytomass in Vegetation of Forest Ecosystems

Estimation of the amount of carbon stored in the vegetation of forest ecosystems is based on the stock of phytomass. There are two methods for determining phytomass storage. The first is to directly apply to regional calculations information about phytomass from research sample plots in different biomes and their divisions. The National Forest Inventories of Russia do not collect such data, so scientists must rely on individual research or obtain this information from the literature. The first data on phytomass were published as part of the International Biological Program in Russia in 1968-80. However, the number of sample plots was insufficient for estimating carbon on a national or regional scale. Moreover, the data collected do not include important information on classifications such as forest age distribution, areas of burns, cuttings, and peatlands.

The second method for determining phytomass storage is to combine two kinds of data in regional calculations: 1) statistical forest-inventory databases, and 2) databases for sample areas in different ecoregions of the country that include information on the fraction of stock of stand phytomass and lower layers of the forest. In the first approach (Bazilevich 1993), data on sample-area phytomass are used as final parameters of productivity; in the second method, they are used to determine coefficients for converting the volume of timber stock estimated by forest inventories to the stock of phytomass and carbon of forest ecosystems.

In 1993, we followed the second approach (Makarevskiy 1991; Birdsey 1990, 1992; and Kurz et al. 1992). Data from the statistical forest inventory (January 1, 1988) of the Forest Fund (See Glossary) of the U.S.S.R. (Goskomles of the U.S.S.R. 1990, 1991) and data (also January 1, 1988) from the forestry farms of the Krasnoyarsk Kray and the Republic of Yakutia (Sakha) were the primary sources of information on the timber stock of Russian forests. Information on the estimates of the forest resources in this report is included in Chapter 2 and Appendix Tables 1 through 4.

Stand timber volume was converted to phytomass of each component of the forest community by a formula developed by V. D. Stakanov. Data on the phytomass of forest vegetation were from 2,290 sample areas established in different parts of the country. Timber volumes were converted to vegetation carbon of forest ecosystems by several hundred conversion coefficients.

Although logistically simple, this method calls attention to problems of missing or unreliable data (see Chapter 4). For example, to convert timber volume units to mass units, we used basic timber-density values, i.e., the ratio of the mass of absolutely dry matter of timber to its fresh volume. This method substantially affects timber-density parameters.

Reference materials about forests are included here for the administrative territories: republics, krays, and oblasts. These units are responsible for managing economic activity, including forest management. Values for carbon storage for these territories (Chapter 6) and forecasts of their dynamics can aid in developing management strategies with respect to changing climate conditions by accounting for the role of forests and peatlands in global systems.

Forest-inventory data are collected within economic, political, or ownership boundaries, and those boundaries form the management or policy unit. However, administrative territorial borders do not always match the boundaries of natural ecoregions. Because the distribution and function of forests and, consequently, of carbon dynamics are closely correlated with climate, surface geomorphology, and other local and regional manifestations of natural properties, manipulating data within an economic or political framework prevents a complete understanding of processes that govern formation of stock and transport of carbon. Therefore, in addition to evaluating carbon stock for administrative territories, we calculated carbon for forest ecoregions (Chapter 6). A classification of ecoregions for the territory of Russia and the former U.S.S.R. republics has been developed (Chapter 3).

Evaluating Carbon in Forest Soils

Information on organic matter (and carbon) in the soils in different regions (including administrative territories) is based on numerous data from the literature describing soils, results of chemical analyses, and spatial distribution of soil cover from soil maps. Methods for deriving data on organic matter stock, soil carbon, and the distribution of carbon in soils of different ecoregions of the country are discussed in Chapter 8.

Analysis of data and methods in the literature showed that soil scientists generally do not account for the volume of rocky inclusions in the soil layer. As a result, the stock of carbon on many forest areas is overestimated. We have included estimates of soil rockiness (Chapter 7). Correcting for rockiness changes the estimate of the carbon stock in forest soils in many regions.

Evaluating Carbon in Peatland Ecosystems

Information on the area of peatlands, peat storage in them, and other initial estimates for administrative territories is largely from handbooks and statistical volumes, e.g., Sabo et al. (1981) and Markov et al. (1991). Yet, different agencies disagree as to what areas should be included. This results in the absence of reliable statistical data on peat storage and distribution throughout Russia. Methods and results of carbon estimates in peatland ecosystems are given in Chapter 10. At present, reference materials do not include information on timber stock for excessively moist forested areas. These data are combined with those for other forests (Chapter 6).

Evaluating Biomass and Carbon Content of Forest-Ecosystem Consumers

The content of biomass and carbon of wildlife, mycobionts, and microorganisms frequently is lower than the estimation error of the stock of phytomass and carbon of green plants. Moreover, the biomass of microorganisms, fungal hyphae, and spores is not evaluated separately in estimating the carbon content of soils and plants. However, each of these components is important in decomposing organic matter and affects the carbon balance. The role of these consumers and estimates of their carbon stock are discussed in Chapter 9.

Chapter 2. The Forest Resources of Russia

V.A. Alexeyev, V.D. Stakanov, and I.A. Korotkov

2.1 Background

The forests of Russia extend along the meridian from 27° to 163° eastern longitude, and cross Northern Hemisphere latitudes from 72°30' to 42°30'. The forested area accounts for 22 percent of the world's total and 43 percent of the forests in the temperate zone (United Nations 1992).

The most complete and accessible source of data on the forest resources of Russia is the statistical collection of the Forest Fund of the U.S.S.R. as of January 1, 1988 (Goskomles of the U.S.S.R. 1990, 1991). This database for 6 krays, 49 oblasts, and 16 republics of the Russian Federation contains information on Forest Fund areas by land category (stocked, unstocked, and nonforest lands), distribution of forest land by primary species, stand age by species group, quality and density classes, growing stock by primary forest-forming species (for forests under the management of forest entities), and other classifications.

Information is lacking on the distribution of areas and growing stock of forest-forming species by age group (except mature and overmature stands) and species on the stocked areas of collective farms and other lands assigned for long-term use or assigned to other agencies. Some administrative regions and forestry farms (e.g., in northern parts of Siberia and the Far East) are so vast that available statistical data are insufficient to characterize these areas. In addition to using Forest Fund data, we relied on other information sources (e.g., Alimov et al. 1989; Goskomles of the RSFSR 1962; Nikolayuk 1973), as well as archives from the forestry farms of Krasnoyarsk Kray and the Republic of Yakutia (Sakha).

The data in this chapter and Appendix Tables 1 through 4 do not replicate those of the national statistical reference book (Goskomles of the U.S.S.R. 1990, 1991). Rather they represent an adapted version of its tables (Tables 2.1 and 3.1) or were calculated from statistics in the reference book (Table 2.5). The data of Appendix Table 5 and Tables 2.2 and 2.4 were prepared on the basis of different statistical data. All statistical data for these tables for the Krasnoyarsk Kray and Republic of Yakutia (Sakha) are from forest management data for the forestry farms as of January 1, 1988. The remaining data in Appendix Table 5 were derived as follows.

We used statistical data on stocked areas, total growing stock, and the stock of mature and overmature forests for the administrative units of Russia (Goskomles of the U.S.S.R. 1990, Table 1). For these administrative territories we used data on the distribution of stocked areas under the management of forestry entities (including forests assigned for long-term use) and on the distribution of stocks by species and age groups (Goskomles of the U.S.S.R. 1991, Tables 22 and 69).

For other land management categories we used information on areas and stocks (total and for mature and overmature forests) by species group (Goskomles of the U.S.S.R. 1990, Table 1). Information on species groups for other land management categories lacked distribution data by area and stocks for young, middle-aged, and premature stands. Since these missing data represent less than 5 percent of all forest biomass, we assume that these forests can be distributed over the groups of young, middle-aged, and maturing stands in the same proportions as in forests under the management of forest entities.

The next problem was to convert data on species groups into data on specific forest-forming species. We used statistical data on species distribution of forest trees by age group as of January 1, 1961 (Goskomles of the RSFSR 1962). This made it possible to prepare a table of the current distribution of the major forest trees of Russia by age group (Appendix Table 5) based on data on stocked forest lands and growing stock by the major forest tree species of the Forest Fund of Russia (Goskomles of the U.S.S.R. 1990, Table 10), growing stock of species groups by age group (Goskomles of the U.S.S.R. 1991, Table 22), and earlier data (Goskomles of the RSFSR 1962). We also used data on the regional distribution of krummholz (*Pinus pumila*) areas (Nikolayuk 1973), information on total area and growing stock by age group of shrubby birches and krummholz in the U.S.S.R. (Goskomles of the U.S.S.R. 1990, Tables 3 and 9), and information on the distribution of a given species in the territories under consideration (Sokolov et al. 1977, 1980). Taking into consideration that the growing stock of the main forest tree species in the administrative regions of Russia could not change by more than 10 percent during 27 years (January 1, 1961, to January 1, 1988), it can be assumed that the data in Appendix Table 5 differ little from reality.

2.2 Forest Area and Growing Stock

The distribution of stocked area and growing-stock volume for various land-management categories of Russian forests is presented in Table 2.1. The total area of Russian Fund amounts to 1,182.6 million ha; stocked lands equal 771.1 million ha. The total volume of growing stock is 81.6 billion m^3, more than 58 percent of which is in mature and overmature stands. The growing stock of overbark timber in mature and overmature forests totals 136.7 m^3/ha.

State property comprises 98.7 percent of the total forest area and 98.1 percent of the stocked area; there are no privately owned forests. Collective property (private cooperative agricultural farms) constitutes 1.3 percent (15.5 million ha) of the total area, nearly all of which is stocked. About 27 million ha are on state agricultural farms. In 1961, collective farms owned 26.6 million ha of stocked area (Goskomles of the RSFSR 1962), about twice the current total. Much of the reduction in area is due to the conversion of collective farms into state farms.

In 1988, 63.7 percent of the total area under the management of forestry entities was stocked (691.6 million ha). More than 102 million ha of the forest territory (including 37.4 million ha of stocked area) have been assigned to different fund holders for long-term use. More than 64 million ha of stocked area are assigned to other agencies. As a result, the Russian Forest Service maintains forest practices over a somewhat smaller area. Forest distribution, total stock, and the stock of mature and overmature forests of Russia's administrative regions vary over a broad range of land categories (Appendix Tables 1 through 4) on the basis of boundaries, size, and economic development of individual territories.

Primary Forest Tree Species

The species composition of forests is more diverse in the southern than northern regions. A complete inventory of trees and shrubs with maps of their ranges and ecological characteristics is included in the three-volume report "Natural Habitats of Trees and Shrubs of the U.S.S.R." (Sokolov et al. 1977, 1980, 1986). The database of the Forest Fund of the U.S.S.R. (Goskomles of the U.S.S.R. 1990, 1991) provides statistical evidence of the composition of the primary forest tree species (the statistical reference book indicates their taxonomic classification generally at the genus level): Scotch pine (*Pinus sylvestris*), spruce (*Picea* sp.), fir (*Abies* sp.), larch (*Larix* sp.), pine (*Pinus* sp.), oak (*Quercus* sp.), beech (*Fagus* sp.), birch (*Betula* sp.), aspen (*Populus tremula*), and alder (*Alnus* sp.).

The data in the reference book generally are grouped by coniferous species, deciduous hardwoods, and deciduous softwoods. The total stock and the stock of mature and overmature stands for the administrative regions are shown in Appendix Table 4.

Additional reference materials (Nikolayuk 1973 and Goskomles of the RSFSR 1962) and the database of the forestry farms of the Krasnoyarsk Kray and the Republic of Yakutia (Sakha) made it possible to expand the inventory of forest trees and shrubs for the administrative regions (Appendix Table 5), including additional information on stone birch (*Betula ermanii*), hornbeam (*Carpinus betulus*), elm (*Ulmus sp.*), linden (*Tilia sp.*), and Siberian krummholz pine (*Pinus pumila*). The average species composition of the total growing stock of Russian forests is shown in Figure 2.1.

In range and volume of growing stock, species of *Larix* (*L. sibirica*, *L. gmelinii*, *L. cajanderi*, etc.) are the most common and are found primarily in Siberia (Table 2.2). Scotch pine, second in volume of growing stock (and first in economic value), is found in nearly every administrative region of Russia (Table 2.2). Birches also are common, primarily softwood birch (*Betula pendula* and *B. pubescens*) followed by hardwood birches (*B. ermanii*) and shrub birch (*B. nana*, *B. divaricata*, *B. fruticosa*).

Although oaks, (predominantly *Quercus robur*, *Q. petraea*, *Q. mongolica*) are the primary tree species in many regions of Russia, they account for only slightly more than 1 percent of the total growing stock. Several species that are dominant in some administrative regions and therefore important to many districts and the country as a whole include beech, linden, and poplar. These account for about 1 percent of the total stock (Appendix Table 5). The growing stock of krummholz and shrub birch, the most common shrub species, totals 1,110 and 87 million m^3, respectively (Goskomles of the U.S.S.R. 1990).

Age Distribution of Forest Trees

The published database does not give the age distribution of specific forest trees, but shows the distribution of groups of coniferous and deciduous stands by economic age group

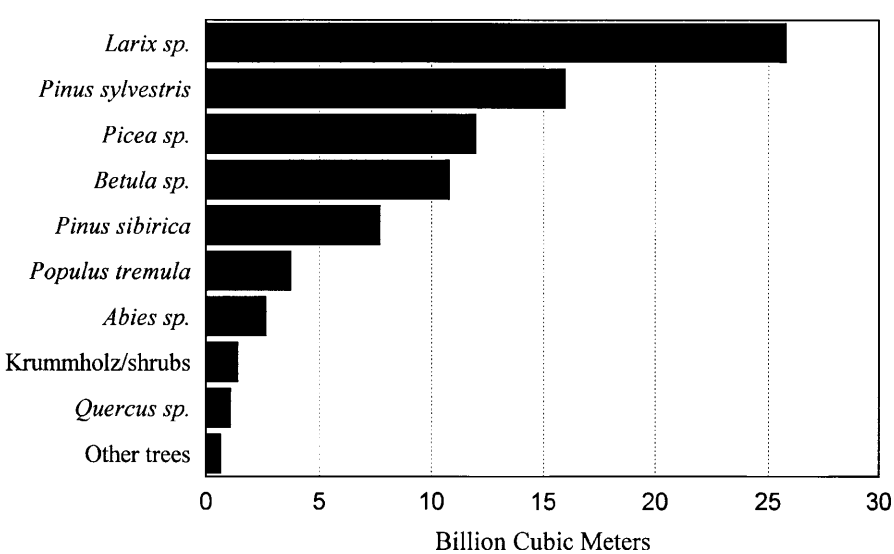

Figure 2.1.—Average species composition of total growing stock in Russian forests.

(Table 2.3). The considerable prevalence (1.5 to 6.0 times) of middle-aged stands over maturing stands is evident in all administrative regions except Tuva (Goskomles of the U.S.S.R. 1991, Table 22). This is partly a reflection of the fact that the middle-aged category includes stands of two to four age classes, while the category of maturing stands includes only one age class.

The age structure of stands in administrative territories is not uniform. The forests of the European part of Russia are strongly depleted by logging, and areas of mature and overmature forests in some regions make up 7 to 12 percent of the total area (Voronezh, Smolensk, Ivanovo, Pskov, Yaroslavl, etc.). By contrast, Siberia and the Far East each have a large portion of mature and overmature forests. On the basis of statistical data, we have calculated the stock of the primary forest-forming species by age group within each administrative unit (Appendix Table 5 and Table 2.4).

Forest Productivity

The productivity of stands is determined by the conditions of growth coded by site quality class (see glossary). Forested areas are classified by quality as follows: class II and higher (the best quality): 9.5 percent of the area; class III: 25.4 percent; class IV: 24.9 percent; class V: 25.8 percent; class Va and Vb: 14.4 percent. The relative basal area of stands depends to a certain extent on quality classes, decreasing markedly with conditions of lower growth (Fig. 2.2).

The available statistical data do not allow us to estimate real values of stand density: they may be substantially higher for high-quality stands and lower for low-quality stands. From the Forest Fund of the U.S.S.R. (Goskomles of the U.S.S.R. 1991), it is evident that average stock per hectare of stocked area of Russia varies with age in a peculiar manner: in coniferous and deciduous hardwood species groups, the stock is highest in maturing stands and lower in older forests (Table 2.5). The latter may be due to the prevalence of declining stands in the mature and overmature category and/or the most productive stands have been cut and the remaining ones are old and of poor quality.

The distribution of average stock per hectare of stands in the administrative territories of Russia is shown in Appendix Table 4. These data reflect both forest habitat conditions and the results of economic activity. The average growing stock varies in a regular pattern, increasing from north to south from the forest-tundra to the broad-leaved forest zone, then decreasing in the southern arid areas. However, for similar natural conditions of Siberia and the Far East, the growing stock is much higher. The principal reason for this situation is long-term intensive commercial logging in the regions of European Russia (the Republics of Karelia, Murmansk, Smolensk, Tver, Bryansk, and other regions). In the Vologda and Pskov regions where there are many collective and Soviet agricultural farms with small areas of mature and overmature stands, the age structure of forests is disrupted and the growing stock is lower. The indices of average growing stock in European Russia generally are much lower than would be expected given the natural potential of the area.

Reliability of Statistical Data

According to Shvidenko (1993), by the time of the collapse of the U.S.S.R. (autumn of 1991), 700 million ha of the forest fund were covered by forest inventory and more than 300 million ha were surveyed by aerial photography (Russia only). From earlier statistical data (Goskomles of the RSFSR 1962) it can be presumed that as of January 1, 1988, the estimate of at least 400 million ha of boreal forests was based on aerial visual observations during the 1950's. We can assume the accuracy of these estimates for these areas is no better than ± 20 to 25 percent.

According to the "Regulations for Forest Management" (Anonymous 1986), the permissible regular error for all ground-based inventory estimates, including those for

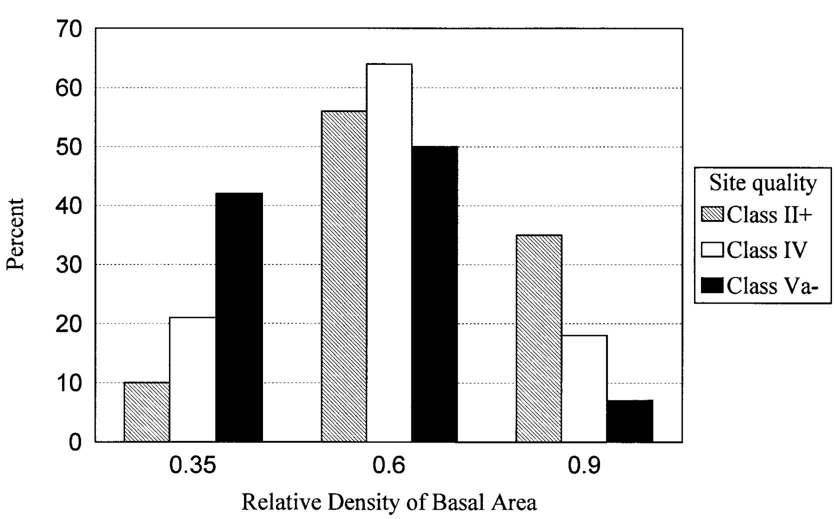

Figure 2.2.—Distribution of stands under management of forest entities of Russia (excluding forests assigned for long-term use) by density group: stands of quality class II and higher, stands of quality class IV, and stands of quality class Va and lower (Goskomles of the U.S.S.R. 1990).

growing stock, must not exceed 5 percent. Yet special studies show that inventories of exploited forests underestimate growing stock by 10 to 15 percent (Lebkov 1965; Filippov 1975; Fedosimov 1986) with the standard error increasing as the nonuniformity of sites increases (Filippov 1975). However, our experience suggests that in sparse, nonproductive, northern forests that are not subject to commercial exploitation, growing stock is overestimated. Considering the different signs of the standard errors, it can be assumed that the average growing stock of Russia is underestimated in statistical reference books by at least 10 percent.

Along with the stocked area, the forest resources of Russia incorporate vast territories that are temporarily or permanently unstocked with forest trees (Appendix Tables 2 and 3).

2.3 Comments on the Published Database

Since there are no critical reviews of the "Forest Fund of the U.S.S.R." (Goskomles of the U.S.S.R. 1990) and the American-Canadian analysis (Backman and Waggener 1991) deals with commercial-economic issues, it is necessary to comment on this important publication. The information contained in this reference book is unique and will be used for many years, though new reference books are being published for each of the countries of the former U.S.S.R.

Interpreting data in "Forest Fund of the U.S.S.R." (Goskomles of the U.S.S.R. 1990, 1991) is difficult for a number of reasons. It is not consistent with earlier works such as the "Forest Fund of RSFSR" (Goskomles of the RSFSR 1962) and Nikolayuk (1973), which include important statistical materials as well as maps. There is a lack of even minimal explanation on the conceptual content and rules for compiling tables. For example, values for absolute stand age in the published database should be replaced by "age groups" and its duration determined by growth conditions, biological properties of the forest trees, the forest group to which they belong, etc. However, while the previous statistical review (Forest Fund of RSFSR 1962) includes reference tables for cutting ages of different forest stands in different regions and average absolute ages of young, middle-aged, mature, and overmature stands, the newer reference book does not include these data. Consequently, it is impossible to analyze trends in age-class distributions without additional data. Consistency in statistical presentation over time would improve our understanding of why the areas and the growing stock of middle-aged forests are considerably higher than those of the maturing forests. The lack of reliable data on age also makes it difficult to forecast dynamics of the forest cover of Russia.

The authors of the reference book do not present data on statistical reliability. The Forest Fund of 1962 does include such information but both the forest inventory and amount of financial support for the inventory have changed since 1961. Thus, the accuracy of statistical data and standard errors would be affected (Moshkalev 1975; Anuchin 1982).

Compared with the materials in the Forest Fund of Russia published in 1962 (Goskomles of the RSFSR 1962), the new edition with its fewer geographical data is at a disadvantage. For the regions under drastically different climatic conditions, the authors confine themselves to data on species groups (coniferous, deciduous hardwoods, softwoods) or data on a narrow range of forest trees. Also, the list of woody plants in their tables of growing stock and covered areas is primarily at the genus level and presented only for the U.S.S.R. as the whole and its European and Asian parts. No such data are given for Russia and other republics of the former U.S.S.R. Shrubs are not mentioned except in tables for the whole U.S.S.R. Meanwhile, shrub formations are part of the stocked area and included in the final graphs, overrating the areas and underrating the indices of the growing stock of stands and their productivity.

Intentionally or not, the authors of the statistical reference book distorted the idea of the production diversity of Russian forests, grouping their areas beginning with quality class "II and higher" and terminating with "Va and lower" classes (Goskomles of the U.S.S.R. 1990, Table 16). Thus, the actual potential productivity of forests in many regions of the European part of the country is underrated by more than one quality class. Finally, some of the information on stand density collected by the forest inventories has been lost.

The administrative units of Russia are vastly different in size and forest cover. For example, Krasnoyarsk Kray extends from the polar deserts to the arid steppes of Tuva. Its forest fund is in the forest-tundra, northern, central, southern taiga, forest-steppe, steppe, and mountain systems with subarctic, boreal, and subboreal belts. The composition and productivity of the forests of this kray that spans many climatic and physiographic zones is not useful in characterizing forests for commercial and sustainable forest management. For such regions, a statistical reference book should include data on smaller areas (forestry farms) confined to more uniform forest-vegetation ecoregions. But for the purposes of this project, even such a detailed characteristic is not always sufficient. For example, the area of Evenk forestry farm of the Krasnoyarsk Kray is 76.7 million ha (equal to the area of Ukraine, Lithuania, Latvia, and Estonia combined), and extends over the territory of forest-tundra, northern and middle taiga. Data from forestry farms are insufficient, making it necessary to use data on forestry districts.

2.4 Applying Statistical Data to Estimate Carbon

The statistical database, including data for the administrative territories supplemented with data from forestry farms and their subunits, is the most important information for estimating the true stock of carbon in Russian forests. Since the data are collected from a statistical sample, the estimates represent the true characteristics of the forests at the time of their sampling, subject to unbiased sampling and estimation errors.

A limitation of data from administrative territories is that the boundaries do not necessarily correspond to the natural patterns of composition, structure, productivity, and other parameters related to the site and forest cover. So the estimates cannot be used to understand and explain observed patterns. To facilitate this understanding, data are needed on the distribution of forests and their characteristics compiled for natural forest ecoregions. A classification system for use with statistical data is discussed in the next chapter.

Table 2.1.—Areas (thousand ha) and growing-stock volume (million m^3) in Russian Forest Fund, by land-management category[a]

Land management	Statistic	Total area	Forest area	Area and growing stock				
				Stocked area	Conifer	Deciduous hardwood	Deciduous softwood	Shrub/other tree species
Federal (national) forests	Area	1,167,050	868,589	756,088	546,002	19,251	128,730	62,105
	Volume			79,831	63,124	1,996	13,328	1,383
Forest Service	Area	1,085,720	800,194	691,551	508,858	17,047	104,980	60,665
	Volume			71,636	57,715	1,810	10,785	1,325
Long-term lease (included in Forest Service)	Area	102,132	49,445	37,357	20,067	1,934	2,258	13,099
	Volume			2,312	1,553	175	138	447
Other agencies	Area	81,330	68,394	64,538	37,143	2,204	23,750	1,436
	Volume			8,186	5,409	186	2,543	48
Forest industry (included in Other agencies)	Area	30,101	23,412	22,001	17,245	50	4,700	7
	Volume			3,002	2,448	10	543	0
State farm forests	Area	27,837	27,837	26,730	9,785	1,089	15,857	0
	Volume			3,209	1,501	64	1,645	0
Collective farm forests	Area	15,505	15,505	15,021	5,997	552	8,471	0
	Volume			1,813	914	37	862	0
Total area		1,182,555	884,094	771,109	551,999	19,803	137,202	62,105
Total volume				81,644	64,037	2,033	14,191	1,383

[a]Compiled from Goskomles of the U.S.S.R. 1990.

Table 2.2.—Growing-stock of primary species (million m^3) in forests of administrative territories of Russia[a]

Administrative territory	Dominant tree species								Other trees	Krummholz and shrub	Total
	Pinus sylvestris	*Picea* sp.	*Abies* sp.	*Larix* sp.	*Pinus sibirica*	*Betula* sp.	*Populus tremula*	*Quercus* sp.			
1. Kaliningrad Oblast	7.3	7.0	0.0	0.0	0.0	9.9	6.3	9.0	0.0	0.0	39.4
2. Arkhangel'sk Oblast	585.3	1,599.7	0.0	9.4	0.0	152.7	29.3	0.0	0.0	0.0	2,376.3
3. Vologda Oblast	331.8	486.5	0.0	0.1	0.0	411.6	102.3	0.0	3.0	0.0	1,335.4
4. Murmansk Oblast	93.0	89.7	0.0	0.0	0.0	27.9	0.0	0.0	0.0	0.0	210.5
5. Rep. of Karelia	467.7	270.7	0.0	0.1	0.0	75.3	7.8	0.0	0.0	0.0	821.5
6. Rep. of Komi	672.0	1,768.8	19.8	30.0	3.1	271.8	89.7	0.0	0.0	0.2	2,855.5
7. Leningrad Oblast	263.3	252.8	0.0	0.1	0.0	196.6	77.7	0.0	0.0	0.0	790.5
8. Novgorod Oblast	123.0	103.1	0.0	0.1	0.0	206.4	87.7	0.6	5.7	0.1	526.7
9. Pskov Oblast	101.4	35.4	0.0	0.0	0.0	116.1	38.4	0.7	15.9	0.0	308.0
10. Brjansk Oblast	70.8	13.2	0.0	0.0	0.0	36.1	20.7	10.2	7.0	0.0	157.9
11. Vladimir Oblast	121.5	15.8	0.0	0.1	0.0	51.1	16.9	3.4	0.9	0.0	209.7
12. Ivanovo Oblast	61.2	25.6	0.0	0.1	0.0	47.1	21.9	0.5	0.5	0.0	156.9
13. Tver' Oblast	177.7	166.8	0.0	0.1	0.0	217.6	92.2	0.0	8.8	0.0	663.2
14. Kaluga Oblast	30.9	33.8	0.0	0.1	0.0	85.9	51.7	8.3	1.5	0.0	212.0
15. Kostroma Oblast	179.3	154.5	0.0	0.1	0.0	253.5	62.0	0.1	0.0	0.0	649.4
16. Moscow Oblast	79.9	96.0	0.0	0.4	0.0	121.6	34.5	7.3	0.7	0.0	340.4
17. Orel Oblast	4.3	0.7	0.0	0.1	0.0	5.2	4.9	7.5	0.0	0.0	22.6
18. Ryazan' Oblast	63.9	2.9	0.0	0.0	0.0	37.3	16.3	16.3	0.8	0.0	137.6
19. Smolensk Oblast	21.3	56.8	0.0	0.1	0.0	100.6	46.8	0.8	8.2	0.0	234.6
20. Tula Oblast	2.6	1.1	0.0	0.2	0.0	9.5	9.9	16.0	4.5	0.0	43.8
21. Yaroslavl' Oblast	34.5	51.3	0.0	0.0	0.0	86.0	38.6	0.4	2.6	0.0	213.4
22. Nizhniy Novgorod Oblast	195.9	49.0	0.1	0.1	0.0	139.9	63.6	14.5	1.9	0.1	465.0
23. Kirov Oblast	255.4	351.6	1.1	0.2	0.0	281.7	102.6	1.0	2.2	0.0	995.7
24. Rep.of Mari El	61.0	23.8	0.2	0.1	0.0	49.2	26.9	2.3	1.0	0.0	164.6
25. Rep. of Mordvinia	29.9	1.1	0.0	0.1	0.0	24.2	12.4	11.9	4.1	0.0	83.8
26. Rep. of Chuvashia	23.0	1.0	0.0	0.3	0.0	17.9	9.1	17.8	8.9	0.1	78.0
27. Belgorod Oblast	3.5	0.0	0.0	0.0	0.0	0.7	1.4	27.1	0.0	0.0	32.7
28. Voronezh Oblast	17.0	0.0	0.0	0.0	0.0	1.3	5.1	29.0	0.0	0.1	52.4
29. Kursk Oblast	2.9	0.1	0.0	0.0	0.0	1.6	2.0	12.9	0.1	0.0	19.6
30. Lipetsk Oblast	13.2	0.0	0.0	0.0	0.0	2.5	3.0	10.3	0.0	0.0	29.1
31. Tambov Oblast	25.7	0.0	0.0	0.0	0.0	7.0	8.4	8.0	0.0	0.0	49.3
32. Astrakhan' Oblast	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	5.2	0.2	6.1
33. Volgograd Oblast	3.3	0.0	0.0	0.0	0.0	0.5	1.7	16.4	6.6	0.4	29.0
34. Samara Oblast	14.7	0.0	0.0	0.1	0.0	4.3	19.4	27.1	14.4	0.2	80.2
35. Penza Oblast	47.2	0.2	0.0	0.1	0.0	23.5	25.7	22.7	0.0	0.0	119.4
36. Saratov Oblast	4.2	0.0	0.0	0.1	0.0	2.6	5.9	32.8	6.2	0.2	52.0
37. Ul'yanovsk Oblast	67.4	0.1	0.0	0.1	0.0	30.2	27.0	16.6	0.0	0.0	141.4

Continued

Table 2.2—Continued

Administrative territory	Dominant tree species								Other trees	Krummholz and shrub	Total
	Pinus sylvestris	*Picea* sp.	*Abies* sp.	*Larix* sp.	*Pinus sibirica*	*Betula* sp.	*Populus tremula*	*Quercus* sp.			
38. Rep. of Kalmykia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2
39. Rep. of Tatarstan	29.1	3.8	0.5	0.5	0.0	22.1	34.6	24.6	29.6	0.0	144.6
40. Krasnodar Kray	3.2	0.8	30.0	0.0	0.0	0.6	8.3	147.7	114.8	16.5	321.9
41. Stavropol' Kray	15.3	7.3	15.8	0.0	0.0	10.2	7.5	9.0	27.9	0.3	93.2
42. Rostov Oblast	3.4	0.0	0.0	0.0	0.0	0.1	0.6	7.3	1.7	0.5	13.7
43. Rep. of Dagestan	9.9	0.0	0.0	0.0	0.0	3.7	0.8	10.8	15.9	0.2	41.3
44. Rep. of Kabardino-Balkaria	0.9	0.0	0.0	0.0	0.0	1.7	2.1	1.1	19.1	0.3	25.1
45. Rep. of North Osetia	0.9	0.0	0.0	0.0	0.0	1.1	0.8	1.3	26.7	0.1	30.8
46. Rep. of Checheno-Ingushetia	0.9	0.0	0.0	0.0	0.0	2.8	1.1	7.8	40.6	0.4	53.6
47. Kurgan Oblast	63.4	0.1	0.0	0.0	0.0	104.1	15.5	0.0	0.0	0.1	183.3
48. Orenburg Oblast.	10.7	0.0	0.0	0.0	0.0	7.2	8.0	19.7	14.1	0.4	60.1
49. Perm' Oblast	159.1	894.1	20.2	0.2	1.4	322.9	89.5	0.2	6.4	0.0	1,494.1
50. Sverdlovsk Oblast	744.3	327.9	25.5	3.3	145.1	426.5	85.0	0.0	1.3	0.0	1,758.8
51. Chelyabinsk Oblast	110.1	23.3	10.6	3.9	0.0	150.1	28.7	4.4	14.8	0.1	345.9
52. Rep. of Bashkortostan	118.3	35.6	15.3	5.0	0.0	182.8	124.6	81.7	165.2	0.3	728.6
53. Rep. of Udmurtia	49.1	114.6	1.9	0.3	0.0	77.3	33.8	0.5	2.0	0.0	279.5
54. Altai Kray	307.6	9.3	126.3	191.4	176.1	133.0	114.3	0.0	0.0	2.4	1,060.3
55. Kemerovo Oblast	17.6	8.8	273.6	0.7	58.0	122.3	116.7	0.0	0.0	0.2	597.7
56. Novosibirsk Oblast	99.1	2.6	7.9	0.4	7.2	251.1	65.9	0.0	0.0	0.3	434.6
57. Omsk Oblast	72.9	11.0	7.2	0.3	28.9	304.4	89.1	0.0	0.0	0.0	513.7
58. Tomsk Oblast	669.2	76.9	93.8	1.4	737.1	848.2	338.5	0.0	0.0	0.1	2,765.2
59. Tyumen' Oblast	2,054.0	540.0	31.9	512.3	1,098.0	918.4	264.8	0.0	0.0	3.3	5,422.8
60. Krasnoyarsk Kray	1,954.5	1,268.1	1,297.6	6,070.4	1,997.2	1,373.9	390.4	0.0	0.0	18.2	14,370.2
61. Irkutsk Oblast	3,081.4	485.6	313.2	2,648.4	1,595.3	600.1	285.8	0.0	0.0	122.1	9,131.8
62. Chita Oblast	328.8	2.4	1.0	1,690.1	200.0	251.2	21.5	0.0	0.0	60.9	2,555.8
63. Rep. of Buryatia	484.6	19.5	46.8	1,064.9	331.0	74.7	46.5	0.3	0.0	72.9	2,141.1
64. Rep. of Tuva	26.1	8.0	0.1	573.7	477.6	24.9	3.8	0.0	0.0	1.5	1,115.7
65. Primor'ye Kray	0.2	562.5	45.0	176.9	550.6	151.8	106.1	338.3	4.7	2.1	1,938.2
66. Khabarovsk Kray	132.1	1,502.8	89.1	2,701.5	191.9	335.5	165.5	67.1	0.0	193.0	5,378.5
67. Amur Oblast	71.6	71.2	8.8	1,492.0	1.1	286.8	25.6	26.8	0.0	49.3	2,033.2
68. Kamtchatka Oblast	0.1	46.6	0.0	100.2	0.0	555.9	54.6	0.0	0.0	473.0	1,230.4
69. Magadan Oblast	0.0	0.0	0.0	383.6	0.0	1.9	0.0	0.0	35.5	154.0	574.9
70. Sakhalin Oblast	0.8	243.2	152.5	201.2	0.0	62.2	1.0	0.0	10.4	18.5	689.7
71. Rep. of Yakutia (Sakha)	1,088.0	48.5	4.0	7,921.2	75.0	67.1	18.5	0.0	0.0	190.9	9,413.0
Total	15,964	11,973	2,640	25,786	7,674	10,783	3,719	1,081	641	1,383	81,644

[a]Estimated from: Forest Fund of U.S.S.R. 1990, 1991; database for Krasnoyarsk Kray and Republic Yakutia (Sakha); Forest Fund of Russian Federation RSFSR 1962; Nikolayuk 1973.

Table 2.3.—Growing stock of stands under Forest Service and forest industry management (million m³)[a]

Tree-species group	Age-class group: Young stands Class I[b]	Young stands Class II[c]	Middle-aged	Maturing	Mature/ overmature	Total
Conifer	602	2,007	10,964	7,306	37,730	58,608
Deciduous hardwood	17	69	490	219	851	1,646
Deciduous softwood	108	390	3,265	1,619	5,807	11,189
Total	733	2,521	15,277	9,226	44,575	72,331

[a]Compiled from Goskomles of the U.S.S.R. 1991.
[b] Early regeneration.
[c]Advanced regeneration.

Table 2.4.—Growing stock of primary tree species of Russia by age group (million m³)[a]

Dominant tree species	Age-class group: Young stands Class I[b]	Young stands Class II[c]	Middle-aged	Maturing	Mature/ overmature	Total
Conifer						
Pinus sylvestris	264	800	3,909	2,232	8,759	15,964
Picea sp.	182	536	2,224	1,395	7,636	11,973
Abies sp.	21	57	446	343	1,773	2,640
Larix sp.	190	705	3,801	3,500	17,590	25,786
Pinus sibirica	23	169	1,293	1,536	4,653	7,674
Subtotal	680	2,267	11,672	9,007	40,411	64,037
Deciduous Hardwood						
Quercus sp.	15	52	407	206	400	1,081
Fagus sp.	1	5	84	25	72	187
Carpinus betulus	0	1	20	6	17	44
Ulmus sp.	0	0	1	1	2	4
Betula ermani	1	7	201	54	454	717
Subtotal	17	66	714	292	944	2,033
Deciduous Softwood						
Betula sp.	104	371	3,313	1,623	4,655	10,066
Poulus tremula	37	121	1,154	560	1,847	3,719
Populus sp.	1	3	21	11	43	78
Tilia sp.	3	10	99	49	112	273
Alnus sp.	0	2	29	14	10	54
Subtotal	144	507	4,616	2,257	6,667	14,191
All tree species	842	2,840	17,002	11,555	48,022	80,261

[a]Estimated from Goskomles of the U.S.S.R. 1990, 1991; Goskomles of the the R.S.F.S.R. 1962; Nikolayuk 1973; Forest database for Krasnoyarsk Kray and Republic of Yakutia (Sakha).
[b] Early regeneration.
[c]Advanced regeneration.

Table 2.5.—Average growing-stock volume (m^3/ha) of Russian coniferous and deciduous stands by age groups[a]

Tree-species group	Age-class group				
	Young stands		Middle-aged	Maturing	Mature/ overmature
	Class I[b]	Class II[c]			
Conifer	13.1	52.1	113.3	151.5	136.4
Deciduous hardwood	18.7	55.3	115.8	127.2	120.6
Deciduous softwood	9.5	32.7	92.7	131.5	158.8
Total[d]	12.8	49.9	111.0	148.7	138.6

[a]Estimated from Goskomles of the U.S.S.R. 1991.
[b]Early regeneration.
[c]Advanced regeneration.
[d]Does not include krummholz and shrubs.

Chapter 3. Classification of Forest Regions of Russia and Former U.S.S.R. Republics

I.A. Korotkov

To reveal ecological-geographical patterns of carbon distribution and dynamics in Russian forest ecosystems, it is necessary to divide the land area into forest regions. Forest classification was explored by numerous scientists beginning with Morozov (1924). Most works have dealt with separate parts of the country. The classification systems differed in basic approaches, taxon definitions, and sizes of areas (Ivanenko 1961; Krylov 1961, 1962; Popov 1962; Gulisashvili 1964; Krylov and Rechan 1965; Yurkevich and Geltman 1965; Nazimova 1968; Kolesnikov 1973).

A comprehensive classification of the entire U.S.S.R. was attempted by Kurnayev (1973). Proclaiming a complex approach that considers the most important factors for determining the distribution of forest vegetation as groundwork for dividing the land, Kurnayev nevertheless followed principles of the "Geobotanic Classification of the U.S.S.R." (Lavrenko 1947) that were based on floristic evidence. Kurnayev emphasized the natural habitats of the primary forest-forming species. However, such species in different parts of their range do not always define the habitat, resulting in considerable confusion of ecoregion boundaries. For example, according to Kurnayev the Urals forest region comprised the lowlands of the Pechora River Basins in European Russia and the Irtysh River in the East; the Western Siberian province encompassed the Yenisei ridge, all of the Angara watershed, and the mountains of southern Siberia (Altai, Western, and Eastern Sayan). According to Kurnayev, the Middle-Siberian province in the southeast extends to the low reaches of the Amur River (Russian Far East).

In the more than 20 years since Kurnayev's study was published, a substantial body of basic literature on Russian vegetation has evolved, including "Vegetation of the European Part of the U.S.S.R.", and a series of vegetation maps of Siberia published in 1979-81 (Isachenko and Lavrenko 1979; Gribova et al. 1980). Special studies by researchers of the Institute for Forest Research provided additional detail and considerably altered the position of the southern boundary of subarctic forests (Korotkov 1991). Other zonal and subzonal boundaries in Asian Russia also have undergone changes, generating a need for a new forest regionalization.

3.1 Principles and Taxons of Forest Classification

The forest classification we have developed is based on the concept of chorological and functional unity of forests and their territorial complexes (Smagin 1985, 1987). Using this approach makes it possible to construct a system of forest taxons by region that is consistent with the system of forest classification taxons (Table 3.1).

Regionalization of Russia and adjacent states (republics of the former U.S.S.R.) occurs at four hierarchic levels: bioclimatic sectors, forest oblasts (FO), forest provinces (FP), and districts**.** The bioclimatic sectors are determined by variation in climate continentality within northern Eurasia. To distinguish the sectors, we used data on the Earth's climatic belts (Ivanov 1959; Prokayev 1967, 1983), and the climate continentality coefficient (Ivanov 1959). Because an incomplete network of meteorological stations made it difficult to accurately plot the boundaries of the bioclimatic sectors, we also considered vegetation indicators: the structure and composition of the tree stands forming zonal and subzonal forest communities.

In several cases, the boundaries of the sectors were mountain systems such as the Urals, the Yenisei Hills, and the western escarpment of the Middle Siberian tableland.

The eight bioclimatic sectors distinguished in the former U.S.S.R. include the Middle European Atlantic moderate maritime, Eastern European moderate continental, Eastern European temperate continental, Western Siberian continental, Middle Siberian strongly continental, Eastern Siberian extremely continental, Far Eastern continental monsoon, and Interior extremely continental subarid and arid.

Latitudinally, Northern Eurasia is crossed by six bioclimatic belts (zones): arctic; subarctic; boreal (taiga with northern, middle, southern taiga, and subtaiga subzones); subboreal (forest-steppe and steppe); subarid; and arid (desertified steppes and deserts). The zonal and subzonal partitioning of the former U.S.S.R. is well developed (Isachenko and Lavrenko 1980) and represented in vegetation maps published during the last two decades.

Further partition of the bioclimatic sectors into FO, FP, and districts is based on the system of forest classification taxons (Table 3.1). For the intrasectoral regionalization, territorial relief is important and distinguishes among plain, tableland, and mountain FO. On the plains and tablelands, patterns of latitudinal zones are apparent; in the mountains, altitudinal zones are strongest.

A plain or a tableland FO is characterized by parts of zones successively replacing each other within one bioclimatic sector (for example, the Western Siberian plain FO of boreal and subboreal altitudinal zone).

A plain FP is a part of a zone within an FO. It is characterized by a zonal-provincial complex of forest types, for example, Dvina-Pechora-Upper-Volga FP of taiga forests.

A plain forest district is a part of a forest province representing a section of a subzone within a bioclimatic sector. A district is characterized by a subzonal provincial complex of forest types, for example, Volkhov district of southern taiga forests.

In mountainous regions, the primary classification taxon of the intermediately ranked forest is the altitudinal complex (AC) of forest types. The AC characterizes the forest vegetation in a mountain system belonging to one bioclimatic sector, for example, mountain pine-larch subtaiga or mountain Siberian pine-fir taiga. The AC title represents the primary forest-forming species.

In mountain systems, AC forms a spectrum representative of the distribution and changing of the absolute height of forest vegetation. The type of altitudinal zone characterizes a mountain system located in one latitudinal bioclimatic belt, for example, subboreal, boreal, subarctic, or arid within a bioclimatic sector (Western Siberian subboreal, Middle Siberian boreal, Middle Asian arid, etc.).

A mountain FO is characterized by AC spectra assigned to one or several altitudinal types. For example, the Urals FO is characterized by three altitudinal types: subarctic, boreal, and subboreal.

A mountain FP is characterized by an AC type spectra (or spectrum) different from another type in an AC complex. For example, the Northern Altai-Sayan FP has the following AC spectra: mountain *Pinus sylvestris-Betula pendula* subtaiga-forest-steppe, mountain *Abies sibirica-Pinus sibirica*, mountain-taiga *Pinus sibirica*, and subnival-subalpine. The ecoregions of Russia and the former U.S.S.R. republics are shown in Figure 3.1 and Table 3.2.

3.2 Short Description of Bioclimatic Sectors and Forest Oblasts

Middle European Atlantic Moderate Maritime Sector

The northern edge of this sector extends over the coast of the Baltic Sea in the Carpathian and Transcarparthian Mountains, and encompasses the taiga zone (a subzone of mixed forests) and the hardwood forest zone. The primary species are *Picea abies*, *Pinus sylvestris*, *Quercus robur*, and *Fagus sylvatica*. The altitudinal belt distinguished in the Carpathians is composed of oak-hornbeam, beech, spruce, and subalpine alder-aspen open forests with *Alnus viridis* and *Pinus mughus*.

Eastern European Moderate Continental Sector

This sector encompasses the Kola-Karelian and Dnieper-Baltic FO's. The Kola-Karelian tableland FO extends over the eastern part of the Scandinavian Shield on the Kola Peninsula and in Karelia. The zone type is boreal. In the northern Kola Peninsula, a narrow band represents the forest-tundra zone with woodlands formed by *Betula tortuosa*, *Picea x fennica*, and *P. obovata*. Most of the oblast is covered by the taiga forests (northern and middle taiga subzones). The predominant tree species are Scotch pine *(Pinus sylvestris)* and European spruce *(Picea abies)*.

The Dnieper-Baltic plain FO covers the western part of the Eastern European plain (up to the western boundary of the Valdai Hills) and the Crimea Peninsula. It covers the basins of the Zapadnaya Dvina, Volkhov, Dnieper, Southern Bug, and Dniester Rivers. In the Dnieper Basin, the eastern boundary of the region matches the eastern boundary of hornbeam *(Carpinus betulus)* distribution. The territory is occupied by boreal and subboreal forests.

The zones and subzones of the Dnieper-Baltic FO are the taiga zone with subzones of southern taiga and mixed forests; the broad-leaved forest zone with pine and broad-leaved tree species (in Polesye); the forest-steppe zone; the steppe zone; and the Crimean Mountains.

The subzone of mixed forests in this oblast is represented by a broad band; the southern taiga is considerably narrowed. The primary forest-forming species are *Picea abies*, *Pinus sylvestris*, *Quercus robur*, and *Betula pendula*.

In Polesye, the typical forest is formed by pine with mixtures of oak, maple, and linden. Pure "dubravas" (forests dominated with oak on rich, fertile soils) cover much less area. *Carpinus betulus* is abundant in the mixtures. Dominating the forest-steppe is *Quercus robur*. Scotch pine is sparse, found primarily on sand and river terraces. There are some small forest islands in the steppe zone.

The Crimean Mountains are somewhat distinct (they can be assigned to the Caucasus Mountain country). Distinguished in the altitudinal spectrum are the dry subtropics with *Quercus petraea* and *Fagus sylvatica* forests.

The subboreal and subarid Caucasus FO covers the Great and Little Caucasus Mountains and the Colchis and Kura-Araks Lowlands. Spectra of altitudinal belts differ considerably over the region. Distinguished in the Great and Little Caucasus are steppe and forest-steppe belts where the forests are formed by several species of oaks and hornbeam (*Quercus imeretina*, *Q. iberica*, *Carpinus caucasica*), the eastern beech (*Fagus orientalis*) forest belt, the eastern spruce (*Picea orientalis*) belt, and the subalpine and alpine belts.

In the Colchis Lowland with its humid subtropics, the species composition of woody vegetation is diverse. The most common species are *Alnus barbata* and *Castanea sativa*. Prevalent in the Kura-Araks Lowland are dry and desertified steppes.

Eastern European Temperate Continental Sector

The orography of the territory and vegetation distinctions make it possible to divide this sector into two FO's: Eastern European and the Urals. The Eastern European plain FO encompasses parts of four zones: forest-tundra; taiga (with northern, middle and southern taiga, and mixed subzones); broad-leaved forests (forest-steppe); and steppes. The primary forest species are *Picea abies*, *P. obovata*, and their hybrid *P. x fennica*. Penetrating the oblast from the East and found as mixtures are Siberian fir *(Abies sibirica)* and Siberian pine or "kedr" *(Pinus sibirica)*. Among the broad-leaved species, *Quercus robur* and linden *(Tilia cordata*) are

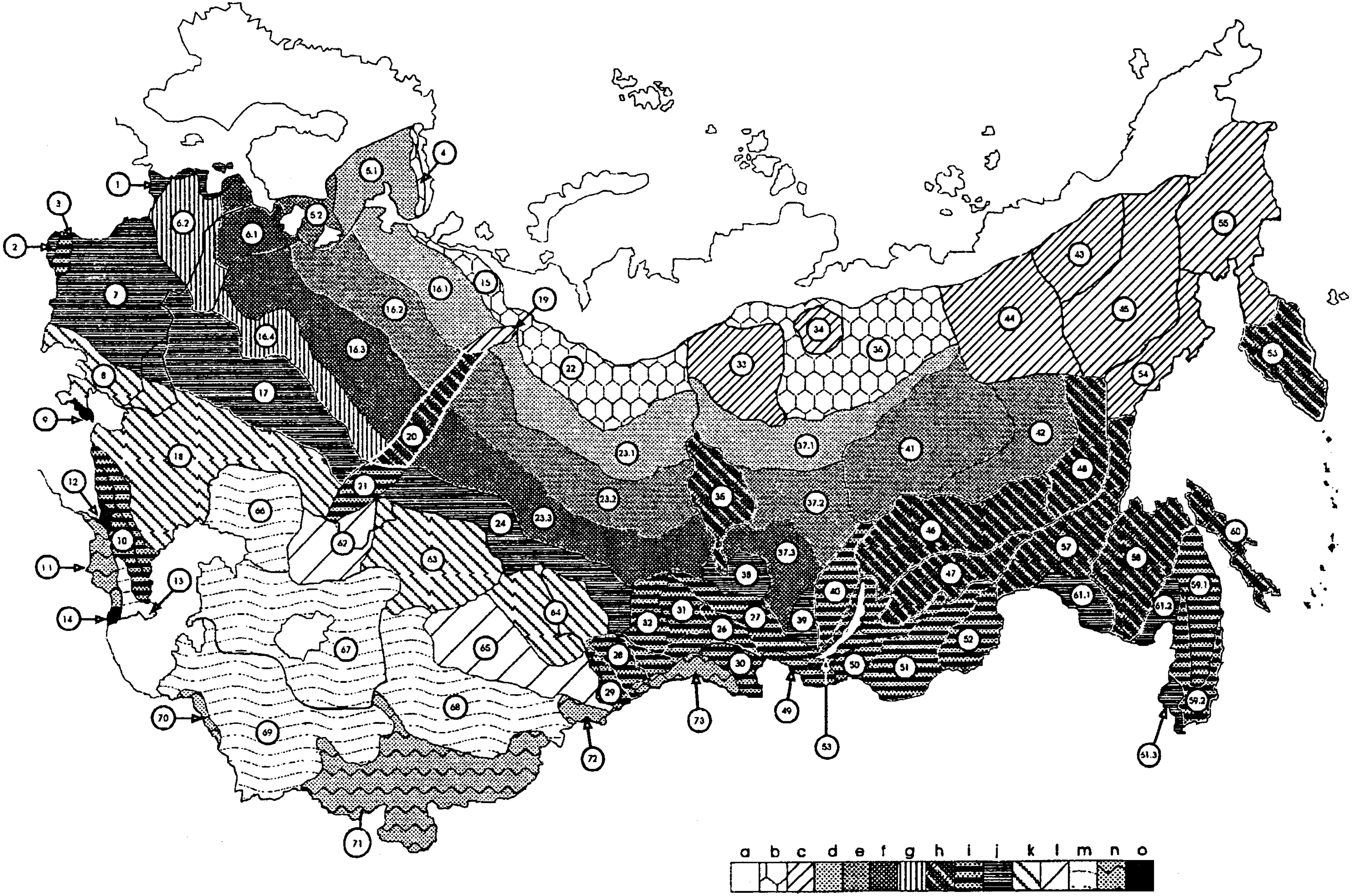

Figure 3.1.—Ecoregions of Russia and former U.S.S.R. republics: a = arctic deserts, tundras, water or other country; b = forest-tundra and sparse subarctic forests; c = montane territories of the subarctic; d = northern taiga; e = middle taiga; f = southern taiga; g = mixed forests; h = montane boreal territories; i = montane subboreal territories; j = forest-steppes (broad-leaved deciduous forests); k = steppes; l = semideserts; m = deserts; n = montane subarid territories; o = subtropics. (numbers in circles refer to names of ecoregions).

common. The Urals Mountains FO is a specific geocomplex barrier with different forest belts. The basic zones are forest-tundra, taiga, and forest-steppe. Prevalent among the forest-forming trees are Siberian tree species--*Picea obovata* and *Abies sibirica*. Linden is the most common broad-leaved species.

Western Siberian Continental Sector

The Western Siberian FO encompasses the forest-tundra, taiga (northern taiga, open forests and woodlands, northern, middle, and southern taiga) and forest-steppe zones. The primary species in the taiga are *Pinus sibirica* and *Abies sibirica*; *Picea obovata* occupies a subdominant position. *Larix sibirica* is found in the north. The forest-steppe is represented by aspen-birch kolki (small forest islands in forest-steppe) consisting of *Populus tremula*, *Betula pendula*, and *B. pubescens* in combination with meadow steppes and community complexes on saline soils.

Middle Siberian Strongly Continental Sector

This sector covers the Middle Siberian tableland and Central Yakutia and is divided into three oblasts. The Middle Siberian FO is represented by two zones: forest-tundra and taiga (subzone: northern taiga with sparse forests and woodlands, northern taiga, middle taiga, southern taiga, subtaiga). The primary forest-forming species are *Larix sibirica*, *L. gmelinii,* and *Pinus sylvestris,* which form zonal communities in the subzones of middle, southern, and subtaiga. The forest-steppe here is not continuous and is represented by isolated forest massifs: Krasnoyarsk-Kansk and Angara Scotch pine-birch forest-steppe (*Betula pendula*, *Pinus sylvestris*).

The western edge of the Middle Siberian tableland, the Yenisei Ridge, is a barrier to humid western winds and forms a separate low-mountain province with conifer (*Abies sibirica*, *Pinus sibirica*, *Picea obovata*, *Larix sibirica*) forests. Prominent in the north of the oblast are the Putoran Plateau and Anabar Shield with sparse mountain subarctic forests and woodlands formed by *Larix gmelinii*.

The Central Yakutia plain FO covers Lena-Vilyui and the Aldan-Amgin Plains. Only northern taiga and middle taiga forests of *Larix gmelinii* and *Pinus sylvestris* are represented here. Specific to forest landscapes are the natural complexes (alasses) with meadow-steppe vegetation. The origin of alasses is associated with thermokarst lakes formed at the site of burnt forests, subsequently dried, and followed by meadow-steppe communities. Although the thermokarst is common in the permafrost territory, alasses are found only in Yakutia due to the arid climate (particularly in the summer) and saline bedrock, which is common.

The Altai-Sayan mountain FO has subboreal Western Siberian and Middle Siberian altitude zones. The mountain belts are steppe, forest-steppe, subtaiga, mountain-taiga, and subnivals. In the provinces with a cyclonic weather regime, *Abies sibirica* and *Pinus sibirica* are common; while *Larix sibirica* is the primary tree species in the provinces with an anticyclonic weather regime.

Eastern Siberian Extremely Continental Sector

This sector, which covers the mountains in northeast Siberia and the Northern Transbaikal area; is divided into four FO's. The Yana-Kolyma mountain FO is a subarctic mountain region occupying the basins of the Yana, Indigirka, and Kolyma Rivers. The northern taiga forests are confined to large river valleys. In the subnival, sparse open forests and woodlands with *Larix cajanderi* are common. Krummholz communities of *Pinus pumila* are distributed widely. Large areas of this sector are covered by mountain tundra and rocky deserts.

The Northern Transbaikal mountain FO covers vast mountain boreal forests of the Stanovoi Ridge, Vitim Tableland, Aldan Highland, and Jugjur Range. The mountain-taiga forests, formed by *Larix gmelinii* and *L. cajanderi*, are widely distributed in the oblast. There are pine forests along river valleys and mountain basins. Along with larch, the subscree belt features krummholz *(Pinus pumila*) and stone birch (*Betula ermanii*).

The Southern Transbaikal mountain-basin FO encompasses the basins of the Selenga, Ingoda, upper Shilka, and Argun Rivers. Represented here are the subboreal type mountain forests: steppe, subtaiga-forest-steppe (formed by forests of *Pinus silvestris*, *Larix gmelinii* and *L. sibirica*), and mountain *Pinus sibirica-Larix sibirica* taiga. The subnival belt is fragmentary.

The Baikal mountain FO encompasses the territory of mountain ranges surrounding Lake Baikal: Primorsky, Barguzin, Ulan-Burgasy, and Khamar-Daban. The continentality of the climate is reduced considerably by the impact of the water basin of huge Lake Baikal. The spectrum of subboreal altitudinal belts features subtaiga-forest-steppe of pine and larch forests, taiga of fir forests, and mountain-taiga of Siberian pine, fir-Siberian pine, and larch forests. The subscree belt is represented on the Barguzin Range by fir and Siberian pine sparse open forests and woodlands. Common here is the subalpine-tundra belt with fragmentary krummholz (*Pinus pumila*) communities.

Far Eastern Continental Monsoon Sector

This sector includes Okhotsk-Bering and Amur-Sakhalin mountain FO's. The Okhotsk-Bering mountain FO covers the coast of the Okhotsk Sea, Penzhina-Anadyr Low Mountains, and the Kamchatka Peninsula. It is predominantly a subarctic altitudinal zone. Prevalent are open *Larix cajanderi* forests with krummholz of *Pinus pumila*. Relatively closed stands of *Larix cajanderi*, *Populus suaveolens*, and *Chosenia arbutifolia* are found in river valleys. Common on the Kamchatka Peninsula are stands of *Betula ermanii* with *Pinus pumila* krummholz. *Larix kamtschatica* forests of the taiga type are found in the Kamchatka River Valley.

The Amur-Sakhalin mountain FO covers the basin of the Amur River, Sakhalin Island, and Kuril Islands. The mountain forests are boreal and subboreal. The primary tree species are *Picea glennii*, *Abies sachalinenisis*, and *Larix kamtschatica*. Most common in the north part of the basin of the Zeya, Bureya, Amgun, Selemja, and Uda Rivers are mountain taiga forests of *Larix gmelinii* and *L. cajanderi* mixed with *Picea ajanensis*. Close to timberline, forest vegetation is represented by larch, stone birch, and krummholz communities.

Developed on the Sikhote-Alin Range is the belt of broad-leaved and conifer forests of *Pinus koraiensis*, *Abies nephrolepis*, *Quercus mongolica*, *Tilia amurensis*, and other species. The mountain taiga is formed by *Picea ajanensis* forests mixed with *Pinus koraiensis*. The subscree area is small with forest communities of *Picea ajanensis*, *Betula costata*, *Larix gmelinii*, and *Pinus pumila*.

Represented on Sakhalin Island are *Larix sachalinensis* and *Picea glenii* northern taiga and middle taiga mixed with broad-leaved species. In the valleys of the Amur, Ussuri, and Khanka Lowland are complexes of meadows, meadow-steppes, and stands of *Quercus mongolica* and *Chosenia arbutifolia*. These complexes can be assigned to the subtaiga-forest-steppe.

Interior Extremely Continental Subarid and Arid Sector

This sector encompasses four forest oblasts: Kazakhstan, Tura, Mid-Asian, and Central Asian. In the Kazakhstan plain-tableland forest-vegetation oblast, the dominant vegetation covers are true zonal and arid steppes. The zonality type is subarid. The forest vegetation is intrazonal and represented by band forests of *Pinus sylvestris* subsp. *ulundensis* and Scotch pine forests in different parts of the region.

Vegetation of the Tura plain oblast is represented by desertified steppes and northern and southern deserts. The bush and scrub communities consist of *Haloxylon persicum*, *H. ammodendron* desert woodlands, thickets of *Salsola richteri*, and other desert species. In the Amur-Darya and Ili River Valleys are thickets of *Populus diversifolia*, different species of *Salix*, *Tamarix,* and other woody plants.

The Middle Asian mountain FO is located in the mountains of Tien Shan, Pamirs, and Kopet Dagh and covers the Saur and Tarbagatai Ranges. The altitudinal belts are desert, savanna-like, fragmentary forest, subalpine, and alpine. The forest belt is represented by different species of arborescent junipers (e.g., *Juniperus seravschanica)*, Shrenk spruce (*Picea schrenkiana*), and Semenov fir (*Abies semenovii*). Found in the mountains of Tien Shan, Pamirs, and Kopet Dagh are groves and woodlands of pistachio (*Pistacea vera*), walnut (*Juglans regia*), apple (*Malus sieversii*), and other fruit trees. In the Saur and Tarbagatai Ranges are *Larix sibirica* forests.

Within the limits of Russia, the Central Asian mountain FO is represented in the subarid territories of the Southern Eastern Altai and Southern Tuva. The forests found on the northern aspects of mountains are represented by pseudotaiga, mountain-taiga, and subscree woodlands of *Larix sibirica*. The leading altitudinal belts are forest-steppe, steppe, tundra-steppe, and mountain-tundra.

3.3 Summary

The territory of the former U.S.S.R. has been assigned 87 ecoregions (Table 3.2), 67 of which are located in Russia. Titles of many ecoregions are unknown to people who are unfamiliar with the country's geography. Further, to understand general geographic distribution of carbon storage, it is enough to use well-known bioclimatic ecoregions such as the European part of Russia, Western, Central, and Eastern Siberia plus Yakutia, and the Russian Far East. These large ecoregions, subdivided into zones, subzones, and forests of montane altitudinal zones, are listed in Tables 3.3 (numbers of ecoregions from Table 3.2) and 3.4 (areas of these ecoregions).

Table 3.1.—Interrelations between taxons of forest classification and ecoregions within bioclimatic sectors

Taxon of forest classification	Taxon of ecoregions	Mapping scale
Forest type	Forest county	1:10,000-1:50,000
Series of forest types	Forest county	1:100,000-1:200,000
Landscape Line of forest types	Forest county	1:100,000-1:200,000
Subzone-provincial complex of forest types	Forest district	1:500,000-1:1,000,000
Zone-provincial complex of forest types	Forest province	1:1,000,000-1:5,000,000
Spectrum of zone-provincial complexes of forest types (type of zone)	Forest oblast	1:5,000,000-1:10,000,000
Spectrum of altitudinal complexes of forest types	Forest mountain district	1:500,000-1:1,000,000
Spectrum of altitudinal complexes of forest types (within one zone)	Forest mountain province	1:1,000,000-1:5,000,000
Type of mountain belts	Forest mountain oblast	1:5,000,000-1:10,000,000
Bioclimatic sector		1:25,000,000

Table 3.2.—Forest ecoregions of Russia and former Soviet Union Republics

Ecoregion	Zone, subzone, or altitudinal belt	Main forest-forming species; % of forested area (FA); quality class
	Middle European Atlantic Moderate Maritime Sector	
	Middle European Plain Forest Oblast	
1. Baltic forest province	Subzone of mixed forests (subtaiga)	*Pinus sylvestris, Quercus robur, Fagus sylvatica, Carpinus betulus;* FA 12%; II.2
2. Trans Carpathian forest province	Zone of forest-steppes (deciduous hardwood)	*Quercus robur, Fagus sylvatica, Carpinus betulus;* FA 25%; II.2
	Carpathian Mountain Forest Oblast	
3. Eastern Carpathian forest province	Belts: oak-hornbeam, beech, spruce, pine-alder	*Picea abies, Fagus sylvatica, Carpinus betulus, Fraxinus excelsior, Acer platanoides, Pinus mugho;* FA 20%; II.4
	Eastern European Moderate Continental Sector	
	Kola-Karelian Tableland Forest Oblast	
4. Northern Kola forest province	Forest tundra	*Picea obovata, Betula pendula, B. tortuosa;* FA 20%; V[b]
5. Kola-Karelian forest province	Boreal zone	
5.1. Northern taiga district	Subzone of northern taiga	*Pinus sylvestris, Picea obovata, Betula pendula;* FA 53%; IV.2
5.2. Middle taiga district	Subzone of middle taiga	*Pinus sylvestris, Picea obovata, Betula pendula, Populus tremula, Alnus incana;* FA 50%; III.2
	Dnieper-Baltic Plain Forest Oblast	
6. Western Dvina forest province	Boreal zone	
6.1. Southern taiga district	Subzone of southern taiga	*Picea abies, Pinus sylvestris, Betula pendula;* FA 35%; II.6
6.2. Mixed (subtaiga) forest district	Subzone of mixed forests (subtaiga)	*Picea abies, Pinus sylvestris, Betula pendula,*

Continued

Table 3.2— Continued

Ecoregion	Zone, subzone, or altitudinal belt	Main forest-forming species; % of forested area (FA); quality class
		Quercus robur, Alnus glutinosa; FA 25%; II.6
7. Polesye-Mid-Dnieper forest province	Zone of forest steppes	
7.1. Polesye district	Subzone of mixed forests	*Pinus sylvestris, Betula pendula, Quercus robur, Alnus glutinosa;* FA 35%; II.0
7.2. Podolsk-Mid-Dnieper district	Zones of forest-steppes and steppes	*Quercus robur, Pinus sylvestris, Carpinus betulus, Tilia cordata;* FA 12.5%; I.7
8. Lower Dnieper forest province	Zone of steppes	*Quercus petraea, Quercus robur, Pinus sylvestris;* FA 3.3%; II.4
9. Southern-Crimean Mountain forest province	Dry subtropics	*Quercus petraea, Fagus sylvatica, Carpinus betulus, Pinus pinea;* FA 10.5%; IV.7
	Caucasian Mountain Forest Oblast	
10. Great Caucasus forest province	Belts: steppe, forest-steppe, beech forests, fir-spruce mountain taiga, subalpine, alpine, nival	*Quercus imeretina, Q. iberica, Q. petraea, Fagus orientalis, Carpinus caucasica, Picea orientalis;* FA 25%; I-II
11. Small Caucasus forest province	Belts: steppe, forest-steppe, beech forests, subalpine, alpine	*Quercus iberica, Fagus orientalis, Carpinus caucasica;* FA 20%; II-IV
12. Colchis forest province	Humid subtropics	*Alnus barbata, Acer pseudoplatinus, Quercus imeretina, Carpinus caucasica, Taxus baccata, Ulmus glabra;* FA 25%; I-III
13. Kura-Araksin forest province	Desertified steppes, steppes	*Pistacia mutica, Celtis caucasica, Juniperus polycarpos, Ju. exelsa;* FA 6%; III-IV
14. Talysh forest province	Subtropics	*Quercus castaneifolia, Fagus orientalis, Parrotia persica, Populus hyrcana;* FA 45%; I-II
	Eastern European Temperate-Continental Sector	
	Eastern European Plain Forest Oblast	
15. Kaninsk-Pechersk forest province	Forest-tundra	*Picea obovata, Betula pendula;* FA 80%; Va-Vb
16. Dvina-Pechersk-Upper-Volga forest province	Boreal zone	
16.1. Northern taiga district	Subzone of northern taiga	*Pinus sylvestris, Betula pendula, Picea* x *fennica, P. obovata;* FA 60%; V
16.2. Middle taiga district	Subzone of middle taiga	*Picea* x *fennica, P. abies, P. obovata, Pinus sylvestris;* FA 65%; III-IV
16.3. Southern taiga district	Subzone of southern taiga	*Picea* x *fennica, P. Abies, P. obovata, Pinus sylvestris, Betula pendula, Populus tremula;* FA 55%; II-III
16.4. Mixed (subtaiga) district	Subzone of mixed forests (subtaiga)	*Picea* x *fennica, P. Abies, P. obovata, Pinus sylvestris, Quercus robur, Tilia cordata, Betula pendula;* FA 45%; II
17. Central Russian forest province	Zone of forest-steppe	*Pinus sylvestris, Quercus robur, Tilia cordata, Betula pendula;* FA 25-30%; I-III
18. Volga-Don forest province	Zone of steppes	*Quercus robur, Populus alba;* FA 5%; III-IV
	The Ural Mountains Forest Oblast	
19. Northern Urals forest province	Forest-tundra woodlands and belt of mountain tundra	*Picea obovata, Betula tortuosa;* FA 20%; V-Va

Continued

Table 3.2— Continued

Ecoregion	Zone, subzone, or altitudinal belt	Main forest-forming species; % of forested area (FA); quality class
20. Central Urals forest province	Mountain taiga forests	*Picea obovata, Abies sibirica, Pinus sibirica;* FA 60%; II-IV
21. Southern Urals forest province	Belts: forest-steppe, mountain taiga forests	*Abies sibirica, Picea obovata, Pinus sylvestris, Quercus robur*, *Tilia cordata, Betula pendula;* FA 60%; I-II
	Western Siberian Sector	
	Western Siberian Plain Forest Oblast	
22. Trans Urals-Yenisei forest province of pre-tundra forests and woodlands		*Larix sibirica, Picea obovata;* FA 23%; Va
22.1. District of forest-tundra	Forest-tundra	See No.22
22.2. Northern taiga sparse forests and woodlands	Northern taiga forests and woodlands	See No. 22
23. Transurals-Yenisei forest province of taiga forests		
23.1. Northern taiga district	Subzone of northern taiga	*Pinus sibirica, Pinus sylvestris, Picea obovata, Betula pendula;* FA 40%; V
23.2. Middle-taiga district	Subzone of middle taiga	*Pinus sibirica, Pinus sylvestris, Picea obovata, Betula pendula;* FA 40%; III.8
23.3. Southern taiga and subtaiga district	Subzone of southern taiga and subtaiga	*Abies sibirica, Pinus sibirica, Pinus sylvestris, Betula pendula, Populus tremula;* FA 35%; II.6
24. Irtysh-Ob forest-steppe forest province	Subzone of forest-steppe	*Betula pendula, B. pubescens, Populus tremula;* FA 20%; II.1
25. Achinsk forest-steppe forest province	Subzone of forest-steppe	*Pinus sylvestris, Populus tremula, Betula pendula, B. pubescens;* FA 25%; II-III
	Altai-Sayan Mountain Forest Oblast	
26. Northern Atlai-Sayan forest province	Belts: subtaiga; Siberian pine-fir; mountain taiga with fir and Siberian pine; subscree-subalpine belt with Siberian pine	*Pinus sibirica, Betula pendula, Populus tremula;* FA 75-80%; II-V
27. Eastern-Saayan forest province	Belts: subtaiga with Scotch pine; mountain taiga with Siberian pine; subscree with Siberian pine	*Pinus sibirica, Pinus sylvestris, Betula pendula, Abies sibirica;* FA 80%; II-V
28. Central-Altai forest province	Belts: forest-steppe and subtaiga with larch; Scotch pine; mountain taiga with larch and Siberian pine; subscree-subalpine belt with larch and Siberian pine	*Larix sibirica, Pinus sibirica, Betula pendula;* FA 40%; II-V
29. Western-Altai forest province	Belts: forest-steppe; subtaiga with larch; mountain taiga with fir and Siberian pine; subalpine belt with Siberian pine	*Pinus sibirica, Abies sibirica;* FA 40%; II-V
30. EasternTuva (Todjin) forest province	Belts: subtaiga with larch; mountain taiga with larch and Siberian pine; subscree with Siberian pine	*Larix sibirica, Pinus sibirica, Picea obovata;* FA 75%; III-Va
31. Khakass-Minusinsk forest province	Belts: steppe, forest-steppe, and subtaiga with larch; mountain taiga with larch and Siberian pine	*Larix sibirica, Pinus sibirica, Pinus sylvestris, Betula pendula;* FA 15%; II-V

Continued

Table 3.2— Continued

Ecoregion	Zone, subzone, or altitudinal belt	Main forest-forming species; % of forested area (FA); quality class
32. Salair-Kuznetsk forest province	Belts: forest steppe with Scotch pine, mountain taiga with aspen, fir, and Siberian pine	*Abies sibirica, Pinus sibirica, Pinus sylvestris, Populus tremula, Tilia sibirica;* FA 45%; III-IV
	Middle Siberian Strongly Continental Sector	
	Middle Siberian Tableland Forest Oblast	
33. Putoran Mountain forest province	Belts: mountain taiga with spruce and larch; scree with larch; mountain tundra; arctic deserts	*Larix gmelinii, Picea obovata;* FA 35%; V[a]
34. Anabar	Belts: subscree with larch woodland, mountain tundra	*Larix gmelinii;* FA 20%; Vb
35. Near-Yenisei forest province	Belts: mountain taiga with fir, Siberian pine, and larch-fir-spruce; subscree with Siberian pine, and larch	*Pinus sibirica*, *Abies sibirica, Picea obovata, Larix sibirica, Betula pendula;* FA 85%; III-Va
36. Khetsk-Kotui-Olenek forest province	Forest tundra	*Larix gmelinii;* FA 30%; Va-Vb
36.1. Northern-Siberian district	Forest tundra	*Larix gmelinii;* Va-Vb
36.2. Kotui-Olenek district	Pre-forest tundra, northern taiga larch forests, and woodlands	*Larix gmelinii;* Va-Vb
37. Angara-Tunguska forest province of taiga forests		
37.1. Lower Tunguska district	Northern taiga larch forests	*Larix gmelinii, Betula pendula;* FA 80%; V
37.2. Stony Tunguska district	Middle taiga larch and Scotch pine forests	*Larix sibirica, Pinus sylvestris, Betula pendula;* FA 85%; IV
37.3 Angara district	Southern taiga and subtaiga Scotch pine and larch forests	*Pinus sylvestris, Larix sibirica, Betula pendula;* FA 85%; III
38. Kansk-Krasnoyarsk-Biryusa forest province	Forest-steppe	*Pinus sylvestris, Betula pendula;* FA 40%; II-III
39. Upper Angara forest province	Forest-steppe	*Pinus sylvestris, Betula pendula;* FA 35%; II-III
40. Upper Lena forest province	Belts: subtaiga with larch and Scotch pine, mountain taiga with Siberian pine	*Pinus sibirica, Larix gmelinii, Pinus sylvestris;* FA 85%; III-IV
	Central Yakutian Plain Alass Forest Oblast	
41. Lena-Vilyui forest province	Subzone of middle taiga	*Larix gmelinii, Pinus sylvestris, Betula pendula;* FA 75%; IV
42. Aldan forest province	Subzone of middle taiga	*Larix gmelinii, Pinus sylvestris, Betula pendula;* FA 75%; IV
	Eastern Siberian Extremely Continental Sector	
	Yana-Kolyma Mountain Forest Oblast	
43. Lower Kolyma forest province	Forest tundra	*Larix cajanderi, Pinus pumila;* FA 25%; Va-Vb
44. Yana-Indigirka forest province	Belts: taiga valley larch forests; subscree larch forests; krummholz belt	*Larix cajanderi, Pinus pumila;* FA 25%; Va-Vb
45. Kolyma forest province	Belts: taiga valley larch forests; subscree larch forests; krummholz belt	*Larix cajanderi, Pinus pumila;* FA 25%; Va-Vb

Continued

Table 3.2— Continued

Ecoregion	Zone, subzone, or altitudinal belt	Main forest-forming species; % of forested area (FA); quality class
	Northern Transbaikal Mountain Forest Oblast	
46. Upper-Vitim-Olekma tableland forest province	Taiga larch forests, krummholz; mountain tundras	*Larix cajanderi, Pinus sylvestris, Pinus pumila, Betula ermanii;* FA 35%; V
47. Baikal-Stanovoi forest province	Taiga larch forests, krummholz; mountain tundras	*Larix cajanderi, Pinus sylvestris, Pinus pumila, Betula ermanii;* FA 35%; V
	Southern Transbaikal Mountain Forest Oblast	
48. Uchur-Maisk forest province	Taiga larch forests, krummholz; mountain tundras	*Larix cajanderi, Pinus sylvestris, Pinus pumila, Betula ermanii;* FA 35%; V
49. Jiddin forest province	Belts: steppe, larch subtaiga, larch and larch-Siberian pine mountain taiga	*Larix sibirica, Pinus sibirica, P. sylvestris;* FA 45%; III-IV
50. Selenga forest province	Belts: subtaiga-steppe Scotch pine forests, mountain taiga larch-pine forests	*Larix sibirica, Pinus sylvestris;* FA 45%; III-IV
51. Chikoi-Ingodin forest province	Belts: subtaiga-forest-steppe Scotch pine and larch forests, mountain Siberian pine and Siberian pine-larch forests	*Larix gmelinii, Pinus sibirica, P. sylvestris;* FA 75%; III-IV
52. Dahurian forest province	Belts: steppe, subtaiga-Scotch pine and larch forests	*Pinus sylvestris, Larix gmelinii;* FA 15%; III-IV
	Near-Baikal Mountains Forest Oblast	
53. Near-Baikal forest province	Belts: subtaiga-forest-steppe Scotch pine and larch forests, taiga-fir forests, mountain taiga fir-Siberian pine, mountain taiga, larch forests	*Abies sibirica, Pinus sibirica, Larix sibirica, Pinus sylvestris, Betula pendula;* FA 60%; III-IV
	Far Eastern Continental-Monsoon Sector	
	Okhotsk-Bering Mountain Forest Oblast	
54. Magadan forest province	Taiga valley and mountain sparse larch forests and woodlands; krummholz thicket, mountain tundras	*Larix cajanderi, Pinus pumila, Chosenia arbutifolia;* FA 15%; V-Va
55. Penzhin-Anadyr forest province	Valley sparse forests and woodlands, krummholz thickets, and mountain tundras	*Larix cajanderi, Pinus pumila, Chosenia arbutifolia, Populus suaveolens;* FA 25%; Vb
56. Kamchatka forest province	Belts: meadow; stone birch; taiga larch; krummholz thickets; mountain tundras	*Larix kamtchatica, Alnus hyrsuta, Betula ermanii, Pinus pumila;* FA 40%; III-Va
	Amur-Sakhalin Mountain Forest Oblast	
57. Zeya-Uda forest province	Belts: mountain taiga larch, spruce-larch forests; krummholz thicket; mountain tundras	*Larix gmelinii, Picea ajanensis, Pinus pumila;* FA 55%; IV-Va
58. Amgun-Selenjin forest province	Belts: mountain taiga larch forests, spruce forests, mires	*Larix gmelinii, Picea ajanensis;* FA 70%; III-V
59. Sikhote-Alin forest province		
59.1. Sikhote-Alin district	Belts: mountain taiga spruce-Korean pine, spruce-larch-birch, krummholz	*Picea ajanensis, Pinus koraiensis, Larix gmelinii, Pinus pumila, Betula costata;* FA 80%; III-V

Continued

Table 3.2— Continued

Ecoregion	Zone, subzone, or altitudinal belt	Main forest-forming species; % of forested area (FA); quality class
59.2. Ussuri-Primorye district	Belts: hardwood forests, mixed forests	*Picea ajanensis, Pinus koraiensis, Abies nephrolepis, Quercus mongolica, Tilia amurensis, Acer pseudosieboldianum;* FA 60%; II-III
60. Sakhalin-Kurily forest province	Northern taiga larch forests, middle taiga spruce and larch-spruce forests	*Larix kamtschatica, Picea ajanensis, Abies sachalinensis, Betula costata;* FA 65%; III-V
61. Near-Amur forest province	Subtaiga-forest-steppe hardwoods, grass fens and meadows	*Quercus mongolica, Larix gmelinii, Betula pendula, Pinus sylvestris;* FA 15%; III-V
61.1 Upper Amur district	Subtaiga-forest-steppe hardwoods, grass fens and meadows	See No. 61
61.2. Lower Amur district	Subtaiga-forest-steppe hardwoods, grass fens and meadows	See No. 61
61.3. Khanka district	Subtaiga-forest-steppe hardwoods, grass fens and meadows	See No. 61
Inerior Extremely Continental Subarid and Arid Sector		
Kazakhstan Plain-Tableland Forest Oblast		
62. Southern Urals-Mugojar forest province	Zone of steppe with true and dry subzones of steppe	*Betula pendula, Pinus sylvestris;* FA 1-2%; IV
63. Tobol-Ishim forest province	Zone of steppe with true and dry subzones of steppe	*Betula pendula, Pinus sylvestris;* FA 3-4%; III-IV
64. Kulunda forest province	True steppes and dry strip Scotch pine forests	*Pinus sylvestris, Betula pendula;* FA 8%; II-III
65. Kazakh hummocky topography forest province	Steppes; true and desertified	*Pinus sylvestris;* FA 1-3%; IV-V
Tura Plain Forest Oblast		
66. Near-Caspian forest province	Desertified steppes, northern deserts	Flooded valley thickets; FA < 1%
67. Aral forest province	Desertified steppes, northern deserts	Flooded valley thickets; FA < 1%
68. Bet-Pak-Dal forest province	Northern deserts, southern deserts	*Populus diversifolia, Salix acmophylla, Ulmus carpinifolia;* FA < 1%
69. Turkestan forest province	Southern deserts	*Populus diversifolia, Salix acmophylla, Ulmus carpinifolia;* FA less than 1%
Middle Asian Mountain Forest Oblast		
70. Kopet-Dhag Turkestan-Pamirs forest province	Belts: desert; savanana, dry woodland; subalpine; mountain tundra; nival	*Pistacea vera, Juniperus seravschanica, Juglans regia*, *Malus sieversii, Acer turkestanicum;* FA 3-4%
71. Tien-Shan forest province	Belts: desert; steppe, forest, subalpine, alpine, nival	*Picea schrenkiana, Abies semonovii, Juniperus turkestanica, Juniperous seravschanica, Populus diversifolia;* FA 5%
72. Saur-Tarbagatai forest province	Belts: desert; steppe; larch subtaiga	*Picea schrenkiana, Larix sibirica;* FA 2-3%; III-IV
Central Asian Mountain Forest Oblast		
73. Southern-Altai-Tuva forest province	Belts: desertified steppes; subtaiga-forest-steppe larch forest; mountain-taiga larch and Siberian pine-larch forests; subscree larch forests	*Larix sibirica, Pinus sibirica, Populus suaveolens;* FA 20%; IV-V

Table 3.3.—Distribution of forest ecoregions (numbers of zones and subzones; data from Table 3.2) for major geographic subdivisions of Russia

Zone or subzone	European Russia	Asian Russia: Western Siberia	Asian Russia: Middle Siberia	Asian Russia: Eastern Siberia and Yakutia	Asian Russia: Far East
			Plains		
Forest-tundra zone	4; 15	22	36	--	--
Boreal zone					
Northern taiga subzone	5.1; 16.1	23.1	37.1	--	--
Middle taiga subzone	5.2; 16.2	23.2	37.2	41; 42	--
Southern taiga subzone	6.1; 16.3	23.3; 25	37.3	--	--
Mixed forests subzone	1; 6.2; 16.4	--	--	--	--
Forest-steppe zone	17	24	38; 39	--	61(x3)
Steppes zone	18	63; 64	--	--	--
Desert zone	66	--	--	--	--
			Mountains		
Subarctic zone	19	--	33; 34	43; 44; 45	54; 55
Boreal zone	20	--	35	46; 47; 48	56; 57; 58; 60
Subboreal zone	21	--	26-32; 40	49-53	59.1; 59.2
Subboreal (Caucasus)	10	--	--	--	--
Subarid zone	62	--	73	--	--

Table 3.4.—Stocked areas (million ha) of ecoregions for major geographic subdivisions of Russia

Zone or subzone	European Russia	Asian Russia: Western Siberia	Asian Russia: Middle Siberia	Asian Russia: Eastern Siberia and Yakutia	Asian Russia: Far East	Total
			Plains			
Forest-tundra zone	3	12	27	--	--	42
Boreal zone						
North taiga subzone	36	21	33	--	--	90
Middle taiga subzone	37	41	25	68	--	171
South taiga subzone	36	30	25	--	--	91
Mixed forest subzone	13	--	--	--	--	13
Forest-steppe zone	10	7	4	--	6	26
Steppe zone	2	2	--	--	--	4
Deserts zone	0	--	--	--	--	0
Subtotal	137	113	114	68	6	437
			Mountains			
Subarctic zone	0	--	8	39	18	66
Boreal zone	8	--	23	63	63	157
Subboreal zone	6	--	45	27	27	105
Subboreal (Caucasus)	3	--	--	--	--	3
Subarid zone	0	--	2	--	--	3
Subtotal	18	--	79	129	109	334
Total	155	113	193	196	115	771

Chapter 4. Methods for Evaluating Phytomass and Carbon in Forest Communities

V.D. Stakanov, V.A. Alexeyev, and I.A. Korotkov

To estimate carbon in forest ecosystems, we used statistical forest inventories like other researchers in recent years (Makarevskiy 1991; Birdsey 1992; Kurz et al. 1992). Data on the phytomass of forest communities obtained from a large number of sample sites were used to derive coefficients for converting estimates of the growing stock of wood in the statistical reports to estimates of the stock of the phytomass in forest ecosystems of the different administrative units and ecoregions of Russia.

The literature on forest phytomass is voluminous, with various authors also discussing the growth and structure of tree stands (Utkin 1970, 1975; Smirnov 1971; Alexeyev 1975; Bazilevich et al. 1986; Usol'tsev 1988; Bazilevich 1993). Rather than repeat this information, data from sample sites on stand phytomass and the lower layers of the forest vegetation are given selectively and reflect mostly the publications concerning Siberia that are little known among the scientific community (Appendix Tables 7 to 17).

4.1 Tree Stands

Equations for Converting Growing-Stock Volume to Phytomass of Stands

The volume of growing stock includes both wood and bark. Bark is different from wood in density, chemical composition, and rate of decay. These properties of bark make it necessary to account for this fraction separately from wood:

$$V_{tb} = V_t + V_b \qquad (1)$$

where V_{tb} is the volume of growing stock outside of the bark, V_t is the underbark volume of growing stock, and V_b is bark volume.

Volume of growing stock can be converted to mass by:

$$V_{tb} = \frac{M_t}{P_t} + \frac{M_b}{P_b} \qquad (2)$$

where M_t and M_b are the mass of wood and bark of the stem, and P_t and P_b are the density of wood and bark in t/m^3 or kg/m^3.

Equation 2 has two unknowns: M_t and M_b. To exclude one of them, we can introduce a bark conversion factor (K_b), which is the ratio of the bark mass to the timber mass:

$$K_b = \frac{M_b}{M_t} \text{ or } = \frac{V_b P_b}{V_t P_t} \qquad (3)$$

Transforming Equation 2 we have:

$$M_t = V_{tb} \frac{P_t P_b}{P_b + (K_b P_t)} \qquad (4)$$

Density of Wood and Bark

Because values for wood density are used for different purposes, density has been defined as 12, 5, and 0 percent moisture content. We use basic wood density (P_o), which is defined as the oven-dry mass (absolutely dry matter) in a unit of the growing-stock volume. Values for wood density also depend on the species growth conditions, age of the tree, and height and diameter of the tree for sampling purposes (Zakrevskiy 1972; Isaeva 1970, 1975; Alexeyev and Rakhmanov 1973; Poluboyarinov 1973, 1976).

Each species differs in density characteristics with respect to age. For example, in pine stands growing in the southern taiga (Leningrad Oblast), wood density increases up to 80 to 120 years (Polubayarinov 1976) (Fig. 4.1, curve 1). For the spruce forests of the same forest types, P_o in young and middle-aged stands varies insignificantly and then increases rapidly at 100 to 140 years (Fig. 4.1, curve 3). At an advanced age, wood density decreases due to changes in the thickness of cell walls (Poluboyarinov 1976) and damage by fungi (Konstantnaya and Volnova 1975).

The specific weight of wood of the major tree species varies considerably within their range (Fig. 4.1, curves 2 and 4). Therefore, we did not use average density parameters but their regional values along with an account of age changes (Anonymous 1962; Kazimirov et al. 1978; Poluboyarinov 1973, 1976; Isaeva 1975; Pozdnyakov 1985).

Calculating Phytomass of Growing Stock from Stem Wood Volume

To determine the mass of wood from the volume of growing stock for various tree species, we need to know the density of wood and bark of these species.

Stand phytomass (M_{st}) is equal to the sum of its constituent fractions:

$$M_{st} = M_t + M_b + M_{cr} + M_r \qquad (5)$$

where M_t is the mass of stem wood, M_b is the mass of bark, M_{cr} is the mass of the crown, and M_r is the mass of roots.

Expressing the mass of fractions of Equation 5 through the mass of stem wood, we have:

$$M_{st} = M_t + (K_b M_t) + (K_{cr} M_t) + (K_r M_t) \qquad (6)$$

where K_{cr} is the conversion factor of the crown, equal to the ratio of the crown mass to the stem wood mass ($K_{cr} = M_{cr}/M_t$), and K_r is the conversion factor of roots, equal to the ratio of the mass of root to the mass of stem wood ($K_r = M_r/M_t$).

Transforming Equation 6, we have:

$$M_{st} = V_{tb} \frac{P_t P_b}{P_b + (K_b P_t)} (1 + K_b + K_{cr} + K_r) \quad (7)$$

Designate the second multiplier of Equation 7 as K_{ph}:

$$K_{ph} = \frac{P_t P_b}{P_t + (K_b P_t)} (1 + K_b + K_{cr} + K_r) \quad (8)$$

Equation 7 takes a form more convenient for many calculations:

$$M_{st} = K_{ph} V_{tb} \quad (9)$$

The adopted K_{ph} coefficient reflects the relationship between the volume of growing stock and the phytomass of tree stands. It can be calculated only when all its constituent indices are calculated. Thus, to estimate stand phytomass and carbon using the volume of growing stock it is necessary to know: (1) the density of wood and bark of the forest tree species, (2) conversion factors of bark, crown, and roots of species (ratios of their masses to the stem timber mass), and (3) the content of carbon in phytomass.

To include all living parts of forest plant communities, we need data on the undergrowth and other live vegetation. To include the dead part of forest vegetation, it is necessary to use data on coarse woody debris and litter.

Coefficients for Converting Phytomass to Carbon

Different researchers have estimated carbon content as 0.5 times the absolutely dry mass of the stem, roots, and leafless branches. For the green parts of plants, carbon content is estimated at 0.5 (Birdsey 1992; Kurz et al. 1992) or 0.45 (Kobak 1988; Isaev et al. 1993) of their mass. We adopted a single conversion coefficient of 0.5 since the carbon content of all of the primary forest trees and widespread plants of the aboveground cover is close to this value (Appendix Table 18).

By incorporating the coefficient 0.5 into Equation 9, it is possible to evaluate the stock of carbon in a stand C_{st}:

$$C_{st} = 0.5\, K_{ph} V_{tb} \quad (10)$$

Conversion Coefficients for Bark

To evaluate the portion of bark in the stands of different forest trees and calculate conversion coefficients K_b, we used reference data on the mass of bark. By way of example, we give conversion coefficients for bark mass for the primary forest trees of Siberia (Table 4.1). The coefficients for the same tree species in analogous zones of the European part of the country are fairly close to those for Siberia.

There are several peculiarities of the bark conversion coefficient K_b. The high values of this coefficient in coniferous and deciduous species are typical for the young forests of age class I, while the low values are typical of mature and overmature stands. Exceptions are the coefficients for birch and aspen at the northern boundary of their range; here, the bark portion varies slightly with age. The variable estimates for birch and aspen probably are due to questionable data for these regions. The highest percentage of bark that is typical for larch (Table 4.1) is associated with its fire resistance.

Conversion Coefficients for Crown Mass

Crown mass includes the fractions of living and dead branches and the fraction of leaves (needles). Dead branches generally are accounted for separately. However, because they account for a small portion of the mass of other parts of the crown (0.1 to 5.0 percent), we did not separate them.

Conversion coefficients for crown mass ($K_{cr} = M_{cr}/M_t$) were calculated by the forest zones and subzones for the main tree species by age groups. The data in Figures 4.2 and 4.3 and Appendix Tables 7 to 12 are examples of data used to estimate the ratios of crown masses and stem timber of the forest trees. The data show that K_{cr} is highest in the first 10 to 20 years of life. During this time, the total mass of the crown may exceed the mass of the stem timber. Soon after the crowns close and the processes of tree competition increase, the M_{cr}/M_t ratio decreases rapidly; these decreases then remain nearly constant until the trees begin to die.

Age variation of K_{cr} in the stands is approximated by:

$$Y = aX^b \quad (11)$$

where Y is the ratio of the crown mass to the timber mass, i.e., K_{cr}, X is the age, and a and b are coefficients. In Figure 4.2, a = 3.4314 and b = -0.6789.

In pine stands, estimates of the crown and timber mass illustrate the dependence of K_{cr} on age (Figure 4.2). The coefficients differ considerably not only in age but also in density and habitat conditions (the I-V quality classes), accounting for the large scattering of the data. Analogous changes of the coefficient K_{cr} are typical for other forest trees (Appendix Tables 7 through 12).

Young larch stands with poorly developed crowns differ from other species by lower K_{cr} coefficients at their initial period of life (Table 4.2, Appendix Table 9). We emphasize that small K_{cr} values in young stands also can be associated with high stand density after fire.

The lowest K_{cr} coefficients for middle-aged, maturing, mature, and overmature stands are typical for tree species that are shade intolerant (Table 4.2, Appendix Tables 7 to 9). The highest values are typical for the shade-tolerant species such as spruce, fir, and Siberian pine (Fig. 4.3, Appendix Tables 8 to 10). Deciduous stands have intermediate values (Appendix Tables 11 and 12).

Attention should be paid to the considerable regional differences in K_{cr} coefficients. These differences result from uneven edaphic and climatic factors, development of stands with different growth rates, and different allocation patterns for phytomass (Fig. 4.4).

The northern forests with typically low-yield and poor-quality stands are characteristic of the highest K_{cr} values (Table 4.2). Conversion coefficients for the northern taiga differ from those of the more southern forests; coefficients for the middle and southern taiga differ slightly.

Conversion Factors for Root Systems

The mass of roots accounts for 20 to 92 percent of the stem timber mass (Polikarpov 1962; Pozdnyakov et al. 1969; Gorbatenko 1971; Kazimirov and Morozova1973; Kazimirov and Volkov 1977; Semechkina 1978; Gabeyev 1990). Like the crown, the portion of roots is highest in northern and swamp forests (Appendix Table 13). The high values of this fraction are due to intensive regrowth of superficial physiologically active roots after flooded and dry periods (Orlov 1967; Veretennikov 1973; Orlov and Koshelkov 1971; Bobkova 1987).

Values of the root conversion coefficient K_r in stands of the middle and southern taiga and forest-steppe for different species on drained soils range from 0.20 to 0.35 (Figs. 4.5 to 4.7, Appendix Tables 9 to11). K_r coefficients were similar in the forests of Altai and Kazakh hummocky topography (Atkin 1984).

As opposed to the crown conversion coefficient, K_r varies little in the course of tree ontogenesis (Figs. 4.5 to 4.7, Table 4.3, Appendix Tables 10 and 11). Regional differences in K_r in the forests of the northern and middle taiga are reliable (99 percent validity) for all forest trees.

Conversion Factors for Stand Phytomass

Values for converting stand phytomass K_{ph} for the primary tree species by age classes and ecoregions are given in Table 4.4. The data reveal a high variability of ratios between the total mass of forest trees and overbark volume of growing stock. The coefficient can change by a factor of 2 even within a single species. For example, for spruce growing in the northern taiga of European Russia, K_{ph} in the young stand of age class I is 1.144 versus 0.684 for mature and overmature stands. Other tree species also feature analogous age variations of K_{ph}. Conversion coefficients also vary with growth conditions in the zones and subzones (Table 4.4).

We used Equations 9 and 10, data from Table 4.4, and data on growing stock (Goskomles of the U.S.S.R. 1990) to estimate the phytomass stock and carbon storage for various regions. Data in Table 4.4 for the European part of Russia were applied for all forests of European Russia without changes. For Asian Russia, the estimates represent averages over too large an area, so they were not used when data on basic timber density were available for smaller regions of Siberia and the Far East. So for the Krasnoyarsk Kray and the Republic of Yakutia (Sakha), carbon was calculated for every forestry enterprise. For some tree species with relatively small timber stock (less than 1 percent of total growing stock), conversion coefficients are from Isaev et al. (1993).

4.2 Phytomass of Understory and Other Vegetation

Understory Vegetation

The phytomass of the lower layers of the forest communities consists of seedlings, shrubs, dwarf-shrubs, herbs, mosses, and lichens. Experimental data (Appendix Tables 14 through 17) reveal high variability of this part of the ecosystem vegetation due to differences in climatic, edaphic, and phytocenotic growth conditions. Data on the phytomass of the lower layers of larch, fir, cedar, birch, and aspen forests are included in Figures 4.8 to 4.12.

The data reveal considerable differences between the mass of the lower layer plants under stands of different tree-species composition. Phytomass in the understory vegetation is highest in the open northern larch forests of Siberia and Yakutia (Fig. 4.8, Appendix Table 15). The major portion of phytomass in the understory vegetation in northern forests consists of mosses (Sofronov and Volokitina 1990). In northern spruce forests, the phytomass of the understory is as much as 15 t/ha (Kazimirov and Morozova 1973; Bobkova 1987); it is as much as 11 t/ha in the Scotch pine forests (Kazimirov and Volkov 1977). In the middle and southern taiga, the mass of the understory generally is less (Figs. 4.9, 4.11, 4.12; Appendix Tables 16 and 17). The phytomass of seedlings and saplings is substantially less than the stock of the herb, dwarf-shrub, and moss layers (Appendix Tables 14, 16, and 17). The mass of the lower layers is minimal in dense young forests (Figs. 4.11, 4.12), and in middle-aged forests (Figs. 4.8 to 4.12). The lower layers' mass generally increases with age and thinning of the canopy (Figs. 4.8, 4.9, 4.11, 4.12). The exception is in Protopopov's (1975) data (Fig. 4.10, line 1).

As noted by many researchers, the underground mass of the herb and dwarf-shrub layers substantially exceeds their aboveground mass. Conversion coefficients for the root mass (K_r) of this part of plant communities ($K_r = M_r/M_{sh}$, where M_{sh} is the mass of the aboveground part of the herb and dwarf-shrub layers) range from 1.0 to 6.3 in boreal forests (Appendix Tables 16 and 17).

The average phytomass per hectare of the lower layers in forests of the primary species is given in Table 4.5. Taking these values, areas of species by age group and carbon content of phytomass (0.5 of absolutely dry phytomass matter) into consideration, we can estimate carbon storage in the lower layers of forest communities.

Other Vegetation

Epiphytic lichens and several species of lianas forming the nonlayered vegetation of the temperate forests contribute little to total carbon storage. Even in the forests that are richest in plant composition (those of the Far East), the carbon storage of lianas is about 3 percent of the aboveground phytomass of the lower layers (Dyukarev and Rozenberg 1975), or 0.01 to 0.2 t/ha. The Far Eastern researchers include the mass of lianas in the undergrowth mass.

The mass of oven-dry matter of epiphytic lichens in blueberry-sedge-sphagnum spruce forests (Central Forest Reserve, southern taiga) was 1 to 2 percent of the model-tree crown mass (Alexeyev, unpublished). The available data are insufficient to calculate the epiphytic lichen fraction.

4.3 Krummholz and Shrub Communities

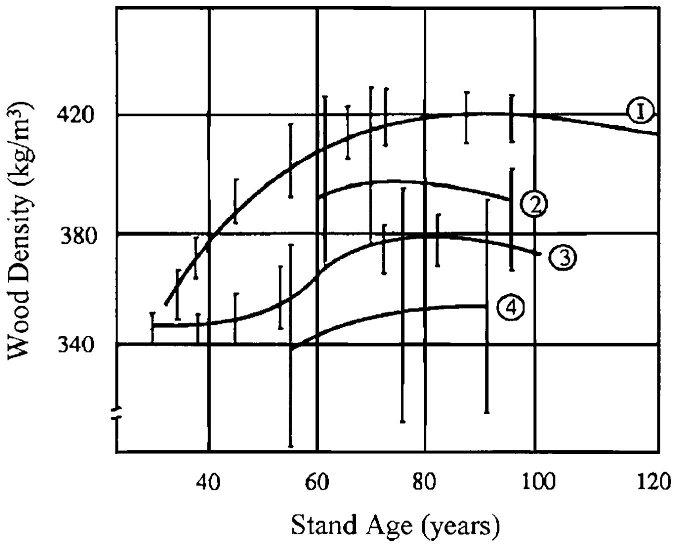

Figure 4.1.—Basic wood density at different ages for Scotch pine (*Pinus sylvestris*), European spruce (*Picea abies*), and Siberian spruce (*Picea obovata*). Vertical lines show limits of wood-density variations: 1. *Pinus sylvestris* southern taiga forests of different types, Leningrad Oblast (from Poluboyarinov 1976); 2. *Pinus sylvestris* forests of different types for all of Russia (Anonymous 1962; Pozdnyakov et al. 1969, 1985; Kazimirov and Morozova 1973; Poluboyarinov 1973, 1976; Semechkina 1984); 3. *Picea abies*, southern taiga spruce forests of different types, Leningrad Oblast (Poluboyarinov 1976); 4. *Picea* sp. forests of different types for all of Russia (Anonymous 1962; Alexeyev and Rakhmanov 1973; Poluboyarinov 1973, 1976; Kazimirov and Volkov 1977; Pozdnyakov 1985).

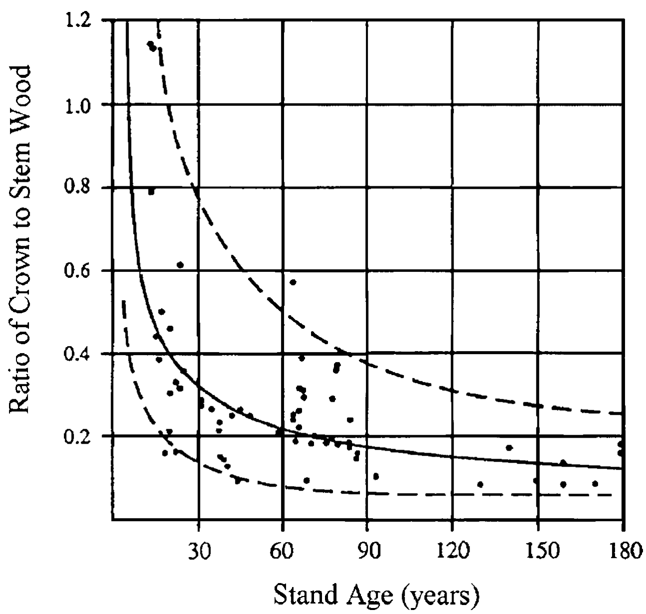

Figure 4.2.—Variation of K_{cr} (ratio of crown mass to stem wood mass) in pine stands of I - V quality sites with stand age. The solid line is average value; dashed lines are confidential values for 95-percent probability (Pozdnyakov et al. 1969; Kazimirov and Morozova 1973; Alexeyev 1975; Atkin 1984; Onuchin and Borisov 1984; Semechkina 1978; Gabeyev 1990; Stakanov 1990).

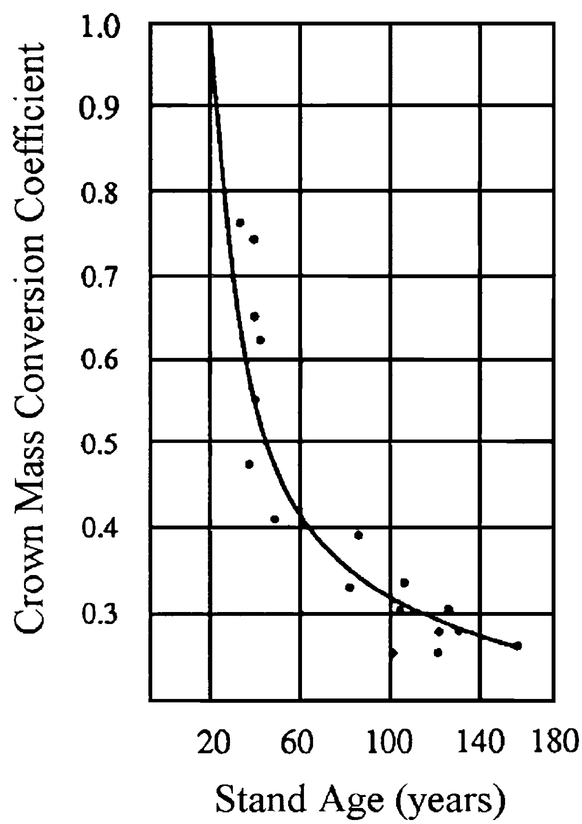

Figure 4.3.—Variation in conversion coefficient for crown mass (K_{cr}) in spruce forests of the European part of the southern taiga with stand age (Smirnov 1971; Alexeyev and Rakhmanov 1973; Kazimirov and Morozova 1973; Bobkova 1987).

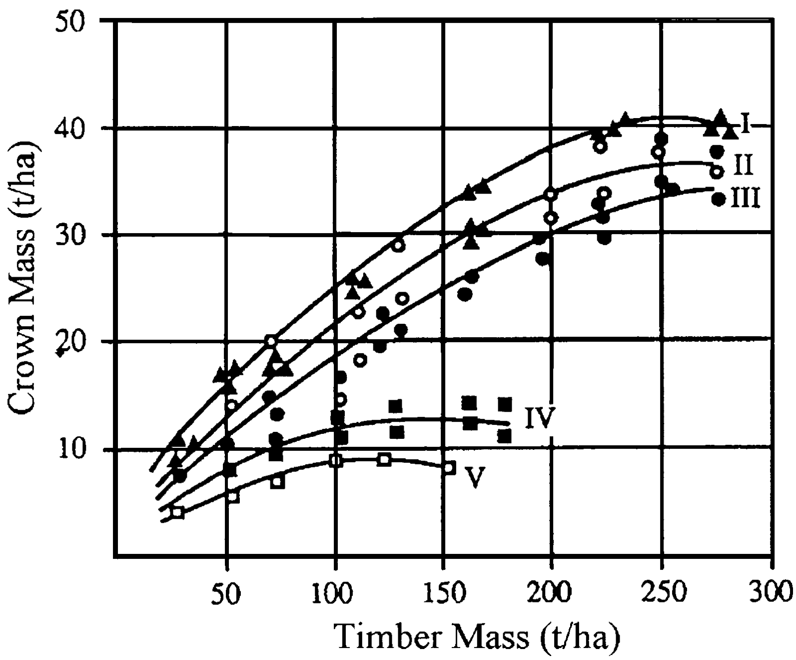

Figure 4.4—Effect of growth conditions on ratio of crown mass (M_{cr}) to timber mass (M_t) of Scotch pine stands of Siberia; quality site classes: I to V; mass estimated at zero moisture content (from Pozdnyakov et al. 1969; Semechkina 1978; Lashchinsky 1981; Onuchin and Borisov 1984; Gabeyev 1990; Atkin 1993).

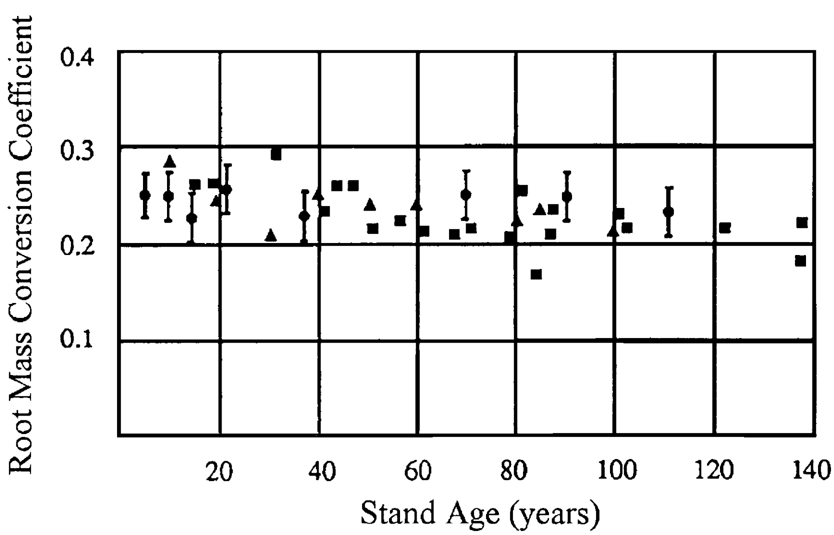

Figure 4.5.—Variation limits of conversion factors K_r with age in Scotch pine stands: ● = Krasnoyarsk forest-steppe (Stakanov 1990); ■ = southern taiga of Karelia (Kazimirov and Volkov 1977); ▲ = forest-steppe, Tambov Oblast (Uspenskiy 1983).

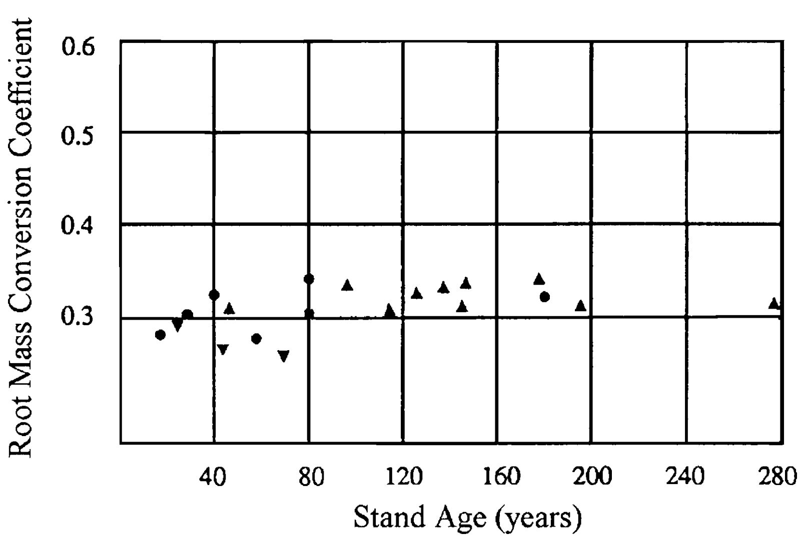

Figure 4.6.—Variation limits of conversion factors Kr with age in larch stands in Siberia and Yakutia: ● = Western Sayan (Protopopov 1975); ▲ = Yakutia (Pozdnyakov et al. 1969); ▼ = Kuznetsk Ala Tau Mountains (V.D. Stakanov, personal communication).

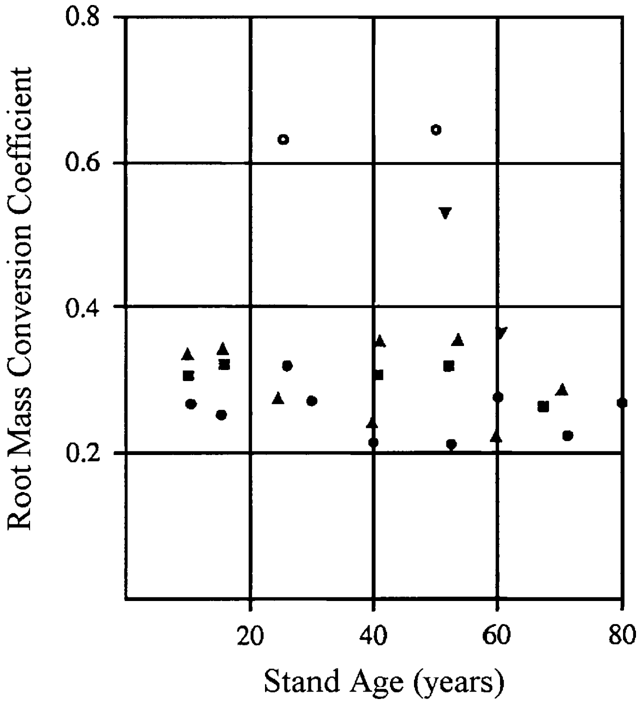

Figure 4.7.—Variation limits of conversion factors K_r with age in birch stands (1 - 4) and aspen stands (5) in Siberia: ▼ (1) = northern taiga (Gorchakovskiy and Andreyashkina 1975); ▲ (2) = middle and southern taiga (Gabeyev 1976); ● (3) = forest-steppe (Gabeyev 1976); ○ (4) = swampy birch forests of northern taiga (Gorchakovskiy and Andreyashkina 1975); ■ (5) = aspen forests of middle and southern taiga (Demidenko 1978).

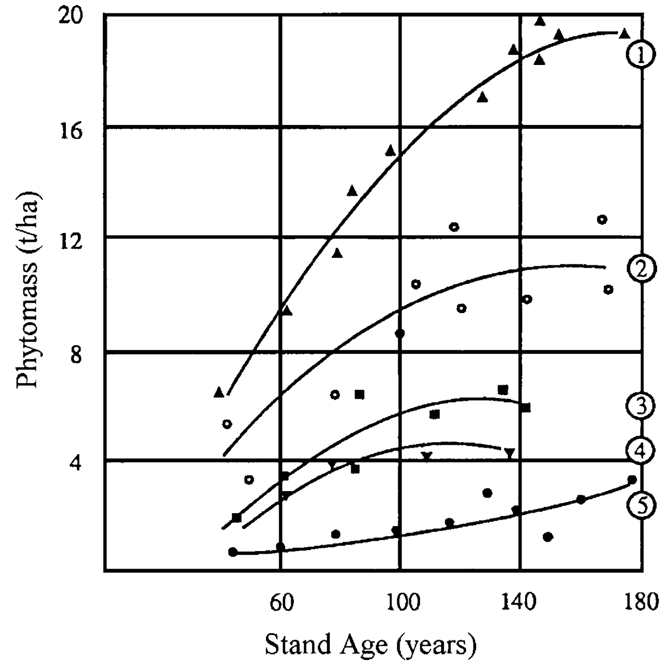

Figure 4.8.—Correlation between vegetation mass of lower layers (tons of oven-dry matter/ha) in larch forests of Siberia and the Republic of Yakutia (Sakha) and stand age: 1 = northern taiga and subarctic territories (Ignatenko et al. 1973; Gorchakovskiy and Andreyashkina 1975; Sofronov and Volokitina 1990); 2 = middle taiga (Pozdnyakov et al. 1969; Atkin and Atkina 1994); 3 = southern taiga (Sofronov and Volokitina 1990); 4 = mountains in southern Siberia (Ermolenko and Ermolenko 1982); 5 = middle taiga of Yakutia (Pozdnyakov et al. 1969).

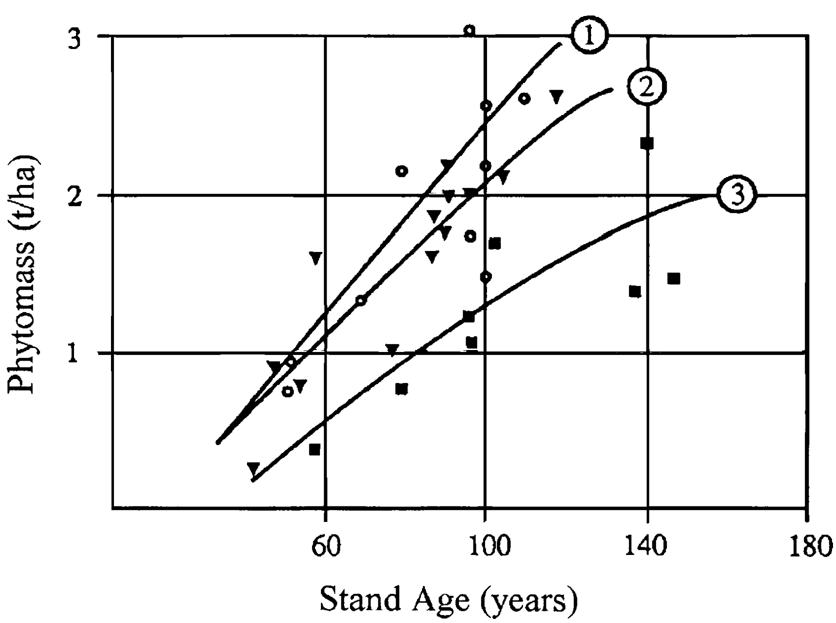

Figure 4.9.—Correlation between vegetation mass of lower layers (tons of oven-dry matter/ha) in fir stands of Siberia and stand age: 1 = middle taiga (Kuzikov 1975; Falaleyev 1985; Atkin and Atkina 1994); 2 = mountains in southern Siberia (Protopopov 1975; Kuzikov 1979); 3 = southern taiga (Kuzikov 1975, 1979; Atkin and Atkina 1986, 1994).

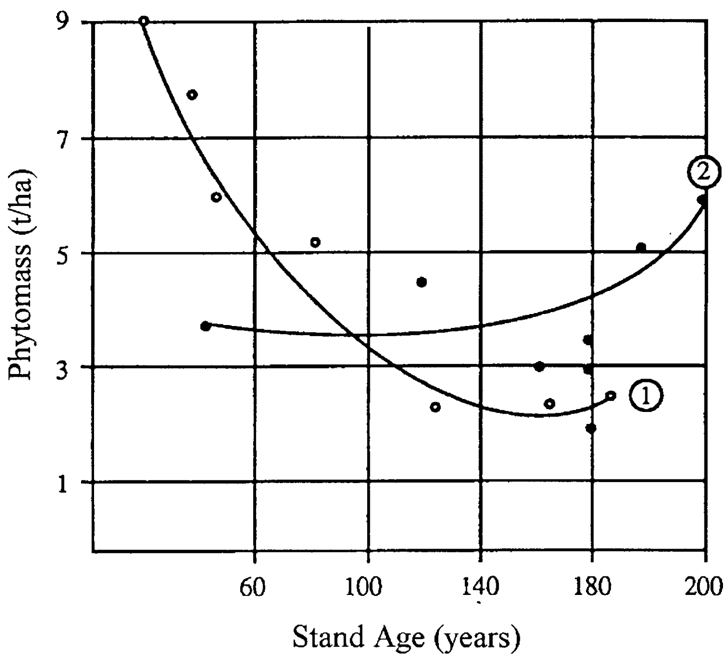

Figure 4.10.—Correlation between vegetation mass of lower layers (tons of oven-dry matter/ha) and stand age in *Pinus sibirica* stands of Siberia: 1 = mountains in southern Siberia (Protopopov 1975); 2 = southern taiga in the Tomsk region (Isakov 1975; Vorob'ev 1983).

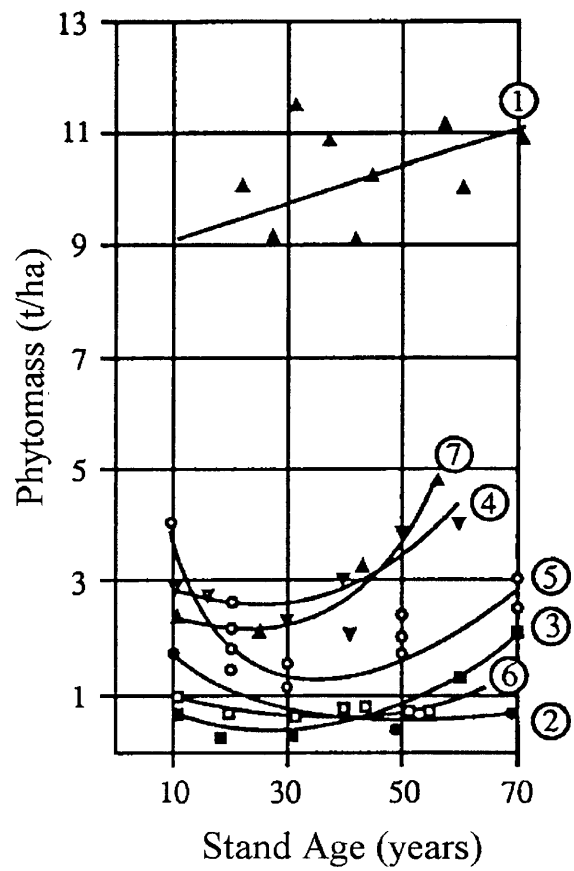

Figure 4.11.—Correlation between vegetation mass of lower layers (tons of oven-dry matter/ha) in birch forests of the European (1-3) and Asian (4-7) parts of Russia and stand age: 1 = northern taiga (Bobkova 1987); 2 = middle taiga (Ignatenko et al. 1973; Kazimirov et al. 1978; Bobkova 1987); 3 = southern taiga (Zvorykina 1977; Kazimirov et al. 1978; Zyabchenko and Zaguralskaya 1991; 4 = northen taiga (Popov 1982); 5 = middle taiga (Gabeyev 1976); 6 = southern taiga (Gabeyev 1976; Popov 1982); 7 = mountains in southern Siberia (Ermolenko and Ermolenko 1982).

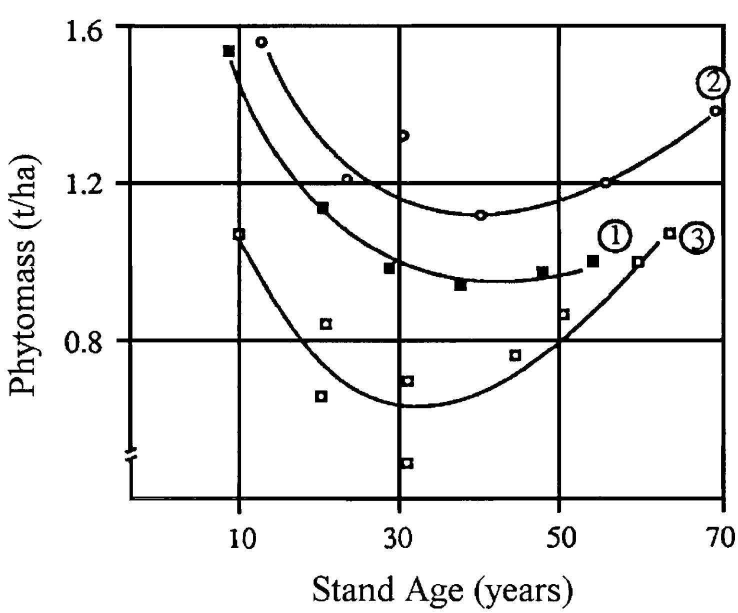

Figure 4.12.—Correlation between vegetation mass of lower layers in aspen-dominated forests and stand age: 1 = southern taiga of the European part of Russia (Dranichnikov et al. 1976); 2 = middle taiga (Demidenko 1978); 3 = southern taiga of the Asian part of Russia (Demidenko 1978; Danilin 1983).

Krummholz is a peculiar life form of woody plants. In Siberia and the Far East, communities of krummholz of Siberian pine (*Pinus pumila*) cover 38.3 million ha with a timber stock of more than 1.1. billion m^3 (Goskomles of the U.S.S.R. 1990). The phytomass structure of *Pinus pumila* was studied by Molozhnikov (1975), Moskalyuk (1988), and Khlynovskaya et al. (1988). The conversion coefficient K_{ph} for mature and overmature krummholz communities is 0.68.

Large areas in Northeastern Siberia are covered by shrub birches such as *Betula nana*, *B. tortuosa*, and *B. mittendorfii*. Their stock averages about 5 m^3/ha. The ratio between the aboveground and underground parts of dwarf birches is from Pozdnyakov et al. (1969).

4.4 Coarse Woody Debris

Trees in forest ecosystems continually grow, die, and fall, thus contributing to the mass of standing dead trees and debris on the forest floor. Fires, windfalls, windbreaks, droughts, extremely low winter temperatures, air pollution, insect invasions, and fungal and bacterial diseases are additional causes of new standing and fallen dead trees. Rots, microorganisms, and pedofauna decay and transform woody debris into organic matter of soil and carbon dioxide .

The mass of standing and fallen dead trees and branches can be derived from available growth tables for standard even-aged stands with a single dominant species (Tretyakov et al. 1952; Kozlovski and Pavlov 1967; Koryakin 1990). Since such stands are rare and the regularities of formation and the standing time of dry trees frequently are altered by various factors, data derived from such growth tables do not agree with actual values estimated in forest inventories. Nevertheless, because of a lack of comprehensive and representative data on coarse woody debris from forest inventories, estimates were based partly on even-age growth tables. For the forests of Krasnoyarsk and the Republic of Yakutia (Sakha), volumes of coarse woody debris were taken from the unpublished forest-inventory database for forest enterprises. The standing time of dead trees was determined from Molchanov (1971) and Sofronov and Volokitina (pers. commun.). The estimated standing time of dead trees is 40 years for larch, 20 years for Scotch pine and Siberian pine, 6 years for spruce, and 5 years for fir, birch, aspen, and alder. To account for the lower density of partially decayed wood, the density of coarse woody debris was reduced by 10 percent from the total for healthy live trees.

4.5 Estimating Phytomass and Carbon Storage in Natural Ecoregions

Estimates of carbon storage in the administrative territories are useful for planning forest management strategies. But for a better understanding of the carbon balance and carbon dynamics, it is necessary to know the distribution of carbon storage in natural ecoregions. Information on forest lands by ecoregion is from I. A. Korotkov (Chapter 3). The carbon storage of tree stands, vegetation of lower layers of forests, and coarse woody debris have been estimated on the basis of data derived for administrative territories.

Where areas of an ecoregion and an administrative unit coincide (for example, Kaliningrad, Kamchatka, Sakhalin, Baltic, Kamchatka, and Kuril-Sakhalin provinces), estimates of carbon stocks required no additional calculation. Accurate calculations were made easily for provinces and districts that completely enclose administrative territories, for example, Leningrad, Novgorod, Pskov, Tver, and Kostroma. Carbon storage of the forests in the ecoregions that covered parts of administrative territories was evaluated in two ways. For the largest administrative territories, Krasnoyarsk and Republic of Yakutia (Sakha), we used the 1988 forest-inventory databases for forest enterprises. For other provinces, additional statistical data were used (Goskomles of the U.S.S.R. 1990, 1991; Zhukov 1966 a, b, c, 1969, 1970; Nikolayuk 1973) to determine stocked areas and model stand characteristics.

4.6 Uncertainties and Errors

Determining the stock of phytomass and carbon at the regional level requires numerous conversion factors, each of which contains a certain error. As mentioned in Chapter 2, the initial error is in the forest-inventory data. In the section that follows we consider some "bottlenecks" and possible errors that could result from using the data in this chapter.

Basic Timber Density

Values for timber density depend on growth conditions of the species and tree age (Fig. 4.1) that affect the thickness of cell walls and their density. Decay processes affect timber density even more. In living and seemingly normally functioning trees, timber is decaying and carbon is lost in parallel with annual ring formation. Because in the last stages of decay development the density of timber decreases by 50 to 88 percent, the effect of timber-destroying fungi for living trees can be expected to affect both the stock and dynamics of carbon. We are not aware of studies in which this factor was included in estimates of the carbon balance. The available evidence (insufficient for generalization) indicates that for some forest trees, for example, Siberian fir, (Table 4.6), excluding rot damage may result in overestimating the carbon stock by at least 10 percent.

The available information on wood and bark density needs further refinement (in quality and age classes for primary forest species). Also needed are additional geographic detail and an indication of the accuracy of published data. We estimate that average regional parameters of basic density are accurate to within ± 15 to 20 percent.

Estimating Phytomass and Carbon Storage of Stands and Forest Plant Communities

Although 2,290 sampling areas were used, the resulting data are insufficient for characterizing the phytomass of forest tree stands in all age groups under different growth conditions. Least accurate are conversion coefficients for the young forests of age class I, with the broadest natural variability due to differences in composition and initial thickness. The error of K_{cr} and K_r for this age group may exceed ± 50 percent. For other age groups the error is ±10 to 20 percent. Insufficient accounting by researchers of physiologically active roots less than 1 mm in diameter may be the cause of underestimated K_r. Some publications do not provide data on the accuracy of phytomass estimates, so our estimation of errors is approximate.

Conversion factors for the analogous stands of the middle, southern taiga, subtaiga, mixed and broadleaved-deciduous forests differ little (Tables 4.2 and 4.3). However, our current knowledge of these forests is insufficient to state that these values will not change in the future. At present, the data are least reliable for root phytomass. Also, data are lacking for Siberia and the Russian Far East.

Estimates of phytomass and carbon storage are inaccurate partly because many forests are of mixed species of uneven age and have a complex stand structure (multilayered). Two examples of such stands are shown in Table 4.7.

We can presume that the fractional composition of the phytomass and conversion factors for forest trees in mixed-species stands differ from those for the same trees in forests dominated by a single species.

The uncertainties associated with uneven-aged forests are important in understanding the dynamics of carbon. According to forest-inventory regulations, uneven-aged forests are classified as “mature and overmature”, yet the strategy of succession in these forests is not the same as that in stands of another age composition. Questions of composition, structure, and age of forests will be addressed in future research.

Taking the various assumptions outlined in this chapter into consideration, we estimate that our estimates of phytomass and carbon storage are accurate to within ± 10 to 20 percent. Errors in estimating the carbon storage in individual ecoregions are approximately in this same range. However, since there are many uncertainties in forest-inventory data for ecoregions (for many provinces, the distribution of the growing stock with respect to dominant species, age groups, and distribution of areas of cuttings, burns, peatlands, etc. are not known), we consider statistical inventory data for administrative territories as the principal basis for estimating carbon storage in the forests of Russia.

Table 4.1.—Ratio of bark mass to timber mass (K_b) for stands of the major tree species in the Siberian boreal and subboreal ecoregions[a]

	Age-class group				
	Young stands				
Dominant tree species	Class I[b]	Class II[c]	Middle-aged	Maturing	Mature / overmature
Northern Taiga					
Pinus sylvestris	0.18	0.18	0.10	0.08	0.08
Picea obovata	0.18	0.12	0.12	0.09	0.09
Abies sibirica	0.25	0.22	0.20	0.18	0.17
Larix sp.	0.30	0.30	0.26	0.25	0.25
Pinus sibirica	0.20	0.19	0.19	0.18	0.18
Betula pendula	0.15	0.15	0.15	0.15	0.15
Populus tremula	0.11	0.11	0.11	0.11	0.11
Middle and Southern Taiga, Forest Steppe					
Pinus sylvestris	0.20	0.18	0.15	0.10	0.10
Picea obovata	0.19	0.12	0.12	0.11	0.11
Abies sibirica	0.21	0.21	0.16	0.11	0.10
Larix sp.	0.29	0.29	0.26	0.18	0.16
Pinus sibirica	0.16	0.14	0.12	0.10	0.09
Betula pendula	0.15	0.12	0.10	0.08	0.07
Populus tremula	0.10	0.09	0.08	0.07	0.06

[a]Estimated from Tretyakov et al. 1952; Pozdnyakov et al. 1969; Stakanov 1983, 1990; Anonymous 1990.
[b]Early regeneration.
[c]Advanced regeneration.

Table 4.2.—Ratio of crown mass to timber mass (K_{cr}) for stands of the major tree species in ecoregions of Russia[a]

Dominant tree species	Age-class group				
	Young stands				
	Class I[b]	Class II[c]	Middle-aged	Maturing	Mature / overmature
			Northern Taiga		
Pinus sylvestris	1.22	0.48	0.36	0.25	0.18
Picea sp.	1.29	0.78	0.52	0.41	0.30
Larix sp.	0.26	0.16	0.14	0.14	0.13
Betula sp.	1.08	0.32	0.28	0.25	0.25
			Middle Taiga		
Pinus sylvestris	0.84	0.26	0.15	0.12	0.11
Picea sp.	1.12	0.65	0.45	0.35	0.28
Abies sp.	1.20	0.80	0.50	0.38	0.29
Larix sp.	0.26	0.15	0.14	0.12	0.12
Pinus sibirica	0.80	0.60	0.42	0.35	0.32
Betula sp.	1.02	0.28	0.24	0.22	0.22
Populus tremula	1.06	0.22	0.19	0.17	0.16
			Southern Taiga and Forest Steppe		
Pinus sylvestris	0.80	0.25	0.15	0.12	0.11
Picea sp.	1.10	0.55	0.45	0.35	0.28
Abies sp.	1.00	0.74	0.42	0.30	0.28
Larix sp.	0.26	0.15	0.14	0.12	0.12
Pinus siberica & *P. koriensis*	0.80	0.35	0.30	0.25	0.25
Betula sp.	1.00	0.26	0.22	0.21	0.21
Populus tremula	1.00	0.20	0.19	0.17	0.16

[a]Estimated from Smirnov 1971; Alexeyev 1967; Slemnev 1969; Alexeyev and Rakhmanov 1973; Gabeyev 1990; Alexeyev et al. 1985; Kazimirov and Morozova 1973; Protopopov 1975; Dylis and Nosova 1977; Demidenko 1978; Utkin 1970, 1975; Stakanov 1983, 1990.
[b]Early regeneration.
[c]Advanced regeneration.

Table 4.3.—Ratio of root mass to timber mass (K_r) for the major tree species in ecoregions of Russia[a]

Dominant tree species	Age-class group				
	Young stands				
	Class I[b]	Class II[c]	Middle-aged	Maturing	Mature / overmature
			Northern Taiga		
Pinus sylvestris	0.45	0.45	0.40	0.35	0.35
Picea obovata	0.65	0.65	0.60	0.60	0.60
Larix sp.	0.35	0.35	0.35	0.35	0.35
Betula sp.	0.50	0.50	0.40	0.40	0.40
Populus tremula	0.50	0.50	0.40	0.40	0.40
			Middle and Southern Taiga, Forest Steppe		
Pinus sylvestris	0.26	0.26	0.25	0.25	0.25
Picea sp.	0.40	0.40	0.30	0.25	0.25
Abies sp.	0.34	0.30	0.30	0.30	0.30
Larix sp.	0.35	0.35	0.32	0.32	0.32
Pinus sibirica	0.30	0.26	0.25	0.25	0.25
Betula sp.	0.35	0.30	0.25	0.25	0.25
Populus tremula	0.35	0.30	0.25	0.25	0.25

[a]Estimated from Pozdnyakov et al. 1969; Abrazhko 1973; Kazimirov and Morozova 1973; Smirnov 1971; Stakanov 1978, 1983, 1990; Atkin 1984; Bobkova 1987; Gabeyev 1990.
[b]Early regeneration.
[c]Advanced regeneration.

Table 4.4.—Factors to convert the volume of growing stock to stand phytomass (K_{ph}) for the major tree species in ecoregions of Russia

Dominant tree species	Age-class group				
	Young stands				
	Class I[a]	Class II[b]	Middle-aged	Maturing	Mature / overmature
			European Part of Russia		
			Northern Taiga		
Pinus sylvestris	0.888	0.696	0.694	0.675	0.621
Picea sp.	1.144	0.750	0.736	0.732	0.684
Betula sp.	1.106	0.840	0.834	0.894	0.864
			Middle Taiga		
Pinus sylvestris	0.696	0.556	0.568	0.612	0.586
Picea sp.	0.880	0.686	0.678	0.686	0.649
Betula sp.	1.034	0.744	0.750	0.806	0.778
Populus tremula	0.786	0.510	0.540	0.556	0.496
			Southern Taiga and Forest Steppe		
Pinus sylvestris	0.696	0.556	0.568	0.612	0.586
Picea sp.	0.830	0.668	0.608	0.670	0.632
Betula sp.	1.034	0.736	0.750	0.802	0.780
Populus tremula	0.786	0.540	0.540	0.558	0.496
			Asian Part of Russia		
			Northern Taiga		
Pinus sylvestris	0.835	0.661	0.666	0.648	0.590
Picea sp.	0.984	0.723	0.710	0.704	0.650
Larix sp.	0.806	0.762	0.768	0.802	0.795
Betula sp.	1.102	0.834	0.828	0.886	0.858
			Middle Taiga		
Pinus sylvestris	0.654	0.528	0.545	0.587	0.557
Picea sp.	0.857	0.670	0.640	0.620	0.602
Abies sp.	0.660	0.604	0.544	0.596	0.468
Larix sp.	0.726	0.714	0.708	0.738	0.724
Pinus sibirica	0.714	0.710	0.668	0.646	0.600
Betula sp.	1.026	0.740	0.752	0.778	0.771
Populus tremula	0.779	0.504	0.534	0.548	0.484
			Southern Taiga and Forest Steppe		
Pinus sylvestris	0.735	0.638	0.545	0.585	0.557
Picea sp.	0.847	0.630	0.621	0.632	0.584
Abies sp.	0.714	0.660	0.576	0.546	0.510
Larix sp.	0.726	0.714	0.704	0.738	0.724
Pinus sylvestris	0.610	0.522	0.528	0.506	0.488
Betula sp.	1.026	0.735	0.744	0.775	0.762
Populus tremula	0.779	0.504	0.534	0.548	0.484

[a]Early regeneration.
[b]Advanced regeneration.

Table 4.5.—Phytomass (oven dry, t/ha) of understory in forests of the major tree species in ecoregions of Russia[a]

Dominant tree species	Age-class group				
	Young stands				
	Class I[b]	Class II[c]	Middle-aged	Maturing	Mature / overmature
			European Part of Russia		
			Northern Taiga		
Pinus sylvestris	9.5	9.7	10.0	10.4	11.0
Picea obovata	2.2	2.8	3.2	4.3	8.5
Betula sp.	9.0	9.5	9.7	10.0	10.5
			Middle Taiga		
Pinus sylvestris	5.7	5.3	6.8	7.5	8.5
Picea sp.	0.5	0.7	2.2	3.1	4.5
Betula sp.	2.0	1.2	0.8	0.6	0.6
Populus tremula	1.8	0.8	0.6	0.5	0.5
			Southern Taiga		
Pinus sylvestris	1.8	1.3	2.4	2.4	2.5
Picea abies	1.2	1.3	1.4	2.5	4.4
Quercus robur	0.6	0.7	0.8	0.7	0.7
Betula sp.	1.5	1.5	1.4	1.6	1.7
Populus tremula	2.5	2.3	2.0	1.9	2.0
			Asian Part of Russia		
			Northern Taiga		
Pinus sylvestris	3.0	3.2	3.4	3.5	4.1
Picea obovata	1.4	1.5	1.7	2.2	2.3
Larix sp.	1.2	6.0	9.2	12.0	16.0
			Middle Taiga		
Pinus sylvestris	1.2	0.8	2.2	2.5	2.8
Picea obovata	0.3	0.4	0.8	1.2	1.6
Abies sibirica	0.1	0.5	1.2	1.7	2.8
Larix sp.	0.5	2.0	3.2	4.1	5.0
Pinus sibirica	6.0	3.0	3.6	3.6	4.0
Betula sp.	4.0	1.2	2.5	2.5	2.0
Populus tremula	1.5	1.2	2.3	2.3	1.2
			Southern Taiga and Forest Steppe		
Pinus sylvestris	1.2	1.0	2.0	2.4	2.5
Picea obovata	0.5	0.6	1.0	1.2	2.0
Abies sibirica	0.2	0.3	1.1	1.5	2.5
Larix sp.	0.2	1.8	3.0	4.4	6.0
Pinus sibirica	8.0	4.0	3.5	2.2	2.5
Betula sp.	1.0	0.8	0.6	0.6	0.7
Popula tremula	1.0	0.8	0.6	0.6	1.0
			Mountains of Southern Siberia		
Pinus sylvestris	1.1	1.4	1.6	1.8	1.9
Abies sibirica	0.1	0.5	1.0	1.5	2.4
Larix sibirica	0.2	1.6	2.4	3.6	4.0
Pinus sibirica	5.0	3.6	3.8	4.0	4.4
Betula sp.	1.5	1.6	2.2	3.0	3.5
Populus tremula	1.1	1.2	1.8	2.8	2.9

[a]Estimated from data from Appendix Tables 7-18.
[b]Early regeneration.
[c]Advanced regeneration.

Table 4.6.—Frequency of occurrence of interior decay of *Abies sibirica* trees in forests on Mariinski Forest Farm of Kemerovo Oblast, by d.b.h. and age of trees (from Falaleyev et al. 1983)

D.b.h. (cm)	Occurrence of interior decay (%)						
	21 - 40 years	41 - 60 years	61 - 80 years	81 - 100 years	101 - 120 years	121 - 140 years	141 + years
16[a]	7	7	n.d.	n.d.	n.d.	n.d.	n.d.
20	22	9	7	13	n.d.	n.d.	n.d.
24	71	42	32	30	29	n.d.	n.d.
28	63	72	58	23	36	38	n.d.
32	93	95	86	61	51	38	n.d.
36	100	100	87	61	58	78	n.d.
40	n.d.	100	81	64	75	75	67
44	n.d.	n.d.	100	83	61	78	50
48	n.d.	n.d.	100	72	83	94	80
52	n.d.	n.d.	100	100	100	67	100
56	n.d.	n.d.	100	n.d.	100	100	100
60	n.d.	n.d.	n.d.	n.d.	100	n.d.	n.d.

[a]No data for 8 and 12 cm d.b.h.
[b]n.d. = no data.

Table 4.7.—Structure of phytomass (t/ha, absolutely dry) in polydominant tree stands of the Sikhote-Alin ecoregion (district 59.1)[a]

Tree species	Canopy layer	Stem			Crown			Crown / timber mass ratio
		Bole	Bark	Subtotal	Leave	Branch	Subtotal	
				Sample Plot 1				
Picea ajanensis	I	1.4	0.3	1.7	0.3	0.4	0.7	0.50
	II	47.8	6.9	54.7	6.7	9.3	16.0	0.33
Abies nephrolepis	I	1.1	0.1	1.2	0.2	0.3	0.5	0.41
	II	20.2	3.4	23.6	2.9	3.3	6.2	0.27
Betula lanata	I	23.3	3.8	27.1	0.5	4.8	5.3	0.23
	II	14.6	2.7	17.3	0.4	2.8	3.1	0.21
Acer ucurunduense	I	1.1	0.4	1.5	0.1	0.7	0.8	0.72
Tilia taquetii	I	2.6	0.6	3.2	0.1	0.8	0.9	0.34
				Sample Plot 2				
Picea ajanensis	I	43.1	4.7	47.8	6.5	12.2	18.7	0.39
Abies nephrolepis	I	11.7	1.4	13.1	2.7	3.2	5.9	0.50
Pinus koriensis	I	1.6	0.2	1.8	0.4	0.4	0.8	0.50
Betula lanata	I	70.2	7.8	78.0	0.8	28.7	29.5	0.42
Tilia amurensis	I	2.1	0.2	2.3	0.2	0.5	0.7	0.33
Acer ucurunduense	I	2.8	0.3	3.1	0.2	1.0	1.2	0.42

[a]From Dyukarev and Rosenberg 1975.

Chapter 5. Estimating Phytomass and Carbon Storage in Vegetation of Unstocked and Nonforest Areas

V.A. Alexeyev, V.D. Stakanov, and I.A. Korotkov

5.1 Unstocked Lands

Woodlands

Woodlands by definition are composed of widely separated trees or small tree groups with a generally open canopy and relative basal area less than 25 percent of the standard density for a forest stand. The average relative basal area of trees in woodlands is equal to 15 percent of the standard density. The estimated phytomass of the lower layers of woodlands was 20 percent greater than for a similar category of mature and overmature forest stands of corresponding dominant species. The carbon storage of woodlands was calculated after estimating the carbon of stocked areas by:

$$C_{wl} = 0.15\,(C_{st}/D \times 10) + 1.2C_{ll} = 1.5\,C_{st}/D + 1.2C_{ll} \qquad (12)$$

where C_{wl} is the woodland carbon in tons/ha, C_{st} is the average forest stand carbon of an administrative unit or an ecoregion, D is weighted average relative basal area of the forest stand determined from the Forest Fund of U.S.S.R. (Goskomles of the U.S.S.R. 1990, Table 16), and C_{ll} is the carbon in the lower layers (t/ha).

Burned Areas

The estimated timber mass of burned areas was 60 to 70 percent of an average volume of model stands. Estimated stem density was 10 to 15 percent less than that for healthy mature stands. The conversion coefficients K_{cr} and K_r were reduced from the values for the mature stands by 15 and 10 percent, respectively.

Clearcut Areas

According to the Forest Fund of the U.S.S.R. (Goskomles of the U.S.S.R. 1990), there are 8.45 million ha of clearings in Russia. The estimated mass of residues in the clearcut areas is 10 percent of the growing stock (Shariy 1983). In sparsely wooded regions, the mass of felling debris (which is used for fuel) was not taken into account. The estimated mass of stems and roots is 25 percent of the model stand volume. The mass of the lower layers in the clearings is 10 to 20 percent higher than under the forest canopy (Ermolenko 1987; Isakov 1973; Bizyukin 1980; Burenina 1981).

Open Forest Plantations

There are 3.8 million hectares of “open” forest plantations (0.4 percent of the forested area) in Russia. According to the estimates of foresters and our own experience, this area is mostly unstocked with trees and the sites are covered with undergrowth: herbs, dwarf-shrubs, mosses, or lichens. The mass of live plants is twice that of the understories of mature and overmature stands. The estimated mass of dead plant parts is 50 percent of the residues in clearings.

Forest Nurseries

Forest nurseries cover 51,000 ha or 0.004 percent of the forested area (Goskomles of the U.S.S.R. 1990). The estimated phytomass of living plants per unit area is 10 percent of that of the young forests of age class I.

Wastelands and Glades

The estimated phytomass of wastelands and glades is 50 percent of that of forest meadows.

5.2 Nonforest Lands

Plowed Lands

The phytomass of 70 percent of the plowed land is assumed to equal that of the major crops of the region. The remaining 30 percent of the plowed land is assumed to lie fallow.

Hay Fields and Pastures

The aboveground and underground mass of plants in hay fields and pastures was evaluated with the data on forest-meadow yield in different regions (Andreyev 1974; Rabotnov 1984).

Estates

Estates occupy 0.06 percent of the total area of the Forest Fund (Goskomles of the U.S.S.R. 1990). We consider 70 percent of its area to be productive and equate the phytomass of estates to that of hay fields of the respective regions. Buildings are assumed to occupy 30 percent of the area.

Forest Roads and Survey Lines

At least 75 percent of the land in this category is in forest survey lines. We estimate that they account for 50 percent of the phytomass in the lower layers of the most common stands.

Other Lands

The Forest Fund (Goskomles of the U.S.S.R. 1990) includes 90.225 million ha (7.6 percent) of “other” nonforest lands lands under the management of forestry authorities and forest industry. In the European part of the Russian Federation, “other” lands account for slightly more than 2 million ha; the remaining 88 million ha are in the Asian part of the country, primarily in the Yakutia and Magadan regions.

According to the “Regulations for the National Inventory of Forests” (Anonymous 1982), “other” areas include 22 items, for example, rock exposures, talus slopes, gravel fields, ravines, electric power lines, oil pipeline areas, mountain and plain tundras, warehouses, and parking lots. Probable vegetation cover and its carbon stock were evaluated by expert estimation proceeding from a knowledge of that administrative territory.

Chapter 6. Storage and Territorial Distribution of Carbon in Vegetation of Russian Forests

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6.1 Carbon in Vegetation of Forest Ecosystems

The second chapter and part the fourth chapter characterize the growing stock of Russia and its distribution among administrative territories. Quantitative values for phytomass and carbon have undergone essential changes (Tables 6.1 and 6.2). However, relative values for carbon storage are similar to those for growing stock.

We estimate that the carbon stock in the forest stands of Russia is 25.6 Gt, or 26.1 Gt when krummholz and shrubs are included (Table 6.2). Previously, we discussed errors arising from procedures for estimating the growing stock as well as uncertainties in evaluating phytomass and carbon storage. The sum of errors in estimating the vegetation carbon storage of stocked areas is ±10 to 20 percent; for the administrative territories with commercially important forests, the data can be underestimated by approximately 10 percent. Currently, the absence of information on the distribution of decay and losses of phytomass and corresponding losses of carbon makes it impossible to correct the estimates.

Considering that the lower forest layers account for 1.9 Gt of carbon (Table 6.3) and communities of krummholz and shrubs account for 610 million tons, the total carbon pool of forest vegetation is 28 Gt. The weighted average carbon density in forest vegetation is 36.3 t/ha.

The composition of a hypothetical average forest community of Russia expressed in carbon stock differs little from the tree composition, as shown in Figure 6.1. Krummholz and shrubs are included in the composition formula.

More than 75 percent of the carbon accumulated in the forest communities is in coniferous forests. Larch forests account for nearly half of the carbon of all other conifers combined. For all coniferous species, the highest portion of accumulated carbon is in mature and overmature stands, while other age groups are most common in the deciduous stands that have replaced the cutover coniferous stands (Fig. 6.2, Tables 6.1, 6.2).

In Chapter 2 it was stated that the phytomass and carbon in the young stands of age class I (accounting for 325.6 million tons of carbon) could be estimated only with significant error. Figure 6.2 reveals that the portion of these young stands is not great and that the magnitude of a possible error in estimates of total carbon stock is slight.

The peculiarities of distribution of carbon storage in forest communities over administrative units (Appendix Table 19) largely replicate those of the distribution of growing stock (Appendix Table 5), with the distinction that some changes are attributed to the lower layers of the forests. The latter contribute markedly only in the open northern forest communities, as the lower layers of vegetation have better development under open stand canopies.

6.2 Geographic Distribution of Carbon Storage in Vegetation of Forest Ecosystems

Forest-Tundra and Mountain Subarctic Forests

The forested area of the extreme northern part of the forest biome is more than 108 million ha (14 percent of total stocked area), including 66.3 million ha of mountain forests. In Western and Central Siberia there is a broad band of open, nonproductive near-tundra forests and woodlands. Following Kolesnikov (1969), we do not include extremely northern open stands and woodlands in the boreal zone, but consider them as subarctic vegetation.

A low average carbon density of 15 t/ha in the tundra and subarctic vegetation is determined by the scanty composition of tree species (Table 3.2), low productivity (Va-Vb quality classes prevalent), and open stands (relative d.b.h. density is 0.3 to 0.4) (Table 6.4). The amount of carbon of plants in the lower layers of such forests is 20 percent of that of vegetation. Severe climatic conditions (average yearly temperature is - 8^{o} to -16^{o}C) in the north of the Asian part of the country caused the development of krummholz species (*Pinus pumila*, *Dushekia fruticosa*), which are more productive than the European species of the subarctic region. This makes the carbon density in the Siberian and Yakutian forest-tundra higher than in the European part of Russia (Table 6.4).

Closed stands subject to exploitation for local and (in Western Siberia) industrial needs of the petroleum and gas industry are common in the plain forest-tundra along river valleys. In the mountain subarctic forests (Putorany, Polar Urals, Anabar shield, Northeast Yakutia, and the Okhotsk sea coast) is a belt of subscree, woodlands, and open forests. Closed northern taiga forests are found only on large river terraces and in the narrow band of the lower parts of slopes.

Zone of Boreal Plain and Mountain Forests

The stocked area of the boreal (taiga) zone in Russia totals 521.9 million ha (67.7 percent), 157.2 million of which are classified as mountain forests. This part of the forest biome makes the largest contribution to the carbon pool of forest vegetation (Fig. 6.3). The phytomass of boreal forests contains 70 percent (19.6 Gt) of the carbon in forest vegetation; average carbon density is 37.5 t/ha.

In the plains ecoregions, differences in vegetation structure, productivity, and floristic composition are characteristic of the northern, middle, and southern taiga subzones, and of the mixed-forest subzone (subtaiga). These parts of the boreal forests essentially differ in carbon content, which increases from the northern subzone to the south (Fig. 6.3, Table 6.4). The lower layers of the taiga forests are less developed under the closed forests and account for only 3 to 5 percent of the carbon stored in the upper canopies.

Productivity of taiga and the more southern forests is determined not only by the natural environment conditions but also by the human activities. A natural characteristic of the Northern European and Western Siberian taiga is its bottomland forests. Wet bottomlands account for about 45 percent of the forests in the Republic of Komi and about 53 percent in the Tyumen region. Notwithstanding the milder climate and drier site conditions, carbon storage of the northern forests of the European part of Russia that are subjected to perennial intensive fellings is lower than that of similar forests in Siberia.

Less affected by clearcutting are the southern taiga forests of Middle Siberia. These areas contain the maximum amount of carbon for the boreal zone--62 t/ha (Table 6.4). In the European part of the country, carbon storage in the southern-taiga forests is 48 t/ha.

Permafrost is one of the factors that determines the yield and carbon stock of forests in the Asian part of the country. Nearly half of the forests in Russia (46 percent) are subject to its effect. The forest communities of Middle, Eastern Siberia, and Yakutia growing on permafrost contain 9.3 Gt of carbon; average density is 26 t/ha.

In most climatic sectors, the amount of accumulated carbon increases from forest-tundra (and mountain subarctic forests) to the forest-steppe and mountain subboreal forests, and decreases in the zone of steppes and deserts (Fig. 6.3). The exceptions are the plain regions of the Middle and partly of Western Siberia (the plain of Kemerovo Oblast, for example) where birch and aspen replaced conifers following intensive fellings. A more continental climate in Siberia and Yakutia precludes growth of high-yield hardwood deciduous species. Therefore, the carbon density culminates in the southern taiga (Fig. 6.4, Table 6.4).

Zone of Deciduous Hardwood (Forest-Steppes)
and Mountain Subboreal Forests

The deciduous hardwood and mountain subboreal forests cover an area of 134.6 million ha (17.5 percent of the stocked territory). Mountain forests are the predominant vegetation community. The total storage of carbon accumulated in vegetation is 6.5 Gt, with an average density of 48 t/ha. In the plains the carbon stock is somewhat higher but substantially less than it might have been absent the permanent impact of human disturbances.

The regional carbon density is highest in the Caucasus Mountains (82 t/ha). The mountain belt of these forests is traditionally classified as subboreal even though the region has a warmer climate and a much higher accumulation of carbon.

Forests of Steppes, Deserts, and Mountain
Forests of Subarid and Arid Zones

The forests of steppes, deserts, and mountain forests of subarid and arid zones cover 0.8 percent of the stocked area and contribute little to the total stock of carbon in the forests of Russia. The forests of the steppe biome generally grow on lands that are not suitable for agriculture. Low available moisture affects productivity and carbon storage; the higher the moisture deficit, the lower the productivity and carbon stock. Some riparian thickets along the river banks have high productivity.

6.3 Carbon Storage in Vegetation of Unstocked and Nonforest Areas

Unstocked Lands

The area of woodlands, burns, and other unstocked areas of the Forest Fund (Goskomles of the U.S.S.R. 1990, Table 2) covers 109.1 million ha, 98 million of which are under forest management. Although the portion of this category of land is large (12.3 percent of the forest area), the estimated carbon stock of the vegetation is small--633.3 million tonnes, (Table 6.5) or 2 percent of the total carbon pool of forest vegetation.

Nonforest Lands

The total nonforest area of the Forest Fund of Russia is 298.46 million ha, 239.45 million of which are under forest management (Goskomles of the U.S.S.R. 1990, Tables 1 and 2). The available data describe only the lands under forest management (Appendix Table 3). Estimates of carbon storage in the vegetation and peats of the mires covering 122 million ha are considered in Chapter 10. In addition to the peatlands represented in the nonforest lands, the category of “other” areas, e.g., rock exposures, talus slopes, and mountain and plain tundras, must be considered. According to our estimates, the 90.2 million ha of vegetation in these different lands contain 136.3 million tons of carbon (Table 11.1).

Areas of plowed land, pastures, hay fields, estates, survey lines, and roads of the Forest Fund are not large; their combined vegetation contains only 10 million tons of carbon.

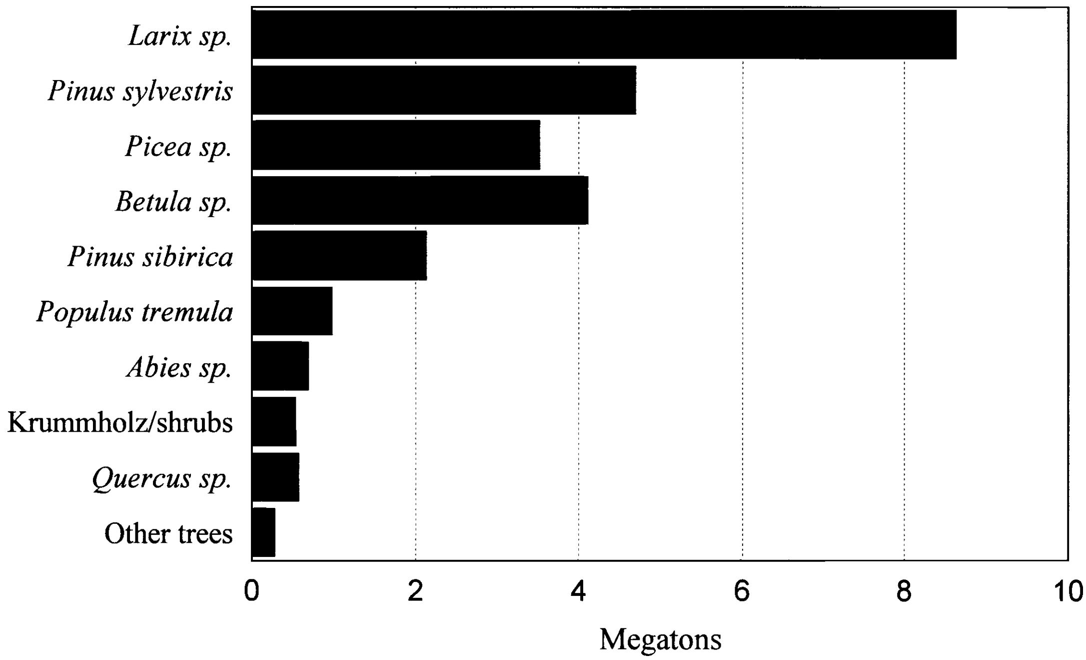

Figure 6.1.—Distribution of carbon storage in Russian forests by species.

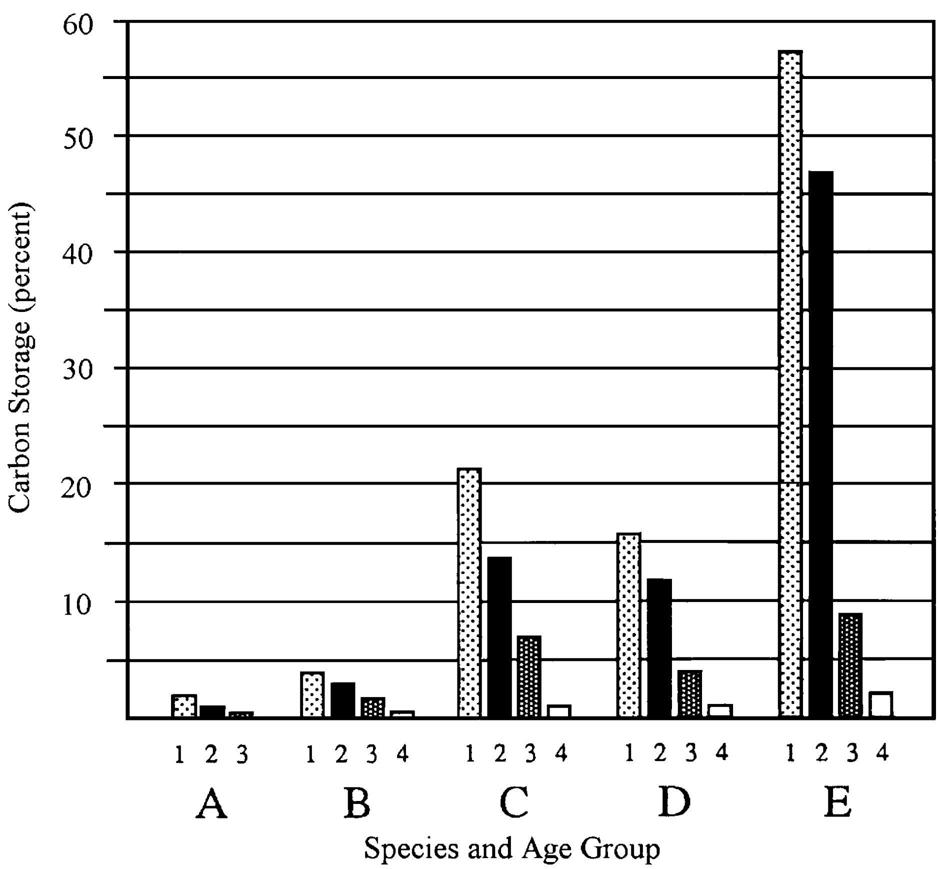

Figure 6.2.—Distribution of carbon storage in Russian stands by species and age group (A = young stands, class I; B = young stands, class II; C = middle-aged; D = maturing; E = mature and overmature stands; 1 = all species; 2 = conifers; 3 = softwood deciduous; 4 = hardwood deciduous).

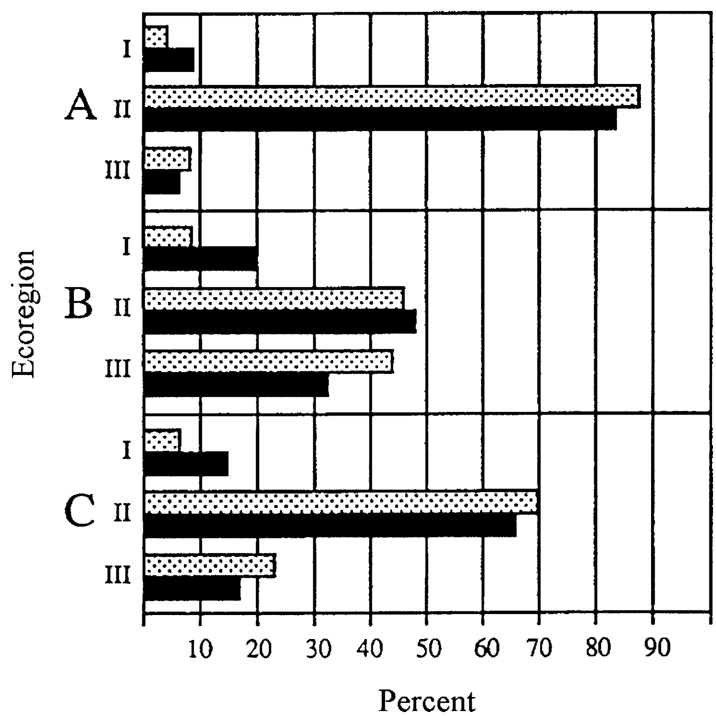

Figure 6.3.—Distribution of stocked areas (black) and carbon storage (gray) in forests of the ecoregions of Russia (A = plains forests: I = forest-tundra, II = boreal zone, III = forest-steppe zone; B = mountain forests: I = subarctic, II = boreal, III = subboreal; C = total Russian forests: I = forest-tundra and mountain subarctic forests, II = boreal plains and mountain forests, III = forest steppes and mountain subboreal forests).

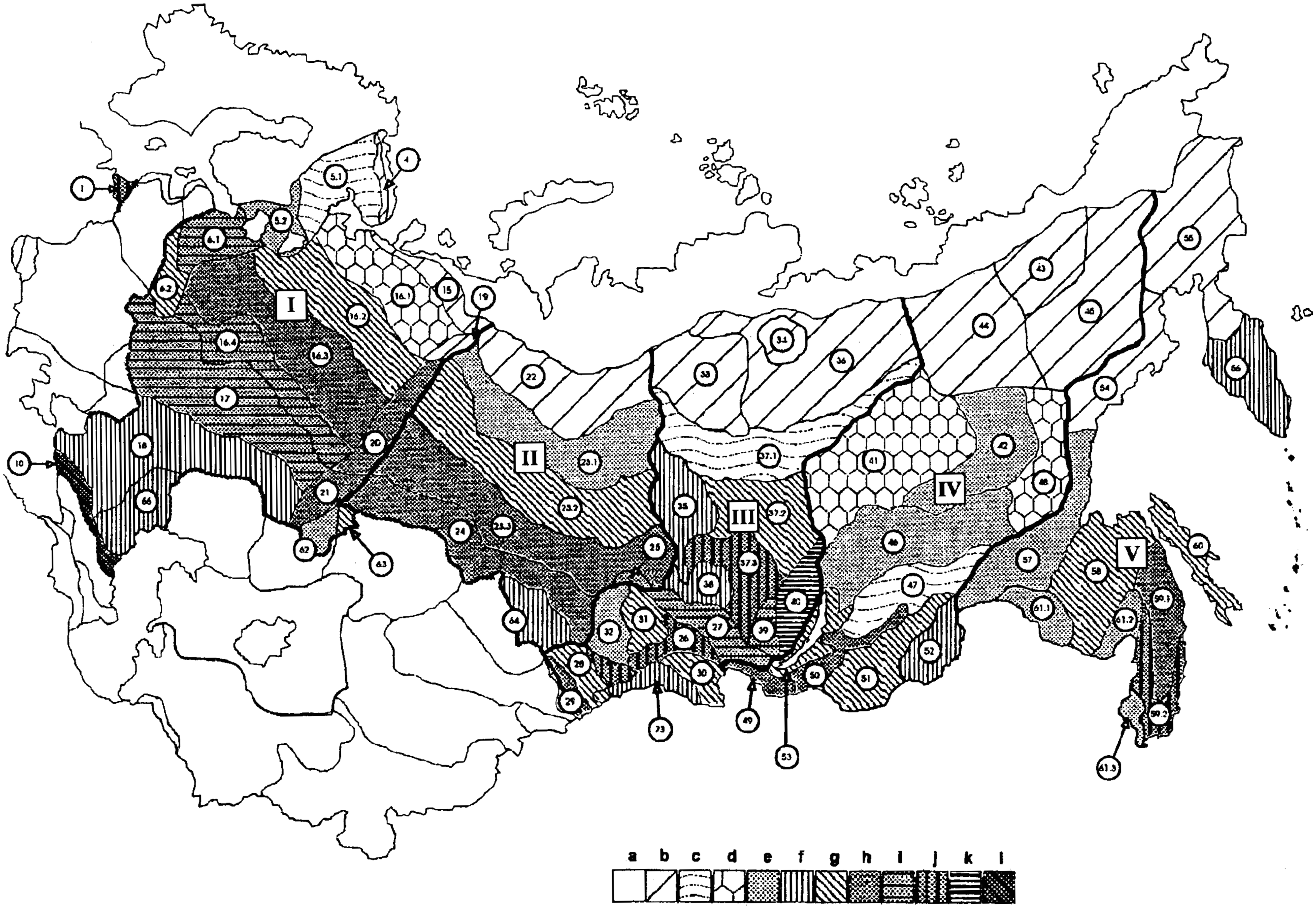

Figure 6.4.—Density (t/ha) of forest vegetation carbon in ecoregions of Russia: a = arctic zone, water or other country; b = 15 to 20; c = 21 to 25; d = 26 to 30; e = 31 to 35; f = 36 to 40; g = 41 to 45; h = 46 to 50; i = 51 to 55; j = 56 to 60; k = 61 to 65; l = 66 to 70. Geographic regions are: I = European Part of Russia (including Ural mountains); II = Western Siberia; III = Middle Siberia; IV = Eastern Siberia (including Yakutia); V = Far East.

Table 6.1.—Carbon storage in phytomass (Mt) of tree stands in Russia

Dominant tree species	Age-class group: Young stands: Class I[a]	Class II[b]	Middle-aged	Maturing	Mature / overmature	Total
			Conifer			
Pinus sylvestris	96	245	1,083	731	2,535	4,690
Picea sp.	77	182	635	434	2,184	3,512
Abies sp.	6	17	120	99	440	682
Larix sp.	73	254	1,260	1,347	5,696	8,630
Pinus sibirica	8	53	341	468	1,255	2,125
Subtotal	260	751	3,439	3,079	12,110	19,639
			Deciduous Hardwood			
Quercus sp.	10	35	209	99	212	566
Fagus sp.	0.5	3	42	14	37	97
Carpinus sp.	0.1	0.6	11	3	8	22
Ulmus sp.	0.0	0.1	0.6	0.3	0.9	2
Betula ermanii	0.4	3	17	23	283	327
Subtotal	11	42	279	140	541	1,013
			Deciduous Softwood			
Betula sp.	53	141	1,188	683	1,720	3,784
Populus tremula	14	34	305	166	457	975
Populus sp.	0.1	0.6	8	3	13	25
Tilia sp.	1	4	41	19	45	110
Alnus sp.	0.3	0.8	11	5	4	21
Subtotal	68	180	1,553	875	2,239	4,915
All tree species	339	974	5,271	4,094	14,890	25,567

[a]Early regeneration.
[b]Advanced regeneration.

Table 6.2.—Carbon storage (Mt) in phytomass of tree stands and bushes (including krummholz) in administrative territories of Russia

Administrative territory	*Larix* sp.	*Pinus sylvestris*	*Picea* sp.	*Pinus sibirica and koriensis*	*Abies* sp.	*Betula* sp.	*Populus tremula*	*Quercus* sp.	Other trees[a]	Bushes[b]	Total
1. Kaliningrad Oblast	0.0	2.0	2.4	0.0	0.0	3.4	1.8	5.4	0.0	0.0	15.0
2. Arkhangel'sk Oblast	3.4	173.4	530.8	0.0	0.0	57.5	7.4	0.0	0.0	0.0	772.5
3. Vologoda Oblast	0.0	97.5	142.9	0.0	0.0	159.4	27.2	0.0	1.1	0.0	428.1
4. Murmansk Oblast	0.0	28.5	31.3	0.0	0.0	11.0	0.0	0.0	0.0	0.0	70.8
5. Rep. of Karelia	0.0	137.3	79.9	0.0	0.0	28.3	2.1	0.0	0.0	0.0	247.6
6. Rep. of Komi	10.8	195.7	562.1	0.9	5.3	106.2	22.6	0.0	0.0	0.1	903.7
7. Leningrad Oblast	0.0	79.6	72.7	0.0	0.0	73.5	21.5	0.0	0.0	0.0	247.2
8. Novgorod Oblast	0.0	36.4	35.7	0.0	0.0	84.7	24.5	0.4	2.2	0.0	183.9
9. Pskov Oblast	0.0	30.7	10.5	0.0	0.0	41.5	10.5	0.1	5.4	0.0	98.7
10. Bryansk Oblast	0.0	22.7	5.1	0.0	0.0	13.3	5.3	3.0	3.8	0.0	53.3
11. Vladimir Oblast	0.0	35.8	5.0	0.0	0.0	19.3	4.7	1.9	0.3	0.0	67.0
12. Ivanovo Oblast	0.0	17.6	8.0	0.0	0.0	19.7	4.9	0.3	0.1	0.0	50.4
13. Tver' Oblast	0.0	54.8	50.3	0.0	0.0	85.8	23.1	0.0	3.3	0.0	217.3
14. Kaluga Oblast	0.0	9.8	10.5	0.0	0.0	29.4	13.8	3.7	0.6	0.0	67.7
15. Kostroma Oblast	0.0	52.8	42.9	0.0	0.0	97.2	16.4	0.0	0.0	0.0	209.2
16. Moscow Oblast	0.0	23.6	26.8	0.0	0.0	5.3	10.2	5.3	0.3	0.0	111.4
17. Orel Oblast	0.0	1.5	0.0	0.0	0.0	2.1	1.3	3.7	0.0	0.0	8.6
18. Ryazan' Oblast	0.0	19.4	0.9	0.0	0.0	14.0	4.5	10.0	0.2	0.0	49.0
19. Smolensk Oblast	0.0	6.4	17.3	0.0	0.0	38.2	12.2	0.4	2.0	0.0	76.3
20. Tula Oblast	0.0	0.8	0.4	0.0	0.0	3.3	3.2	6.6	1.6	0.0	15.8
21. Yaroslavl' Oblast	0.0	9.5	16.1	0.0	0.0	31.6	9.6	0.0	1.0	0.0	67.8
22. Nizhniy Novgorod Oblast	0.0	57.1	15.1	0.0	0.0	56.7	16.7	6.4	0.7	0.0	152.7
23. Kirov Oblast	0.0	76.2	108.4	0.0	0.0	106.0	26.6	0.1	0.9	0.0	318.2
24. Rep. of Mari El	0.0	18.6	6.7	0.0	0.0	19.4	4.3	2.0	0.4	0.0	51.3
25. Rep. of Mordvinia	0.0	10.8	0.5	0.0	0.0	8.9	3.3	5.0	1.7	0.0	30.2
26. Rep. of Chuvashia	0.0	7.2	0.3	0.0	0.0	6.7	2.8	5.9	3.6	0.0	26.5
27. Belgorod Oblast	0.0	1.1	0.0	0.0	0.0	0.3	0.3	15.1	0.0	0.0	16.8
28. Voronezh Oblast	0.0	5.3	0.0	0.0	0.0	0.5	1.0	13.6	0.0	0.0	20.4
29. Kursk Oblast	0.0	1.0	0.0	0.0	0.0	0.7	0.6	8.2	0.1	0.0	10.6
30. Lipetsk Oblast	0.0	5.4	0.0	0.0	0.0	0.7	0.8	3.5	0.0	0.0	10.4
31. Tambov Oblast	0.0	7.6	0.0	0.0	0.0	3.2	2.1	4.1	0.0	0.0	17.0
32. Astrakhan' Oblast	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.9	0.1	3.4
33. Volgograd Oblast	0.0	0.9	0.0	0.0	0.0	0.1	0.5	9.6	2.4	0.2	13.8
34. Samara Oblast	0.0	4.7	0.0	0.0	0.0	1.6	4.6	17.0	7.2	0.1	35.2
35. Penza Oblast	0.0	15.3	0.0	0.0	0.0	6.8	6.0	12.2	0.0	0.0	40.4
36. Saratov Oblast	0.0	1.4	0.0	0.0	0.0	0.7	1.8	14.3	1.7	0.1	19.8
37. Ul'yanovsk Oblast	0.0	21.6	0.0	0.0	0.0	10.0	6.8	9.7	0.0	0.0	48.1
38. Rep. of Kalmykia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1

Continued

Table 6.2–Continued

Administrative territory	*Larix* sp.	*Pinus sylvestris*	*Picea* sp.	*Pinus sibirica and koriensis*	*Abies* sp.	*Betula* sp.	*Populus tremula*	*Quercus* sp.	Other trees[a]	Bushes[b]	Total
39. Rep. of Tatarstan	0.0	9.2	1.3	0.0	0.0	8.2	10.0	11.4	11.8	0.0	52.0
40. Krasnodar Kray	0.0	0.9	0.0	0.0	10.7	0.1	2.7	76.1	55.9	6.4	152.8
41. Stavropol' Kray	0.0	4.9	2.1	0.0	4.3	4.3	2.0	2.7	15.0	0.1	35.3
42. Rostov Oblast	0.0	1.1	0.0	0.0	0.0	0.0	0.2	4.0	0.3	0.2	5.8
43. Rep. of Dagestan	0.0	3.7	0.0	0.0	0.0	0.8	0.2	6.1	9.3	0.1	20.1
44. Rep. of Kabardino-Balkaria	0.0	1.2	0.0	0.0	0.0	1.5	0.6	0.6	6.4	0.1	10.5
45. Rep. of North Osetia	0.0	0.2	0.0	0.0	0.0	0.0	0.8	0.6	13.6	0.0	15.3
46. Rep. of Checheno-Ingushetia	0.0	0.3	0.0	0.0	0.0	0.6	0.5	4.2	24.0	0.2	29.8
47. Kurgan Oblast	0.0	18.5	0.0	0.0	0.0	39.7	4.2	0.0	0.0	0.1	62.5
48. Orenburg Oblast	0.0	3.6	0.0	0.0	0.0	3.0	2.3	10.7	4.5	0.2	24.2
49. Perm' Oblast	0.0	47.3	269.1	0.3	5.5	122.1	24.0	0.0	2.6	0.0	471.0
50. Sverdlovsk Oblast	1.3	222.2	95.2	37.3	7.0	163.5	22.0	0.0	0.4	0.0	548.9
51. Chelyabinsk Oblast	1.4	32.4	7.5	0.0	3.0	58.0	7.6	2.0	5.6	0.0	117.5
52. Rep. of Bashkortostan	1.8	34.7	11.0	0.0	4.2	72.6	31.3	28.1	67.2	0.1	251.0
53. Rep. of Udmurtia	0.0	14.2	40.4	0.0	0.0	29.9	9.1	0.3	0.8	0.0	94.6
54. Altai Kray	67.0	88.5	2.6	38.7	28.8	51.3	30.4	0.0	0.0	0.9	308.2
55. Kemerovo Oblast	0.0	5.0	2.5	12.7	68.4	36.8	36.4	0.0	0.0	0.1	161.8
56. Novosibirsk Oblast	0.0	28.0	0.7	1.6	2.0	96.9	17.7	0.0	0.0	0.1	146.9
57. Omsk Oblast	0.0	21.6	3.7	9.8	2.1	117.8	28.0	0.0	0.0	0.0	183.0
58. Tomsk Oblast	0.0	188.2	23.0	192.6	24.6	280.8	85.3	0.0	0.0	0.0	794.6
59. Tyumen' Oblast	167.0	567.2	162.0	296.3	7.8	352.8	64.9	0.0	0.0	1.3	1,619.2
60. Krasnoyarsk Kray	1,782.7	609.4	337.6	578.4	326.3	518.3	98.3	0.0	0.0	3.9	4,254.9
61. Irkutsk Oblast	966.5	913.9	140.8	489.3	90.0	226.5	71.5	0.0	0.0	47.6	2,946.2
62. Chita Oblast	624.9	103.5	0.7	59.3	0.0	86.4	5.9	0.0	0.0	23.8	904.5
63. Rep. of Buryatia	394.7	154.1	5.7	93.3	11.3	32.3	12.4	0.0	0.0	28.4	732.3
64. Rep. of Tuva	193.6	5.7	2.0	104.3	0.0	9.4	1.0	0.0	0.0	0.6	316.5
65. Primor'ye Kray	58.3	0.0	137.6	138.5	12.0	61.7	27.4	193.5	1.9	0.8	631.7
66. Khabarovsk Kray	921.1	38.6	376.0	56.0	24.3	137.1	42.8	40.8	0.0	75.3	1,711.9
67. Amur Oblast	506.3	18.8	17.4	0.0	2.4	113.3	6.9	16.9	0.0	19.2	701.1
68. Kamtchatka Oblast	45.8	0.0	13.9	0.0	0.0	249.4	14.1	0.0	0.0	184.5	507.5
69. Magadan Oblast	136.7	0.0	0.0	0.0	0.0	0.6	0.0	0.0	13.6	60.0	211.0
70. Sakhalin Oblast	68.6	0.0	63.0	0.0	40.5	27.4	5.5	0.0	0.0	7.2	212.2
71. Rep. of Yakutia-Sakha	2,677.9	283.6	13.9	15.9	1.3	20.8	4.8	0.0	0.0	74.4	3,092.7
Total	8,629.7	4,690.3	3,511.9	2,125.1	681.7	4,110.9	975.2	566.0	276.2	536.2	26,103.3

[a]Includes tree species that comprise less than 0.5 percent of the total carbon in tree stands.
[b]Krummholz included with bushes.

Table 6.3.—Carbon storage (Mt) and density (t/ha) in vegetation of forest ecosystems of Russian administrative territories

Administrative territory	Carbon storage: Tree stands	Carbon storage: Understory	Total	Carbon density
1. Kaliningrad Oblast	15	1	16	59
2. Arkhangel’sk Oblast	772	101	874	40
3. Vologoda Oblast	428	16	445	44
4. Murmansk Oblast	71	25	96	19
5. Rep. of Karelia	248	22	270	30
6. Rep. of Komi	904	145	1,049	36
7. Leningrad Oblast	247	10	257	54
8. Novgorod Oblast	184	7	191	55
9. Pskov Oblast	99	5	104	48
10. Bryansk Oblast	53	3	56	51
11. Vladimir Oblast	67	3	71	48
12. Ivanov Oblast	50	2	53	51
13. Tver’ Oblast	217	10	228	55
14. Kaluga Oblast	68	1	69	53
15. Kostroma Oblast	209	12	222	51
16. Moscow Oblast	111	7	118	61
17. Orel Oblast	9	0	9	50
18. Ryazan’ Oblast	49	2	51	51
19. Smolensk Oblast	76	4	80	42
20. Tula Oblast	16	0	16	48
21. Yaroslavl’ Oblast	68	5	72	45
22. Nizhniy Novgorod Oblast	153	9	161	46
23. Kirov Oblast	318	20	338	46
24. Rep. of Mari El	51	3	55	44
25. Rep. of Mordvinia	30	1	32	48
26. Rep. of Chuvashia	27	2	28	50
28. Voronezh Oblast	20	1	21	51
28. Voronezh Oblast	20	1	21	51
29. Kursk Oblast	11	1	11	49
30. Lipetsk Oblast	10	0	11	57
31. Tambov Oblast	17	1	18	48
32. Astrakhan’ Oblast	3	0	3	38
33. Volgograd Oblast	14	0	14	30
34. Samara Oblast	35	1	36	53
35. Penza Oblast	40	2	42	48
36. Saratov Oblast	20	1	21	37
37. Ul’yanovsk Oblast	48	2	50	52
38. Rep. of Kalmykia	0	0	0	15
39. Rep. of Tatarstan	52	3	55	49
40. Krasnodar Kray	153	8	160	94
41. Stavropol’ Kray	35	1	37	71
42. Rostov Oblast	6	0	6	20
43. Rep. of Dagestan	20	1	21	54
44. Rep. of Kabardino-Balkaria	10	0	11	62
45. Rep. of North Osetia	15	0	16	84
46. Rep. of Checheno-Ingushetia	30	1	31	84
47. Kurgan Oblast	62	1	63	41
48. Orenburg Oblast	24	1	25	47

Continued

Table 6.3—Continued

Administrative territory	Carbon storage			Carbon density
	Tree stands	Understory	Total	
49. Perm' Oblast	471	29	500	45
50. Sverdlovsk Oblast	549	28	577	45
51. Chelyabinsk Oblast	118	4	121	49
52. Rep. of Bashkortostan	251	11	262	48
53. Rep. of Udmurtia	95	4	99	52
54. Altai Kray	308	15	323	44
55. Kemerov Oblast	162	13	175	31
56. Novosibirsk Oblast	147	5	152	36
57. Omsk Oblast	183	5	188	43
58. Tomsk Oblast	795	31	825	44
59. Tyumen' Oblast	1,619	117	1,737	35
60. Krasnoyarsk Kray	4,255	246	4,501	39
61. Irkutsk Oblast	2,946	101	3,047	52
62. Chita Oblast	904	40	945	33
63. Rep. of Buryatia	732	29	762	34
64. Rep. of Tuva	316	16	332	41
65. Primor'ye Kray	632	36	667	53
66. Khabarovsk Kray	1,712	136	1,848	37
67. Amur Oblast	701	45	746	33
68. Kamtchatka Oblast	508	63	570	29
69. Magadan Oblast	211	82	293	13
70. Sakhalin Oblast	212	17	229	41
71. Rep. of Yakutia (Sakha)	3,093	359	3,451	23
Total	26,103	1,877	27,980	36

Table 6.4.—Carbon storage and density of forest vegetation in ecoregions of Russia

Ecoregion	European Russia		Asian Russia: Western Siberia		Asian Russia: Middle Siberia		Asian Russia: Eastern Siberia and Yakutia		Asian Russia: Far East		Total	
	Storage	Density	Storage	Density	Storage	Density	Storage	Density	Storage	Density	Storage	Density
	Gt	t/ha	Gt	t/ha	Gt	t/ha	Gt	t/ha	Gt	t/ha	Gt	t/ha
Plains												
Forest-tundra zone	0.04	12	0.14	12	0.41	15	0.00	0	0.00	0	0.59	14
Boreal zone												
Northern taiga subzone	0.99	28	0.66	32	0.79	24	0.00	0	0.00	0	2.43	27
Middle taiga subzone	1.60	43	1.75	42	1.09	45	1.95	29	0.00	0	6.39	37
Southern taiga subzone	1.70	48	1.50	50	1.55	62	0.00	0	0.00	0	4.75	52
Mixed forests subzone	0.64	49	0.00	0	0.00	0	0.00	0	0.00	0	0.64	49
Forest-steppe zone	0.49	51	0.34	50	0.17	43	0.00	0	0.20	34	1.20	46
Steppe zone	0.06	36	0.07	40	0.00	0	0.00	0	0.00	0	0.13	38
Desert zone	0.01	36	0.00	0	0.00	0	0.00	0	0.00	0	0.01	36
Subtotal	5.53	40	4.46	39	4.01	35	1.95	29	0.20	34	16.14	37
Mountains												
Subarctic zone	0.00	10	0.00	0	0.13	15	0.67	17	0.25	14	1.05	16
Boreal zone	0.37	46	0.00	0	0.89	39	1.78	28	2.33	37	5.37	34
Subboreal zone	0.28	48	0.00	0	2.29	50	1.14	43	1.32	49	5.04	48
Subboreal (Caucasus)	0.27	82	0.00	0	0.00	0	0.00	0	0.00	0	0.27	82
Subarid zone	0.00	0	0.00	0	0.10	39	0.00	0	0.00	0	0.10	39
Subtotal	0.92	53	0.00	0	3.41	43	3.59	28	3.90	36	11.83	35
Total	6.45	42	4.46	39	7.42	39	5.54	29	4.10	36	27.97	36

Table 6.5.—Carbon storage (Mt) for vegetation of unstocked areas in administrative territories of Russia

Administrative territory	Open plantations	Unstocked area: Clearcuts	Burned and dead stands	Woodlands	Waste areas	Total
1. Kaliningrad Oblast	0.03	--	--	--	--	0.03
2. Arkhangel'sk Oblast	2.57	3.66	0.18	0.02	0.08	6.51
3. Vologda Oblast	0.36	0.23	--	--	--	0.59
4. Murmansk Oblast	0.20	0.91	0.08	0.18	--	1.37
5. Rep. of Karelia	1.52	0.93	0.04	0.04	0.01	2.54
6. Rep. of Komi	1.38	3.33	0.07	0.07	0.03	4.88
7. Leningrad Oblast	0.39	0.10	0.01	--	0.01	0.51
8. Novgorod Oblast	0.18	0.06	--	--	--	0.24
9. Pskov Oblast	0.13	0.03	--	--	--	0.16
10. Bryansk Oblast	0.10	0.03	--	--	--	0.13
11. Vladimir Oblast	0.18	0.05	--	--	0.01	0.24
12. Ivanov Oblast	0.14	0.05	--	--	0.01	0.20
13. Tver' Oblast	0.26	0.09	0.03	--	0.01	0.39
14. Kaluga Oblast	0.03	0.01	--	--	0.01	0.05
15. Kostroma Oblast	0.45	0.21	0.01	0.01	0.02	0.70
16. Moscow Oblast	0.19	0.04	--	0.01	0.01	0.25
17. Orel Oblast	0.02	--	--	--	--	0.02
18. Ryazan' Oblast	0.09	0.03	--	--	0.01	0.13
19. Smolensk Oblast	0.11	0.01	--	--	--	0.12
20. Tula Oblast	0.03	--	--	--	--	0.03
21. Yaroslavl' Oblast	0.17	0.03	0.01	--	0.01	0.22
22. Nizhniy Novgorod Oblast	0.47	0.10	0.01	0.01	0.02	0.61
23. Kirov Oblast	0.86	0.50	0.01	0.02	0.01	1.40
24. Rep. of Mari El	0.10	0.06	0.01	--	--	0.17
25. Rep. of Mordvina	0.08	0.04	--	--	--	0.12
26. Rep. of Chuvashia	0.14	0.04	--	0.01	--	0.19
27. Belgorod Oblast	0.04	--	--	--	--	0.04
28. Voronezh Oblast	0.09	0.02	--	0.01	0.01	0.13
29. Kursk Oblast	0.04	--	--	--	--	0.04
30. Lipetsk Oblast	0.02	--	--	--	--	0.02
31. Tambov Oblast	0.01	0.01	--	0.01	--	0.03
32. Astrakhan' Oblast	0.05	--	--	0.01	0.02	0.08
33. Volgograd Oblast	0.03	0.01	--	0.02	0.08	0.14
34. Samara Oblast	0.03	0.01	--	0.02	0.02	0.08
35. Penza Oblast	0.12	0.03	--	--	0.01	0.16
36. Saratov Oblast	0.04	0.01	--	0.01	0.03	0.09
37. Ul'yanovsk Oblast	0.17	0.04	--	--	0.01	0.22
38. Rep. of Kalmykia	--	--	--	--	0.02	0.02
39. Rep. of Tatarstan	0.25	0.05	0.02	0.05	0.01	0.38
40. Krasnodar Kray	0.18	0.06	--	0.02	0.02	0.28
41. Stavropol' Kray	0.02	--	--	0.01	0.02	0.05
42. Rostov Oblast	0.03	--	--	0.01	0.02	0.06
43. Rep. of Dagestan	0.02	--	--	0.04	0.01	0.07
44. Rep. of Kabardino-Balkaria	0.01	--	--	0.02	--	0.03
45. Rep. of North Osetia	--	--	--	0.02	--	0.02
46. Rep. of Checheno-Ingushetia	0.02	--	--	0.02	0.01	0.05
47. Kurgan Oblast	0.04	0.01	--	0.01	0.02	0.08
48. Orenburg Oblast	0.05	0.01	--	0.02	0.04	0.12

Continued

Table 6.5—Continued

Administrative territory	Open plantations	Unstocked area: Clearcuts	Unstocked area: Burned and dead stands	Unstocked area: Woodlands	Unstocked area: Waste areas	Total
49. Perm' Oblast	1.10	1.01	0.02	0.10	0.03	2.26
50. Sverdlovsk Oblast	0.70	0.76	0.09	0.06	0.02	1.63
51. Chelyabinsk Oblast	0.20	0.08	--	0.14	0.06	0.48
52. Rep. of Bashkortostan	0.40	0.14	0.03	0.08	0.02	0.67
53. Rep. of Udmurtia	0.25	0.10	--	--	0.01	0.36
54. Altai Kray	0.36	0.17	0.09	1.73	0.05	2.40
55. Kemerov Oblast	0.44	0.17	0.01	0.27	0.03	0.92
56. Novosibirsk Oblast	0.04	0.05	0.06	0.29	0.03	0.47
57. Omsk Oblast	0.08	0.04	0.01	0.08	0.01	0.22
58. Tomsk Oblast	0.26	0.46	0.50	0.32	0.07	1.61
59. Tyumen' Oblast	0.42	1.33	1.66	17.53	0.30	21.24
60. Krasnoyarsk Kray	0.77	2.07	7.41	45.09	0.32	55.66
61. Irkutsk Oblast	0.71	1.39	8.42	12.39	0.79	23.70
62. Chita Oblast	0.12	0.29	1.10	5.46	0.11	7.08
63. Rep. of Buryatia	0.12	0.26	0.56	4.48	0.02	5.44
64. Rep. of Tuva	0.02	0.04	0.46	2.26	0.07	2.85
65. Primor'ye Kray	0.05	0.10	0.59	1.00	0.18	1.92
66. Khabarovsk Kray	0.65	2.62	10.25	25.31	0.72	39.55
67. Amur Oblast	0.14	1.35	1.46	12.26	0.92	16.13
68. Kamtchatka Oblast	0.24	0.24	0.04	5.41	0.55	6.48
69. Magadan Oblast	0.16	0.36	12.59	117.97	0.15	131.23
70. Sakhalin Oblast	0.35	1.04	1.11	1.45	0.28	4.23
71. Rep. of Yakutia (Sakha)	0.01	2.08	22.97	255.94	1.73	282.73
Total	19.03	26.95	69.91	510.29	7.07	633.25

Chapter 7. Soil Rockiness in Russian Forests

V.A. Alexeyev and I.A. Korotkov

Often overlooked in calculating the carbon content of soils is that a part of the soil-layer volume is occupied by stony inclusions, either carbon free or containing mineral carbonate. Calculations are made for fine earth, the "soil proper." Estimates that account for soil rockiness are the exception rather than the rule.

For arable lands, the corrections for stone inclusions usually are less than the errors for the mosaic structure of soil conditions, and generally are not significant. But the situation is different on forest lands. Forests grow both on deep drained or swampy soils with little stony content, and on rocky soils with little fine earth. In the first case, a correction for soil rockiness is not necessary, but in the second it may be necessary to accurately estimate the actual storage of carbon accumulated by the soil. When the content of hard inclusions (gravel, cobble, stones, rock detritus) in the soil surpasses 30 percent of the soil volume, it is presumed to affect forest productivity (Kazimirov 1993).

Soil rockiness depends on the depth of soil-forming rocks and the intensity of the physical, chemical, and biological breaking and transformation into fine earth. On the European Plain, soils that have formed on the glacial deposits are abundant in boulders**.** Rockiness is high (50 to 60 percent) in some parts of the northern and middle taiga. In the vast plains of Western Siberia and Central Yakutia, glaciation was not continuous and warming was not accompanied by bouldered till deposits. The thawing glaciers deposited only fluvioglacial sands.

Soil rockiness is highest in the mountains. In the Northern, Middle, and Southern Urals, rockiness is at least 60 percent (Firsova and Dedkov 1983). Rockiness is even higher in the upper belts of Caucasus, Putoran, Magadan, and other regions where the fine earth layer is thin.

The apparent significance of soil rockiness led us to make an expert estimation of rockiness in forest soils. After 35 to 40 years of field work, we have formed an opinion about the parameters of the indices under consideration in different parts of the country. These ideas formed the basis of Table 7.1 (vegetation ecoregions) and Table 7.2 (administrative units).

Soil rockiness in the tables is rounded to 10 percent. In many cases, the values are reduced somewhat. For some regions of European Russia and parts of Siberia, values of less than 20 percent are not presented because of the uncertainty of expert estimations and difficulty in determining average values for large areas.

By introducing the rockiness index and seeking to improve the estimates of the carbon stock in soils, we hope to focus attention on the need for more representative data on forest soils. The given data should be considered as the first approximation of the actual situation.

Appropriate corrections also should be made for estimates of forest litter and coarse woody debris. Soil scientists, particularly those interested in soil genesis, study mostly undamaged soils with no trace of recent fires or other natural or anthropogenic stresses. Meanwhile, vast areas of forests in many regions of Russia are regularly subjected to fires after which 12 to 92 percent of the debris layer burns out (Furyaev 1975; Valendik and Isakov, 1978; Popova 1982). In the southern parts of the country where debris decomposes intensively and the carbon storage of the forest litter is minimal, these losses are quickly replenished and do not affect the quantitative characteristic of the litter. In the northern forests, particularly those in the cryolithic zone, replenishment of losses due to fires extends over many years. As a result, estimates of carbon stock from accounts of mostly undamaged forest floor are overrated. Also contributing to reductions in the litter storage are different kinds of damage to the forest canopy that, in turn, might affect the amount of litter and debris. Intensive grazing in sparsely wooded regions also damages the forest floor and could reduce its carbon density.

Table 7.1.—Percent rockiness of forest soils in ecoregions of Russia[a]

Ecoregion	Rockiness in soil layers	
	0-20 cm	20-50 cm
4. Northern Kola forest province	20	40
5. Kola-Karelian forest province		
5.1. Northern taiga district	20	40
5.2. Middle taiga district	10	30
6. Western Dvina forest province		
6.1. Southern taiga district	10	20
10. Great Caucasus forest province	20	50
15. Kaninsk-Pechorsk forest province	10	30
16. Dvina-Pechorsk-Upper-Volga forest province		
16.1. Northern taiga district	20	40
16.2. Middle taiga district	10	20
16.3. Southern taiga district	--	20
19. Northern Ural forest province	30	70
20. Middle Ural forest province	20	70
21. Southern Ural forest province	20	70
26. Northern Altai-Sayan forest province	30	50
27. Eastern-Sayan forest province	30	50
28. Central-Altay forest province	30	50
29. Western-Altay forest province	30	50
30. Eastern Tuva forest province	30	50
31. Khakass-Minusinsk forest province	10	30
32. Salair-Kuznetsk forest province	10	30
33. Putoran forest province	50	70
34. Anabar forest province	50	70
35. Near-Enisey forest province	20	40
36. Khetsk-Kotui-Olenek forest tundra forest province	20	40
37. Angara-Tunguska forest province		
37.1. Lower Tunguska northern taiga district	20	50
37.2. Stony Tunguska middle taiga district	10	30
37.3. Angara southern taiga district	--	20
40. Upper Lena forest province	30	50
41. Lena-Vilyui forest province	--	10
42. Aldan forest province	10	20
43+44+45. Yana-Kolyma Subarctic FVA	40	70
46. Vitim-Olekma tableland forest province	30	60
47. Baikal-Stanovoi forest province	30	60
48. Uchur-Maisk forest province	30	60
49. Jiddin forest province	30	50
50. Selenga forest province	--	10
51. Chikoi-Ingodin forest province	30	50
52. Dahurian forest province	20	40
53. Near-Baikal forest province	30	50
54+55. Magadan and Penzhin-Anadyr forest province	50	70
56. Kamtchatka forest province	20	40
57. Zeya-Uda forest province	20	50
58. Amgun-Selenjin forest province	20	40
59. Sikhote-Alin forest province		
59.1. Sikhote-Alin district	30	50
59.2. Ussuri-Primorye district	10	40
60. Sakhalin-Kurily forest province	30	60
73. Southern-Altai-Tuva forest province	20	50

[a]Includes only ecoregions with rockiness of 10 percent or more.

Table 7.2.—Percent rockiness of forest soils in administrative territories of Russia[a]

Administrative territory	Rockiness (%) in soil layers	
	0-20 cm	20-50 cm
2. Arkhangel’sk Oblast	20	30
3. Vologoda Oblast	10	20
4. Murmansk Oblast	20	50
5. Rep. of Karelia	10	30
6. Rep. of Komi	10	20
7. Leningrad Oblast	--	20
8. Novgorod Oblast	--	20
9. Pskov Oblast	10	20
40. Krasnodar Kray	20	50
41. Stavropol’ Kray	20	50
43. Rep. of Dagestan	50	70
44. Rep. of Kabardino-Balkaria	50	70
45. Rep. of North Osetia	50	70
46. Rep. of Checheno-Ingushetia	50	70
49. Perm’ Oblast	10	30
50. Sverdlovsk Oblast	20	40
51. Chelyabinsk Oblast	20	40
52. Rep. of Bashkortostan	10	40
54. Altai Kray	20	40
55. Kemerov Oblast	20	40
59. Tyumen’ Oblast	--	10
60. Krasnoyarsk Kray	20	50
61. Irkutsk Oblast	30	50
62. Chita Oblast	20	50
63. Rep. of Buryatia	20	50
64. Rep. of Tuva	30	50
65. Primor’ye Kray	10	40
66. Khabarovsk Kray	20	40
67. Amur Oblast	20	40
68. Kamtchatka Oblast	20	40
69. Magadan Oblast	40	70
70. Sakhalin Oblast	30	60
71. Rep. of Yakutia (Sakha)	20	50

[a]Includes only territories with rockiness of 10 percent or more.

Chapter 8. Organic Carbon Storage in Soils of Russian Forests

L.S. Shugalei, E.P. Popova, and V.A. Alexeyev

This chapter constitutes the first generalization of carbon storage in the forest soils of Russia. Two published works (Bolotina 1947; Kononova 1963) included estimates of carbon and nitrogen storage in arable soils.

8.1 Methodology for Estimating Carbon Storage in Soils

The stock of organic matter in the Russian forests soils has been estimated on the basis of regional data published by Russian pedologists because: 1) soil scientists estimate the qualitative composition of the organic matter, volume mass, and texture by unified techniques; 2) the dominant classes of soil in each administrative territory can be identified with published data; and 3) most studies of soil genesis include detailed descriptions of the morphological composition of soil profiles and data on soil texture.

The storage of organic matter and carbon in forest soils has been evaluated separately for the forest floor and for soil depths of 0 to 20, 0 to 50, 0 to 100, and 100+ cm, which is determined by the following:

- A considerable portion of carbon in the forest floor is closely related to the mineral topsoil.

- A major portion of plant roots, particularly physiologically active roots, is concentrated in organic and mineral topsoil at depths of 10 to 20 cm.

- Soil-formation processes (humus formation and infiltration, soil solution migration, thixotropy, movement of soil mass, fracturing, etc.) are most active in the upper 50-cm layer even in shallow northern and mountain soils.

- Meadow-chernozem, podzolic, soddy-podzolic, grey forest soils with the second humus horizon, and gleyed genera of other soil types have deep humus profiles that can exceed 100 cm.

In some cases, the carbon content of soils has been determined by expert estimations. When necessary, carbon storage of the litter has been calculated using its thickness, which always is indicated in morphological description of soil profiles. The estimated density of absolutely dry matter of peaty forest floor is 0.20 to 0.24 g/cm^3 versus 0.05 to 0.10 g/cm^3 for the litter of moss forest types, and 0.02 to 0.50 g/cm^3 for the herb forest type. Lacking specific data on the carbon content in litters, we used data averaged from losses resulting from ignition (0.5). The estimated conversion coefficient of humus to carbon is 0.579 (Arinushkina 1970).

Because humus (carbon) has been evaluated over genetic horizons in most works, the interpolation has been done for the estimation of the carbon density in the 0- to 50-cm soil column. If the source of information did not contain data on soil density we used our own average values for soils of different texture (Table 8.1).

Soil scientists calculate the storage of chemical elements and organic matter per unit of soil volume from their content in fine earth without correcting for soil rockiness. However, a considerable portion of forests grows on stony soils where the stone fraction may be greater than the fine earth fraction. Ignoring this fact would lead to biased estimates. Therefore, in our calculations of carbon, we accounted for soil rockiness as outlined in Chapter 7.

In the absence of published information on forest soils of some administrative territories or ecoregions, we prepared approximate averaged data calculated for forest soils placed in 22 groups (Appendix Table 21). They were unified primarily by soil type and subtype, taking into account ecological conditions, storage, and qualitative composition of the organic matter. We placed the brown and dark-grey soils of the Caucasus Mountains in one group. The meadow-chernozem soils include chernozem-like soils of larch stands of Altai and Kuznetsk Ala Tau.

Carbon in unstocked and nonforest soils has been evaluated by the same approach used for stocked lands. Because of specific characteristics of these areas, some changes in the methods have been made. It was considered that forest nurseries and estate lands have the most fertile soils; forest litter storage has been reduced by 30 percent on clearcutting areas and by 50 percent on burned areas.

8.2 Territorial Distribution of Carbon Storage in Forest Soils of Natural Ecoregions

The territorial distribution of carbon density in soils in forest provinces of Russia is shown in Table 8.2. The estimated carbon storage in the mineral part of forest soils is 74.0 Gt; the estimated carbon storage in litter is 3.5 Gt (Tables 8.2 through 8.4). The average density of carbon excluding the litter is 96 t/ha versus 113 t/ha when litter is included.

The accumulation of carbon by forest soils is determined by the general processes of soil formation within geographic zones. Maximum carbon was recorded in the soil cover of the forest-steppe; minimum carbon was reported in dry steppe provinces and districts (Tables 8.2 through 8.4). The carbon density per unit area is similar for forest-tundra, taiga, and mixed forests, the primary differences being in the qualitative state of carbon, degree of organic-matter transformations, and distribution of organic matter in the soil profile.

Forest-Tundra

Carbon density typically is lowest for forest-tundra in the European part of the country and highest for forest-tundra of Western Siberia (Table 8.4). These differences are due to the climate, lithology, and geomorphology of the territory.

The light texture and gravel content of the soil-forming bedrock and the relatively mild climatic conditions of the Murmansk Coast result in more intense decomposition of litterfall than in Siberian forest-tundras. The spotty distribution of perennial permafrost stimulates illuvial processes. As a result of these processes, along with surface-gleyed peat soils in this region, there also are distributed tundra-illuival-humus podsols.

The tundra soils of Western Siberia are formed over a thick mass of loose quaternary depositions of the vast, poorly drained, Western Siberian lowland. Permanent excessive moisture, the general distribution of permafrost, and a continental climate help accumulate poorly transformed organic remnants in the form of peaty litter and coarse humus. Carbon accumulation in the soil profile is twice as large as in the soils of western forest-tundra.

The tundra soils of the Northern Siberian lowland in Middle Siberia formed under the most continental climate conditions. Ancient permafrost here is continuous and 400 to 600 m deep. Soil-formation processes take place only in the shallow surface layer during melting in the short summer period.

Climate continentality, lithological, and geomorphological conditions drastically decreased the swampiness of the territory compared with Western Siberian and European forest-tundra. Along with primitive and dry peaty soils, these conditions form tundra-gley illuvial-humus soils which are saturated with mobile humus compounds. The lower horizons of these soils are frequently above the cryogenic-accumulative horizons. Carbon storage in the soil profile of the Middle Siberian forest-tundra is 1.5 times greater than in the European forest tundra, but lower than in the Western Siberian forest-tundra.

Forest-tundra soils have the following features with respect to carbon accumulation: 1) retarded transformation of litterfall and its accumulation as mortmass and humus-accumulative or coarse-humus horizons, 2) shortened profile due to restricted vertical transfer of products of organic matter transformation beyond its limits, and 3) carbon density within a range of 35 to 100 t/ha.

Boreal Forests

The subzone of the northern taiga in the European part of Russia has considerable litter (Tables 8.2 and 8.3) that is promoted by higher (compared to forest-tundra) productivity and low biological activity of soils.

Warmth and better drainage southward increase the forest productivity and intensity of biological turnover. Therefore, carbon density of litter and the mineral horizons of soils in the middle and southern taiga are lower than in the northern taiga (Table 8.4). A reduction in carbon storage is partly the result of weak fixation of organic matter in sandy soils, which are distributed widely. The carbon density of the soil profile in the soil cover of the Western Siberian forests is 1.5 to 3 times greater due to the waterlogged lowland territory and restricted vertical discharge beyond the soil-profile limits. The carbon storage of litter decreases from the northern taiga to the southern (Table 8.3), while in the mineral profile it increases in the same sequence (Table 8.4). This classic distribution of carbon in the soil cover is due to the flat orographic structure of Western Siberia.

In the taiga zone of Middle Siberia, which is distinct in the continentality of its climate and the general permafrost and eluvial-deluvial deposits of bedrocks, the territory is much less swampy compared with Western Siberia. The density of soil carbon in the northern taiga is 1.7 times lower than in Western Siberia, but similar in the middle and southern taiga. Yet the soils of Western Siberia have an extended humus profile that is typical for northern and middle taiga soils. Such a distribution of humus in the soil profile is due to permafrost, which promotes humus retention in the above-permafrost horizon.

The accumulation of cryogenic humus is important in the formation of cryogenic-pale-yellow soils of the Yakutian southern taiga; 76 percent of the carbon in the soil profile is concentrated in the 0- to 20-cm layer.

The distribution of carbon storage in the forest floor of the taiga zone in Middle and Eastern Siberia shows no distinct patterns (Table 8.3), probably the consequence of frequent fires.

The organic matter in some Siberian soils is higher than in their western counterparts, a phenomenon noted by Blagoveshchenskiy (1913), Nikiforov (1914), and Turkevich (1914). The primary reasons for this are the increasing continentality of the climate eastward and northward of the Urals and the general distribution of permafrost: ancient, perennial, or long seasonal. In spring, the frozen layer acts as a barrier for thaw waters that form surface flows. Thus, annual washing out of water-soluble components of the organic matter beyond the limits of the soil profile is limited over vast territories. The heavy texture and excessive moisture content of soil horizons in spring and early summer helps develop gleying processes in taiga zone soils and meadow formation in forest-steppe zone soils. A low heat supply in Siberian soils reduces the period of intensive biological activity, resulting in passive mineralization of vegetation remnants and accumulation in the north of considerable mortmass both in the litter and upper layers of the soil profile.

Parts of the boreal zone are distinct in soil-formation processes, patterns of soil-cover structure, and component texture (Chertov 1981; Grishina 1986; Korsunov and Krasekha 1990). However, its vast territory demonstrates common features of organic matter deposited in the soils. Typical features of soils in the boreal zone include: 1) coarse humus and various intermediate forms of humus-illuvial, and incompletely developed accumulative profiles, 2) poor humification of the organic matter, and 3) overlapping of maximum and minimum carbon density in different taiga subzones: density ranges from 40 to 100 t/ha in the northern taiga and 40 to 140 t/ha in the middle and southern taiga.

Forest-Steppe

The forest-steppe soils of the western part of Russia, Siberia, and the Far East have maximum carbon storage (Table 8.4), the major portion of which is accumulated in the mineral horizons (Table 8.2). This accumulation is due to the high productivity of vegetation and the equilibrated processes of mineralization and humification of incoming organic matter.

In Western and Middle Siberia, many forests are on meadow-chernozem soils, accounting for as much as 20 percent of the soil cover. Because of the considerable contribution of meadow-chernozem soils to the formation of soil cover in forest-steppes, average carbon density is more than twice that in the forest soils of the European forest-steppe.

Soil formation in the Amur Basin area depends on low precipitation in winter, which results in a thin snow layer and deep freezing and long thawing of soils. Excess moisture in spring delays the transformation of litterfall and promotes the formation of soils with extended humus profiles (brown soils of the plains and meadow-chernozem soils). The high carbon density in the soil profile of the forest-steppe is due to the prevalence of these soils.

Soils of forest-steppes have an extended humus profile, medium and high humification of organic matter, and high carbon density (90 to 170 t/ha).

Subarid and Arid Territories

Carbon density of forest soils is minimal in dry steppes and deserts. Forest massifs in steppes grow on sandy deposits and have low productivity. The organic-matter input from the litterfall quickly decomposes in autumn and spring. The bulk of organic matter mineralizes and the humified organic matter is not fixed efficiently by bedrocks of light texture.

In dry steppes, forest soils are noted for an extended humus profile, high humification of organic remnants, and a carbon density of 40 to 70 t/ha.

The primary patterns of the succession of vegetation and soil cover in the mountains are similar to those in the plains. Carbon density in mountain soils of the European part of Russia is about 1.5 times greater than in mountain soils of Asia due to more favorable climatic conditions and better disintegration and grading of the soil-forming bedrocks of the Urals and Caucasus compared to the Altai, Sayan, Transbaikal, and Far Eastern Mountains.

8.3 Carbon Storage in Forest Soils of Administrative Territories

The distribution of soil carbon storage for administrative units (Table 8.5) is determined primarily by the size of the territory and do not reflect natural peculiarities. Differences in the boundaries of ecoregions and administrative units make it difficult to calculate carbon storage in the latter. In addition to the averaging done for the natural regions, it also is necessary to average the data for soils of different types. While the zonal nature of carbon accumulation by the soils can be clearly traced with respect to forest classification, the average of carbon (t/ha) with respect to administrative units of Russia involving different natural regions is evened substantially (Table 8.5). Several examples follow.

The average carbon content in the soils under forests of Tyumen Oblast is lower than the average density in the dominant podzol soils due to the considerable area of tundra soils. Although the soil cover of the Krasnoyarsk Kray is highly diverse, a major portion of the forest territory is occupied by cryogenic-taiga and podzol soils, which determine total carbon storage in the soil cover of the Kray even though high-yield soddy, gray, and dark-gray soils are dominant in the subtaiga and forest-steppe part of the territory. Cryogenic-taiga soils are dominant in the mountain territory of Khabarovsk; they reduce average carbon accumulation despite a considerable area of alpha-humus and brown soils. Average carbon density in the forest soils of the Altai Kray is low due to low storage of organic matter in the soils of the intermittent pine and birch forests (“kolki”) of the Kulunda, which occupy a considerable area (1.46 million ha).

Carbon content in the soil cover of nonstocked and nonforest soils of the forest sector of Russia is somewhat lower than in forested areas. From the “Regulations for the National Inventory in the Forest Fund of the U.S.S.R.” (Anonymous 1986) it follows that the list of these categories includes more than 20 types of land. To estimate carbon storage in these areas with respect to each administrative unit requires additional research. We estimated only the total approximate values of carbon storage (Table 8.6).

8.4 Uncertainties and Errors

The absence of clearly defined criteria for separating taxonometric units of soils, incomplete data on soil composition in some ecoregions, and absence of data on volume density, soil rockiness, thickness, density, and chemical composition of the forest floor in most studies made it difficult to interpret the vast amount of material accumulated in several decades of genetic-geographic research on the humus state of soils. We used interpolation and analogy, which affect the accuracy of calculations.

Also, little is known about the soil cover of the Asian part of Russia. Most studies are concerned with the agricultural zone so only portions of the vast regions to the north of Tyumen Oblast, Krasnoyarsk Kray, and Republic of Yakutia (Sakha) have been investigated. Data on humus content in soils of the same type can differ widely from author to author.

Finally, calculation of carbon, oxides, and salt storage at depths of 0 to 20 and 0 to 50 cm on the basis of averaged density is more prominent for arable soils where the density and content of chemical elements are comparatively uniform throughout the profile. In virgin forest soils, soddy and accumulative horizons frequently differ in thickness and carbon content. In this case, averaged values can distort the true estimate considerably.

Table 8.1.—Density (g/cm^3) of forest soils[a]

Texture	Depth	Number of samples	Range	Weighted mean	Error of mean	δ	Percent variance
	cm						
Sand	0-20	16	1.51-1.29	1.35	0.01	0.06	4
	0-50	16	1.59-1.36	1.46	0.01	0.06	4
Sandy soil	0-20	32	1.44-0.74	1.17	0.03	0.17	14
	0-50	32	1.56-1.02	1.34	0.02	0.13	10
Loamy soil	0-20	119	1.37-0.59	1.08	0.01	0.17	16
	0-50	119	1.46-0.66	1.24	0.02	0.18	14
Clay	0-20	157	1.40-0.94	1.22	0.01	0.10	8
	0-50	157	1.51-1.16	1.34	0.01	0.08	6

[a]From Veredchenko 1961; Zonn et al. 1963; Orfanitskiy 1963; Fridland 1966a,b; Firsova 1969; Orfanitskiy and Orfanitskaya 1971; Sokolov and Ivanitskaya 1971; Koval' and Bityukov 1973; Shumakov 1973; Korsunov 1974; Taranov 1974; Voronkova 1975; Il'inskiy and Tupikov 1975; Rassypnov 1975; Trofimov 1975; Shakirov and Shishkina 1975; Shumakov and Kuraev 1975; Gorbachev 1978; Karpachevskiy 1977; Karetin and Gorin 1978; Kovaleva 1978; Chashchina and Landina 1978; Dugarov 1979; Erupov and Vlaskova 1979; Ignatenko 1979; Korableva 1979; Shugalei 1979; Tanzybaev 1979; Vedrova 1980; Zueva 1980; Rusanova et al. 1980; Aparin 1981; Rudneva 1981; Gorbachev et al. 1982; Karavaeva 1982; Karpachevskiy et al.1982; Nosova and Gel'tser 1982; Kholopova 1982; Shugalei and Dmitrienko 1982; Shugalei 1991; Yashikhin 1991.

Table 8.2.—Average (t/ha) and total carbon (Mt) in soils (depth in cm) of forest ecosystems in ecoregions of Russia[a]

Ecoregion	Average carbon				Total carbon			
	Litter	0-20 cm	0-50 cm	0-100 cm	Litter	0-20 cm	0-50 cm	0-100 cm
	Middle European Plain Forest Oblast of Boreal Zone							
1. Baltic forest province	12	68	92	100	3.2	18.2	24.0	27.0
	Kola-Karelian Tableland Forest Oblast of Boreal Zone							
4. Northern Kola forest province	28	46	55	60	30.7	47.7	57.1	62.8
5. Kola-Karelian forest province								
5.1. Northern taiga district	29	43	72	79	278.4	415.6	695.9	765.5
5.2. Middle taiga district	18	44	69	78	65.2	157.5	250.0	283.0
	Dnieper-Baltic Plain Forest Oblast of Boreal and Subboreal Zone							
6. Western Dvina forest province								
6.1. Southern taiga district	14	35	58	69	138.2	361.2	598.6	718.3
6.2. Mixed (subtaiga) forest district	9	39	58	70	17.1	74.0	110.4	132.5
	Caucasian Mountain Forest Oblast of Subboreal Zone							
10. Great Caucasus forest province	3	83	127	152	9.9	273.7	418.8	502.6
	Eastern European Plain Forest Oblast of Boreal and Subboreal Zones							
15. Kaninsk-Pechorsk forest province	24	44	61	67	56.4	103.5	143.4	157.7
16. Dvina-Pechorsk-Upper-Volga forest province								
16.1. Northern taiga district	30	51	67	74	875.4	1335.3	1754.2	1929.6
16.2. Middle taiga district	26	40	53	64	874.7	1345.7	1783.0	2139.6
16.3. Southern taiga district	13	26	39	47	328.6	657.2	985.8	1183.0
16.4. Mixed (subtaiga) forest district	10	45	67	80	109.6	493.3	734.5	881.4
17. Middle Russian forest province (forest -steppe)	8	52	87	104	76.4	496.6	830.8	997.0
18. Volga-Don Steppe forest province	1	40	75	90	1.8	70.2	131.7	158.0

Continued

Table 8.2—Continued

Ecoregion	Average carbon				Total carbon			
	Litter	0-20 cm	0-50 cm	0-100 cm	Litter	0-20 cm	0-50 cm	0-100 cm
	The Ural Mountain Forest Oblast of Boreal and Subboreal Zones							
19. Northern Ural forest province	26	56	60	99	4.3	18.5	29.8	32.8
20. Middle Ural forest province	13	42	56	62	105.4	340.5	454.1	499.5
21. Southern Ural forest province	8	62	80	88	46.5	360.6	465.3	511.8
	Western Siberian Plain Forest Oblast of Subarctic and Boreal Zones							
22. TransUrals-Enisey Forest - Tundra forest province	26	67	101	111	318.4	820.5	1237.0	1360.7
23. TransUrals-Enisey forest province of taiga								
23.1. Northern taiga district	21	70	114	125	437.5	1454.0	2367.9	2604.7
23.2. Middle taiga district	16	72	117	129	659.5	2967.9	4822.9	5305.1
23.3+25. Southern taiga and subtaiga district	16	76	121	133	483.1	2294.9	3653.7	4019.1
24. Irtysh-Ob Forest -Steppe forest province	15	96	151	179	102.5	656.0	1033.0	1225.0
	Altai-Sayan Mountain Forest Oblast of Boreal and Subboreal Zones							
26. Northern Altai-Sayan forest province	17	50	88	97	101.3	298.0	524.5	576.9
27. Eastern Sayan forest province	15	53	95	104	163.3	577.0	1034.3	1137.7
28. Central Altay forest province	12	51	90	99	30.1	128.1	226.0	248.6
29. Western Altay forest province	12	54	94	105	4.9	21.9	38.1	41.9
30. Eastern Tuva forest province	14	48	71	78	105.2	360.7	533.5	586.8
31. Khakass-Minusinsk forest province	12	76	131	153	25.4	160.9	277.4	324.6
32. Salair-Kuznetsk forest province	12	60	116	136	65.2	326.1	630.5	737.8
	Middle Siberian Tableland Forest Oblast of Boreal and Subboreal Zones							
33. Putoran forest province	19	36	46	51	153.2	290.2	370.8	407.9
34. Anabar forest province	19	36	46	51	2.9	5.5	7.0	7.7
35. Near-Enisey forest province	16	57	98	113	368.8	1313.8	2261.1	2600.1
36. Khetsk-Kotui-Olenek forest province of forest-tundra zone	25	57	74	81	654.8	1511.2	1961.9	2158.1
37. Angara-Tunguska forest province								
37.1. Lower Tunguska northern taiga district	11	53	69	76	368.2	1774.0	2309.6	2540.6
37.2. Stony Tunguska middle taiga district	16	64	89	128	392.2	1568.7	2176.0	3128.8
37.3. Angara southern taiga district	17	73	127	146	426.2	1830.0	3183.6	3661.1
38. Kansk-Krasnoyarsk Biryusa forest province (forest - steppe)	14	107	188	236	30.4	232.7	408.9	511.1
39. Upper Angara forest province	14	85	172	201	24.9	151.0	305.5	357.4
40. Upper Lena forest province	16	51	83	107	170.1	542.2	882.4	1132.4
	Central Yakutian Plain Forest Oblast of Boreal Zone							
41. Lena-Vilyui forest province	14	68	97	107	658.4	3197.9	4561.6	5017.8
42. Aldan forest province	13	60	89	98	268.0	1237.1	1835.1	2018.6
	Yana-Kolyma Mountain Forest Oblast of Subarctic Zone							
43+44+45. Yana-Kolyma Subarctic forest province	18	43	53	58	848.4	1689.5	2082.4	2290.6
	Northern Transbaikal Mountain Forest Oblast of Boreal Zone							
46. Vitim-Olekma Tableland forest province	16	49	74	81	532.0	1629.2	2460.5	2706.6
47. Baikal-Stanovoi forest province	18	50	64	70	350.2	972.8	1245.1	1369.6

Continued

Table 8.2—Continued

Ecoregion	Average carbon				Total carbon			
	Litter	0-20 cm	0-50 cm	0-100 cm	Litter	0-20 cm	0-50 cm	0-100 cm
48. Uchur-Maisk forest province	19	50	64	61	188.7	496.5	535.5	609.1
Southern Transbaikal Mountain Forest Oblast of Subboreal Zone								
49. Jidin forest province	12	52	90	110	26.6	115.2	199.4	245.3
50. Selenga forest province	12	69	124	140	53.2	305.9	549.7	621.2
51. Chikoi-Ingodin forest province	19	56	95	111	181.1	533.8	905.6	1053.3
52. Dahurian forest province	13	74	102	117	63.8	363.4	500.9	576.0
Near-Baikal Mountain Forest Oblast of Subboreal Zone								
53. Near-Baikal forest province	12	41	77	85	67.0	228.9	430.0	473.0
Okhotsk-Bering Mountain Forest Oblast of Subarctic Zone								
54+55. Magadan and Penzhin-Anadyr forest province	14	40	51	56	258.1	737.4	940.2	1034.2
56. Kamtchatka forest province	30	56	74	87	356.5	665.5	879.4	1037.7
Amur-Sakhalin Mountain Forest Oblast of Boreal and Subboreal Zones								
57. Zeya-Uda forest province	18	51	79	92	468.6	1327.8	2056.8	2406.5
58. Amgun-Selenjin forest province	16	54	92	106	316.3	1067.4	1818.6	2100.5
59. Sikhote-Alin forest province								
59.1. Sikhote-Alin district	18	45	85	94	392.5	981.2	1853.3	2038.6
59.2. Ussuri-Primorye district	19	73	131	159	101.3	389.0	698.1	846.8
60. Sakhalin-Kurily forest province	21	41	75	88	118.2	230.8	422.2	494.0
61. Near-Amur forest province	19	96	141	170	109.9	555.1	813.4	982.0
Kazakhstan Plain-Tableland Forest Oblast of Subarid and Arid Zones								
62. Southern Urals- Mugojar forest province	3	37	74	88	0.8	10.3	20.5	24.6
63. Tobol-Ishim forest province	12	89	172	213	4.2	30.8	59.6	74.5
64. Kulunda forest province	6	33	59	69	8.9	49.2	88.0	103.0
Tura Plain Forest Oblast of Arid Zone								
66. Near-Kaspian forest province	1	23	57	70	0.1	2.6	6.4	7.7
Central Asian Mountain Forest Oblast of Subarid Zone								
73. Southern Altai-Tuva forest province	10	60	93	102	23.1	138.8	215.1	236.6
Total					13,506	42,811	64,891	74,024

[a]Description of soils for forest sectors and forest oblasts from Shugalei et al. 1994.

Table 8.3.—Carbon storage and density of forest litter in ecoregions of Russia

Ecoregion	European Russia		Asian Russia: Western Siberia		Asian Russia: Middle Siberia		Asian Russia: Eastern Siberia and Yakutia		Asian Russia: Far East		Total	
	Storage	Density	Storage	Density	Storage	Density	Storage	Density	Storage	Density	Storage	Density
	Mt	t/ha	Mt	t/ha	Mt	t/ha	Mt	t/ha	Mt	t/ha	Mt	t/ha
Plains												
Forest tundra zone	87	26	318	26	655	25	--	--	--	--	1,060	25
Boreal zone												
Northern taiga subzone	1,154	32	438	21	368	11	--	--	--	--	1,960	22
Middle taiga subzone	940	25	660	16	392	16	926	14	--	--	2,918	17
Southern taiga subzone	467	13	483	16	426	17	--	--	--	--	1,376	15
Mixed forest subzone	130	10	--	--	--	--	--	--	--	--	130	10
Forest steppe zone	76	8	103	15	55	14	--	--	110	19	344	13
Steppe zone	2	1	13	7	--	--	--	--	--	--	15	4
Desert zone	0	1	--	--	--	--	--	--	--	--	0	1
Subtotal	2,856	21	2,014	18	1,897	17	926	14	110	19	7,803	18
Mountains												
Subarctic zone	4	13	--	--	156	19	848	22	258	14	1,267	19
Boreal zone	105	13	--	--	369	16	1,071	17	1,260	20	2,805	18
Subboreal zone	47	8	--	--	666	15	392	15	494	18	1,598	15
Subboreal (Caucasus)	10	3	--	--	--	--	--	--	--	--	10	3
Subarid zone	1	3	--	--	23	10	--	--	--	--	24	9
Subtotal	167	9	--	--	1,214	15	2,311	18	2,012	18	5,703	17
Total	3,023	20	2,014	18	3,110	16	3,237	16	2,121	18	13,506	18

Table 8.4.—Carbon storage and density of forest soils in ecoregions of Russia

Ecoregion	European Russia		Asian Russia: Western Siberia		Asian Russia: Middle Siberia		Asian Russia: Eastern Siberia and Yakutia		Asian Russia: Far East		Total	
	Storage	Density	Storage	Density	Storage	Density	Storage	Density	Storage	Density	Storage	Density
	Mt	t/ha	Mt	t/ha	Mt	t/ha	Mt	t/ha	Mt	t/ha	Mt	t/ha
Plains												
Forest tundra zone	221	65	1,361	111	2,158	81	--	--	--	--	3,739	89
Boreal zone												
Northern taiga subzone	2,695	75	2,605	125	2,541	76	--	--	--	--	7,840	87
Middle taiga subzone	2,423	65	5,305	129	3,129	128	7,036	104	--	--	17,893	105
Southern taiga subzone	1,901	53	4,019	133	3,661	146	--	--	--	--	9,582	105
Mixed forest subzone	1,041	79	--	--	--	--	--	--	--	--	1,041	79
Forest steppe zone	997	104	1,225	179	869	220	--	--	982	170	4,073	156
Steppe zone	158	90	178	97	--	--	--	--	--	--	336	93
Desert zone	8	70	--	--	--	--	--	--	--	--	8	70
Subtotal	9,443	69	14,692	130	12,357	109	7,036	104	982	170	44,511	102
Mountains												
Subarctic zone	33	99	--	--	416	51	2,291	58	1,034	56	3,773	57
Boreal zone	500	62	--	--	2,600	113	4,685	75	6,039	95	13,824	88
Subboreal zone	512	88	--	--	4,787	105	2,969	111	2,885	106	11,153	106
Subboreal (Caucasus)	503	152	--	--	--	--	--	--	--	--	503	152
Subarid zone	25	88	--	--	237	102	--	--	--	--	261	101
Subtotal	1,571	88	--	--	8,039	102	9,945	77	9,958	91	29,513	88
Total	11,014	71	14,692	130	20,396	106	16,981	87	10,940	95	74,024	96

Table 8.5.—Average (t/ha) and total (Mt) carbon storage in forest soils (depth in cm) of administrative territories of Russia

Administrative territory	Average carbon				Total carbon			
	Litter	0-20 cm	0-50 cm	0-100 cm	Litter	0-20 cm	0-50 cm	0-100 cm
1. Kaliningrad Oblast	12	68	92	100	3	18	25	27
2. Arkhangel'sk Oblast	36	45	74	86	791	989	1,611	1,885
3. Vologda Oblast	13	36	55	66	132	244	601	672
4. Murmansk Oblast	26	68	100	120	114	353	519	623
5. Rep. of Karelia	18	46	66	79	164	420	603	721
6. Rep. of Komi	26	63	75	88	769	1,864	2,216	2,615
7. Leningrad Oblast	18	32	51	59	86	152	243	280
8. Novgorod Oblast	18	32	51	59	63	112	178	205
9. Pskov Oblast	18	29	48	55	39	62	103	119
10. Bryansk Oblast	11	22	34	41	12	24	38	45
11. Vladimir Oblast	12	35	56	67	18	51	82	99
12. Ivanovo Oblast	10	33	47	53	10	34	48	53
13. Tver' Oblast	26	28	55	64	107	116	225	263
14. Kaluga Oblast	7	48	78	93	9	63	102	122
15. Kostroma Oblast	10	34	56	66	43	146	244	287
16. Moscow Oblast	9	48	78	93	17	92	150	179
17. Orel Oblast	7	54	87	106	1	10	16	19
18. Ryazan' Oblast	8	27	47	56	8	27	46	56
19. Smolensk Oblast	9	26	39	47	17	49	74	89
20. Tula Oblast	8	62	102	122	3	21	34	41
21. Yaroslavl' Oblast	9	36	53	63	14	58	85	101
22. Nijniy Novgorod Oblast	16	25	44	52	56	88	155	183
23. Kirov Oblast	14	36	53	62	103	264	389	453
24. Rep. of Mari El	7	30	44	53	9	37	54	65
25. Rep. of Mordvinia	8	66	100	119	5	43	66	79
26. Rep. of Chuvashia	8	65	98	118	5	36	55	66
27. Belgorod Oblast	8	68	111	132	2	18	30	36
28. Voronezh Oblast	8	68	111	133	3	29	47	56
29. Kursk Oblast	8	68	111	131	2	15	25	30
30. Lipetsk Oblast	8	68	111	133	2	13	21	25
31. Tambov Oblast	8	68	81	97	3	25	30	36
32. Astrakhan' Oblast	1	13	40	49	0	1	4	4
33. Volgograd Oblast	1	26	60	73	1	12	28	34
34. Samara Oblast	1	26	60	73	1	18	41	50
35. Penza Oblast	7	68	111	130	6	61	99	118
36. Saratov Oblast	1	26	60	73	1	15	34	41
37. Ul'yanovsk Oblast	7	68	111	133	7	65	106	127
38. Rep. of Kalmykia	1	13	40	60	--	0	1	1
39. Rep. of Tatarstan	9	39	62	75	10	44	69	83
40. Krasnodar Kray	1	57	90	110	2	98	154	188
41. Stavropol' Kray	2	57	90	111	1	29	46	56
42. Rostov Oblast	1	20	61	72	0	6	19	23
43. Rep. of Dagestan	7	83	123	141	3	32	48	55
44. Rep. of Kabardino-Balka	7	83	123	138	1	15	22	25
45. Rep. of Northern Osetia	7	83	123	140	1	15	23	27
46. Rep. of Checheno-Ingushetia	7	83	123	145	3	31	45	54
47. Kurgan Oblast	15	92	179	206	23	142	277	318
48. Orenburg Oblast	1	13	40	48	1	7	22	26
49. Perm' Oblast	13	19	30	35	144	210	331	391
50. Sverdlovsk Oblast	15	61	104	98	192	779	1,328	1,527

Continued

Table 8.5—Continued

Administrative territory	Average carbon				Total carbon			
	Litter	0-20 cm	0-50 cm	0-100 cm	Litter	0-20 cm	0-50 cm	0-100 cm
51. Chelyabinsk Oblast	10	61	104	125	25	151	257	309
52. Rep. of Bashkortostan	6	67	99	120	33	368	544	658
53. Rep. of Udmurtia	15	24	40	46	28	45	76	87
54. Altai Kray	11	46	63	73	81	339	464	534
55. Kemerovo Oblast	12	53	101	111	67	298	567	624
56. Novosibirsk Oblast	16	86	169	186	68	365	718	790
57. Omsk Oblast	16	80	154	169	70	350	674	741
58. Tomsk Oblast	15	75	123	135	283	1,416	2,323	2,555
59. Tyumen’ Oblast	20	78	124	156	992	3,870	6,152	7,725
60. Krasnoyarsk Kray	20	58	90	102	2,335	6,772	10,509	11,875
61. Irkutsk Oblast	16	52	74	86	937	3,044	4,331	5,024
62. Chita Oblast	17	62	88	99	491	1,791	2,542	2,873
63. Rep. of Buryatia	17	63	97	107	377	1,396	2,150	2,365
64. Rep. of Tuva	13	51	78	86	106	414	633	697
65. Primor’ye Kray	19	65	110	126	241	825	1,396	1,605
66. Khabarovsk Kray	20	57	93	102	988	2,817	4,596	5,055
67. Amur Oblast	18	54	92	108	406	1,217	2,074	2,427
68. Kamtchatka Oblast	30	56	74	87	594	1,109	1,466	1,729
69. Magadan Oblast	17	41	52	57	391	942	1,195	1,314
70. Sakhalin Oblast	21	41	75	88	118	231	422	494
71. Rep. of Yakutia (Sakha)	15	55	74	81	2,212	8,112	10,914	12,006
Total					13,849	42,924	64,811	74,162

Table 8.6.—Total carbon (Mt) in soils (depth of 0-100cm) of nonstocked and nonforest areas of Russian forests

Administrative territory	Nonstocked area		Nonforest area
	Litter	Soil	Soil
1. Kaliningrad Oblast	0.1	0.9	2.1
2. Arkhangel’sk Oblast	11.1	86.6	16.3
3. Vologda Oblast	1.5	15.4	7.3
4. Murmansk Oblast	2.5	25.2	35.0
5. Rep. of Karelia	5.9	52.1	7.9
6. Rep. of Komi	9.6	65.3	29.8
7. Leningrad Oblast	1.2	8.0	6.3
8. Novgorod Oblast	0.6	4.2	2.1
9. Pskov Oblast	0.4	2.3	1.6
10. Bryansk Oblast	0.2	1.2	1.3
11. Vladimir Oblast	0.3	3.9	2.5
12. Ivanovo Oblast	0.3	3.1	1.6
13. Tver’ Oblast	1.3	6.2	3.3
14. Kaluga Oblast	0.1	2.8	2.2
15. Kostroma Oblast	0.7	9.8	4.7
16. Moscow Oblast	0.2	4.1	7.1
17. Orel Oblast	--	0.6	0.5
18. Ryazan’ Oblast	0.1	1.8	2.0
19. Smolensk Oblast	0.2	1.6	0.8
20. Tula Oblast	0.1	1.6	1.5
21. Yaroslavl’ Oblast	0.2	2.9	1.7

Continued

Table 8.6—Continued

Administrative territory	Nonstocked area		Nonforest area
	Litter	Soil	Soil
22. Nizhniy Novgorod Oblast	1.1	7.4	5.5
23. Kirov Oblast	2.2	19.7	6.7
24. Rep. of Mari El	0.2	2.8	1.8
25. Rep. of Mordvinia	0.1	4.1	2.0
26. Rep. of Chuvashia	0.1	4.4	2.9
27. Belgorod Oblast	--	0.9	0.9
28. Voronezh Oblast	0.1	3.8	3.0
29. Kursk Oblast	--	1.3	1.3
30. Lipetsk Oblast	--	1.2	0.9
31. Tambov Oblast	0.1	1.8	1.4
32. Astrakhan' Oblast	--	1.1	1.0
33. Volgograd Oblast	--	4.9	3.5
34. Samara Oblast	--	2.5	2.4
35. Penza Oblast	0.1	5.4	3.6
36. Saratov Oblast	--	2.8	2.2
37. Ul'yanovsk Oblast	0.2	7.7	3.4
38. Rep. of Kalmykia	--	0.9	0.6
39. Rep. of Tatarstan	0.3	5.9	3.1
40. Krasnodar Kray	--	4.3	6.5
41. Stavropol' Kray	--	1.6	2.8
42. Rostov Oblast	--	2.2	3.3
43. Rep. of Dagestan	--	2.3	8.3
44. Rep. of Kabardino--Balkaria	--	1.1	3.2
45. Rep. of Northern Osetia	--	0.8	0.9
46. Rep. of Checheno--Ingushetia	--	1.6	2.0
47. Kurgan Oblast	0.5	15.0	11.6
48. Orenburg Oblast	--	2.1	2.8
49. Perm' Oblast	3.7	20.5	10.5
50. Sverdlovsk Oblast	3.7	49.4	36.8
51. Chelyabinsk Oblast	0.7	20.3	23.6
52. Rep. of Bashkortostan	0.6	23.6	39.0
53. Rep. of Udmurtia	0.7	4.4	2.2
54. Altai Kray	1.3	32.7	51.7
55. Kemerovo Oblast	1.0	22.1	24.5
56. Novosibirsk Oblast	0.9	28.5	27.2
57. Omsk Oblast	0.6	14.8	15.8
58. Tomsk Oblast	4.7	90.3	18.8
59. Tyumen' Oblast	13.7	520.3	523.4
60. Krasnoyarsk Kray	43.8	939.1	580.3
61. Irkutsk Oblast	45.9	624.2	179.9
62. Chita Oblast	8.5	168.9	125.3
63. Rep. of Buryatia	5.2	127.4	306.3
64. Rep. of Tuva	1.8	46.8	65.8
65. Primor'ye Kray	3.1	54.8	16.3
66. Khabarovsk Kray	47.1	755.4	257.7
67. Amur Oblast	15.9	347.0	81.6
68. Kamtchatka Oblast	5.9	81.8	108.7
69. Magadan Oblast	28.9	844.3	455.2
70. Sakhalin Oblast	8.8	86.8	9.3
71. Rep. of Yakutia (Sakha)	77.7	3143.9	1034.1
Total	365.8	8456.7	4219.2

Chapter 9. Biomass and Carbon of Forest Consumers

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Groups and communities of fungi, microorganisms, and meso- and macrofauna are important components of forests. Unlike phototrophs, these components of forest ecosystems consume organic matter. The biomass and carbon stored by forest consumers is lower than the error of estimation of the phytomass and carbon in vegetation; they could be ignored if not for their important role in the decomposition of organic matter.

9.1 Biomass and Carbon Content of Animals

Animals are an integral part of the structure of forest ecosystems. Although their mass is exceeded by the phytomass, sometimes by a factor of 1,000 (Valter 1982), they are among the most efficient regulators of the flow of matter and energy in ecosystems (Volkenstein 1979).

In some cases, animals play a leading role in the decomposition of the phytomass. In outbreaks of phyllofagous insects, up to 100 percent of the foliage may be consumed and tree stands considerably weakened or destroyed. In turn, this results in outbreaks of xylophage insects that weaken stands. Dead trees are used by saprophagous invertebrates.

Vertebrates can inflict substantial damage to forest vegetation and especially young trees. The grazing of ungulates can destroy regenerating stands, particularly in plantations. Rodents also inflict significant damage.

The available information on the biomass of different animal groups is ambiguous. In the vertebrate group, most of these data concern mouse-like rodents and birds; there are even fewer data on reptiles and amphibians. The amount of information on the density of animal populations is related to the commercial value of a species.

Information on the biomass of invertebrates also is sporadic. Most common are data on the soil invertebrate group. For dendrophagous insects, the availability of biomass estimates depend on the economic importance of various species.

Biomass Content of Animals in Forests of Different Natural Zones

Zoomass is determined by the ecological condition of a region. For example, it totals 67.2 kg/ha in the taiga forest zone (dry-matter basis) and 181.0 kg/ha in the deciduous hardwood forests (Pokarzhevskiy 1985). There are considerable variations within a zone. Most systematic in this respect are the data on the biomass of soil invertebrates. The large differences among regions are shown in Table 9.1.

There are differences in zoomass even within a single region. According to Verzhutskiy (1975), the mass of soil invertebrates over a 3-km transect in spruce-fir forests varied by a factor of 5 or more.

No less distinct is the temporal dynamic of soil invertebrate biomass. In the fern-herbs Scotch pine forest, the mass of soil invertebrates changed by about 300 percent during a year and by 1300 percent in 2 succeeding years (Dmitriyenko et al. 1974). Under most homogeneous conditions in fir forests, annual changes were by a factor of 2.9, 3.3, and 4 (Dmitriyenko and Sukhinina 1978).

This situation is identical for other animal groups. There is some difference in the density of insectivorous bird populations in different forest ecosystems of the southern taiga (Vladyshevskiy 1980; Ravkin 1984).

In summary, different forest conditions including productivity result in substantial spatial differences in zoomass. The variation in animal mass is dependent on seasonal and perennial ecological conditions. The high spatial and temporal variability of the zoomass make it difficult to estimate the weighted mean value both for large regions and within an individual ecosystem.

Role of Different Taxons in Total Zoomass

Invertebrate animals, primarily pedofauna, form the basis of forest zoomass. They account for one-third of the zoomass in coniferous forests, one-half in mixed forests, and two-thirds in hardwood forests. Phyllophagous insects account for a substantial portion of this mass. In fir crowns, their mass is approximately 1 kg/ha in humid years and 4 kg/ha in dry years (Verzhutskiy 1975). During outbreaks, this figure increases substantially. During a gypsy moth outbreak, a fir tree may contain as many as 6,000 caterpillars (Kondakov 1974); converted to dry weight, this amounts to 0.3 to 0.5 t/ha.

Among vertebrates, rodents and insectivorous animals have the highest specific weight. In oak forests, their mass averages 2.6 kg/ha; in the taiga of the European part of Russia, it decreases to 0.5 kg/ha (Khodasheva 1966). The taiga forests of Western Siberia have a similar mass-0.5 to 0.6 kg/ha (Ravkin and Lukyanova 1976), but in high-productive conifer forests of the Western Sayan, the biomass of small mammals can be as much as 3.0 kg/ha (Sokolov et al. 1974). It should be noted that the characteristically cyclical changes within rodent populations increases their abundance by a factor of 10 to 100.

The contribution of other vertebrate species to total zoomass is negligible. For moose, this portion is 0.01 kg/ha (Filonov 1983). Despite their abundance, birds contribute little to total zoomass. Even in high-yield southern taiga ecosystems, bird biomass is only 0.04 to 0.09 kg/ha (Ravkin and Lukyanova 1976; Ravkin 1984).

Sparse information on the content and dynamics of zoomass with respect to different ecological conditions and ecosystems makes it difficult to obtain statistically reliable data. To acquire a confident understanding of the order of the zoomass of particular ecosystems, including an account of population dynamics of species, an extended ecological-faunistic and population research program is needed. It would be expedient to perform such works in climax-forest communities with stable structures, relations, and energy exchange. From such a study it would be possible to develop appropriate techniques and methods for estimating zoomass.

Also important are estimates of the regulatory capacities of animals in distributing the matter and energy flows in an ecosystem, as well as their role in the destruction of phytomass. To a certain extent this may complement the analysis of intensity and rate of transformation of biogenic elements.

9.2 Biomass and Carbon Content of Microorganisms in Forest Soils

The importance of microorganisms of forest ecosystems frequently is determined by their ability to decompose polymers of vegetative origin. Their contribution to the carbon cycle as a destructive component is presumed to account for the mineralizing of 80 to 90 percent of the total primary production of the terrestrial ecosystems (Stanier et al. 1979). Microorganisms also play an important role in extracting the carbon from minerals (limestone, shales) and calcareous structures of invertebrates.

The biomass of organisms is an important constituent of soil organic matter. However, high temporal dynamics of microorganisms, spatial inhomogeneity of their distribution, and imperfect investigative techniques make it difficult to evaluate its stock at any time. As a result, the available data on the total amount of the microbial mass in different soils frequently are conflicting.

The first estimates of the biomass of soil microorganisms indicated a total of 0.04 to 1.0 t/ha of dry matter (Mishustin 1956; Krasilnikov 1958; Latter and Gragg 1967), and that this matter did not exceed 0.5 to 2.5 percent of the total amount of humus in the soil (Tyurin 1946). As quantitative techniques improved, the values for this biomass increased. According to some researchers, the mass of soil microorganisms in different ecosystems ranges from 1 to 8 t/ha (Berestetskiy and Torzhevskiy 1975; Mishustin 1975).

Nikitina et al. (1982) noted relatively small amounts of microbial biomass in the humus layer of taiga soils in the Southern Irtysh area (0.3 t/ha of dry matter). According to Efremov (1988), the biomass of fungi and bacteria in the litter and the humic soil layers of flat interfluvial and flooded oak forests in Belorussia ranges from 1.4 to 2.0 and 0.04 to 0.89 mg/g of soil, respectively. The biomass of micromycets and bacteria in the soils of the Scotch pine forests in Belorussia is 1.8 to 2.6 and 0.1 to 0.2 t/ha, respectively, and their total mass is 1 to 3 percent of organic matter of forest soils. According to Witkamp (1974), the biomass content of microorganisms of the F soil layer in poplar and oak forests is 80 kg/ha. In the black spruce ecosystem, the average mass of microorganisms in the L and F layers was 60 kg/ha and comprised 85 percent of fungi and 15 percent of bacteria (Flavagan and Van Cleve 1977). The forest soils of the Yaroslavl, Moscow, and Novgorod Oblasts contained 0.06 to 0.07 mg of mycelia per gram of soil (Mirchink 1984); in the soils in Sweden, the mass of microorganisms ranged from 5 to 240 kg/ha (Soderstron 1979). In soddy-podzol soils of coniferous forests in the Western part of Russia, the biomass of fungi (mycelium plus spores) is as much as 2.0 t/ha versus 0.37 t/ha for bacteria (Mirchink and Panikov 1985). The litter of beech forests in Denmark contains 0.3 t/ha of bacterial matter when absolutely dry (Holm and Jensen 1972).

The carbon content in microbial cells is 48 to 50 percent (absolutely dry basis) (Schlegel 1987). In meadow soils, the microbial carbon content is 0.2 to 5.0 mg/g of dry soil; this is considerably higher than the microbial carbon content in forest soils. In the soils of improved and protected meadows, the carbon of microorganisms is 1.0 to 1.4 t/ha or 1.4 to 6.5 percent of soil content of carbon (Tesarzheva 1986). The average carbon content of microbiomass in mesophytic meadow soil is about 1.9 t/ha in the 0- to 20-cm layer (Titlyanova et al. 1993). Sparling and West (1988) found that the microbial carbon is 0.4 to 0.6 mg/g of dry soil.

It is commonly known that the number of microorganisms and their biomass change over short periods, showing daily and hourly asynchronous oscillations (Khudyakov 1958; Egorova 1973; Parinkina 1989). The data on the variability of bacterial biomass obtained in studies of soddy podzol soils in the Scotch pine forests of Middle Angara (Fig. 9.1) show the inadequacy of evaluating biomass and carbon content in microorganisms only at a single point in time (Sorokin 1981).

Thus, in boreal forests, the carbon content of the dry biomass of microorganisms in the humic layer of forest soils ranges from 0.1 to 1.9 t/ha. Data on the biomass of microorganisms are determined at the time of soil sampling. Additional information is needed to estimate annual production of microorganisms.

9.3 Biomass and Carbon Content of Fungi

There are three major locations of fungal biomass in forest communities: 1) soil mineral horizons to a depth of approximately 70 cm, 2) litter and coarse woody debris, and 3) living trees affected by stem and root rot. The major part of mycelium is concentrated in the upper mineral layer (0 to 20 cm) of soil.

Quantitative techniques for measuring soil fungi abound, yet to acquire accurate data on the total fungal biomass in a certain volume of soil, only two methods are appropriate: the Jones and Mollison (1942) agar-film method and the membrane-filter method of Hansen et al. (1974). Unfortunately, there is little published information on this topic.

Mirchink and Stepanova (1982) used the membrane-filter technique to compare the biomass of mycelium and spores

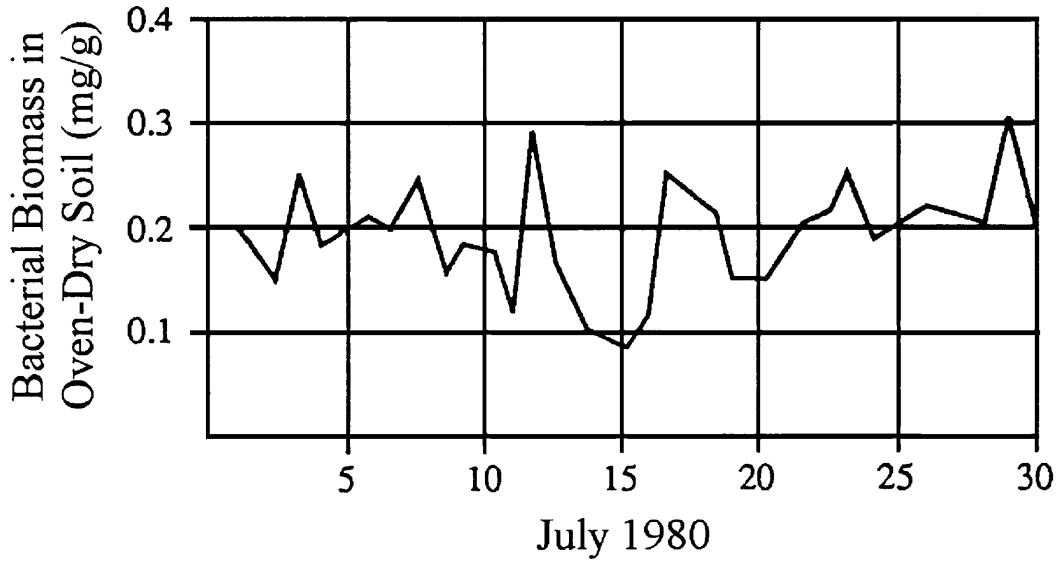

Figure 9.1—Per-diem variation of bacterial biomass in sod-pseudopodsolic soil under Scotch pine forest of the middle-near Angara territory (mg/g oven-dry soil) (Sorokin 1981)

in the zonal series of soils under forest vegetation. Samplings were repeated numerous times. Unfortunately in this study authors indicated only the soil and forest types of the ecosystem studied. The biomass value is given in milligrams per gram of soil (absolutely dry mass) for the litter and humus horizon. Taking the hypothetical mass of litter as 15 t/ha and the total biomass of mycelium and spores in the mineral-soil profile as twice that of the fungi of the humus horizon, the data provided by Mirchink and Stepanova (1982) can form the basis for the following values of total fungal biomass. For mid-podzol soil under spruce forests in the boreal zone spruce, the value is about 50 kg/ha in the litter and about 800 kg/ha in the mineral portion of soil. For podzol soil under Scotch pine forests of the same zone, fungal biomass totals 45 kg/ha in the litter and 35 kg/ha in the mineral portion. For the black soil under oak forests of the hardwood zone, fungal biomass is about 13 kg/ha in the litter and 300 kg/ha in the mineral portion.

Using the same technique, Demkina and Mirchink (1985) studied the seasonal dynamics of fungal biomass in the gray forest soil under the linden-oak forest of the Moscow Oblast; the soil profile was 0 to 77 cm deep. The total biomass of fungi (mycelium plus spores) ranged from 4,587 kg/ha in early June to 1,266 kg/ha in late October. Spores were prevalent--88.6 percent in June versus 73.1 percent in October. During the course of the season under study, the average total biomass was about 2,500 kg/ha.

Antonenko and Nikitina (1984) used the Jones and Mollison agar-film technique during a long-term (1976-80) study of mycelium and spore dynamics in the forest soils of the Siberian southern taiga along the Irtysh River. For the strong-podzol soil with the second humus horizon under a forest dominated by fir (*Abies sibirica*) and Siberian pine (*Pinus sibirica*), perennial average fungal biomass was about 150 kg/ha in the litter (3.3 mg/g with the litter layer equals 45 t/ha) and an approximately similar amount in the mineral layer (5 to 20 cm deep). For the strong-podzol soil under the Scotch pine forest, fungal biomass was 175 kg/ha in the litter (about 3.5 mg/g with the litter mass equals 50 t/ha) and 110 kg/ha in the mineral layer. The maximum biomass of fungi in the litter under the fir-Siberian pine forest was about 1,080 kg/ha; in the mineral layer (5 to 10 cm deep), the total was about 1,500 kg/ha (hypothetical soil density of 1 g/cm^3). Under the Scotch pine forest, maximum values were 550 kg/ha in the litter and about 1,700 kg/ha in the mineral layer at the same volume weight of soil.

Using data on fungal biomass in several soil layers (5 to 10, 10 to 20, 20 to 30, and 40 to 50 cm) as a guide, and using the average for the summer of only one year (1979) to derive indices for the 5- to 50-cm profile, estimates for the 5- to 10-cm profile should be at least doubled. Thus, the total biomass of soil fungi in the southern taiga along the Irtysh River during periods favorable for their development may be as much as 4 t/ha.

An indirect method for estimating mycelium biomass of macroscopic fungi developed by Burova (1986) is based on empirically obtained coefficients of the correlation between the mycelium mass and the fruit body produced by it. For the fungi forming mycorrhiza, the ratio is 154:1, according to Fogel and Hunt (1979). For the litter saprotrophs, Burova (1986) reported a ratio of 62.6:1. Burova estimated the biomass of micromycete mycelium in a spruce forest (Moscow Oblast) at 2,500 kg/ha. On the basis of the data from ecosystem studies conducted at this forest site, Burova compared the derived value to the biomass value for other components of the forest ecosystem. The biomass of fungi was comparable to that of the undergrowth mass.

The mycelium mass of wood-destroying fungi is thought to be small. It is important to note that the dry mass of mycelium is ignored in studies of the dynamics of its decomposition by fungi. Rypacek and Navratilova (1971) inoculated branch debris of beech with basidiomycetes *Trametes versicolor* (L.:Fr.) *Pilat* and *Fomitopsis pinicola* (Sw.:Fr.) P. Karst (given in the work as *Fomes marginatus* (Fr.) Gill). The total length of *Trametes versicolor* hyphae was 1,300 m/cm^3 of wood by the end of the experiment. In *Fomitopsis pinicola* the length was 815 m/cm^3, or approximately 0.8 to 2 kg of dry matter per m^3 of wood. This is lower than permissible errors associated with applied analytical methods (0.5 percent). Yet we note that the length of this experiment (2 weeks) is hardly sufficient. It is evident that at the end of the experiment, the total length of hyphae continued to increase at the same rate as at the beginning. As a result, it is difficult to determine the point at which hyphae length would have been stabilized had the experiment continued.

In the absence of other data we use 0.2 as the percentage of timber volume that is affected. With the volume of such timber amounting to a hypothetical 300 m^3, the biomass of wood-destroying fungi does not exceed 600 kg/ha. However, mycelium strands, rhizomorphs, and films specific for some species are ignored. These formations cannot be expected to make a large contribution to the indicated value. The available information on fungal biomass in forest ecosystems does indicate the large amplitude of seasonal and annual variations. It may be possible to determine the upper and lower limits of the content of mycelium and fungal spores in the temperate belt forests of the northern hemisphere-about 0.2 to 5 t/ha in dry matter (0.1 to 2.5 t/ha of carbon). A rough estimate of the stock of fungal carbon in forest ecosystems is 0.5 to 1 t/ha.

Table 9.1.—Variation of forest soil invertebrate biomass (kg/ha), by region and forest type

Region	Forest type	Biomass	Reference
Northern taiga, Timan Ridge	Piceetum herbosum	6.0	Krivolutskiy et al. 1985
Northern taiga, Timan Ridge	Piceetum vaccinosum	1.2	Krivolutskiy et al. 1985
Northern taiga, Timan Ridge	Piceetum lichenosum	0.6	Krivolutskiy et al. 1985
Middle taiga	Different type of forest	40-60	Gilyarov and Chernov 1975
Southern taiga	Different type of forest	40.0	Krivolutskiy and Shilova 1965
Southern taiga, Middle Angara	Betuletum herbosum	16.0	Verzhutskiy 1975
Southern taiga, Middle Angara	Spruce-fir forest	8.0	Verzhutskiy 1975
Southern taiga, Middle Angara	Scotch pine-larch-pine forest	11.0	Verzhutskiy 1975
Southern taiga, Lower Angara	Pinetum herbosum	4.0	Dmitriyenko et al. 1974
Southern taiga, Lower Angara	Abietum brium-oxalidosum	1.2	Dmitriyenko and Sukhinina 1978
Southern Ural, Ilmen Reserve	Pinetum herboso-fernosum	12.0	Korobeinikov 1978
Southern Ural, Ilmen Reserve	Pinetum herbosum	3.6	Korobeinikov 1978
Southern Ural, Ilmen Reserve	Betuletum herboso-fernosum	13.0	Korobeinikov 1978
Mixed Forests, Moscow Oblast	Scotch pine forest	0.6 - 16.0	Tikhomirova et al. 1979
Broad-leaved forest, Volgo-Kama Reserve	Spruce-decidious forest	20.0	Aleinikov et al. 1979

Chapter 10. Carbon Storage in Peatland Ecosystems

S.P. Efremov, T.T. Efremova, and N.V. Melentyeva

This study is the first attempt to estimate the storage of organic matter and carbon in peatlands for every administrative territory and ecoregion in Russia. The important biospheric role of peatlands is not confined to that of a carbon reservoir. The accumulation of huge amounts of undecomposed vegetation remnants includes not only carbon but other elements such as oxygen, hydrogen, sulfur, and nitrogen. Peatlands also receive and evapotranspire substantial volumes of fresh water.

10.1 Methods for Estimating Storage of Phytomass, Peat, and Carbon

Phytomass of Peatlands

To calculate phytomass, we used our own (Efremov and Efremova 1973) and unpublished data, as well as published data of other authors. For sparsely wooded peatlands, tree stocking is assumed to be 1 to 10 m^3/ha. Tree volume was converted to phytomass and carbon with the conversion coefficients discussed in Chapter 4.

The correlation between the area of nonforested and sparsely wooded bogs was established by expert estimation; for the taiga zone it is 1:1. Peatlands are mostly nonforested in the steppe and forest-steppe regions.

Dominant peatland species have lower carbon content than dominant forest species. In sphagnum mosses and sedges it ranges from 42 to 48 percent of the mass; it is 41 to 49 percent in the leaves and rhizomes of marsh trefoil (*Menyanthes trifoliata* L.) and 35 to 36 percent in horse-tails (Tyuremnov 1976; Kozlovskaya et al. 1978; Efremova 1988). According to our estimates, the average conversion coefficient for carbon is 0.48.

Peat and Carbon of Peatlands

The total area of nonforest and sparsely wooded peatlands as well as that of other excessively moist peat formations were derived from available data (Nikolayuk 1973; Sabo et al. 1981; Goskomles of the U.S.S.R. 1990) supplemented with information on individual administrative units. The total area of peatlands also includes the total area of excessively moist lands with peat and peat soils. According to the classification adopted in Russia, peat deposits are subdivided into four types: low-lying, transitional, raised, and mixed. Proceeding from the objectives of this work, we divided the peatlands into the three previously mentioned categories.

Deep deposits of organic matter (more than 1.5 m) were conditionally divided into the upper (peat-producing), bottom, and middle layers. The upper 40 cm of carbon accumulation was assumed to be the most active in producing peat.

The need to distinguish the bottom layer of deposits is based on physical compaction, microbial decomposition, and eutrophication phases in the formation of minerotrophic (fen) and mesotrophic (transitional) peats. The bottom layer has an elevated carbon content and the most burned remnants of vegetation. Along with Chechkin (1970) we estimate that the thickness of the bottom layer is 1/45 of the deposit depth in undisturbed (natural) condition. Where mineral-rich groundwater feeds the bottom of the peat deposit, the upper boundary of the mineral-rich water defines the fen development phase that also is reflected in the botanical composition of peat and physical-chemical parameters. The middle layer is defined as the difference between the total depth of the deposit and the sum of thicknesses of the upper and bottom layers.

Carbon is the basic component of the organic part of peat. Its content ranges from 34 to 65 percent and is not correlated with the type of peat.

The upper 45 cm of most peat deposits is considered the active zone of water-table fluctuation and variable aeration, and contains the most diverse microbial populations. Large pore spaces readily transport water and densities are low ($<$ 0.10 g/cm^3). This active layer is sometimes called the acrotelm. Peat density beneath the active zone increases with ash content, humification, and deposit depth. This layer is anaerobic because it always is below the water table (except during severe droughts), and it receives decomposed material from the active layer above. Further decomposition is much slower. This zone of dead-material storage is sometimes called the catotelm. Peat densities typically range from 0.10 to 0.20 g/cm^3 but can reach 0.35 g/cm^3 where mineral-soil material or sediment is added (high mineral-ash content).

Densities of peat and carbon storage in peatlands of administrative territories were calculated with averaged indices of the peat density and carbon content. The values of these indices were derived from our own data and the literature (Table 10.1). The data in Table 10.1 were used primarily to estimate carbon in different layers of deep deposits of Siberia.

Medium (less than 1.5 m) and shallow (less than 0.7 m) peatlands were not divided into layers. For the fen, transitional, and raised types of peat deposits we used the following values: 0.133, 0.085, and 0.073 g/cm^3 for density and 50.4, 51.8, and 53.9 percent for carbon content, respectively.

Peat and carbon storage in the Far East were calculated differently. Peatlands in the Lower Amur Lowlands, Sakhalin, and Kamtchatka are high in ash content (30 to 50 percent) due to siltation, mineral inclusions of alluvial and colluvium origin, and volcanic emissions (Vlastova 1960; Prozorov 1974; Tyuremnov 1976). In addition, the wide distribution of shallow peatlands as well as poorly studied physical-chemical properties of peat and organic-matter composition of the peat deposits were considered as a whole.

The mass and carbon contents assumed for the Far East were, respectively, 0.350 g/cm^3 and 25 percent for the lowland peatlands, 0.120 g/cm^3 and 49.8 percent for transitional peatlands, and 0.094 g/cm^3 and 46.7 percent for upland peatlands.

Total peat and carbon storage in the peatlands of Russia were calculated separately for peat deposits and peat ecosystems, excluding peat deposits in the category of resource-commercial geological formations. In the latter case these generally were poor peat formations or were shallow, burned, or small. In the calculations, weighted average values of mass and carbon content (Table 10.2) were derived for large regions of Russia proceeding from a tentative distribution of peatland types (Sabo et al. 1981). The exception was the Krasnoyarsk Kray, for which the distribution of peatland types was corrected by P'yavchenko (1963). Characteristics of peat deposits were taken from the following handbooks: Olenin 1956; Markov et al. 1982, 1988, 1991; Korol' and Kurov 1990.

10.2 Carbon Storage in Peatlands of Administrative Territories and Ecoregions

The Forest Fund of Russia contains 114 million ha of waterlogged forests with some peat (Nikolayuk 1973; Sabo et al. 1981). Currently, it is nearly impossible for peatland researchers to estimate the carbon contained in these forests because the carbon in the growing stock was included with that of automorphous soil forests. Their combined phytomass and the carbon of vegetation and soils are given in Chapters 6 and 8.

The estimated area of peatlands on the nonforest part of the Forest Fund totals 122 million ha with 54 Gt of carbon (Table 10.3), or about 45 percent of the territory of the total Russian peatlands.

Table 10.4 combines data on peat and carbon storage in the peatlands of Russia. Some of these data are suspect because governmental sources of statistical information on peat storage are confined to “peat deposits”, and data from different agencies are inconsistent. Also, many nonforested peatlands are under exploration for commercial and agricultural purposes.

Areas, storage, and densities of carbon in peatlands of different natural ecoregions are listed in Tables 10.5 and 10.6. These estimates are based on data from the administrative territories.

Peat storage is well known for the European part of Russia, particularly for the central and southern regions. As for the northern and eastern regions in the Asian part of Russia, estimates of peatland area and mass of deposited peat are less reliable. It is important to note that sparse forests which formed on peat soils and sometimes on thin and even thick peat deposits have not been surveyed for peat storage. The total area of such formations is so large that estimates could change considerably should these forests be investigated thoroughly.

Compared to automorphic growth conditions, peatland ecosystems have low productivity. Still, it is in these areas where the major portion of accumulated carbon is found. During the peat accumulation process, decomposition results in a loss of 60 to 80 percent of the organic matter formed by the process of photosynthesis (P'yavchenko 1983).

The total peat storage of Russia is 275 Gt. Peat deposits contain more than 118 Gt of carbon, of which deep commercial peat deposits account for 43 percent. The average absolutely dry mass of peat in Russia is about 1,000 t/ha; average carbon density is about 433 t/ha (from Table 10.4).

Nonforested peatlands and excessively moist territories (including areas beyond the forest sector), account for 155 million ha (56.8 percent). Average carbon density of phytomass in them is 6.2 t/ha (Efremov et al. 1994). The average stock of phytomass per hectare of peatlands shows an increase within the taiga zone with increasing mildness of climate, and from north to south. However, these changes are not great and are incompatible with the scale of changes in stands. The amounts of phytomass found in most peatlands are relatively uniform due to elevated humidity, poor and late heating of rooting zones (which tempers growth conditions for peatland plants), and similar species compositions (sphagnum mosses, many species of sedges, peatland dwarf-shrubs, and some lichen species). The stock of phytomass differs little even with considerable changes in latitude.

The carbon in Russian peatland ecosystems comprises a significant portion of the Earth's carbon pool. Our data complement those from of other studies (Tyuremnov 1976; Botch and Masing 1988; P'yavchenko 1980; 1985; Markov et al. 1988; Kivinen and Pakarinen 1981). The accuracy of estimates of peat carbon is ± 10 to 15 percent for the European part of Russia and ± 20 to 30 percent for the Asian part of the country.

Table 10.1.—Peat density (absolutely dry mass) and carbon content in different types of peatlands[a]

Peatland type	Layer of peat deposit					
	Upper (peat soil)		Middle		Lower	
	Peat density	Carbon	Peat density	Carbon	Peat density	Carbon
	g/cm³	*percent*	*g/cm³*	*percent*	*g/cm³*	*percent*
Low lying	0.13	49	0.12	55	0.24	57
Transitional	0.07	50	0.11	51	0.16	55
Raised	0.05	47	0.09	50	0.16	54

[a]From Scrynnikova 1961; Platonov 1964; Vomperskiy 1968; Efremov 1972, 1987; Efremova 1975, 1992; Tyuremnov 1976; Rakovskiy and Pigulevskaya 1978; Melent'eva 1980; Bambalov 1984; P'yavchenko 1985; Efimof 1986; Pereverzev 1987; Lishtvan et al. 1989.

Table 10.2.—Weighted average density and carbon content of peat in Russia, by region and administrative territory[a]

Region and administrative territory	Average density	Carbon content
	g/cm³	*percent*
Northwestern: Arkhangel'sk, Vologoda, Leningrad, Murmansk, Novgorod, Pskov Oblasts; Republics: Karelia, Komi	0.08	52
Central: Bryansk, Vladimir, Ivanov, Tver', Kaluga, Kostroma, Moscow, Orel, Ryazan', Smolensk, Tula, Yaroslavl' Oblasts	0.08	52
Volga-Vyatka: Nizhniy Novgorod, Kirov, Oblasts; Republics: Mari El, Mordovia, Chuvashia	0.07	52
Central-Chernozemniy: Belgorod, Voronezh, Kursk, Lipetsk, Tambov Oblasts	0.34	26
Povolzhskiy: Astrakhan', Volgograd, Samara, Penza, Saratov, Ulyanovsk Oblasts; Republics: Tatarstan, Kalmykia	0.34	26
North Caucasus: Rostov Oblast; Krasnodar and Stavropol Krays; Republics: Dagestan, Kabardino-Balkaria, Northern Osetia, Chechen-Ingu-shetia	0.35	25
Uralskiy: Kurgan, Orenburg, Chelyabinsk, Perm', Sverdlovsk Oblasts; Republics: Bashkortostan, Udmurtia	0.10	52
Western Siberian: Altay Kray; Kemerov, Novosibirsk, Omsk, Tomsk, Tyumen' Oblasts	0.08	52
Eastern Siberian: Krasnoyarsk Kray; Irkutsk, Chita, Oblasts; Republics: Buryatia, Tuva	0.11	53
Republic of Yakutia (Sakha) and Magadan Oblasts	0.10	52
Far Eastern: Primor'ye, Khabarovsk Krays; Amur, Kamtchatka, and Sakhalin Oblasts	0.29	30
Baltic: Kaliningrad Oblast	0.10	52

[a]From Olenin 1956; Markov et al. 1982, 1988, 1991; Korol' and Kurov 1990.

Table 10.3.—Area, total phytomass, total carbon of phytomass, total peat and total carbon of peat in nonforested peatlands of the Russian Forest Fund

Administrative territory	Area	Phytomass	Carbon of phytomass	Peat	Carbon of peat
	thousand ha	-----------------	----------------- *Mt*	-----------------	-----------------
1. Kaliningrad Oblast	10	0	0	114	59
2. Arkhangel’sk Oblast	5,056	84	40	2,194	1,131
3. Vologda Oblast	1,097	20	10	996	515
4. Murmansk Oblast	2,680	27	13	1,135	591
5. Rep. of Karelia	3,539	60	29	2,336	1,208
6. Rep. of Komi	3,319	56	27	1,940	1,002
7. Leningrad Oblast	695	11	5	579	298
8. Novgorod Oblast	422	7	3	427	220
9. Pskov Oblast	229	4	2	297	154
10. Bryansk Oblast	11	0	0	18	9
11. Vladimir Oblast	14	0	0	13	7
12. Ivanovo Oblast	15	0	0	13	7
13. Tver’ Oblast	231	4	2	277	143
14. Kaluga Oblast	8	0	0	6	3
15. Kostroma Oblast	43	1	0	36	19
16. Moscow Oblast	23	0	0	21	11
17. Orel Oblast	1	0	0	1	0
18. Ryazan’ Oblast	21	0	0	21	11
19. Smolensk Oblast	23	0	0	26	13
20. Tula Oblast	0	0	0	0	0
21. Yaroslavl’ Oblast	28	0	0	29	15
22. Nizhniy Novgorod Oblast	63	1	1	46	24
23. Kirov Oblast	87	1	1	58	30
24. Rep. of Mari El	26	0	0	20	10
25. Rep. of Mordvinia	6	0	0	5	3
26. Rep. of Chuvashia	3	0	0	3	2
27. Belgorod Oblast	1	0	0	1	0
28. Voronezh Oblast	6	0	0	13	3
29. Kursk Oblast	3	0	0	6	1
30. Lipetsk Oblast	4	0	0	7	2
31. Tambov Oblast	11	0	0	23	6
32. Astrakhan’ Oblast	23	1	0	37	15
33. Volgograd Oblast	10	0	0	16	4
34. Samara Oblast	4	0	0	9	2
35. Penza Oblast	5	0	0	10	3
36. Saratov Oblast	4	0	0	6	2
37. Ul’yanovsk Oblast	4	0	0	7	2
38. Rep. of Kalmykia	0	0	0	0	0
39. Rep. of Tatarstan	2	0	0	4	1
40. Krasnodar Kray	5	0	0	9	3
41. Stavropol’ Kray	1	0	0	1	0
42. Rostov Oblast	3	0	0	4	2
43. Rep. of Dagestan	1	0	0	2	1
44. Rep. of Kabardino-Balkaria	0	0	0	0	0
45. Rep. of North Osetia	0	0	0	0	0
46. Rep. of Checheno-Ingushetia1	0	0	2	1	
47. Kurgan Oblast	77	1	0	54	27
48. Orenburg Oblast	1	0	0	1	0
49. Perm’ Oblast	307	4	2	308	160
50. Sverdlovsk Oblast	1,759	24	12	1,871	977
51. Chelyabinsk Oblast	23	0	0	22	11
52. Rep. of Bashkortostan	10	0	0	14	7
53. Rep. of Udmurtia	4	0	0	3	2
54. Altai Kray	158	2	1	109	57

Continued

Table 10.3—Continued

Administrative territory	Area	Phytomass	Carbon of phytomass	Peat	Carbon of peat
	thousand ha	----------	*Mt*	----------	
55. Kemerovo Oblast	18	0	0	14	7
56. Novosibirsk Oblast	1,840	24	12	2,208	1,159
57. Omsk Oblast	1,116	14	7	1,064	555
58. Tomsk Oblast	8,645	117	56	11,723	6,055
59. Tyumen' Oblast	29,065	378	181	27,406	14,140
60. Krasnoyarsk Kray	25,114	294	141	18,276	9,604
61. Irkutsk Oblast	1,530	19	9	1,032	544
62. Chita Oblast	898	11	5	831	431
63. Rep. of Buryatia	330	5	2	259	137
64. Rep. of Tuva	953	14	7	1,216	619
65. Primor'ye	134	3	2	237	70
66. Khabarovsk Kray	4,707	111	53	8,940	2,688
67. Amur Oblast	4,352	101	48	8,887	2,669
68. Kamtchatka Oblast	1,781	30	14	2,839	898
69. Magadan Oblast	7,114	99	48	8,363	2,513
70. Sakhalin Oblast	565	11	5	1,058	335
71. Rep. of Yakutia (Sakha)	13,755	76	36	16,176	4,858
Total	121,993	1,615	775	123,671	53,999

Table 10.4.—Area, total storage of peat (absolutely dry mass) and carbon, and average storage of peat and carbon in all Russian peatlands

Administrative territory	Area	Total peat	Total carbon	Average peat	Average carbon
	thousand ha	------- *Mt*	-------	------- *t/ha*	-------
1. Kaliningrad Oblast	288	330	173	1,147	601
2. Arkhangel'sk Oblast	14,645	6,354	3,276	434	224
3. Vologda Oblast	4,659	4,230	2,189	908	470
4. Murmansk Oblast	2,736	1,159	603	424	220
5. Rep. of Karelia	5,433	3,586	1,855	660	341
6. Rep. of Komi	18,550	10,844	5,600	585	302
7. Leningrad Oblast	2,709	2,258	1,163	834	429
8. Novgorod Oblast	1,300	1,315	679	1,012	522
9. Pskov Oblast	1,117	1,446	748	1,294	670
10. Bryansk Oblast	131	202	107	1,550	821
11. Vladimir Oblast	245	226	119	926	488
12. Ivanovo Oblast	121	104	55	862	456
13. Tver' Oblast	1,320	1,579	816	1,197	618
14. Kaluga Oblast	75	55	30	734	395
15. Kostroma Oblast	817	681	356	833	435
16. Moscow Oblast	263	240	126	910	478
17. Orel Oblast	16	18	9	1,154	577
18. Ryazan' Oblast	200	199	105	996	526
19. Smolensk Oblast	324	366	191	1,129	590
20. Tula Oblast	3	3	2	1,063	537
21. Yaroslavl' Oblast	313	332	174	1,061	555
22. Nizhniy Novgorod Oblast	834	600	312	720	375
23. Kirov Oblast	2,596	1,740	903	670	348
24. Rep. of Mari El	278	212	110	764	396
25. Rep. of Mordvinia	41	33	18	804	430
26. Rep. of Chuvashia	23	21	11	927	490
27. Belgorod Oblast	8	13	3	1,685	432

Continued

Table 10.4—Continued

Administrative territory	Area	Total peat	Total carbon	Average peat	Average carbon
	thousand ha	-------------- *Mt* ------------		------------ *t/ha* ------------	
28. Voronezh Oblast	36	74	19	2,065	533
29. Kursk Oblast	43	72	18	1,652	414
30. Lipetsk Oblast	6	10	3	1,793	456
31. Tambov Oblast	45	95	24	2,098	534
32. Astrakhan' Oblast	23	37	15	1,611	642
33. Volgograd Oblast	10	16	4	1,637	421
34. Samara Oblast	16	33	8	1,984	505
35. Penza Oblast	29	56	15	1,925	495
36. Saratov Oblast	4	6	2	1,468	369
37. Ul'yanovsk Oblast	23	41	10	1,792	448
38. Rep. of Kalmykia	0	1	0	1,525	453
39. Rep. of Tatarstan	46	74	20	1,595	420
40. Krasnodar Kray	14	27	8	1,934	564
41. Stavropol' Kray	1	1	0	1,517	587
42. Rostov Oblast	3	4	2	1,426	550
43. Rep. of Dagestan	1	2	1	1,818	545
44. Rep. of Kabardino-Balkaria	0	0	0	2,000	500
45. Rep. of North Osetia	0	0	0	2,000	500
46. Rep. of Checheno-Ingushetia	1	2	1	1,833	500
47. Kurgan Oblast	390	276	139	707	356
48. Orenburg Oblast	16	10	5	636	318
49. Perm' Oblast	2,183	2,191	1,141	1,003	523
50. Sverdlovsk Oblast	6,350	6,755	3,528	1,064	556
51. Chelyabinsk Oblast	247	227	120	919	486
52. Rep. of Bashkortostan	100	130	68	1,307	683
53. Rep. of Udmurtia	246	224	118	912	479
54. Altai Kray	609	419	218	688	358
55. Kemerovo Oblast	274	204	107	745	390
56. Novosibirsk Oblast	4,149	4,979	2,613	1,200	630
57. Omsk Oblast	3,088	2,944	1,536	954	498
58. Tomsk Oblast	15,492	21,008	10,851	1,356	700
59. Tyumen' Oblast	55,501	52,329	27,003	943	487
60. Krasnoyarsk Kray	25,114	18,275	9,602	728	382
61. Irkutsk Oblast	12,470	8,411	4,431	675	355
62. Chita Oblast	3,623	3,351	1,739	925	480
63. Rep. of Buryatia	1,060	831	438	784	413
64. Rep. of Tuva	1,399	1,785	908	1,276	649
65. Primor'ye Kray	476	841	249	1,766	524
66. Khabarovsk Kray	12,112	23,006	6,917	1,899	571
67. Amur Oblast	6,588	13,451	4,039	2,042	613
68. Kamtchatka Oblast	1,781	2,840	898	1,594	504
69. Magadan Oblast	17,244	20,272	6,093	1,176	353
70. Sakhalin Oblast	929	1,738	550	1,872	593
71. Rep. of Yakutia (Sakha)	42,230	49,663	14,914	1,176	353
Total	273,013	274,858	118,103	1,007	433

Table 10.5.—Peatland areas (thousand ha) in ecoregions of Russia[a]

Zone / subzone	European Russia	Asian Russia: Western Siberia	Asian Russia: Middle Siberia	Asian Russia: Eastern Siberia and Yakutia	Asian Russia: Far East	Total
			Plains			
Forest-tundra zone	0.6	10.8	1.8	0.0	0.0	13.3
Boreal zone						
Northern taiga subzone	17.5	22.6	1.0	0.0	0.0	41.1
Middle taiga subzone	18.3	25.4	2.4	13.6	0.0	59.7
Southern taiga subzone	20.6	31.6	4.5	0.0	0.0	56.7
Mixed forests subzone	5.3	0.0	0.0	0.0	10.1	15.4
Forest-steppe zone	0.6	3.2	1.1	0.0	0.0	5.0
Steppes zone	0.1	1.2	0.0	0.0	0.0	1.3
Desert zone	0.02	0.00	0.00	0.00	0.00	0.02
Subtotal	63.2	94.8	10.8	13.6	10.1	192.5
			Mountains			
Subarctic zone	0.1	0.0	0.6	12.6	17.6	30.9
Boreal zone	1.9	0.0	8.3	2.4	15.4	28.0
Subboreal zone	0.01	0.0	2.1	1.9	6.0	10.0
Subboreal (Caucasus)	0.02	0.0	0.0	0.0	0.0	0.02
Subarid zone	0.01	0.0	1.1	0.0	0.0	1.1
Subtotal	2.1	0.0	12.1	16.9	39.0	70.0
Total	65.3	94.8	22.9	30.5	49.0	262.5

[a]Does not include peatlands of the arctic ecoregion (10.5 million ha).

Table 10.6.—Storage and density of carbon of peatlands in ecoregions of Russia[a]

Ecoregion	European Russia		Asian Russia: Western Siberia		Asian Russia: Middle Siberia		Asian Russia: Eastern Siberia and Yakutia		Asian Russia: Far East		Total	
	Storage	Density	Storage	Density	Storage	Density	Storage	Density	Storage	Density	Storage	Density
	Gt	*t/ha*	*Gt*	*t/ha*	*Gt*	*t/ha*	*Gt*	*t/ha*	*Gt*	*t/ha*	*Gt*	*t/ha*
Plains												
Forest-tundra zone	0.1	75	1.9	177	0.4	232	0.0	0	0.0	0	2.4	180
Boreal zone												
Northern taiga subzone	4.1	234	6.4	284	0.4	398	0.0	0	0.0	0	10.9	265
Middle taiga subzone	7.5	406	12.9	508	1.1	474	5.6	415	0.0	0	27.1	454
Southern taiga subzone	8.9	431	28.3	897	2.4	539	0.0	0	0.0	0	39.7	699
Mixed forests subzone	2.4	448	0.0	0	0.0	0	0.0	0	0.0	0	2.4	448
Forest-steppe zone	0.6	881	1.1	347	0.6	517	0.0	0	0.7	64	2.9	193
Steppes zone	0.1	907	0.4	293	0.0	0	0.0	0	0.0	0	0.5	346
Desert zone	0.0	458	0.0	0	0.0	0	0.0	0	0.0	0	0.0	458
Subtotal	23.5	372	51.1	538	4.9	456	5.6	415	0.7	64	85.8	446
Mountains												
Subarctic zone	0.0	180	0.0	0	0.3	402	4.1	329	9.5	542	14.0	451
Boreal zone	0.5	276	0.0	0	3.9	467	0.9	379	5.4	354	10.8	384
Subboreal zone	< 0.01	308	0.0	0	1.0	482	1.0	516	2.8	471	4.8	482
Subboreal (Caucasus)	0.0	579	0.0	0	0.0	0	0.0	0	0.0	0	0.0	579
Subarid zone	0.0	0	0.0	0	0.7	472	0.0	0	0.0	0	0.7	472
Subtotal	0.6	283	0.0	0	5.9	485	6.0	357	17.8	457	30.5	435
Total	24	370	51	538	11	471	12	383	18	377	116	443

[a]Does not include arctic peatlands (storage = 2Gt, density = 173 t/ha).

Chapter 11. Total Carbon Storage in Forests and Peatlands of Russia

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11.1 Carbon Storage in Forest Fund Lands

We estimate that the lands of the Forest Fund of Russia contain 187.9 Gt of carbon, 63 percent of which (118.1 Gt) is in forest ecosystems (Table 11.1). Most of this carbon is in forest soils, which accounts for 46 percent of the carbon in the entire area and 62.3 percent in the stocked area.

The principal source of organic matter--vegetation of forest ecosystems--contains 28 Gt of carbon (14.9 percent of carbon of the total area of the forest sector, or 23.7 percent of the carbon of the stocked area). The vegetation of nonstocked and nonforested areas adds little to this total. However, over long periods, the accumulation of carbon in peatlands that appear unproductive is considerable. Peatlands account for 28.8 percent of the carbon of the Forest Fund (Fig. 11.1).

The weighted average carbon density in Russian forests is 153.2 t/ha; this figure is nearly identical to the average value for carbon density (154.8 t/ha) in the boreal portion of forest ecosystems. In the mountains of Siberian subarctic regions, on permafrost, and in extremely continental climate areas, forests and woodlands have accumulated about 90 t/ha of carbon. The forests of the hardwood (forest-steppe) zone and subboreal mountain forests of Caucasus show considerably larger values of deposited carbon, representing the high historical accumulation in soils and the potential for accumulation in modern forest communities (Tables 11.1 and 11.2).

Estimates of carbon for the southern taiga and mixed forests of the boreal zone seem somewhat low (Table 11.2). The drop in accumulated carbon values in these subzones of the taiga is not observed in similar provinces of Asian bioclimatic sectors. The reduction in carbon storage is due to its low accumulation in soils (Table 8.3) and intensive harvest of forests. Possible explanations for low carbon accumulation in soils are that, compared to the forests of the northern and middle taiga of the Kola-Karelian and Eastern-European ecoregions, there are fewer waterlogged ecosystems and mixed forests in the southern taiga and there is less humification of mineral horizons. However, more favorable climatic conditions make the mineralization of organic matter more intensive and allow products of its transformation to become part of the biological turnover. Also, many light-textured soils do not favor the fixation of organic matter. Intensive clearcuttings reduced the current carbon storage of European southern taiga by not less than 14 t/ha compared with Middle Siberia (Table 6.4).

It is interesting to compare our estimates with other published values. For the administrative territories, Makarevskiy's (1991) paper on the carbon balance in the forests and peatlands of the Karelian Republic was the only published study until this report. Makarevskiy was the first researcher in Russia to use forest inventory data for his calculations. His method has been used by other researchers (Isaev et al. 1993), including the authors of this report.

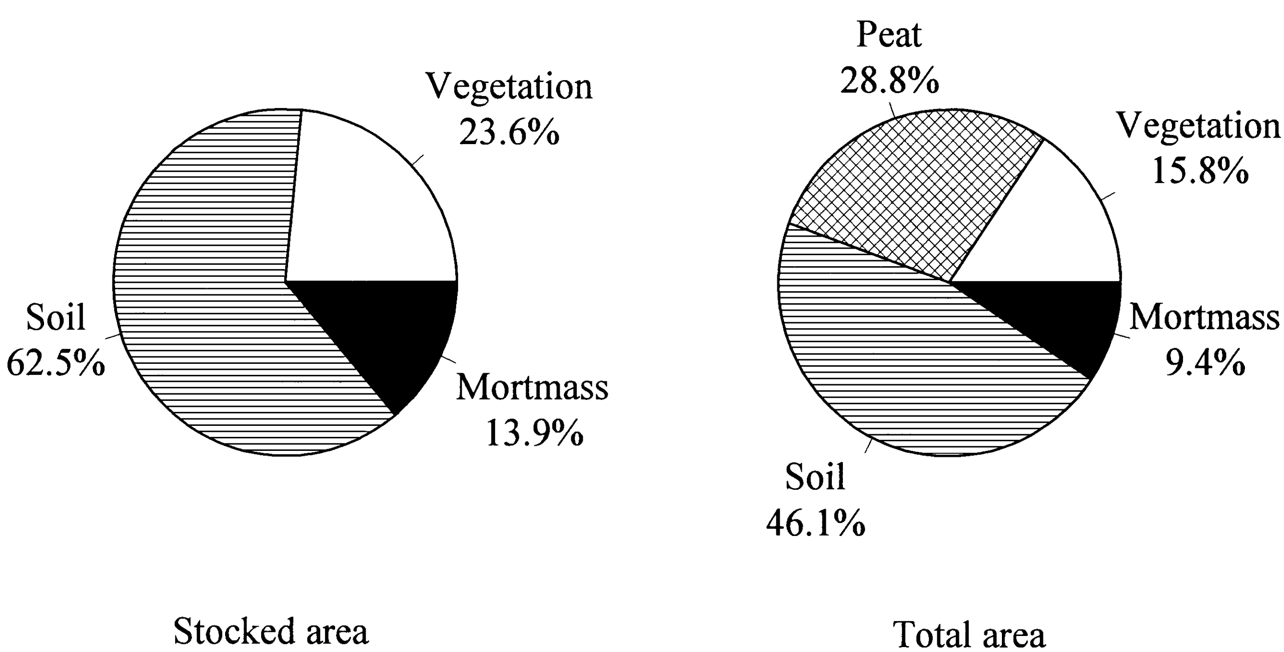

Figure 11.1—Distribution of carbon storage in stocked and total area of forest fund of Russia.

Makarevskiy's estimates of carbon storage in the Karelian stocked area and in forest phytomass differ from ours by 4 and 10 percent, respectively. These differences probably could be resolved had Makarevskiy described his methods in greater detail, particularly with respect to his method for calculating timber density.

Carbon storage in the vegetation of the Russian Forest Fund is given in Isaev et al. (1993). If we exclude differences in estimates of carbon deposits in shrubs, the difference between their estimates of carbon storage and ours for the vegetation of the stocked area would be less than 10 percent. Isaev et al. apparently misplaced decimal points in their data, resulting in a rate of shrub productivity that should be 10 times lower.

In some studies of carbon storage in the forests of Russia and the former U.S.S.R., values for carbon stored in the vegetation of forest ecosystems are significantly higher than our own (Kolchugina and Vinson 1993a, b, c; Dixon et al. 1994). Such differences could be partly due to differences in terminology. For example, some scientists have included mortmass in the vegetation category.

Lakida et al. (1996) estimated carbon storage in forest vegetation of European Russia. Their results differ from ours (Alexeyev and Birdsey 1994) by less than 4 percent. The difference between an unpublished study by International Institute of Applied Systems Analysis and our estimates for Asian Russia is about 13 percent (Shvidenko, pers. commun.).

11.2 Total Carbon Storage in Russian Forests and Peatlands

As mentioned previously, the peatlands of the Forest Fund of Russia contain 54.0 Gt of carbon or 28.8 percent of the carbon of the National Forest Fund (Fig. 11.1). The total amount of peat carbon in Russian peatlands is 118.1 Gt, or 47.0 percent of the carbon in the forests and peatlands of the country. This huge pool of peat carbon has been created by plants for the last 5,000 to 12,000 years. Global climate change could disturb the current peat balance in this pool and destroy this ancient carbon reserve.

The carbon of forest and peatland vegetation in Russia totals 29.5 Gt, or 11.7 percent of total carbon in forests and peatlands (Table 11.1). The photosynthetic activity of plants has created pools of carbon peat (118.1 Gt), mortmass (17.6 Gt), and soils (86.3 Gt). Mortmass is the most dynamic component of forest ecosystems because its carbon is released to the atmosphere primarily by fires and the activity of microorganisms. The distribution (tons/ha) and relative (percent) quantity of carbon in the vegetation, mortmass, soil, and peat of natural ecoregions and administrative territories of Russia differ widely (Table 11.2).

Table 11.1.—Carbon storage (Mt) of Russian Forest Fund

Administrative territory	Areas covered by forest				Total area of Forest Fund				
	Phytomass	Mortmass	Soil	Total	Phytomass	Mortmass	Soil	Peat	Total
1. Kaliningrad Oblast	16	4	27	47	16	5	30	6	56
2. Arkhangel'sk Oblast	874	860	1,885	3,077	921	882	1,446	1,131	4,923
3. Vologda Oblast	445	172	672	1,289	455	176	695	515	1,841
4. Murmansk Oblast	96	126	623	844	113	130	683	591	1,517
5. Rep. of Karelia	270	186	721	1,177	301	198	781	1,208	2,488
6. Rep. of Komi	1,049	845	2,615	4,510	1,082	864	2,711	1,002	5,659
7. Leningrad Oblast	257	100	280	637	263	102	294	298	958
8. Novgorod Oblast	191	78	205	474	195	79	211	220	705
9. Pskov Oblast	104	48	119	270	105	48	123	154	430
10. Bryansk Oblast	56	14	45	115	56	14	48	9	127
11. Vladimir Oblast	71	20	99	189	71	21	105	7	203
12. Ivanovo Oblast	53	13	53	118	53	13	57	7	130
13. Tver' Oblast	228	127	263	617	230	129	273	143	774
14. Kaluga Oblast	69	16	122	207	69	16	127	3	215
15. Kostroma Oblast	222	59	287	567	223	61	302	19	603
16. Moscow Oblast	118	24	179	321	119	24	190	11	344
17. Orel Oblast	9	2	19	30	9	2	20	0	31
18. Ryazan' Oblast	51	13	56	119	52	13	59	11	135
19. Smolensk Oblast	80	23	89	191	80	23	91	13	208
20. Tula Oblast	16	3	41	61	16	3	44	0	64
21. Yaroslavl' Oblast	72	20	101	193	73	20	106	15	214
22. Nizhniy Novgorod Oblast	161	69	183	413	163	71	196	24	453
23. Kirov Oblast	338	131	453	922	340	136	480	30	986
24. Rep. of Mari El	55	13	65	133	55	13	70	10	149
25. Rep. of Mordvinia	32	8	79	118	32	9	85	3	127
26. Rep. of Chuvashia	28	7	66	101	28	7	73	2	110
27. Belgorod Oblast	18	3	36	57	18	3	37	0	59
28. Voronezh Oblast	21	5	56	82	22	5	63	3	93
29. Kursk Oblast	11	2	30	43	11	2	33	1	47
30. Lipetsk Oblast	11	2	25	38	11	2	27	2	41
31. Tambov Oblast	18	4	36	57	18	4	39	6	67
32. Astrakhan' Oblast	3	0	4	8	4	0	7	15	25
33. Volgograd Oblast	14	1	34	49	14	1	43	4	62
34. Samara Oblast	36	2	50	87	36	2	55	2	95
35. Penza Oblast	42	10	118	170	42	10	127	3	182
36. Saratov Oblast	21	1	41	63	21	1	46	2	69

Continued

Table 11.1—Continued

Administrative territory	Areas covered by forest				Total area of Forest Fund				
	Phytomass	Mortmass	Soil	Total	Phytomass	Mortmass	Soil	Peat	Total
37. Ul'yanovsk Oblast	50	9	127	187	50	10	139	2	200
38. Rep. of Kalmykia	0	0	1	1	0	0	2	0	2
39. Rep. of Tatarstan	55	14	83	152	56	15	92	1	163
40. Krasnodar Kray	160	16	188	365	161	16	199	3	379
41. Stavropol' Kray	37	4	56	97	37	4	61	0	101
42. Rostov Oblast	6	1	23	30	6	1	29	2	37
43. Rep. of Dagestan	21	3	55	79	21	3	66	1	91
44. Rep. of Kabardino-Balkaria	11	2	25	37	11	2	29	0	42
45.Rep. of North Osetia	16	2	27	45	16	2	28	0	46
46. Rep. of Checheno-Ingushetia	31	4	54	88	31	4	57	1	92
47. Kurgan Oblast	63	27	318	408	64	28	345	27	463
48. Orenburg Oblast	25	2	26	53	25	2	31	0	59
49. Perm' Oblast	500	180	391	1,070	504	190	422	160	1,276
50. Sverdlovsk Oblast	577	240	1,527	2,345	591	251	1,613	977	3,432
51. Chelyabinsk Oblast	121	34	309	464	122	36	353	11	522
52. Rep. of Bashkortostan	262	52	658	971	263	54	720	7	1,044
53. Rep. of Udmurtia	99	35	87	221	99	36	94	2	231
54. Altai Kray	323	112	534	968	328	116	618	57	1,118
55. Kemerovo Oblast	175	89	624	888	177	91	670	7	945
56. Novosibirsk Oblast	152	79	790	1,021	164	82	846	1,159	2,251
57. Omsk Oblast	188	85	741	1,015	195	86	772	555	1,609
58. Tomsk Oblast	825	358	2,555	3,738	883	376	2,664	6,055	9,978
59. Tyumen' Oblast	1,737	1,174	7,725	10,636	1,946	1,213	8,769	14,140	26,068
60. Krasnoyarsk Kray	4,501	2,923	11,875	19,298	4,713	3,083	13,394	9,604	30,794
61. Irkutsk Oblast	3,047	1,221	5,024	9,293	3,083	1,426	5,828	544	10,881
62. Chita Oblast	945	576	2,873	4,393	959	610	3,167	431	5,167
63. Rep. of Buryatia	762	436	2,365	3,563	774	453	2,799	137	4,161
64. Rep. of Tuva	332	138	697	1,166	343	147	809	619	1,918
65. Primor'ye Kray	667	299	1,605	2,571	671	308	1,676	70	2,726
66. Khabarovsk Kray	1,848	1,211	5,055	8,115	1,949	1,344	6,069	2,688	12,049
67. Amur Oblast	746	478	2,427	3,650	812	521	2,855	2,669	6,856
68. Kamtchatka Oblast	570	635	1,729	2,935	597	642	1,920	898	4,056
69. Magadan Oblast	293	416	1,314	2,023	514	468	2,614	2,513	6,109
70. Sakhalin Oblast	229	139	494	863	239	158	590	335	1,322
71. Rep. of Yakutia (Sakha)	3,451	2,498	12,006	17,955	3,813	2,687	16,184	4,858	27,542
Total	27,981	16,495	74,162	118,095	29,534	17,552	86,295	53,999	187,923

Table 11.2.—Distribution of forest ecosystem carbon storage and carbon density in ecoregions of Russia

Ecoregion	European Russia		Asian Russia: Western Siberia		Asian Russia: Middle Siberia		Asian Russia: Eastern Siberia and Yakutia		Asian Russia: Far East		Total	
	Storage	Density	Storage	Density	Storage	Density	Storage	Density	Storage	Density	Storage	Density
	Gt	*t/ha*	*Gt*	*t/ha*	*Gt*	*t/ha*	*Gt*	*t/ha*	*Gt*	*t/ha*	*Gt*	*t/ha*
Plains												
Forest tundra zone	0.4	103	1.8	149	3.3	125	0.0	0	0.0	0	5.5	130
Boreal zone												
Northern taiga subzone	4.9	137	3.8	181	3.8	113	0.0	0	0.0	0	12.5	138
Middle taiga subzone	5.1	137	7.9	191	4.7	193	10.1	149	0.0	0	27.8	163
Southern taiga subzone	4.2	118	6.1	203	5.8	230	0.0	0	0.0	0	16.1	177
Mixed forest subzone	1.9	142	0.0	0	0.0	0	0.0	0	0.0	0	1.9	142
Forest steppe zone	1.5	156	1.7	246	1.1	281	0.0	0	1.2	204	5.5	208
Steppe zone	0.2	131	0.3	147	0.0	0	0.0	0	0.0	0	0.5	136
Desert zone	0.0	136	0.0	0	0.0	0	0.0	0	0.0	0	0.0	136
Subtotal	18.2	133	21.5	190	18.7	165	10.1	149	1.2	204	69.7	160
Mountains												
Subarctic zone	0.0	123	0.0	0	0.7	88	3.9	99	1.7	91	6.3	95
Boreal zone	1.0	125	0.0	0	3.9	171	7.7	123	9.9	156	22.6	143
Subboreal zone	0.9	148	0.0	0	7.9	174	4.6	174	4.8	177	18.2	168
Subboreal (Caucasus)	0.8	239	0.0	0	0.0	0	0.0	0	0.0	0	0.8	239
Subarid zone	0.4	160	0.0	0	0.0	0	0.0	0	0.0	0	0.4	160
Subtotal	2.7	150	0.0	0	13.0	164	16.3	127	16.3	150	48.2	144
Total	21	135	22	190	32	164	26	134	18	153	118	153

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Appendix

Table 1.—Area (thousand ha) of the Russian Forest Fund, by administrative territory (from Goscomles of the U.S.S.R. 1990)

Administrative territory	Total area of Forest Fund	Forest area (stocked and unstocked)	Stocked area				Percent of admin. territory that is stocked
			Conifer	Deciduous		Total	
				Hardwood	Softwood		
1. Kaliningrad Oblast	386	285	96	53	118	267	18
2. Arkhangel'sk Oblast	29,682	23,032	18,723	0	3,244	21,967	37
3. Vologda Oblast	11,768	10,435	5,820	0	4,344	10,164	69
4. Murmansk Oblast	9,993	5,435	3,844	0	1,346	5,190	36
5. Rep. of Karelia	15,001	9,806	8,074	0	1,061	9,135	53
6. Rep. of Komi	39,031	30,366	24,375	0	5,197	29,592	71
7. Leningrad Oblast	6,101	4,947	3,020	0	1,734	4,755	55
8. Novgorod Oblast	4,076	3,581	1,400	4	2,082	3,487	63
9. Pskov Oblast	2,494	2,199	914	6	1,226	2,146	39
10. Bryansk Oblast	1,198	1,148	525	79	505	1,109	32
11. Vladimir Oblast	1,617	1,544	863	27	578	1,468	51
12. Ivanovo Oblast	1,156	1,091	526	3	499	1,028	43
13. Tver' Oblast	4,642	4,268	1,971	0	2,151	4,123	49
14. Kaluga Oblast	1,383	1,343	457	50	899	1,306	44
15. Kostroma Oblast	4,645	4,507	2,166	1	2,178	4,345	72
16. Moscow Oblast	2,154	1,987	918	47	959	1,924	41
17. Orel Oblast	195	189	31	66	85	182	7
18. Ryazan' Oblast	1,123	1,052	450	111	446	1,008	26
19. Smolensk Oblast	1,999	1,942	531	6	1,363	1,899	38
20. Tula Oblast	378	362	33	132	172	337	13
21. Yaroslavl' Oblast	1,759	1,663	606	5	989	1,599	44
22. Nizhniy Novgorod Oblast	926	3,692	1,737	121	1,661	3,521	47
23. Kirov Oblast	7,934	7,670	4,139	10	3,189	7,337	61
24. Rep. of Mari El	1,374	1,296	646	14	577	1,236	53
25. Rep. of Mordvinia	723	694	214	107	334	655	25
26. Rep. of Chuvashia	631	598	166	137	255	560	31
27. Belgorod Oblast	293	284	31	205	31	267	10
28. Voronezh Oblast	492	451	121	231	62	420	8
29. Kursk Oblast	257	238	30	151	45	226	8
30. Lipetsk Oblast	213	200	71	77	41	189	8
31. Tambov Oblast	422	389	162	67	137	368	11
32. Astrakhan' Oblast	260	118	0	14	64	93	2
33. Volgograd Oblast	690	573	68	279	101	469	4
34. Samara Oblast	781	726	103	253	315	679	13
35. Penza Oblast	978	937	289	202	396	889	21
36. Saratov Oblast	685	627	60	355	135	558	6
37. Ul'yanovsk Oblast	1,058	1,018	389	155	412	957	26
38. Rep. of Kalmykia	41	27	0	7	0	12	0
39. Rep. of Tatarstan	1,258	1,206	251	245	619	1,116	16
40. Krasnodar Kray	1,880	1,764	114	1,423	94	1,716	21
41. Stavropol' Kray	634	538	130	213	7	513	6

Continued

Table 1.—Continued

Administrative territory	Total area of Forest Fund	Forest area (stocked and unstocked)	Stocked area: Conifer	Stocked area: Deciduous: Hardwood	Stocked area: Deciduous: Softwood	Stocked area: Total	Percent of admin. territory that is stocked
42. Rostov Oblast	467	373	77	186	30	315	3
43. Rep. of Dagestan	530	410	68	234	78	390	8
44. Rep. of Kabardino-Balkaria	337	188	7	108	55	176	14
45. Rep. of North Osetia	233	192	9	138	37	186	23
46. Rep. of Checheno-Ingushetia	407	380	9	276	74	369	19
47. Kurgan Oblast	1,796	1,650	385	0	1,157	1,545	22
48. Orenburg Oblast	698	608	63	201	249	538	4
49. Perm' Oblast	12,376	11,679	7,562	2	3,481	11,045	69
50. Sverdlovsk Oblast	15,938	13,388	8,099	0	4,669	12,768	66
51. Chelyabinsk Oblast	2,984	2,675	795	42	1,634	2,475	28
52. Rep. of Bashkortostan	6,230	5,707	1,210	713	3,551	5,489	38
53. Rep. of Udmurtia	2,066	2,000	1,092	5	795	1,893	45
54. Altai Kray	10,232	7,984	4,629	2	2,440	7,363	28
55. Kemerovo Oblast	6,233	5,839	3,051	0	2,556	5,615	59
56. Novosibirsk Oblast	6,497	4,443	965	1	3,264	4,249	24
57. Omsk Oblast	5,833	4,515	1,147	0	3,225	4,376	31
58. Tomsk Oblast	28,746	19,633	10,492	0	8,386	18,883	60
59. Tyumen' Oblast	93,078	53,116	39,152	0	10,111	49,610	35
60. Krasnoyarsk Kray	168,192	126,304	95,837	0	19,831	116,762	49
61. Irkutsk Oblast	71,745	65,923	46,083	0	8,575	58,532	76
62. Chita Oblast	34,328	30,782	20,413	1	5,122	28,888	67
63. Rep. of Buryatia	29,711	23,535	17,131	4	1,640	22,164	63
64. Rep. of Tuva	11,406	8,680	7,609	0	276	8,118	48
65. Primor'ye Kray	13,594	13,212	6,971	3,661	2,010	12,689	77
66. Khabarovsk Kray	77,878	60,447	36,778	1,670	5,017	49,417	60
67. Amur Oblast	31,715	25,909	14,822	760	4,992	22,542	62
68. Kamchatka Oblast	45,171	21,741	1,171	5,996	1,381	19,805	42
69. Magadan Oblast	73,289	38,125	10,033	8	355	22,978	19
70. Sakhalin Oblast	7,615	6,763	3,967	944	383	5,630	65
71. Rep. of Yakutia (Sakha)	257,921	193,665	128,409	0	2,029	147,491	48
Total	1,182,555	884,094	551,999	19,803	137,202	771,109	45

Table 2.—Area (thousand ha) of nonstocked forest land in administrative territories of Russia (from Goscomles of the U.S.S.R. 1990)

Administrative territory	Open plantation	Nonstocked area			
		Woodland	Burned area	Cutover area	Waste ground
1. Kaliningrad Oblast	6	0	0	2	1
2. Arkhangel'sk Oblast	278	1	35	660	33
3. Vologda Oblast	112	0	0	121	1
4. Murmansk Oblast	21	15	15	156	2
5. Rep. of Karelia	315	5	14	322	4
6. Komi	141	6	12	564	18
7. Leningrad Oblast	91	1	3	38	3
8. Novgorod Oblast	45	0	2	25	1
9. Pskov Oblast	29	0	1	11	1
10. Bryansk Oblast	19	0	0	9	2
11. Vladimir Oblast	37	0	1	17	3
12. Ivanovo Oblast	32	0	1	20	5
13. Tver' Oblast	52	0	11	29	5
14. Kaluga Oblast	20	0	0	7	3
15. Kostroma Oblast	78	1	3	60	7
16. Moscow Oblast	27	1	1	9	6
17. Orel Oblast	5	0	0	1	0
18. Ryazan' Oblast	20	0	1	9	2
19. Smolensk Oblast	28	0	0	5	1
20. Tula Oblast	10	0	0	2	1
21. Yaroslavl' Oblast	30	0	2	10	3
22. Nizhniy Novgorod Oblast	94	1	5	33	10
23. Kirov Oblast	156	2	3	151	6
24. Rep. of Mari El	32	0	2	17	3
25. Rep. of Mordvinia	21	0	2	10	2
26. Rep. of Chuvashia	23	1	1	10	2
27. Belgorod Oblast	5	0	0	1	1
28. Voronezh Oblast	19	1	0	6	3
29. Kursk Oblast	8	0	0	1	1
30. Lipetsk Oblast	5	0	1	2	2
31. Tambov Oblast	9	1	1	6	2
32. Astrakhan' Oblast	4	7	1	1	10
33. Volgograd Oblast	18	3	1	11	35
34. Samara Oblast	15	3	2	6	8
35. Penza Oblast	29	0	0	10	2
36. Saratov Oblast	14	2	0	7	14
37. Ul'yanovsk Oblast	40	1	1	14	4
38. Rep. of Kalmykia	4	1	1	2	7
39. Rep. of Tatarstan	45	5	5	15	9
40. Krasnodar Kray	20	2	0	10	8
41. Stavropol' Kray	4	1	1	2	7
42. Rostov Oblast	13	1	3	4	10
43. Rep. of Dagestan	4	5	0	1	7
44. Rep. of Kabardino-Balkaria	2	2	0	1	2
45. Rep. of Osetia	1	2	0	0	2
46. Rep. of Checheno-Ingushetia	2	3	0	0	5
47. Kurgan Oblast	40	1	1	22	9
48. Orenburg Oblast	16	3	1	6	19
49. Perm' Oblast	228	11	6	324	16

Continued

Table 2.—Continued

Administrative territory	Open plantation	Nonstocked area			
		Woodland	Burned area	Cutover area	Waste ground
50. Sverdlovsk Oblast	160	7	38	285	14
51. Chelyabinsk Oblast	66	18	3	43	33
52. Rep. of Bashkortostan	102	8	12	59	15
53. Rep. of Udmurtia	55	0	2	37	3
54. Altai Kray	89	204	42	70	42
55. Kemerov Oblast	92	30	4	60	14
56. Novosibirsk Oblast	18	38	44	33	21
57. Omsk Oblast	35	10	10	26	6
58. Tomsk Oblast	81	39	281	233	36
59. Tyumen' Oblast	89	1,966	639	470	172
60. Krasnoyarsk Kray	182	4,826	3,195	819	184
61. Irkutsk Oblast	207	1,520	4,429	673	430
62. Chita Oblast	45	707	716	172	66
63. Rep. of Buryatia	45	584	383	165	13
64. Rep. of Tuva	5	269	216	17	37
65. Primor'ye Kray	9	112	190	28	96
66. Khabarovsk Kray	117	2,699	3,384	794	412
67. Amur Oblast	34	1,448	665	564	502
68. Kamtchatka Oblast	38	547	12	63	280
69. Magadan Oblast	23	11,409	3,220	84	76
70. Sakhalin Oblast	58	150	334	286	159
71. Rep. of Yakutia (Sakha)	1	28,455	8,588	714	1,056
Total	3,819	55,136	26,544	8,445	3,968

Table 3.—Area (thousand ha) of nonforest lands under management of forest entities in administrative territories of Russia (from Goscomles of the U.S.S.R. 1990) [a]

Administrative territory	Cropland and pasture	Water	Roads and survey lines	Country estates	Peatland	Other
1. Kaliningrad Oblast	11	1	6	2	10	1
2. Arkhangel'sk Oblast	63	304	62	24	5,056	45
3. Vologda Oblast	43	62	46	16	1,097	6
4. Murmansk Oblast	1	695	14	1	2,680	921
5. Rep. of Karelia	22	1,491	45	11	3,539	46
6. Rep. of Komi	68	120	71	23	3,319	334
7. Leningrad Oblast	43	126	34	3	695	28
8. Novgorod Oblast	14	15	13	1	422	9
9. Pskov Oblast	11	13	11	1	229	6
10. Bryansk Oblast	15	2	10	2	11	4
11. Vladimir Oblast	12	3	13	1	14	12
12. Ivanovo Oblast	12	2	11	2	15	6
13. Tver' Oblast	15	19	21	3	231	15
14. Kaluga Oblast	12	1	7	1	8	5
15. Kostroma Oblast	26	6	30	6	43	11
16. Moscow Oblast	26	6	21	17	23	15
17. Orel Oblast	3	0	1	0	1	1
18. Ryazan' Oblast	16	4	13	4	21	2
19. Smolensk Oblast	7	2	7	1	23	4
20. Tula Oblast	6	0	3	2	0	1

Continued

Table 3.—Continued

Administrative territory	Cropland and pasture	Water	Roads and survey lines	Country estates	Peatland	Other
21. Yaroslavl' Oblast	9	3	9	5	28	6
22. Nizhniy Novgorod Oblast	46	11	38	8	63	17
23. Kirov 0blast	41	15	47	15	87	6
24. Rep. of Mari El	11	8	14	3	26	6
25. Rep. of Mordvinia	7	2	7	2	6	2
26. Rep. of Chuvashia	9	2	8	4	3	4
27. Belgorod Oblast	3	1	2	0	1	3
28. Voronezh Oblast	11	5	5	2	6	1
29. Kursk Oblast	6	0	1	1	3	4
30. Lipetsk Oblast	2	1	2	0	4	3
31. Tambov Oblast	7	2	5	2	11	1
32. Astrakhan' Oblast	10	5	1	1	23	10
33. Volgograd Oblast	23	13	4	1	10	27
34. Samara Oblast	18	9	5	2	4	7
35. Penza Oblast	13	2	10	3	5	3
36. Saratov Oblast	13	8	5	1	4	15
37. Ul'yanovsk Oblast	10	3	9	2	4	7
38. Rep. of Kalmykia	4	1	0	0	0	6
39. Rep. of Tatarstan	14	2	11	4	2	17
40. Krasnodar Kray	23	9	11	2	5	33
41. Stavropol' Kray	10	4	2	1	1	19
42. Rostov Oblast	30	2	4	1	3	16
43. Rep. of Dagestan	42	2	1	1	1	49
44. Rep. of Kabardino-Balkaria	10	2	0	0	0	42
45. Rep. of North Osetia	3	2	0	0	0	10
46. Rep. of Checheno-Ingushetia	12	3	1	0	1	4
47. Kurgan Oblast	38	7	10	1	77	10
48. Orenburg Oblast	30	17	4	1	1	32
49. Perm' Oblast	109	41	83	27	307	101
50. Sverdlovsk Oblast	194	88	90	36	1,759	110
51. Chelyabinsk Oblast	149	20	22	4	23	30
52. Rep. of Bashkortostan	197	14	33	11	10	168
53. Rep. of Udmurtia	21	4	15	3	4	11
54. Altai Kray	232	79	30	8	158	1,095
55. Kemerovo Oblast	91	33	13	26	18	130
56. Novosibirsk Oblast	127	18	11	4	1,840	5
57. Omsk Oblast	74	25	14	2	1,116	3
58. Tomsk Oblast	62	304	46	18	8,645	15
59. Tyumen' Oblast	874	4,069	96	55	29,065	2,589
60. Krasnoyarsk Kray	945	2,394	83	44	25,114	11,545
61. Irkutsk Oblast	298	346	506	118	1,530	2,342
62. Chita Oblast	234	96	30	9	898	1,986
63. Rep. of Buryatia	495	222	26	9	330	4,664
64. Rep. of Tuva	116	80	2	1	953	1,292
65. Primor'ye Kray	39	35	17	15	134	83
66. Khabarovsk Kray	90	274	23	42	4,707	3,388
67. Amur Oblast	104	155	30	10	4,352	763
68. Kamtchatka Oblast	122	136	4	3	1,781	2,801
69. Magadan Oblast	8	891	4	6	7,114	26,562
70. Sakhalin Oblast	41	50	11	12	565	84
71. Rep. of Yakutia (Sakha)	1,199	3,284	80	38	13,755	28,622
Total	6,701	15,669	1,929	686	121,993	90,226

[a]Does not include 157,000 ha of gardens.

Table 4.—Total volume (million m³) and average volume (m³/ha) of growing stock in administrative territories of Russia, by species group (from Goscomles of the U.S.S.R. 1990)

Administrative territory	Conifer		Deciduous hardwood		Deciduous softwood		Bush	Total	Average vol. of growing stock
	Total	Mature/ overmature	Total	Mature/ overmature	Total	Mature/ overmature			
1. Kaliningrad Oblast	14	2	9	1	16	3	0	39	148
2. Arkhangel'sk Oblast	2,194	1,656	0	0	182	75	0	2,376	108
3. Vologda Oblast	818	312	0	0	517	220	0	1,335	131
4. Murmansk Oblast	183	111	0	0	28	12	0	211	41
5. Rep. of Karelia	738	378	0	0	83	37	0	822	90
6. Rep. of Komi	2,494	2,027	0	0	361	245	0	2,855	97
7. Leningrad Oblast	516	161	0	0	274	111	0	790	166
8. Novgorod Oblast	226	64	1	0	300	94	0	527	151
9. Pskov Oblast	137	21	1	0	170	37	0	308	144
10. Bryansk Oblast	84	7	10	2	64	11	0	158	142
11. Vladimir Oblast	137	10	3	1	69	12	0	210	143
12. Ivanovo Oblast	87	6	1	0	69	13	0	157	153
13. Tver' Oblast	345	73	0	0	319	82	0	663	161
14. Kaluga Oblast	65	7	8	2	139	38	0	212	162
15. Kostroma Oblast	334	95	0	0	315	73	0	649	150
16. Moscow Oblast	176	11	7	1	157	29	0	340	177
17. Orel Oblast	5	0	8	1	10	2	0	23	125
18. Ryazan' Oblast	67	4	16	3	54	7	0	138	137
19. Smolensk Oblast	78	8	1	0	155	24	0	235	124
20. Tula Oblast	4	0	16	1	24	8	0	44	130
21. Yaroslavl' Oblast	86	7	0	0	127	27		213	133
22. Nizhniy NovgorodOblast	245	35	14	3	205	45	0	465	132
23. Kirov Oblast	608	244	1	1	386	146	0	996	136
24. Rep. of Mari El	85	19	2	1	77	22	0	165	133
25. Rep. of Mordvinia	31	3	12	2	41	8	0	84	128
26. Rep. of Chuvashia	24	3	18	2	36	11	0	78	140
27. Belgorod Oblast	3	0	27	2	2	0	0	33	122
28. Voronezh Oblast	17	0	29	3	6	2	0	52	125
29. Kursk Oblast	3	0	13	0	4	1	0	20	87
30. Lipetsk Oblast	13	0	10	1	6	2	0	29	154
31. Tambov Oblast	26	3	8	1	15	4	0	49	134
32. Astrakhan' Oblast	0	0	1	0	5	3	0	6	66
33. Volgograd Oblast	3	0	16	3	9	5	0	29	62
34. Samara Oblast	15	4	27	6	38	8	0	80	118
35. Penza Oblast	48	6	23	4	49	11	0	119	134

Continued

Table 4.—Continued

Administrative territory	Conifer		Deciduous hardwood		Deciduous softwood		Bush	Total	Average vol. of growing stock
	Total	Mature/ overmature	Total	Mature/ overmature	Total	Mature/ overmature			
36. Saratov Oblast	4	0	33	6	15	4	0	52	93
37. Ul'yanovsk Oblast	68	11	17	4	57	10	0	141	148
38. Rep. of Kalmykia	0	0	0	0	0	0	0	0	17
39. Rep. of Tatarstan	34	2	25	3	86	22	0	145	130
40. Krasnodar Kray	34	26	259	118	13	7	17	322	188
41. Stavropol' Kray	38	17	37	15	18	9	0	93	182
42. Rostov Oblast	3	0	7	1	2	1	1	14	43
43. Rep. of Dagestan	10	1	25	2	6	2	0	41	106
44. Rep. of Kabardino-Balkaria	1	0	20	10	4	1	0	25	143
45. Rep. of North Osetia	1	0	27	8	3	1	0	31	166
46. Rep. of Checheno-Ingushetia	1	0	46	10	6	2	0	54	145
47. Kurgan Oblast	64	13	0	0	120	12	0	183	119
48. Orenburg Oblast	11	4	20	4	29	12	0	60	112
49. Perm' Oblast	1,075	648	0	0	419	163	0	1,494	135
50. Sverdlovsk Oblast	1,246	550	0	0	513	192	0	1,759	138
51. Chelyabinsk Oblast	148	41	4	2	194	59	0	346	140
52. Rep. of Bashkortostan	174	51	82	44	473	225	0	729	133
53. Rep. of Udmurtia	166	43	0	0	113	24	0	279	148
54. Altai Kray	811	361	0	0	247	110	2	1,060	144
55. Kemerovo Oblast	359	175	0	0	239	123	0	598	106
56. Novosibirsk Oblast	117	28	0	0	317	99	0	435	102
57. Omsk Oblast	120	32	0	0	393	209	0	514	117
58. Tomsk Oblast	1,578	1,010	0	0	1,187	919	0	2,765	146
59. Tyumen' Oblast	4,236	2,760	0	0	1,183	889	3	5,423	109
60. Krasnoyarsk Kray	12,588	10,172	0	0	1,764	1,059	18	14,370	123
61. Irkutsk Oblast	8,124	4,985	0	0	886	483	122	9,132	156
62. Chita Oblast	2,222	950	0	0	273	56	61	2,556	88
63. Rep. of Buryatia	1,947	880	0	0	121	48	73	2,141	97
64. Rep. of Tuva	1,086	519	0	0	29	17	2	1,116	137
65. Primor'ye Kray	1,335	749	384	192	217	93	2	1,938	153
66. Khabarovsk Kray	4,617	3,103	181	125	387	173	193	5,378	109
67. Amur Oblast	1,645	910	27	5	312	75	49	2,033	90
68. Kamtchatka Oblast	147	127	505	441	106	65	473	1,230	62
69. Magadan Oblast	384	266	0	0	37	20	154	575	25
70. Sakhalin Oblast	598	385	52	22	22	6	18	690	123
71. Rep. of Yakutia (Sakha)	9,137	5,899	0	0	86	26	191	9,413	64
Total	64,037	39,991	2,032	1,052	14,191	6,644	1,383	81,644	106

Table 5.—Volume of growing stock (million m³) of forest stands in the administrative territories of Russia (from Goscomles of the U.S.S.R. 1990)

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Premature	Mature/ overmature	
	Class I[a]	Class II[b]				
1. Kaliningrad Oblast						
Betula sp.	0.1	0.4	6.7	1.3	1.4	9.9
Quercus robur	0.2	1.1	5.6	1.5	0.6	9.0
Pinus sylvestris	0.7	1.3	3.4	1.0	1.0	7.3
Picea abies	0.6	1.3	3.0	1.1	0.9	7.0
Populus tremula	0.0	0.2	4.0	1.0	1.0	6.3
Other[c]	--[d]	--	--	--	--	0.0
2. Arkhangel'sk Oblast						
Picea sp.	15.0	52.3	237.0	89.9	1,205.4	1,599.7
Pinus sylvestris	5.3	18.4	87.0	31.6	442.9	585.3
Betula pendula	3.1	11.3	59.0	18.6	60.7	152.7
Populus tremula	0.5	2.1	10.9	3.5	12.4	29.3
Larix sukachevii	0.1	0.2	1.1	0.4	7.6	9.4
Other[c]	--	--	--	--	--	0.0
3. Vologda Oblast						
Picea sp.	11.0	34.2	179.9	76.8	184.6	486.5
Betula sp.	4.3	11.1	142.8	78.2	175.3	411.6
Pinus sylvestris	7.7	23.7	123.2	49.6	127.7	331.8
Populus tremula	1.1	2.8	35.5	19.3	43.7	102.3
Alnus incana	0.0	0.1	1.1	0.6	1.2	3.0
Other[c]	--	--	--	--	--	0.1
4. Murmansk Oblast						
Pinus sylvestris	0.8	7.0	22.4	6.0	56.8	93.0
Picea obovata	0.8	6.7	21.8	5.8	54.7	89.7
Betula pendula	0.1	0.9	11.3	3.7	11.9	27.9
Table 5. (Continued)						
5. Republic of Karelia						
Pinus sylvestris	12.0	33.7	119.4	65.4	237.2	467.7
Picea sp.	7.0	19.7	69.2	37.1	137.8	270.7
Betula pendula	0.4	3.7	26.0	13.1	32.1	75.3
Populus tremula	0.0	0.4	2.6	1.3	3.5	7.8
Other[c]	--	--	--	--	--	0.1
6. Republic of Komi						
Picea obovata	10.9	60.8	133.3	105.4	1,458.4	1,768.8
Pinus sylvestris	4.0	21.3	80.4	41.8	524.5	672.0
Betula pendula	2.5	6.4	61.2	17.7	184.1	271.8
Populus tremula	0.8	2.0	20.2	5.8	60.9	89.7
Larix sukachevii	0.2	1.0	3.0	1.4	24.5	30.0
Abies incana	0.1	0.7	2.1	1.0	16.0	19.8
Pinus sibirica	0.0	0.1	0.5	0.1	2.4	3.1
Bushes	--	--	--	--	--	0.2
7. Leningrad Oblast						
Pinus sylvestris	6.2	17.6	79.8	77.0	82.6	263.3
Picea abies	6.1	17.2	76.8	74.4	78.3	252.8
Betula pendula	1.9	5.6	70.5	39.3	79.3	196.6
Populus tremula	0.9	2.1	27.3	16.0	31.4	77.7
Other[c]	--	--	--	--	--	0.1
8. Novgorod Oblast						
Betula pendula	1.2	4.8	82.5	53.2	64.7	206.4
Pinus sylvestris	6.1	9.0	42.9	30.2	34.8	123.0

Continued

Table 5.—Continued

Dominant species	Age-class group: Young stands, Class I[a]	Young stands, Class II[b]	Middle-aged	Premature	Mature/ overmature	Total
Picea abies	5.0	7.5	31.1	30.2	29.4	103.1
Populus tremula	0.6	2.1	34.5	22.5	28.1	87.7
Alnus incana	0.1	0.1	2.7	1.8	1.1	5.7
Quercus robur	0.0	0.1	0.2	0.2	0.1	0.6
Other[c]	--	--	--	--	--	0.1
9. Pskov Oblast						
Betula pendula	0.8	2.7	56.2	31.0	25.4	116.1
Pinus sylvestris	3.2	11.9	42.0	29.1	15.3	101.4
Populus tremula	0.2	1.0	17.3	11.3	8.5	38.4
Picea abies	1.2	4.3	14.5	10.2	5.2	35.4
Alnus incana	0.1	0.4	7.5	4.9	3.1	15.9
Quercus robur	0.0	0.1	0.2	0.3	0.0	0.7
Other[c]	--	--	--	--	--	0.0
10. Bryansk Oblast						
Pinus sylvestris	2.1	17.4	30.4	14.7	6.2	70.8
Betula sp.	0.3	1.5	19.9	7.2	7.1	36.1
Populus tremula	0.2	0.9	12.0	4.2	3.4	20.7
Picea abies	2.0	2.7	5.5	2.2	0.8	13.2
Quercus robur	0.1	0.7	5.2	1.9	2.3	10.2
Alnus sp.	0.1	0.3	4.0	1.4	1.2	7.0
Other[c]	--	--	--	--	--	0.0
11. Vladimir Oblast						
Pinus sylvestris	4.5	22.2	49.5	36.4	8.9	121.5
Betula sp.	0.8	1.6	26.9	13.3	8.6	51.1
Populus tremula	0.3	0.6	8.5	4.3	3.2	16.9
Picea abies	0.7	2.9	6.6	4.6	1.1	15.8
Quercus robur	0.1	0.2	0.3	1.1	1.7	3.4
Alnus sp.	0.0	0.0	0.5	0.3	0.1	0.9
Other[c]	--	--	--	--	--	0.1
12. Ivanovo Oblast						
Pinus sylvestris	2.4	13.6	24.0	16.5	4.8	61.2
Betula sp.	0.4	1.8	23.0	12.1	9.9	47.1
Picea abies	0.9	6.1	10.5	6.4	1.6	25.6
Populus tremula	0.1	0.6	13.8	4.0	3.3	21.9
Quercus robur	0.0	0.0	0.1	0.1	0.4	0.5
Alnus ssp.	0.0	0.0	0.3	0.1	0.0	0.5
Other[c]	--	--	--	--	--	0.1
13. Tver’ Oblast						
Betula pendula	1.4	6.8	109.6	42.8	57.0	217.6
Pinus sylvestris	5.7	18.1	67.0	50.7	36.3	177.7
Picea abies	5.6	17.1	62.0	47.7	34.4	166.8
Populus tremula	0.6	2.7	49.7	16.4	22.9	92.2
Alnus incana	0.1	0.3	4.8	1.8	1.9	8.8
Quercus robur	0.0	0.0	0.0	0.0	0.0	0.0
Other[c]	--	--	--	--	--	0.1
14. Kaluga Oblast						
Betula sp.	0.4	1.4	40.3	19.8	24.0	85.9
Populus tremula	0.3	1.0	24.4	12.4	13.6	51.7
Picea abies	2.4	7.0	11.9	9.2	3.4	33.8
Pinus sylvestris	2.1	7.1	10.3	8.2	3.2	30.9
Quercus robur	0.0	0.2	0.9	6.3	0.8	8.3
Alnus sp.	0.0	0.0	0.8	0.4	0.2	1.5

Continued

Table 5.—Continued

Dominant species	Age-class group: Young stands Class I[a]	Young stands Class II[b]	Middle-aged	Premature	Mature/ overmature	Total
Other[c]	--	--	--	--	--	0.1
15. Kostroma Oblast						
Betula sp.	3.0	12.3	124.8	54.0	59.5	253.5
Pinus sylvestris	9.5	26.8	58.6	33.4	51.0	179.3
Picea abies	8.2	22.9	50.6	28.7	44.1	154.5
Populus tremula	0.8	3.0	30.8	13.2	14.2	62.0
Quercus robur	0.0	0.0	0.0	0.0	0.0	0.1
Other[c]	--	--	--	--	--	0.1
16. Moscow Oblast						
Betula sp.	0.4	12.1	68.0	19.2	22.0	121.6
Picea abies	2.8	13.0	50.8	19.3	5.8	91.7
Pinus sylvestris	2.4	11.0	44.4	17.1	4.9	79.8
Populus tremula	0.2	0.6	21.2	5.8	6.7	34.5
Quercus robur	0.1	0.2	2.9	7.3	1.1	11.7
Alnus sp.	0.0	0.0	0.5	0.1	0.0	0.7
Other[c]	--	--	--	--	--	0.4
17. Orel Oblast						
Quercus robur	0.2	0.9	4.8	0.8	0.8	7.5
Betula pendula	0.0	0.1	2.9	1.2	0.9	5.2
Popula tremula	0.0	0.1	2.7	1.2	0.9	4.9
Pinus sylvestris	0.2	1.4	1.6	0.8	0.4	4.3
Other[c]	--	--	--	--	--	0.8
18. Ryazan' Oblast						
Pinus sylvestris	3.1	14.1	27.5	15.7	3.5	63.9
Betula sp.	0.6	1.5	22.4	7.7	5.2	37.3
Populus tremula	0.3	0.7	10.0	3.3	2.1	16.3
Quercus robur	0.3	1.2	8.7	3.2	2.9	16.3
Picea abies	0.1	0.5	1.2	0.8	0.2	2.9
Tilia cordata	0.0	0.0	0.2	0.0	0.0	0.3
Alnus sp.	0.0	0.0	0.4	0.1	0.0	0.5
Other[c]	--	--	--	--	--	0.0
19. Smolensk Oblast						
Betula pendula	0.2	2.4	60.6	21.4	16.0	100.6
Picea abies	6.1	7.2	21.9	15.5	5.8	56.4
Populus tremula	0.1	1.0	27.9	9.7	8.0	46.8
Pinus sylvestris	2.3	2.9	8.1	6.0	2.1	21.3
Alnus sp.	0.0	0.1	3.6	1.3	0.0	0.2
Tilia cordata	0.0	0.1	2.1	0.7	0.2	3.0
Quercus robur	0.0	0.1	0.9	0.2	0.0	1.2
Other[c]	--	--	--	--	--	0.1
20. Tula Oblast						
Quercus robur	0.6	1.7	11.5	1.5	0.9	16.0
Populus tremula	0.0	0.2	4.8	1.7	3.1	9.9
Betula sp.	0.1	0.2	4.1	1.7	3.5	9.5
Tilia cordata	0.0	0.1	1.9	0.9	1.5	4.5
Pinus sylvestris	0.2	0.9	0.8	0.5	0.1	2.6
Picea abies	0.1	0.4	0.4	0.2	0.0	1.1
Other[c]	--	--	--	--	--	0.2
21. Yaroslavl' Oblast						
Betula sp.	0.3	2.1	47.1	18.5	18.0	86.0
Picea abies	2.6	7.1	11.3	26.0	4.4	51.3

Continued

Table 5.—Continued

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Premature	Mature/ overmature	
	Class I[a]	Class II[b]				
Populus tremula	0.1	1.1	21.1	8.3	8.0	38.6
Pinus sylvestris	1.8	4.7	15.1	10.5	2.5	34.5
Alnus sp.	0.0	0.1	1.4	0.6	0.6	2.6
Quercus robur	0.0	0.1	0.2	0.1	0.0	0.4
Other[c]	--	--	--	--	--	0.0
			22. Nizhniy Novgorod Oblast			
Pinus sylvestris	11.6	42.9	69.8	42.1	29.5	195.9
Betula sp.	3.5	7.9	66.8	30.6	31.1	139.9
Popula tremula	1.6	3.7	30.2	14.4	13.8	63.6
Picea abies	2.8	11.1	18.6	10.8	5.7	49.0
Quercus robur	0.2	0.6	6.2	4.6	2.9	14.5
Tilia cordata	0.0	0.1	0.5	0.2	0.1	0.9
Alnus sp.	0.0	0.1	0.5	0.2	0.1	0.9
Other[c]	--	--	--	--	--	0.2
			23. Kirov Oblast			
Picea abies	13.6	35.3	107.1	54.8	140.9	351.6
Betula sp.	3.9	22.3	109.7	39.8	106.0	281.7
Pinus sylvestris	9.9	25.7	76.9	39.9	103.0	255.4
Popula tremula	1.6	8.8	41.0	11.6	39.6	102.6
Tilia cordata	0.0	0.2	0.7	0.3	0.3	1.5
Quercus robur	0.0	0.0	0.1	0.2	0.6	1.0
Alnus sp.	0.0	0.1	0.4	0.1	0.1	0.7
Other[c]	--	--	--	--	--	1.3
			24. Republic of Mari El			
Pinus sylvestris	2.6	8.6	24.2	11.6	13.9	61.0
Betula	1.4	1.7	21.6	10.2	14.4	49.2
Popula tremula	0.7	0.9	12.6	5.3	7.5	26.9
Picea abies	1.0	3.4	9.9	4.5	5.1	23.8
Quercus robur	0.0	0.0	0.0	1.1	1.1	2.3
Tilia cordata	0.0	0.0	0.4	0.2	0.1	0.8
Alnus sp.	0.0	0.0	0.2	0.1	0.0	0.3
Other[c]	--	--	--	--	--	0.3
			25. Republic of Mordvinia			
Pinus sylvestris	2.4	10.6	7.6	5.9	3.4	29.9
Betula sp.	0.6	1.0	13.4	5.3	3.9	24.2
Populus tremula	0.4	0.7	6.5	2.3	2.6	12.4
Quercus robur	0.3	0.9	6.6	1.7	2.4	11.9
Tilia cordata	0.1	0.1	2.2	0.8	0.9	4.1
Picea abies	0.0	0.1	0.2	0.1	0.7	1.1
Other[c]	--	--	--	--	--	0.1
			26. Republic of Chuvashia			
Pinus sylvestris	1.8	5.0	9.7	3.5	2.9	23.0
Betula sp.	0.5	1.0	7.4	3.5	5.5	17.9
Quercus robur	0.4	2.6	11.8	1.2	1.8	17.8
Populus tremula	0.2	0.4	3.7	1.8	2.9	9.1
Tilia cordata	0.2	0.4	3.6	1.8	2.9	8.9
Picea abies	0.1	0.3	0.4	0.1	0.1	1.0
Other[c]	--	--	--	--	--	0.3
			27. Belgorod Oblast			
Quercus robur	0.3	2.6	19.7	3.0	1.5	27.1
Pinus sylvestris	0.3	1.6	1.4	0.1	0.0	3.5
Populus tremula	0.0	0.1	0.9	0.1	0.3	1.4

Continued

Table 5.—Continued

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Premature	Mature/ overmature	
	Class I[a]	Class II[b]				
Betula sp.	0.0	0.1	0.4	0.2	0.0	0.7
28. Voronezh Oblast						
Quercus robur	0.8	2.6	17.4	5.1	3.1	29.0
Pinus sylvestris	1.5	7.0	6.5	1.7	0.4	17.0
Populus tremula	0.2	0.6	0.9	1.5	1.8	5.1
Betula sp.	0.0	0.0	0.4	0.3	0.5	1.3
Other[c]	--	--	--	--	--	0.1
29. Kursk Oblast						
Quercus robur	0.4	1.5	9.3	1.4	0.3	12.9
Pinus sylvestris	0.6	1.2	1.2	0.0	0.0	2.9
Populus tremula	0.0	0.2	1.0	0.5	0.3	2.0
Betula sp.	0.1	0.2	0.7	0.4	0.3	1.6
Tilia cardata	0.0	0.0	0.1	0.0	0.0	0.1
Other[c]	--	--	--	--	--	0.1
30. Lipetsk Oblast						
Pinus sylvestris	0.4	3.8	7.8	0.9	0.4	13.2
Quercus robur	0.1	1.1	7.2	1.2	0.7	10.3
Populus tremula	0.2	0.1	1.3	0.5	0.9	3.0
Betula sp.	0.0	0.1	1.2	0.5	0.8	2.5
Other[c]	--	--	--	--	--	0.1
31. Tambov Oblast						
Pinus sylvestris	2.1	5.0	10.7	5.1	2.8	25.7
Populus tremula	0.2	0.5	3.7	2.0	2.0	8.4
Quercus robur	0.1	0.4	4.6	1.7	1.2	8.0
Betula sp.	0.2	0.6	2.9	1.7	1.6	7.0
Other[c]	--	--	--	--	--	0.1
32. Astrakhan’ Oblast						
Populus sp.	0.0	0.1	1.1	0.7	3.3	5.2
Quercus robur	0.0	0.0	0.3	0.1	0.3	0.8
Other[c]	--	--	--	--	--	0.2
33. Volgograd Oblast						
Quercus robur	0.4	1.7	8.2	3.1	3.0	16.4
Populus sp.	0.1	0.5	1.3	1.1	3.7	6.6
Pinus sylvestris	0.7	1.2	1.2	0.2	0.0	3.3
Populus tremula	0.0	0.1	0.3	0.3	1.0	1.7
Betula sp.	0.0	0.0	0.2	0.1	0.2	0.5
Other[c]	--	--	--	--	--	0.4
34. Samara Oblast						
Quercus robur	0.2	1.1	14.1	5.8	6.0	27.1
Populus tremula	0.5	1.2	8.9	4.1	4.7	19.4
Pinus sylvestris	0.8	1.7	5.6	2.4	4.2	14.7
Tilia cordata	0.2	0.8	5.7	2.4	2.2	11.3
Betula sp.	0.1	0.4	2.2	0.8	0.9	4.3
Populus sp.	0.1	0.2	1.6	0.7	0.6	3.1
Other[c]	--	--	--	--	--	0.3
35. Penza Oblast						
Pinus sylvestris	4.7	10.1	15.9	10.6	5.9	47.2
Populus tremula	0.7	2.3	10.2	5.8	6.7	25.7
Betula sp.	0.6	1.2	11.8	5.2	4.7	23.5
Quercus robur	0.2	0.9	13.3	4.2	4.2	22.7
Other[c]	--	--	--	--	--	0.3

Continued

Table 5.—Continued

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Premature	Mature/ overmature	
	Class I[a]	Class II[b]				
			36. Saratov Oblast			
Quercus robur	0.2	1.6	14.8	9.9	6.3	32.8
Populus tremula	0.1	0.2	2.8	1.5	1.3	5.9
Pinus sylvestris	0.4	1.2	1.8	0.7	0.2	4.2
Populus sp.	0.0	0.2	1.5	0.7	0.9	3.2
Tilia cordata	0.0	0.2	1.4	0.6	0.8	3.0
Betula sp.	0.0	0.2	1.0	0.4	1.0	2.6
Other[c]	--	--	--	--	--	0.2
			37. Ul'yanovsk Oblast			
Pinus sylvestris	3.7	12.4	26.9	13.1	11.4	67.4
Betula sp.	0.5	1.3	16.7	6.7	4.9	30.2
Populus tremula	0.5	1.7	14.1	5.5	5.2	27.0
Quercus robur	0.2	0.3	7.9	4.0	4.2	16.6
Bushes[e]	--	--	--	--	--	0.2
			38. Republic of Kalmykia			
Quercus sp.	0.0	0.0	0.2	0.0	0.0	0.2
Populus sp.	0.0	0.0	0.0	0.0	0.0	0.0
Other[c]	--	--	--	--	--	0.0
			39. Republic of Tatarstan			
Populus tremula	0.5	2.4	15.3	7.0	9.4	34.6
Tilia cordata	0.5	2.1	13.2	6.1	7.8	29.6
Pinus sylvestris	3.5	8.2	11.7	3.8	1.9	29.1
Quercus robur	1.0	2.3	17.9	3.3	0.1	24.6
Betula sp.	0.4	1.5	10.6	4.4	5.2	22.1
Picea abies	0.4	1.0	1.5	0.5	0.4	3.8
Other[c]	--	--	--	--	--	1.0
			40. Krasnodar Kray			
Quercus sp.	1.2	5.6	45.6	30.6	64.7	147.7
Fagus orientalis	0.7	3.1	26.9	14.5	41.7	86.9
Abies Nordmaniana	1.2	0.8	1.9	2.8	23.3	30.0
Carpinus caucasica	0.2	0.7	6.2	3.3	9.6	20.0
Populus tremula	0.2	0.4	2.2	1.4	4.2	8.3
Ulmus sp.	0.1	0.2	1.3	0.7	2.0	4.2
Populus sp.	0.0	0.2	0.9	0.6	2.0	3.7
Pinus sp.	0.1	0.1	0.2	0.3	2.5	3.2
Betula sp.	0.0	0.0	0.1	0.1	0.3	0.6
Bushes	--	--	--	--	--	16.5
Other[c]	--	--	--	--	--	0.8
			41. Stavropol' Kray			
Fagus orientalis	0.1	0.4	8.5	2.5	8.8	20.3
Abies Nordmaniana	0.3	0.6	5.3	4.1	5.4	15.8
Pinus sylvestris	0.1	0.3	3.7	3.2	8.0	15.3
Betula sp.	0.0	0.1	3.3	1.6	5.2	10.2
Quercus sp.	0.0	0.2	4.1	1.6	3.2	9.0
Populus tremula	0.0	0.1	2.4	1.3	3.6	7.5
Picea orientalis	0.1	0.1	1.8	1.5	3.8	7.3
Carpinus caucasica	0.0	0.1	3.1	0.9	3.1	7.2
Populus sp.	0.0	0.0	0.1	0.1	0.2	0.4
Other[c]	--	--	--	--	--	0.3
			42. Rostov Oblast			
Quercus robur	0.5	2.4	3.0	0.9	0.5	7.3

Continued

Table 5.—Continued

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Premature	Mature/ overmature	
	Class I[a]	Class II[b]				
Pinus sylvestris	1.4	1.3	0.6	0.2	0.0	3.4
Populus sp.	0.1	0.1	0.9	0.2	0.4	1.7
Populus tremula	0.0	0.0	0.3	0.1	0.2	0.6
Betula sp.	0.0	0.0	0.0	0.1	0.0	0.1
Other[c]	--	--	--	--	--	0.5
43. Republic of Dagestan						
Quercus sp.	0.1	0.4	8.0	1.3	1.0	10.8
Pinus sylvestris	0.0	0.4	7.9	1.1	0.6	9.9
Fagus orientalis	0.0	0.2	6.4	1.0	0.7	8.4
Carpinus caucasica	0.0	0.2	4.3	0.7	0.5	5.6
Betula sp.	0.0	0.0	1.2	0.7	1.8	3.7
Tilia sp.	0.0	0.0	0.9	0.4	0.6	1.9
Other[c]	--	--	--	--	--	0.9
44. Republic of Kabardino-Balkaria						
Fagus orientalis	0.0	0.3	6.4	1.0	8.1	15.7
Carpinus caucasica	0.0	0.0	1.5	0.2	1.6	3.4
Populus tremula	0.0	0.0	0.7	0.6	0.8	2.1
Quercus sp.	0.0	0.0	0.6	0.2	0.3	1.1
Other[c]	--	--	--	--	--	2.9
45. Republic of North Osetia						
Fagus orientalis	0.0	0.5	12.7	3.1	6.8	23.1
Carpinus caucasica	0.0	0.1	1.4	0.3	0.7	2.5
Quercus sp.	0.0	0.0	0.6	0.5	0.2	1.3
Tilia sp.	0.0	0.0	0.4	0.3	0.4	1.1
Betula sp.	0.0	0.0	0.6	0.2	0.2	1.1
Other[c]	--	--	--	--	--	1.8
46. Republic of Checheno-Ingushetia						
Fagus orientalis	0.1	0.9	23.3	2.9	5.7	32.9
Quercus sp.	0.0	0.1	4.0	0.7	3.0	7.8
Carpinus caucasica	0.1	0.1	3.6	0.5	1.1	5.3
Betula sp.	0.0	0.0	1.7	0.3	0.8	2.8
Tilia sp.	0.0	0.1	1.3	0.4	0.6	2.4
Other[c]	--	--	--	--	--	2.4
47. Kurgan Oblast						
Betula sp.	1.0	3.3	69.6	19.5	10.7	104.1
Pinus sylvestris	3.7	13.7	20.9	12.2	12.9	63.4
Populus tremula	0.1	0.5	9.9	3.6	1.4	15.5
Other[c]	--	--	--	--	--	0.2
48. Orenburg Oblast						
Quercus robur	0.4	1.2	7.4	6.8	3.9	19.7
Pinus sylvestris	0.7	2.0	3.0	1.4	3.5	10.7
Populus sp.	0.1	0.3	2.8	1.5	3.8	8.4
Populus tremula	0.1	0.3	2.5	1.6	3.4	8.0
Betula sp.	0.2	0.4	2.8	1.2	2.7	7.2
Tilia cordata	0.1	0.2	1.9	1.0	2.5	5.7
Other[c]	--	--	--	--	--	0.4
49. Perm’ Oblast						
Picea sp.	37.0	72.5	138.0	110.7	536.0	894.1
Betula sp.	7.0	34.1	123.1	36.1	122.7	322.9
Pinus sylvestris	6.6	12.5	23.0	19.1	98.0	159.1
Populus tremula	2.0	9.5	30.3	10.0	37.8	89.5

Continued

Table 5.—Continued

Dominant species	Age-class group: Young stands, Class I[a]	Young stands, Class II[b]	Middle-aged	Premature	Mature/ overmature	Total
Abies sibirica	0.9	1.6	3.0	2.5	12.2	20.2
Tilia cordata	0.2	0.7	2.4	0.7	2.5	6.4
Pinus sibirica	0.0	0.0	0.0	0.0	1.4	1.4
Quercus robur	0.0	0.0	0.2	0.0	0.0	0.2
Other[c]	--	--	--	--	--	0.2
50. Sverdlovsk Oblast						
Pinus sylvestris	22.5	69.4	214.4	109.2	328.9	744.3
Betula pendula	6.8	28.0	176.2	54.0	161.4	426.5
Picea obovata	10.0	30.4	95.5	50.6	141.5	327.9
Pinus sibirica	0.0	15.9	38.8	22.5	67.9	145.1
Populus tremula	1.3	5.8	36.5	11.3	30.1	85.0
Abies sibirica	0.7	2.2	7.0	4.0	11.6	25.5
Larix sibirica	0.0	0.3	0.9	0.5	1.6	3.3
Tilia cordata	0.0	0.1	0.6	0.2	0.5	1.3
51. Chelyabinsk Oblast						
Betula pendula	1.3	4.0	63.4	36.3	45.1	150.1
Pinus sylvestris	3.9	13.4	42.4	20.2	30.3	110.1
Populus tremula	0.3	0.7	11.9	6.9	8.8	28.7
Picea obovata	0.8	2.8	9.0	4.3	6.4	23.3
Tilia cordata	0.1	0.4	6.1	3.6	4.6	14.8
Abies sibirica	0.4	1.3	4.1	1.9	2.9	10.6
Quercus robur	0.1	0.2	1.9	0.5	1.7	4.4
Larix sibirica	0.1	0.5	1.5	0.7	1.1	3.9
Other[c]	--	--	--	--	--	0.1
52. Republic of Bashkortostan						
Betula sp.	1.2	5.3	59.5	32.3	84.6	182.8
Tilia cordata	1.0	4.7	49.3	26.9	83.2	165.2
Populus tremula	0.8	3.5	42.3	20.9	57.1	124.6
Pinus sylvestris	5.8	12.1	28.1	38.5	33.7	118.3
Quercus robur	0.2	0.8	26.7	10.3	43.7	81.7
Picea obovata	1.8	3.6	6.8	12.7	10.7	35.6
Abies sibirica	0.8	1.6	3.3	4.9	4.7	15.3
Larix sibirica	0.3	0.5	1.1	1.6	1.5	5.0
Other[c]	--	--	--	--	--	0.3
53. Republic of Udmurtia						
Picea obovata	5.9	19.9	30.6	29.3	29.0	114.6
Betula sp.	0.5	2.8	38.7	19.7	15.6	77.3
Pinus sylvestris	2.5	8.3	12.3	12.5	13.6	49.1
Populus tremula	0.2	1.3	16.6	8.5	7.3	33.8
Tilia cordata	0.0	0.1	1.1	0.5	0.2	2.0
Quercus robur	0.0	0.0	0.2	0.2	0.1	0.5
Other[c]	--	--	--	--	--	2.2
54. Altai Kray						
Pinus sylvestris	1.9	10.3	98.1	62.9	134.3	307.6
Larix sibirica	0.8	5.4	43.7	57.2	84.3	191.4
Pinus sibirica	1.0	5.5	36.9	49.6	83.2	176.1
Betula pendula	1.5	4.6	38.5	31.0	57.3	133.0
Abies sibirica	0.8	4.5	38.1	27.8	55.1	126.3
Populus tremula	1.3	3.6	31.5	25.5	52.4	114.3
Picea obovata	0.1	0.3	2.7	1.9	4.4	9.3
Other[c]	--	--	--	--	--	2.4
55. Kemerovo Oblast						

Continued

Table 5.—Continued

Dominant species	Age-class group: Young stands, Class I[a]	Young stands, Class II[b]	Middle-aged	Premature	Mature/overmature	Total
Abies sibirica	4.3	9.9	62.2	62.8	134.5	273.6
Betula sp.	2.4	5.6	37.9	24.8	51.5	122.3
Populus tremula	1.6	3.6	28.8	15.3	67.5	116.7
Pinus sibirica	0.9	2.1	13.0	13.3	28.8	58.0
Pinus sylvestris	0.4	0.8	4.9	5.0	6.6	17.6
Picea obovata	0.1	0.3	1.9	2.0	4.5	8.8
Other[c]	--	--	--	--	--	0.8
56. Novosibirsk Oblast						
Betula sp.	3.5	10.7	72.7	86.1	78.1	251.1
Pinus sylvestris	1.8	6.4	50.2	17.5	23.2	99.1
Populus tremula	1.0	1.9	18.9	23.4	20.8	65.9
Abies sibirica	0.1	0.5	3.9	1.3	2.0	7.9
Pinus sibirica	0.1	0.5	1.3	3.5	1.9	7.2
Picea obovata	0.1	0.2	1.3	0.4	0.7	2.6
Other[c]	--	--	--	--	--	0.7
57. Omsk Oblast						
Pinus sylvestris	1.8	3.8	33.5	15.4	18.4	72.9
Picea obovata	0.2	0.5	5.6	2.1	2.6	11.0
Abies sibirica	0.2	0.4	3.1	1.4	2.1	7.2
Pinus sibirica	0.7	1.4	5.7	12.6	8.5	28.9
Betula sp.	3.7	8.8	67.0	63.5	161.4	304.4
Populus tremula	1.1	2.6	19.8	18.5	47.2	89.1
Other[c]	--	--	--	--	--	0.3
58. Tomsk Oblast						
Betula sp.	4.0	15.8	85.0	85.8	657.6	848.2
Pinus sibirica	0.3	11.9	102.3	142.1	480.6	737.1
Pinus sylvestris	14.5	10.7	95.3	131.0	417.8	669.2
Populus tremula	1.6	6.3	36.2	33.1	261.3	338.5
Abies sibirica	0.9	1.4	12.8	17.3	61.4	93.8
Picea obovata	0.8	1.2	10.5	14.3	50.1	76.9
Other[c]	--	--	--	--	--	1.5
59. Tyumen’ Oblast						
Pinus sylvestris	10.8	24.8	304.8	375.1	1,338.6	2,054.2
Pinus sibirica	0.2	6.1	177.8	198.1	715.8	1,098.0
Betula pendula	4.7	14.9	107.3	102.3	689.3	918.4
Picea obovata	2.8	6.0	80.0	95.9	355.3	540.0
Larix sibirica	2.7	6.0	81.2	97.0	325.5	512.3
Populus tremula	1.1	4.7	37.3	28.3	193.4	264.8
Abies sibirica	0.2	0.4	4.7	5.6	21.1	31.9
Other[c]	--	--	--	--	--	3.3
60. Krasnoyarsk Kray						
Larix sp.	7.9	16.8	115.7	396.3	5,533.7	6,070.4
Pinus sibirica	4.0	33.5	253.9	374.9	1,330.9	1,997.2
Pinus sylvestris	21.6	53.0	284.6	155.7	1,439.7	1,954.5
Betula pendula	7.4	32.7	311.4	276.9	745.6	1,373.9
Abies sibirica	4.6	14.1	133.2	128.5	1,017.2	1,297.6
Picea obovata	0.9	2.4	42.9	47.4	1,174.5	1,268.1
Populus tremula	3.3	8.3	37.4	39.9	301.6	390.4
Bushes	--	--	--	--	--	18.2
61. Irkutsk Oblast						
Pinus sylvestris	27.0	89.1	646.4	416.8	1,902.1	3,081.4
Larix sp.	21.6	77.9	359.8	537.2	1,651.9	2,648.4

Continued

Table 5.—Continued

Dominant species	Age-class group: Young stands Class I[a]	Class II[b]	Middle-aged	Premature	Mature/ overmature	Total
Pinus sibirica	12.9	46.3	208.2	329.9	998.1	1,595.3
Betula pendula	7.1	20.3	109.8	93.4	369.5	600.1
Picea obovata	3.9	13.1	105.5	61.2	301.9	485.6
Abies sibirica	2.7	8.7	70.0	40.7	191.1	313.2
Populus tremula	3.3	10.8	46.2	54.1	171.4	285.8
Bushes[e]	0.2	5.1	79.1	11.1	26.5	122.1
62. Chita Oblast						
Larix sp.	21.4	100.0	191.6	628.6	748.4	1,690.1
Pinus sylvestris	3.8	17.9	112.5	66.7	127.9	328.8
Betula pendula	8.1	22.7	126.0	43.1	51.4	251.2
Pinus sibirica	0.1	13.1	35.8	69.4	81.7	200.0
Populus tremula	0.7	1.9	11.3	3.3	4.4	21.5
Picea obovata	0.0	0.1	0.8	0.4	1.0	2.4
Bushes[e]	0.1	2.6	40.0	5.5	12.7	60.9
63. Republic of Buryatia						
Larix sp.	1.8	48.1	119.4	382.3	513.3	1,064.9
Pinus sylvestris	5.9	22.4	186.7	80.1	189.6	484.6
Pinus sibirica	0.2	16.9	52.5	115.8	145.7	331.0
Betula pendula	1.3	3.9	27.5	12.5	29.5	74.7
Abies sibirica	0.5	2.1	16.1	6.4	21.8	46.8
Populus tremula	0.9	2.5	17.4	7.4	18.3	46.5
Picea obovata	0.2	0.9	6.7	2.7	9.1	19.5
Bushes[e]	0.1	3.1	47.8	6.6	15.3	72.9
Other[c]	--	--	--	--	--	0.3
64. Republic of Tuva						
Larix sibirica	1.7	17.6	111.2	168.5	274.7	573.7
Pinus sibirica	1.4	14.0	98.0	136.8	227.3	477.6
Pinus sylvestris	0.1	0.5	6.2	9.0	10.3	26.1
Betula pendula	0.0	0.3	6.7	3.5	14.4	24.9
Picea obovata	0.0	0.2	1.6	2.3	3.8	8.0
Populus tremula	0.0	0.1	1.0	0.5	2.2	3.8
Other[c]	--	--	--	--	--	1.6
65. Primor'ye Kray						
Picea sp.	1.5	7.7	120.2	130.1	303.0	562.5
Pinus korajensis	0.1	2.3	117.4	115.0	315.8	550.6
Quercus mongolica	4.5	13.0	72.5	50.4	197.9	338.3
Larix sp.	0.4	2.1	33.6	36.8	104.0	176.9
Popula tremula	0.3	2.8	36.5	19.6	46.8	106.1
Betula sp.	0.4	3.0	36.1	20.8	45.6	105.8
Betula ermanii	--	--	--	--	46.0	46.0
Abies sp.	0.1	0.5	8.7	9.5	26.2	45.0
Tilia sp.	0.0	0.3	2.7	1.3	0.4	4.7
Other[c]	--	--	--	--	--	2.4
66. Khabarovsk Kray						
Larix sp.	25.7	91.7	337.6	411.5	1,835.0	2,701.5
Picea sp.	14.1	50.0	205.8	224.5	1,008.5	1,502.8
Betula sp.	3.9	9.1	78.6	33.3	96.8	221.8
Pinus korajensis	1.6	5.7	35.5	33.0	116.1	191.9
Populus tremula	2.8	6.7	57.9	23.9	74.2	165.5
Pinus sylvestris	1.2	4.5	14.5	24.3	87.6	132.1
Betula ermanii	0.1	0.2	6.0	7.6	100.0	113.8
Abies sp.	0.8	2.8	15.7	14.0	55.9	89.1

Continued

Table 5.—Continued

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Premature	Mature/ overmature	
	Class I[a]	Class II[b]				
Quercus mongolica	0.5	2.5	19.0	21.1	24.0	67.1
Bushes[e]	0.3	8.1	125.2	17.6	41.9	193.0
67. Amur Oblast						
Larix sp.	15.3	72.6	358.7	215.4	830.0	1,492.0
Betula sp.	6.4	19.3	140.8	51.3	69.2	286.8
Pinus sylvestris	0.7	3.2	20.9	11.6	35.2	71.6
Picea sp.	0.7	3.4	17.7	9.4	40.0	71.2
Quercus mongolica	2.7	3.9	11.4	4.3	4.5	26.8
Populus tremula	0.6	1.7	12.7	4.3	6.2	25.6
Abies sp.	0.1	0.4	2.2	1.2	4.9	8.8
Bushes[e]	0.1	2.1	32.0	4.5	10.7	49.3
Other[c]	--	--	--	--	--	1.1
68. Kamtchatka Oblast						
Betula ermanii	0.0	0.2	178.7	40.1	285.8	504.8
Larix camchatica	0.9	2.3	5.3	32.9	58.8	100.2
Populus tremula	0.1	0.8	2.6	19.0	32.2	54.6
Betula sp.	0.2	1.2	9.1	17.4	23.3	51.1
Picea sp.	0.3	1.0	2.6	4.4	38.4	46.6
Bushes[e]	0.8	19.9	306.0	43.7	102.6	473.0
Other[c]	--	--	--	--	--	0.1
69. Magadan Oblast						
Larix sp.	5.2	11.0	25.5	28.9	313.0	383.6
Chosenia arbutifolia	0.1	0.8	15.5	8.1	10.9	35.5
Bushes[e]	0.3	6.5	99.6	14.2	33.4	154.0
Other[c]	--	--	--	--	--	1.9
70. Sakhalin Oblast						
Picea ajanensis	2.4	7.0	49.1	23.6	161.2	243.2
Larix camchatica	2.0	6.1	50.2	20.5	122.4	201.2
Abies sachalinensis	1.5	4.3	31.9	14.1	100.6	152.5
Betula ermanii	0.8	6.9	17.5	5.1	21.9	52.0
Populus sp.	0.1	0.6	6.7	1.6	1.6	10.4
Betula costata	0.1	0.5	4.8	2.3	2.5	10.1
Bushes[e]	0.0	0.8	12.0	1.7	4.0	18.5
Other[c]	--	--	--	--	--	1.8
71. Republic of Yakutia (Sakha)						
Larix gmelinii	88.7	275.7	1,680.1	717.9	5,158.8	7,921.2
Pinus sylvestris	6.6	23.5	281.6	107.1	669.2	1,088.0
Pinus sibirica	0.4	3.1	18.7	5.9	47.0	75.0
Betula pendula	1.8	6.8	39.0	7.0	12.5	67.1
Picea obovata	0.0	0.3	4.0	3.7	40.5	48.5
Populus tremula	0.2	0.6	2.6	2.5	12.7	18.5
Abies sibirica	0.1	0.1	0.2	0.5	3.0	4.0
Bushes[e]	0.6	8.0	123.5	17.4	41.4	190.9

[a]Early regeneration.
[b]Advanced regeneration.
[c]Includes one or more tree species with low volume and unknown age classes.
[d]Age group data unknown.
[e] Including *Pinus pumila* krummholz.

Table 6.—Waterlogged stocked area (thousand ha) of the Russian Forest Fund (from Nikolayuk 1973)

Administrative territory	Waterlogged area	Percent of stocked area
1. Kaliningrad Oblast	195	73
2. Arkhangel'sk Oblast	8,895	40
3. Vologda Oblast	2,060	20
4. Murmansk Oblast	296	6
5. Rep. of Karelia	1,849	20
6. Rep. of Komi	13,436	45
7. Leningrad Oblast	1,068	22
8. Novgorod Oblast	450	13
9. Pskov Oblast	244	11
10. Bryansk Oblast	78	7
11. Vladimir Oblast	86	6
12. Ivanovo Oblast	21	2
13. Tver' Oblast	614	15
14. Kaluga Oblast	31	2
15. Kostroma Oblast	464	11
16. Moscow Oblast	187	10
17. Orel Oblast	0	0
18. Ryazan' Oblast	153	15
19. Smolensk Oblast	75	4
20. Tula Oblast	0	0
21. Yaroslavl' Oblast	118	7
22. Nizhniy Novgorod Oblast	391	11
23. Kirov Oblast	1,871	26
24. Rep. of Mari El	179	15
25. Rep. of Mordovia	22	3
26. Rep. of Chuvashia	11	2
27. Belgorod Oblast	0	0
28. Voronezh Oblast	16	4
29. Kursk Oblast	0	0
30. Lipetsk Oblast	0	0
31. Tambov Oblast	7	2
32. Astrakhan' Oblast	0	0
33. Volgograd Oblast	0	0
34. Samara Oblast	0	0
35. Penza Oblast	11	1
36. Saratov Oblast	0	0
37. Ul'yanovsk Oblast	6	1
38. Rep. of Kalmykia	0	0
39. Rep. of Tatarstan	13	1
40. Krasnodar Kray	0	0
41. Stavropol' Kray	0	0
42. Rostov Oblast	0	0
43. Rep. of Dagestan	0	0
44. Rep. of Kabardino-Balkaria	0	0
45. Rep. of Northern Osetia	0	0
46. Rep. of Chechen-Ingushetia	0	0
47. Kurgan Oblast	149	1
48. Orenburg Oblast	0	0
49. Perm' Oblast	1,610	15
50. Sverdlovsk Oblast	3,512	28
51. Chelyabinsk Oblast	167	7
52. Rep. of Bashkortostan	35	1
53. Rep. of Udmurtia	152	8
54. Altai Kray	137	2

Continued

Table 6.—Continued

Administrative territory	Waterlogged area	Percent of stocked area
55. Kemerovo Oblast	213	4
56. Novosibirsk Oblast	968	23
57. Omsk Oblast	870	20
58. Tomsk Oblast	4,232	22
59. Tyumen' Oblast	25,926	52
60. Krasnoyarsk Kray	67	0
61. Irkutsk Oblast	0	0
62. Chita Oblast	284	1
63. Rep. of Buryatia	10	0
64. Rep. of Tuva	0	0
65. Primor'e Kray	20	0
66. Khabarovsk Kray	484	1
67. Amur Oblast	239	1
68. Kamtchatka Oblast	0	0
69. Magadan Oblast	0	0
70. Sakhalin Oblast	65	1
71. Rep. of Yakutia (Sakha)	0	0
Total	71,987	9.3%

Table 7.—Structure of phytomass (t/ha, oven dry) and ratios of needle and crown mass to timber mass ($K_n + K_c$) in Scotch pine forests of Siberia[a]

Age (years)	Quality class	Bole	Stem bark	Total	Needle	Crown branch	Total	Needle/timber mass ratio	Crown/timber mass ratio
15	III	8.5	2.7	11.2	3.3	6.3	9.6	0.39	1.13
15	III	10.7	3.6	14.3	4.2	8.1	12.3	0.39	1.15
15	III	10.4	2.6	13.0	4.2	4.0	8.2	0.40	0.79
19	I	24.2	4.8	29.0	6.3	4.4	10.7	0.26	0.44
18	II	13.8	3.6	17.4	3.9	3.2	7.1	0.28	0.51
22	III	12.5	2.8	15.3	2.7	2.7	5.4	0.22	0.43
23	III	24.1	3.2	27.3	4.5	4.9	9.4	0.19	0.39
22	II	46.8	5.6	52.4	6.2	16.3	22.5	0.13	0.46
23	II	74.6	15.0	79.6	10.8	22.6	23.4	0.14	0.31
25	II	30.2	4.0	34.2	4.8	5.1	9.9	0.16	0.33
26	II	42.4	10.3	52.7	5.8	7.6	13.4	0.14	0.32
31	II	68.8	12.0	80.8	8.4	12.2	20.6	0.12	0.30
34	III	98.4	24.0	122.4	9.2	18.5	27.7	0.09	0.28
40	II	67.0	14.2	81.2	4.0	10.3	14.3	0.06	0.21
41	II	74.0	12.0	86.1	5.5	11.6	17.1	0.07	0.23
42	III	63.4	8.8	72.2	3.5	5.7	9.2	0.06	0.14
44	III	47.5	9.4	56.9	5.8	6.4	12.2	0.12	0.25
45	I	121.8	14.2	136.0	8.6	13.1	21.7	0.07	0.18
45	I	146.1	27.4	153.5	6.5	8.3	14.8	0.05	0.10
47	III	44.9	9.8	54.7	4.7	7.3	12.0	0.10	0.27
50	III	76.0	7.7	83.7	5.2	13.1	18.3	0.07	0.24
59	II	110.0	24.1	134.1	5.2	16.5	21.7	0.05	0.20
63	I	152.9	32.4	185.3	10.1	28.0	38.1	0.07	0.25
63	I	110.7	24.3	135.0	6.2	19.8	26.0	0.06	0.24
64	I	117.9	25.2	143.1	8.8	22.3	31.1	0.07	0.26
65	III	82.1	15.0	97.1	8.0	29.6	37.6	0.10	0.46
65	III	77.7	13.5	91.2	5.0	19.2	24.2	0.06	0.31
66	I	112.3	19.8	132.1	6.2	22.3	28.5	0.06	0.25
66	I	126.0	22.3	148.3	7.0	30.9	37.9	0.06	0.30

Continued

Table 7.—Continued

Age (years)	Quality class	Bole	Stem bark	Total	Needle	Crown branch	Total	Needle/timber mass ratio	Crown/timber mass ratio
66	I	141.1	24.0	163.1	5.0	20.0	25.0	0.04	0.18
70	III	130.0	22.5	152.5	8.8	13.5	22.3	0.07	0.17
70	III	128.0	22.0	150.0	4.2	10.1	14.3	0.03	0.11
72	III	99.2	16.5	115.7	7.4	12.2	19.6	0.07	0.19
76	I	134.9	24.0	158.9	8.1	15.2	23.3	0.06	0.17
77	IV	85.9	15.0	100.9	6.1	19.3	25.4	0.07	0.29
77	V	65.8	12.0	77.8	5.7	18.5	24.2	0.08	0.36
78	I	151.5	16.8	168.3	8.0	20.4	28.4	0.05	0.19
81	IV	86.0	9.5	95.5	6.3	8.5	14.8	0.07	0.17
83	I	204.8	22.7	227.5	10.5	39.7	50.2	0.05	0.24
85	I	194.8	21.6	216.4	12.1	19.7	31.8	0.06	0.16
87	I	185.9	20.6	206.5	7.8	19.7	27.5	0.04	0.15
88	IV	94.6	10.5	105.1	5.8	9.0	14.8	0.06	0.16
94	III	160.2	17.8	178.0	5.1	12.3	17.4	0.03	0.11
130	I	320.0	35.5	355.6	8.9	14.8	23.7	0.03	0.07
140	V	74.4	7.2	81.6	3.4	9.3	12.7	0.04	0.17
150	III	228.6	25.4	254.0	4.6	16.9	21.5	0.02	0.09
160	III	177.3	19.7	197.0	4.0	10.0	14.0	0.02	0.08
160	V	108.0	12.0	120.0	3.0	7.8	10.8	0.03	0.10
170	III	220.5	24.5	245.0	5.1	13.6	18.7	0.02	0.08
180	V	80.0	8.1	88.1	4.0	11.2	15.2	0.05	0.19
180	V	81.0	9.0	90.0	3.9	9.8	13.7	0.05	0.17

[a]From Pozdnyakov et al. 1969; Buzykin 1978; Laschinskii 1978; Semechkina 1978; Onuchin and Borisov 1984; Gabeyev 1990; Stakanov 1990.

Table 8.—Structure of aboveground phytomass (t/ha, oven dry) and ratios of needle and crown mass to timber mass for Siberian stands with *Pinus Sibirica* dominating[a]

Composition [b]	Quality class	Age	Stem			Crown			Needle/ timber mass ratio	Crown/ timber mass ratio
			Bole	Bark	Total	Needle	Branch	Total		
		Years	*t/ha*							
			Southern Taiga (Ecoregion 23.3)							
5Ps5B	V	28	9.0	3.9	12.9	2.6	2.8	5.4	0.29	0.60
3Ps4P3B	IV	120	126.9	22.5	149.4	6.3	19.8	26.1	0.05	0.21
8Ps1B1S	III	170	130.8	19.6	150.4	7.9	27.0	34.9	0.06	0.27
9Ps1S	III	200	109.9	15.9	125.8	7.8	19.9	27.7	0.07	0.25
4Ps4A1S1B	III	220	106.2	15.3	121.5	10.5	21.9	32.4	0.10	0.31
8Ps1P1B	IV	220	112.2	15.8	128.0	7.1	23.5	30.6	0.06	0.27
			Middle-Elevation Forests of Sayan Mountains (Ecoregion 26)							
3Ps4B2S1L	III	40	20.3	3.2	23.5	3.7	4.9	8.6	0.18	0.42
7Ps3A	II	150	107.4	13.7	121	5.5	8.4	13.9	0.05	0.13
9Ps1A	II	190	169.5	21.8	191	8.8	11.2	20.0	0.05	0.12
5Ps4S1L	III	190	67.6	8.9	76.5	8.9	10.8	19.7	0.13	0.29
8Ps1S1A	III	200	110.6	14.0	124.6	8.8	12.9	21.7	0.08	0.20
10Ps	II	240	139.8	17.3	157.1	10.6	12.4	23.0	0.08	0.16
			High-Elevation Forests of Sayan Mountains (Ecoregion 26)							
6Ps4A	V	120	35.3	5.9	41.2	5.9	8.6	14.5	0.16	0.41
8Ps2A	Va	220	18.5	2.3	20.8	2.2	3.6	5.8	0.12	0.31

[a]From: Pozdnyakov et al. 1969; Isakov 1975; Protopopov 1975; Khramov and Valutskiy 1977.
[b]Ps = *Pinus sibirica*, B = *Betula* sp., P = *Pinus sylvestris*, S = *Picea obovata*, A = *Abies sibirica*, L = *Larix* sp.

Table 9.—Structure of phytomass (t/ha, oven dry) and ratios of root and crown mass to timber mass for larch stands in Siberia and Yakutia[a]

Composition [b]	Quality class	Age	Stem			Crown			Root	Root/ timber mass ratio	Crown/ timber mass ratio
			Bole	Bark	Total	Needle	Branch	Total			
		Years	*t/ha*								
Middle Siberia (Ecoregion 37.1)											
10L	V	77	44.9	9.1	54.0	3.3	7.1	10.4	--	--	0.23
10L	Va	77	35.0	8.7	43.7	2.7	4.6	7.3	--	--	0.21
9L1B	V	75	44.1	1.2	45.3	2.4	4.8	7.2	--	--	0.16
9L1B	V	118	52.4	12.4	64.8	2.6	6.8	9.4	--	--	0.18
5L4S1Ps	IV	128	174.1	30.8	204.9	9.0	20.1	29.1	--	--	0.17
10L	Va	157	88.6	17.8	106.4	6.4	20.2	26.6	--	--	0.30
10L	Va	271	16.1	3.4	19.5	1.1	2.3	3.4	--	--	0.21
7L2Ps1S	IV	--	165.2	34.6	199.8	10.7	19.9	30.6	--	--	0.19
Middle Siberia (Ecoregion 37.2)											
4L3Ps1S2B	IV	126	173.5	34.7	208.2	9.9	18.0	27.9	--	--	0.16
7L2Ps1S	IV	160	114.3	22.7	137.0	5.3	14.5	19.8	--	--	0.17
9L1S	II	180	278.3	42.6	320.9	8.4	34.9	43.3	--	--	0.15
9L1B	IV	190	215.1	39.1	254.2	4.9	21.3	26.2	--	--	0.12
4L3Ps1S2B	IV	210	91.1	20.0	111.1	4.4	12.9	17.3	--	--	0.19
9L1B	III	218	146.4	24.5	170.9	3.4	12.4	15.8	--	--	0.11
Southern Siberia (Ecoregion 30)											
9L1B	IV	40	57.0	8.2	65.2	2.2	5.4	7.6	19.9	0.35	0.13
8L2L	IV	80	77.8	10.9	88.7	1.8	8.2	10.0	26.6	0.34	0.13
10L	IV	180	115.6	21.4	137.0	2.3	9.8	12.1	28.7	0.25	0.10
Yakutia (Ecoregion 41)											
9L1B	IV	50	40.8	10.0	50.8	2.2	2.6	4.8	13.3	0.33	0.12
10L	IV	90	110.0	21.0	131.0	3.4	8.7	12.1	36.6	0.33	0.11
10L	V	120	33.0	11.0	44.0	1.7	3.9	5.6	11.0	0.33	0.17
10L	IV	130	83.7	16.5	100.2	2.1	7.0	9.1	28.0	0.33	0.11
10L	Vá	130	14.2	4.0	18.2	0.6	2.1	2.7	4.7	0.33	0.19
10L	V	150	25.3	5.6	30.9	0.4	2.1	2.5	8.4	0.33	0.10
10L	IV	170	41.2	8.2	49.4	0.8	2.2	3.0	7.0	0.17	0.07
10L	IV	200	88.3	17.5	105.8	2.1	12.6	14.7	29.4	0.33	0.17

[a] From Pozdnyakov et al. 1969; Protopopov and Gorbatenko 1974; Mitrofanov 1983.

[b] Ps = *Pinus sibirica*, B = *Betula* sp., P = *Pinus sylvestris*, S = *Picea obovata*, A = *Abies sibirica*, L = *Larix* sp.

Table 10.—Structure of phytomass (t/ha, oven dry) and ratios of crown and root mass to timber mass of fir stands in Western and Middle Siberia (from Kuzikov 1975, 1979)

Composition[a]	Quality class	Age	Stem		Total	Root	Crown	Crown/ timber mass ratio	Root/ timber mass ratio
			Bole	Bark					
		Years	---------- *t/ha* ----------						
10A	III	41	21.2	5.6	26.8	7.5	9.6	0.45	0.35
10A	III	52	51.8	9.8	61.6	--	13.9	0.27	--
8A2S	V	52	19.8	3.8	23.6	--	11.0	0.56	--
9A1S	V	54	17.7	4.2	21.8	3.7	7.5	0.43	0.21
10A	III	55	36.7	8.7	45.4	9.7	14.1	0.38	0.26
9A1Ps	V	57	25.0	7.2	32.2	8.5	9.9	0.39	0.34
8A2S	III	58	38.9	9.4	49.3	10.2	15.6	0.40	0.26
8A1S1B	IV	69	50.7	10.4	61.1	16.4	14.1	0.28	0.32
10A	III	70	65.4	12.0	77.4	--	21.6	0.33	--
10A	IV	71	43.3	8.1	51.4	10.7	13.9	0.32	0.25
8A2S	IV	74	35.3	5.5	40.8	10.6	14.6	0.41	0.30
8A2S	IV	79	48.4	6.0	54.4	--	15.0	0.37	--
10A	IV	80	41.4	5.2	46.6	10.4	12.1	0.29	0.25
9A1Ps	III	86	66.7	11.5	78.2	20.5	22.2	0.33	0.31
9A1S	III	86	45.3	5.8	51.1	--	16.6	0.35	--
10A	III	88	71.1	11.1	82.2	19.8	23.4	0.33	0.28
10A	III	89	70.0	10.1	80.1	21.3	19.3	0.28	0.31
9A1Ps	III	90	97.7	13.8	111.5	20.8	28.3	0.29	0.21
8A2Ps	III	92	85.1	11.5	96.6	25.8	26.0	0.30	0.31
7A3S	IV	93	61.5	8.0	69.5	--	18.4	0.30	--
7A3Ps	III	94	78.9	14.9	93.8	--	24.8	0.31	--
8A2Ps	III	95	50.8	8.5	59.3	13.7	18.4	0.36	0.27
9A1Ps	III	96	68.3	9.4	77.7	19.9	21.3	0.31	0.29
9A1S	IV	100	53.2	6.7	59.9	--	15.5	0.29	--
10A	IV	100	73.0	12.4	85.4	19.7	21.5	0.29	0.27
10A	III	101	110.2	16.8	127.0	--	30.9	0.28	--
9A1Ps	IV	105	66.5	10.7	77.2	16.4	22.9	0.34	0.25
9A1B	III	111	69.9	10.9	80.8	21.5	21.3	0.31	0.31
9A1Ps	III	116	94.4	11.3	105.7	23.9	28.1	0.30	0.25
10A	IV	122	86.0	11.3	97.3	24.0	28.0	0.33	0.28
8A1S1Ps	IV	124	74.1	10.6	84.7	--	19.1	0.26	--
7A2B1S	IV	130	74.2	9.4	83.6	20.7	20.6	0.28	0.28
9A1S	IV	146	79.5	11.2	90.7	--	25.3	0.28	--

[a] Ps = *Pinus sibirica*, B = *Betula* sp., P = *Pinus sylvestris*, S = *Picea obovata*, A = *Abies sibirica*, L = *Larix* sp.

Table 11.—Phytomass (t/ha, oven dry) and ratios of crown and root mass to timber mass for birch stands in Southern Siberia and Central Yakutia[a]

Age (years)	Stem (over bark)	Crown		Above-ground part	Root	Total	Crown/ timber mass ratio	Root/ timber mass ratio
		Leaf	Branch					
Years	*t/ha*							
			Southern Part of West Sayan Mountains (Ecoregion 26)					
10	0.3	0.1	0.2	0.6	0.1	0.7	1.07	0.37
55	75.0	1.5	9.2	96.0	12.0	108.0	0.16	0.18
55	79.4	1.6	9.4	90.5	14.2	104.7	0.16	0.19
60	83.0	2.2	12.3	97.5	15.0	112.5	0.18	0.20
60	86.0	2.3	12.4	101.2	16.2	117.4	0.19	0.21
60	84.0	2.2	12.4	99.1	15.1	114.2	0.19	0.18
			Northern Foothill Part of West Sayan Mountains (Ecoregion 26)					
40	81.0	1.9	11.1	94.0	14.5	108.5	0.17	0.20
50	50.0	1.2	8.0	60.0	10.0	70.0	0.21	0.22
			Forest Steppe Part of Minusinsk's Bowl (Ecoregion 31)					
35	31.5	0.7	4.0	36.2	5.8	41.0	0.17	0.21
40	32.1	1.0	4.2	37.4	6.0	43.4	0.18	0.21
			Central Part of Yakutia (Ecoregion 41)					
14	11.8	1.4	--[b]	15.8	4.2	20.0	--	0.42
21	23.0	1.7	--	28.0	6.4	34.4	--	0.30
30	39.0	2.4	--	47.0	11.3	58.3	--	0.31

[a] From Gribov 1967; Pozdnyakov et al. 1969
[b] No data

Table 12.—Structure of aboveground phytomass (t/ha, oven dry) and ratio of crown mass to timber mass for aspen stands[a]

Age	Stem			Crown			Crown/ timber mass ratio
	Bole	Bark	Total	Leaf	Branch	Total	
Years	*t/ha*						
			European Part of Russia (Ecoregion 16.3)				
9	19.6	5.1	24.7	2.4	2.7	5.1	0.26
16	32.9	9.0	41.9	2.6	7.8	10.4	0.31
20	46.0	9.1	55.1	2.6	6.2	8.8	0.19
21	40.7	9.2	49.9	2.6	6.0	8.6	0.21
22	49.6	8.9	58.5	2.8	6.4	9.2	0.18
24	52.4	9.8	62.2	2.2	6.8	9.0	0.17
33	87.1	14.5	101.6	2.3	7.6	9.9	0.12
40	74.1	13.9	88.0	2.9	11.7	14.6	0.20
42	84.9	15.3	100.2	3.0	12.5	15.5	0.18
46	114.1	16.5	130.6	3.6	23.0	26.6	0.23
85	125.7	23.1	148.8	2.2	20.8	23.0	0.18
			Asian Part of Russia (Ecoregion 24)				
30	112.5	16.5	129.0	2.9	12.2	15.1	0.13
42	211.9	23.5	235.4	4.3	19.2	23.5	0.12
44	106.3	14.4	120.7	3.3	15.3	18.6	0.17
51	165.8	18.4	184.2	3.8	19.9	23.7	0.14
61	194.5	21.6	216.1	3.1	21.8	24.9	0.13
67	294.3	32.7	327.9	4.3	27.9	32.2	0.11

[a] From Dylis and Nosova 1977; Demidenko 1978; Danilin 1983; Rozhdestvenskiy 1988.

Table 13.—Structure of phytomass (t/ha, oven dry) of spruce and Scotch pine, and ratios of crown and root mass to timber mass in wet and well-drained stands of Northern and Middle Taiga[a]

Forest type	Age	Stem	Crown	Roots	Total	Crown/ timber mass ratio	Root/ timber mass ratio
	Years	----------------------	*t/ha*	------------------------			
	Northern Taiga (Ecoregion 5.1, 16.1)						
Piceetum caricoso-sphagnosum	120	32.6	14.1	31.1	83.8	0.43	0.95
Piceetum caricoso-sphagnosum	70	29.8	13.8	28.6	72.2	0.46	0.96
Piceetum myrtilloso-hylocomiosum	120	22.7	16.0	13.0	51.7	0.70	0.57
Piceetum myrtilloso-hylocomiosum	80	11.7	7.3	10.8	24.5	0.62	0.92
Pinetum myrtilloso-hylocomiosum	90	38.8	11.0	17.6	67.4	0.28	0.45
Pinetum caricoso-sphagnosum	90	19.3	7.2	12.8	39.3	0.37	0.66
	Southern Taiga (Ecoregion 6.1, 16.3)						
Piceetum myrtilloso-oxalidosum	110	146.2	36.0	68.0	250.2	0.25	0.46
Piceetum myrtilloso-sphagnosum	110	98.4	27.4	61.0	186.8	0.28	0.62
P. myrtil.-caricoso-sphagnosum	120	47.9	13.0	28.7	89.6	0.27	0.59
Pinetum fruticuloso-sphagnosum	120	14.8	3.6	12.4	30.8	0.24	0.83
Pinetum herboso-sphagnosum	140	54.9	10.1	24.1	89.1	0.18	0.44

[a] From Abrazhko 1973; Alexeyev and Rakhmanov 1973; Kazimirov and Morozova 1973; Bobkova 1987. Phytomass of codominant tree species is not included.

Table 14.—Mass (t/ha, oven dry) of forest understory vegetation (saplings, seedlings, and bushes) in various regions of Russia[a]

Age group	Dominant tree species						
	Pinus sylvestris	*Picea sp.*	*Abies sp.*	*Larix sp.*	*Pinus sibirica*	*Betula sp.*	*Populus tremula*
			European Part of Russia				
			Northern Taiga				
Middle-aged	1.6	0.3	-	-	-	0.4	-
Maturing	1.4	0.4	-	-	-	0.6	-
Mature and overmature	1.5	0.5	-	-	-	0.6	-
			Middle Taiga				
Middle-aged	0.9	0.3	-	-	-	0.9	0.7
Maturing	1.0	0.4	-	-	-	1.0	0.8
Mature and overmature	1.1	0.6	-	-	-	1.1	1.0
			Southern Taiga and Forest-Steppe				
Middle-aged	1.0	0.4	-	0.3	-	0.7	0.6
Maturing	1.1	0.5	-	0.4	-	0.8	0.7
Mature and overmature	1.2	0.6	-	0.4	-	0.8	0.7
			Western and Middle Siberia				
			Northern Taiga				
Middle-aged	1.3	0.3	-	-	-	0.3	-
Maturing	1.3	0.3	-	-	-	0.4	-
Mature and overmature	1.4	0.4	-	-	-	0.5	-
			Middle Taiga				
Middle-aged	0.7	0.3	0.9	0.3	0.5	0.5	0.6
Maturing	0.6	0.4	0.9	0.4	0.6	0.5	0.7
Mature and overmature	0.8	0.5	1.0	0.4	0.8	0.7	0.8

Continued

Table 14.—Continued

Age group	Dominant tree species						
	Pinus sylvestris	*Picea sp.*	*Abies sp.*	*Larix sp.*	*Pinus sibirica*	*Betula sp.*	*Populus tremula*
Southern Taiga and Forest-Steppe							
Middle-aged	0.6	0.3	0.8	0.3	0.6	0.3	0.4
Maturing	0.6	0.4	0.9	0.5	0.8	0.3	0.4
Mature and overmature	0.8	0.4	1.0	0.5	0.8	0.4	0.5
Mountains of Southern Siberia							
Middle-aged	0.8	0.6	0.8	0.6	0.8	0.7	0.7
Maturing	0.8	0.7	0.8	0.7	0.8	0.8	0.9
Mature and overmature	1.1	0.7	1.2	0.9	0.9	1.0	1.0

[a]From Andreyashkina and Gorchakovskiy 1972; Isakov 1975; Zvorykina 1977; Astrologova 1978; Kazimirov et al. 1978; Popov 1982; Kaderov 1989; Gabeyev 1990.

Table 15.—Phytomass (t/ha, oven dry) of understory shrubs and vegetation of lower layers[a] in *Larix* forests of Yakutia[b]

Forest type	Stand age	Understory	Vegetation of lower layers	Total
	Years	---------- *t/ha* ----------		
Yakutia (Ecoregion 41)				
Laricetum ledoso-hylocomiosum	350	--	10.6	10.6
L. vaccinoso-arctostaphylosum	180	--	2.2	2.2
L. limnoso-vaccinosum	90	0.2	0.6	0.8
L. limnoso-vaccinosum	130	0.3	2.1	2.4
L. alnoso-vaccinosum	120	4.8	4.0	8.8
L. hylocomioso-ledosum	130	0.2	8.6	8.8
Lena-Aldan Upland (Ecoregion 42)				
L. arctouso-uliginosum	180	1.2	4.8	6.0
L. mixoherboso-vaccinosum	200	1.5	5.0	6.5
L. limnoso-vaccinosum	135	0.7	6.3	7.0
L. vaccinoso-ledosum	150	--	15.0	15.0
Magadan Oblast (Ecoregion 54)				
L. muscoso-cladinosum	50	--	18.4	18.4
L. hylocomioso-cladinosum	50	--	3.0	3.0
Magadan Oblast (Ecoregion 45)				
L. graminioso-vaccinosum	30	--	1.4	1.4
L. ledoso-vaccinosum	30	--	10.4	10.4
L. caricoso-sphagnosum	30	--	16.0	16.0
L. polytrichoso-sphagnosum	30	--	10.0	10.0

[a]Includes dwarf-shrubs, herbs, forbs, grasses, mosses, and lichens.
[b]From Pozdnyakov et al. 1969; Ignatenko et al.1976; Moscalyuk 1980.

Table 16.—Phytomass (t/ha, oven dry) of understory in Scotch pine forests of Russia[a]

Forest type	Stand age	Moss and lichen	Dwarf-shrub and grass layer			Total
			Shoot	Root	Root to shoot ratio	
	Years	---------- *t/ha* ----------				*t/ha*
		European Part of Russia				
		Northern Taiga (Ecoregion 5.1)				
Pinetum myrtillosum	46	3.1	1.3	1.9	1.5	6.3
P. empetroso-myrtillosum	45	5.2	1.3	3.9	3.0	10.4
		Middle Taiga (Ecoregion 16.2)				
P. vaccinoso-cladinosum	90	2.9	1.0	2.4	2.4	6.3
P. uliginoso-myrtillosum	100	2.2	2.1	8.4	4.0	12.7
P. myrtilloso-hylocomiosum	100	3.3	2.7	11.0	4.0	17.0
P. uliginoso-hylocomiosum	120	2.3	2.3	8.0	3.5	12.6
P. myrtillosum	120	2.5	2.0	7.0	3.5	11.5
P. caricoso-sphagnosum	140	2.7	1.5	8.0	5.3	12.2
		Middle Taiga (Ecoregion 5.2)				
P. cladinosum	51	0.9	2.3	0.5	0.2	3.7
P. ericosum	53	0.2	2.2	1.2	0.5	3.6
P. vaccinosum	55	0.2	1.4	1.4	1.0	3.0
P. myrtillosum	60	0.2	1.7	2.8	1.6	4.7
P. myrtillosum	63	0.6	2.3	3.3	1.4	6.2
P. fruticuloso-polytrichosum	65	1.8	1.8	4.7	2.6	8.3
P. ledoso-sphagnosum	66	1.9	2.2	5.0	2.3	9.1
		Southern Taiga (Ecoregion 16.3)				
P. polytrichosum	32	0.1	1.1	1.6	1.5	2.8
P. myrtillosum	34	0.1	2.0	4.0	2.0	6.1
P. myrtilloso-sphagnosum	35	0.6	1.2	1.8	1.4	3.6
		Asian Part of Russia				
		Northern Taiga (Ecoregion 37.1)				
P. vaccinoso-hylocomiosum	100	1.2	1.1	2.0	1.8	4.3
“	120	1.6	1.2	1.7	1.4	4.5
“	140	1.8	1.2	1.8	1.5	4.8
“	180	1.9	1.3	1.8	1.4	5.0
		Middle Taiga Ecoregion (37.2)				
P. vaccinoso-hylocomiosum	70	1.1	0.4	0.8	2.0	2.3
“	100	1.8	0.6	1.1	1.8	3.5
“	120	1.8	0.7	1.3	1.8	3.8
		Southern Taiga (Ecoregion 37.3)				
P. rhododendroso-vaccinosum	70	0.0	0.3	0.4	1.2	0.9
P. vaccinoso-mixtoherbosum	75	0.0	1.0	1.2	1.2	2.2
P. vaccinoso-hylocomiosum	95	0.8	1.4	0.6	0.4	2.8
P. ledoso-vaccinosum	170	0.0	1.4	1.1	0.8	2.5
		Forest-Steppe (Ecoregion 24)				
P. cladinosum	63	0.8	0.2	0.4	2.0	1.4
P. vaccinosum	70	1.4	0.4	0.7	1.7	2.5
P. myrtillosum	140	1.0	0.9	1.6	1.7	3.5
		Forest-Steppe (Ecoregion 38)				
P. vaccinoso-mixtoherbosum	18	+[b]	0.7	0.8	1.2	1.5
“	22	+	0.8	0.9	1.2	1.7
“	65	+	1.1	0.9	1.3	2.0

Continued

Table 16.—Continued

Forest type	Stand age	Moss and lichen	Dwarf-shrub and grass layer: Shoot	Root	Root to shoot ratio	Total
	Years	------------------ *t/ha*	------------------			*t/ha*
P. vaccinoso-mixtoherbosum	90	+	1.3	0.9	1.4	2.2
"	120	+	1.5	1.1	1.4	2.6
Asian Part of Russia						
Southern Siberian Mountains (Ecoregion 26)						
P. mixtoherboso-myrtillus	120	1.5	0.2	0.3	1.5	0.5
P. mixtoherboso-vaccinosum	100	+	2.3	2.8	1.2	5.1
P. stepposum	90	+	0.9	1.2	1.3	2.1

[a]From Andreyashkina and Gorchakovskiy 1972; Alexeyev et al. 1985; Zvorykina 1977; Kazimirov et al. 1978, 1983; Kulagina 1978; Lashchinskiy 1981; Ermolenko and Ermolenko 1982; Atkin and Atkina 1986, 1994.
[b]Includes aboveground part of the phytomass of the dwarf-shrub and grass layer.

Table 17.—Phytomass (t/ha, oven dry) of vegetation of lower layers in spruce forests of European part of Russia[a]

Forest type	Stand age	Moss and lichen	Dwarf-shrub and grass layer: Shoot	Root	Root to shoot ratio	Total
	Years	------------------ *t/ha*	------------------			*t/ha*
Northern Taiga (Ecoregion 16.1)						
Piceetum fruticuloso-hylocomiosum	100	3.3	1.3	6.6	5.1	11.2
P. myrtilloso-hylocomiosum	120	5.0	2.6	7.9	3.0	15.5
P. myrtilloso-polytrichosum	120	5.3	1.1	7.4	6.7	13.8
P. myrtilloso-polytrichosum	120	5.3	1.2	7.5	6.3	14.0
P. caricoso-sphagnosum	140	2.5	0.9	5.0	5.6	8.4
Middle Taiga (Ecoregion 16.2)						
P. myrtillosum	100	1.5	0.3	1.1	3.7	2.9
P. myrtilloso-polytrichosum	120	1.1	0.5	2.0	4.0	3.6
P. polytrichoso-sphagnosum	140	1.5	0.5	2.3	4.6	4.3
Middle Taiga (Ecoregion 5.2)						
P. cladinosum	37	2.9	2.9	--[b]	--	5.8
P. polytrichosum	42	3.3	3.4	--	--	6.7
P. herboso- sphagnosum	41	1.2	2.2	--	--	3.4
P. vaccinosum	45	1.7	1.7	--	--	3.4
P. myrtillosum	39	1.0	1.0	--	--	2.0
P. myrtilloso-oxalidosum	43	0.4	0.7	--	--	1.1
P. oxalidosum	38	0.2	0.4	--	--	0.6
Southern Taiga (Ecoregion 16.3)						
P. myrtilloso-sphagnosum	110	1.9	1.4	1.6	1.1	4.9
P. myrtilloso-caricoso- sphagnosum	120	3.3	1.5	3.2	2.1	8.0
P. myrtilloso-oxalidosum	100	1.0	0.5	1.3	2.6	2.8

[a]From Andreyashkina and Gorchakovskiy 1972; Alexeyev and Rakhmanov 1973; Smirnov 1971; Kazimirov et al. 1978; Bobkova 1987.
[b]no data.

Table 18.—Chemical composition of widely distributed plants of boreal forests[a]

Plant name	Plant part	Chemical composition (% absolutely dry mass)				
		C	H	O	N	Ash elements
Pinus sylvestris	Wood	49.5	6.5	43.1	0.5	0.4
	Needles	51.6	6.5	38.1	1.5	2.3
Pinus sibirica	Wood	--[b]	--	--	--	--
	Needles	50.6	6.6	38.9	1.5	2.4
Abies sibirica	Wood	--	--	--	--	0.3
	Needles	52.1	6.5	36.3	1.5	3.6
Picea obovata	Wood	51.0	6.2	41.5	0.9	0.4
	Needles	49.3	6.2	39.5	1.5	3.5
Larix sibirica	Wood	49.9	6.3	43.1	0.4	0.3
	Needles	48.4	6.5	39.5	1.5	3.1
Betula pendula	Leaves	50.2	6.1	38.0	1.5	4.2
Populus tremula	Leaves	51.1	6.5	36.5	1.5	4.4
Vaccinium myrtillus	Leaves	50.6	6.0	37.6	1.5	4.6
V. vitis-idaea	Leaves	52.7	6.1	36.1	1.5	3.6
Calamagrostis sp.	Plant	47.5	6.4	40.1	1.5	4.5
Carex pilosa	Plant	47.2	6.3	40.3	1.5	4.7
Pleurozium schreberi	Plant	49.6	5.6	39.7	1.5	5.6
Cladina sp.	Plant	45.4	6.0	44.6	1.5	2.5

[a]From Nikitin 1962; Filippov 1975; Vshivkova 1982; Pozdnyakov 1985.
[b]No data.

Table 19.—Carbon (Mt) in phytomass of tree stands in Russian administrative territories

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Maturing	Mature/ overmature	
	Class I[a]	Class II[b]				
			1. Kaliningrad Oblast			
Quercus robur	0.1	0.7	3.4	0.8	0.3	5.4
Betula sp.	0.0	0.1	2.2	0.5	0.5	3.4
Picea abies	0.3	0.5	1.1	0.4	0.3	2.4
Pinus sylvestris	0.2	0.3	0.9	0.3	0.3	2.0
Populus tremula	0.0	0.1	1.2	0.3	0.3	1.8
			2. Arkhangel'sk Oblast			
Picea	5.7	17.8	83.9	31.3	392.1	530.8
Pinus sylvestris	2.0	6.2	26.6	10.9	127.8	173.4
Betula	1.6	4.3	23.3	7.7	20.7	57.5
Populus tremula	0.2	0.5	3.0	1.0	2.8	7.4
Larix	0.0	0.1	0.4	0.1	2.7	3.4
			3. Vologda Oblast			
Betula	2.2	4.6	54.3	31.5	66.7	159.4
Picea	4.5	10.8	49.6	20.6	57.4	142.9
Pinus sylvestris	2.7	6.8	35.6	15.5	36.9	97.5
Populus tremula	0.5	0.8	9.9	5.6	10.5	27.2
Alnus	0.0	0.0	0.4	0.2	0.5	1.1
			4. Murmansk Oblast			
Picea	0.5	2.3	8.2	2.1	18.2	31.3
Pinus sylvestris	0.3	2.1	6.7	1.8	17.7	28.5

Continued

Table 19.—Continued

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Maturing	Mature/ overmature	
	Class I[a]	Class II[b]				
Betula	0.0	0.3	4.7	1.5	4.5	11.0
5. Republic of Karelia						
Pinus sylvestris	4.2	9.3	34.6	19.7	69.5	137.3
Picea	3.1	6.9	21.2	10.8	37.9	79.9
Betula	0.2	1.2	9.6	4.9	12.5	28.3
Populus tremula	0.0	0.1	0.8	0.4	0.9	2.1
6. Republic of Komi						
Picea	4.6	20.0	42.6	34.7	460.2	562.1
Pinus sylvestris	1.4	6.4	20.8	12.6	154.5	195.7
Betula	1.3	2.4	24.9	5.7	72.0	106.2
Populus tremula	0.3	0.5	5.7	1.4	14.7	22.6
Larix	0.1	0.3	1.1	0.5	8.9	10.8
Abies	0.1	0.2	0.6	0.3	4.1	5.3
Pinus sibirica	0.0	0.0	0.1	0.1	0.7	0.9
Bushes	--[b]	--	--	--	--	0.1
7. Leningrad Oblast						
Pinus sylvestris	2.0	4.8	25.3	24.4	23.1	79.6
Betula	1.0	2.1	24.4	17.0	29.1	73.5
Picea abies	2.5	5.4	24.0	20.1	20.7	72.7
Populus tremula	0.4	0.8	8.2	4.8	7.2	21.5
8. Novgorod Oblast						
Betula	0.7	2.2	35.5	21.9	24.4	84.7
Pinus sylvestris	2.2	3.1	12.2	8.9	10.0	36.4
Picea	2.4	3.0	11.5	9.9	9.0	35.7
Populus tremula	0.3	1.0	9.8	6.6	6.7	24.5
Alnus	0.0	0.1	1.0	0.7	0.4	2.2
Quercus	0.0	0.1	0.3	0.0	0.0	0.4
Bushes	--	--	--	--	--	0.0
9. Pskov Oblast						
Betula	0.4	1.0	18.0	12.5	9.7	41.5
Pinus sylvestris	1.3	3.6	12.4	9.2	4.3	30.7
Populus tremula	0.1	0.3	5.0	3.1	2.1	10.5
Picea	0.6	1.4	4.3	2.9	1.3	10.5
Alnus	0.0	0.2	2.6	1.7	0.9	5.4
Quercus	0.0	0.0	0.1	0.0	0.0	0.1
10. Bryansk Oblast						
Pinus sylvestris	0.7	4.6	11.1	4.8	1.6	22.7
Betula	0.2	0.6	7.1	2.9	2.5	13.3
Populus tremula	0.1	0.2	2.9	1.2	0.9	5.3
Picea	0.8	1.1	2.1	0.9	0.3	5.1
Alnus	0.2	0.3	2.3	0.4	0.6	3.8
Quercus	0.0	0.1	1.6	0.8	0.6	3.0
11. Vladimir Oblast						
Pinus sylvestris	1.5	6.0	14.5	11.4	2.4	35.8
Betula	0.4	0.7	10.1	5.1	3.0	19.3
Picea	0.2	1.3	2.0	1.3	0.3	5.0
Populus tremula	0.1	0.2	2.4	1.3	0.6	4.7
Quercus	0.0	0.1	0.3	0.3	1.2	1.9

Continued

Table 19.—Continued

Dominant species	Age-class group: Young stands Class I[a]	Young stands Class II[b]	Middle-aged	Maturing	Mature/ overmature	Total
Alnus	0.0	0.0	0.2	0.1	0.0	0.3
12. Ivanovo Oblast						
Betula	0.2	0.6	10.3	5.0	3.6	19.7
Pinus sylvestris	0.7	3.9	6.8	4.9	1.2	17.6
Picea	0.4	1.9	3.1	2.1	0.5	8.0
Populus tremula	0.1	0.2	2.7	1.1	0.8	4.9
Quercus	0.0	0.0	0.0	0.0	0.2	0.3
Alnus	0.0	0.0	0.0	0.0	0.0	0.1
13. Tver' Oblast						
Betula	0.7	2.6	44.1	17.5	20.9	85.8
Pinus sylvestris	2.0	5.5	21.7	15.7	10.0	54.8
Picea	2.1	5.3	17.8	15.1	10.0	50.3
Populus tremula	0.2	0.7	12.3	4.8	5.2	23.1
Alnus	0.0	0.1	1.8	0.7	0.8	3.3
14. Kaluga Oblast						
Betula	0.2	0.7	11.4	8.5	8.7	29.4
Populus	0.1	0.2	6.2	4.0	3.4	13.8
Picea	0.9	2.2	4.0	2.5	0.8	10.5
Pinus sylvestris	0.7	2.0	3.7	2.5	0.9	9.8
Quercus	0.0	0.1	0.3	3.0	0.3	3.7
Alnus	0.0	0.0	0.3	0.2	0.1	0.6
15. Kostroma Oblast						
Betula	1.4	4.7	46.5	22.1	22.5	97.2
Pinus sylvestris	3.2	7.6	17.0	10.2	14.8	52.8
Picea	3.3	7.1	14.0	7.8	10.7	42.9
Populus tremula	0.0	0.8	8.2	3.7	3.5	16.4
Quercus	0.0	0.0	0.0	0.0	0.0	0.0
16. Moscow Oblast						
Betula	0.2	3.9	26.8	7.5	7.0	45.3
Picea	1.0	4.2	14.5	5.4	1.8	26.8
Pinus sylvestris	0.8	3.3	13.0	5.1	1.5	23.6
Populus tremula	0.0	0.2	6.8	1.8	1.4	10.2
Quercus	0.0	0.2	1.5	3.0	0.6	5.3
Alnus	0.0	0.0	0.2	0.1	0.0	0.3
17. Orel Oblast						
Quercus	0.1	0.5	2.3	0.4	0.3	3.7
Betula	0.0	0.0	1.1	0.6	0.3	2.1
Pinus sylvestris	0.1	0.4	0.5	0.5	0.1	1.5
Populus tremula	0.0	0.0	0.7	0.3	0.2	1.3
18. Ryazan' Oblast						
Pinus sylvestris	1.1	4.1	8.3	4.9	1.0	19.4
Betula	0.3	0.6	8.4	3.0	1.8	14.0
Quercus	0.2	0.9	5.3	1.9	1.7	10.0
Populus tremula	0.1	0.2	2.9	0.9	0.5	4.5
Picea	0.0	0.1	0.4	0.3	0.1	0.9
Alnus	0.0	0.0	0.1	0.0	0.0	0.2
19. Smolensk Oblast						
Betula	0.1	1.0	22.6	8.5	6.0	38.2

Continued

Table 19.—Continued

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Maturing	Mature/ overmature	
	Class I[a]	Class II[b]				
Picea	2.5	2.4	6.2	4.4	1.8	17.3
Populus tremula	0.0	0.2	7.4	2.6	1.9	12.2
Pinus sylvestris	0.8	0.8	2.3	1.8	0.6	6.4
Alnus	0.0	0.1	1.3	0.5	0.1	2.0
Quercus	0.0	0.0	0.3	0.1	0.0	0.4
20. Tula Oblast						
Quercus	0.4	0.7	4.5	0.6	0.4	6.6
Betula	0.0	0.1	1.3	0.6	1.2	3.3
Populus tremula	0.0	0.1	1.6	0.7	0.8	3.2
Tilia	0.0	0.1	0.6	0.3	0.6	1.6
Pinus sylvestris	0.1	0.3	0.3	0.2	0.0	0.8
Picea	0.0	0.1	0.2	0.1	0.0	0.4
21. Yaroslavl' Oblast						
Betula	0.2	0.7	16.8	7.3	6.6	31.6
Picea	1.1	2.2	4.4	7.4	1.0	16.1
Populust	0.0	0.2	5.3	2.2	1.9	9.6
Pinus sylvestris	0.6	1.3	3.9	2.9	0.7	9.5
Alnus	0.0	0.0	0.5	0.2	0.2	1.0
Quercus	0.0	0.0	0.0	0.0	0.0	0.0
22. Nizhniy Novgorod Oblast						
Pinus sylvestris	3.8	11.3	20.7	12.7	8.6	57.1
Betula	1.8	3.4	27.5	12.7	11.3	56.7
Populus tremula	0.6	0.9	8.2	3.9	3.2	16.7
Picea	1.2	3.7	5.6	3.0	1.6	15.1
Quercus	0.1	0.3	2.7	1.9	1.4	6.4
Tilia	0.0	0.0	0.2	0.1	0.0	0.4
Alnus	0.0	0.0	0.2	0.1	0.0	0.3
bushes	--	--	--	--	--	0.0
23. Kirov Oblast						
Picea	5.9	12.2	31.0	16.3	43.1	108.4
Betula	1.9	8.1	39.9	16.0	40.1	106.0
Pinus sylvestris	3.4	7.1	22.9	13.1	29.7	76.2
Populus tremula	0.6	2.1	10.5	3.9	9.5	26.6
Tilia	0.0	0.1	0.3	0.1	0.1	0.6
Alnus	0.0	0.0	0.1	0.1	0.1	0.3
Quercus	0.0	0.0	0.0	0.1	0.0	0.1
24. Republic of Mari El						
Betula	0.7	0.9	9.3	3.6	4.8	19.4
Pinus sylvestris	1.0	2.8	7.5	3.5	4.0	18.6
Picea	0.3	1.0	2.9	1.2	1.3	6.7
Populus tremula	0.3	0.2	1.7	0.5	1.6	4.3
Quercus	0.0	0.0	0.0	1.8	0.1	2.0
Tilia	0.0	0.0	0.2	0.1	0.0	0.3
Alnus	0.0	0.0	0.1	0.0	0.0	0.1
25. Republic of Mordvinia						
Pinus sylvestris	0.8	4.3	3.0	2.0	0.7	10.8
Betula	0.2	0.5	4.8	1.9	1.5	8.9
Quercus	0.2	0.4	2.8	0.7	1.0	5.0

Continued

Table 19.—Continued

Dominant species	Age-class group: Young stands, Class I[a]	Class II[b]	Middle-aged	Maturing	Mature/ overmature	Total
Populus tremula	0.2	0.2	1.7	0.6	0.7	3.3
Tilia	0.1	0.0	0.9	0.4	0.4	1.7
Picea	0.0	0.1	0.1	0.1	0.3	0.5
26. Republic of Chuvashia						
Pinus sylvestris	0.6	1.4	3.3	1.1	0.8	7.2
Betula	0.3	0.3	2.8	1.2	2.2	6.7
Quercus	0.5	1.0	3.6	0.4	0.5	5.9
Tilia	0.1	0.2	1.5	0.7	1.2	3.6
Populus tremula	0.1	0.1	1.2	0.6	0.7	2.8
Picea	0.0	0.1	0.1	0.0	0.0	0.3
Bushes	--	--	--	--	--	0.0
27. Belgorod Oblast						
Quercus	0.1	1.5	10.9	1.7	0.9	15.1
Pinus sylvestris	0.1	0.5	0.4	0.0	0.0	1.1
Populus tremula	0.0	0.0	0.2	0.0	0.1	0.3
Betula	0.0	0.0	0.2	0.1	0.0	0.3
28. Voronezh Oblast						
Quercus	0.4	1.7	8.6	2.0	0.9	13.6
Pinus sylvestris	0.7	2.1	2.0	0.5	0.1	5.3
Populus tremula	0.1	0.1	0.4	0.3	0.2	1.0
Betula	0.0	0.0	0.2	0.1	0.2	0.5
Bushes	--	--	--	--	--	0.0
29. Kursk Oblast						
Quercus	0.3	1.1	5.8	0.8	0.2	8.2
Pinus sylvestris	0.3	0.4	0.4	0.0	0.0	1.0
Betula	0.1	0.1	0.4	0.2	0.1	0.7
Populus	0.0	0.1	0.3	0.2	0.1	0.6
Tilia	0.0	0.0	0.0	0.0	0.0	0.1
Bushes	--	--	--	--	--	0.0
30. Lipetsk Oblast						
Pinus sylvestris	0.2	1.9	3.0	0.3	0.1	5.4
Quercus	0.1	0.5	2.4	0.4	0.2	3.5
Populus tremula	0.1	0.0	0.3	0.2	0.2	0.8
Betula	0.0	0.0	0.3	0.1	0.2	0.7
31. Tambov Oblast						
Pinus sylvestris	0.7	1.4	3.1	1.8	0.6	7.6
Quercus	0.2	0.3	2.1	0.8	0.8	4.1
Betula	0.1	0.2	0.9	0.7	1.3	3.2
Populus tremula	0.1	0.1	0.8	0.6	0.5	2.1
Bushes	--	--	--	--	--	0.0
32. Astrakhan' Oblast						
Populus sp.	0.0	0.1	0.4	0.5	1.9	2.9
Quercus	0.0	0.0	0.2	0.1	0.2	0.5
Bushes	--	--	--	--	--	0.1
33. Volgograd Oblast						
Quercus	0.3	1.1	4.8	2.0	1.6	9.6
Populus sp.	0.0	0.1	0.4	0.4	1.5	2.4
Pinus sylvestris	0.2	0.3	0.3	0.1	0.0	0.9

Continued

Table 19.—Continued

Dominant species	Age-class group: Young stands Class I[a]	Class II[b]	Middle-aged	Maturing	Mature/ overmature	Total
Populus tremula	0.0	0.0	0.1	0.1	0.3	0.5
Betula	0.0	0.0	0.0	0.0	0.1	0.1
Bushes	--	--	--	--	--	0.2
34. Samara Oblast						
Quercus	0.1	1.1	9.3	3.7	2.8	17.0
Tilia	0.0	0.4	3.7	1.0	1.1	6.3
Pinus sylvestris	0.3	0.5	2.1	0.8	1.1	4.7
Populus tremula	0.0	0.3	2.7	1.1	0.7	4.6
Betula	0.1	0.1	0.8	0.3	0.3	1.6
Populus sp.	0.0	0.1	0.5	0.2	0.3	0.9
Bushes	--	--	--	--	--	0.1
35. Penza Oblast						
Pinus sylvestris	1.5	3.0	5.6	3.8	1.5	15.3
Quercus	0.1	0.7	7.3	2.1	1.9	12.2
Betula	0.2	0.4	3.2	1.6	1.5	6.8
Populus tremula	0.2	0.3	3.0	1.3	1.2	6.0
Bushes	--	--	--	--	--	0.0
36. Saratov Oblast						
Quercus	0.1	0.8	5.6	4.6	3.2	14.3
Pinus sylvestris	0.1	0.3	0.6	0.3	0.1	1.4
Populus tremula	0.0	0.1	0.8	0.5	0.4	1.8
Populus sp.	0.0	0.1	0.4	0.2	0.3	1.0
Betula	0.0	0.1	0.4	0.1	0.1	0.7
Tilia	0.0	0.0	0.4	0.0	0.2	0.7
Bushes	--	--	--	--	--	0.1
37. Ul’yanovsk Oblast						
Pinus sylvestris	1.3	3.4	9.1	4.6	3.3	21.6
Betula	0.2	0.6	5.4	2.3	1.5	10.0
Quercus	0.1	0.2	4.5	2.4	2.5	9.7
Populus tremula	0.1	0.3	3.9	1.5	1.0	6.8
Bushes	--	--	--	--	--	0.0
38. Republic of Kalmykia						
Quercus	0.0	0.0	0.1	0.0	0.0	0.1
39. Republic of Tatarstan						
Tilia	0.2	0.8	5.3	2.4	3.1	11.8
Quercus	0.8	1.8	7.4	1.4	0.1	11.4
Populus tremula	0.1	0.9	4.4	2.3	2.3	10.0
Pinus sylvestris	1.2	2.4	3.6	1.5	0.5	9.2
Betula	0.1	0.6	3.8	1.7	2.0	8.2
Picea	0.2	0.3	0.5	0.2	0.1	1.3
Bushes	--	--	--	--	--	0.0
40. Krasnodar Kray						
Quercus sp.	0.7	3.2	23.3	12.8	36.1	76.1
Fagus orientalis	0.4	1.3	13.5	7.3	20.8	43.2
Abies	0.0	0.3	0.9	1.0	8.6	10.7
Carpinus	0.1	0.3	2.9	2.0	4.4	9.6
Populus tremula	0.0	0.1	0.9	0.4	1.2	2.7
Ulmus	0.0	0.1	0.6	0.3	0.9	1.9

Continued

Table 19.—Continued

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Maturing	Mature/ overmature	
	Class I[a]	Class II[b]				
Populus sp.	0.0	0.1	0.3	0.2	0.6	1.1
Pinus sylvestris	0.0	0.0	0.1	0.1	0.7	0.9
Betula	0.0	0.0	0.0	0.1	0.0	0.1
Bushes	--	--	--	--	--	6.4
41. Stavropol’ Kray						
Fagus	0.0	0.2	5.1	1.4	4.4	11.2
Pinus sylvestris	0.0	0.2	1.1	1.4	2.1	4.9
Abies	0.1	0.1	1.5	1.2	1.3	4.3
Betula	0.0	0.0	1.4	0.8	2.1	4.3
Carpinus	0.0	0.1	2.0	0.0	1.6	3.7
Quercus	0.0	0.0	0.4	0.6	1.6	2.7
Picea	0.0	0.0	0.5	0.4	1.1	2.1
Populus tremula	0.0	0.0	0.7	0.4	0.9	2.0
Populus sp.	0.0	0.0	0.0	0.0	0.1	0.1
Bushes	--	--	--	--	--	0.1
42. Rostov Oblast						
Quercus	0.3	1.5	1.6	0.5	0.2	4.0
Pinus sylvestris	0.5	0.4	0.2	0.1	0.0	1.1
Populus sp.	0.0	0.0	0.1	0.1	0.1	0.3
Populus tremula	0.0	0.0	0.1	0.0	0.1	0.2
Betula	0.0	0.0	0.0	0.0	0.0	0.0
Bushes	--	--	--	--	--	0.2
43. Republic of Dagestan						
Quercus	0.1	0.3	4.5	0.8	0.6	6.1
Fagus	0.0	0.1	3.9	0.6	0.5	5.1
Pinus sylvestris	0.0	0.1	2.9	0.4	0.2	3.7
Carpinus	0.0	0.1	2.6	0.4	0.3	3.4
Betula	0.0	0.0	0.0	0.2	0.6	0.8
Tilia	0.0	0.0	0.4	0.1	0.3	0.8
Populus tremula	0.0	0.0	0.1	0.0	0.1	0.2
Bushes	--	--	--	--	--	0.1
44. Republic of Kabardino-Balkaria						
Fagus	0.0	0.2	2.1	0.4	2.9	5.5
Pinus sylvestris	0.0	0.0	0.6	0.2	0.5	1.2
Betula	0.0	0.0	0.5	0.5	0.5	1.5
Carpinus	0.0	0.0	0.5	0.1	0.3	0.9
Populus tremula	0.0	0.0	0.2	0.2	0.2	0.6
Quercus	0.0	0.0	0.3	0.1	0.2	0.6
Tilia	0.0	0.0	0.0	0.0	0.0	0.0
Bushes	--	--	--	--	--	0.1
45. Republic of North Osetia						
Fagus	0.0	0.3	5.3	2.3	3.9	11.8
Carpinus	0.0	0.1	0.8	0.2	0.4	1.5
Populus tremula	0.0	0.3	0.3	0.3	0.0	0.8
Quercus	0.0	0.0	0.3	0.2	0.1	0.6
Tilia	0.0	0.0	0.0	0.1	0.2	0.3
Pinus sylvestris	0.0	0.0	0.2	0.0	0.0	0.2
Betula	0.0	0.0	0.0	0.0	0.0	0.0
Bushes	--	--	--	--	--	0.0

Continued

Table 19.—Continued

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Maturing	Mature/ overmature	
	Class I[a]	Class II[b]				
46. Republic of Checheno-Ingushetia						
Fagus	0.1	1.0	12.2	2.2	4.4	19.9
Quercus	0.0	0.3	1.6	0.5	1.8	4.2
Carpinus	0.0	0.1	2.1	0.3	0.5	3.1
Tilia	0.0	0.0	0.7	0.2	0.3	1.1
Betula	0.0	0.0	0.3	0.1	0.2	0.6
Populus tremula	0.0	0.0	0.3	0.1	0.1	0.5
Pinus sylvestris	0.0	0.0	0.2	0.0	0.0	0.3
Bushes	--	--	--	--	--	0.2
47. Kurgan Oblast						
Betula	0.5	1.2	26.2	7.9	4.0	39.7
Pinus sylvestris	1.3	3.7	5.9	3.8	3.8	18.5
Populus	0.0	0.1	2.6	1.1	0.4	4.2
Bushes	--	--	--	--	--	0.1
48. Orenburg Oblast						
Quercus	0.2	0.7	4.4	3.7	1.7	10.7
Pinus sylvestris	0.2	0.7	1.0	0.4	1.3	3.6
Betula	0.1	0.2	1.1	0.6	1.0	3.0
Populus tremula	0.1	0.1	0.6	0.5	1.1	2.3
Tilia	0.0	0.1	0.8	0.4	1.0	2.3
Populus sp.	0.0	0.1	0.8	0.4	0.9	2.2
Bushes	--	--	--	--	--	0.2
49. Perm' Oblast						
Picea	15.2	22.1	36.5	31.9	163.4	269.1
Betula	3.4	12.1	44.4	14.2	48.0	122.1
Pinus sylvestris	2.3	3.6	6.9	5.9	28.7	47.3
Populus tremula	0.8	2.4	9.3	2.8	8.8	24.0
Abies	0.3	0.5	0.9	0.7	3.1	5.5
Tilia	0.1	0.3	1.0	0.3	1.0	2.6
Pinus sibirica	0.0	0.0	0.0	0.0	0.3	0.3
Quercus	0.0	0.0	0.0	0.0	0.0	0.0
50. Sverdlovsk Oblast						
Pinus sylvestris	7.9	19.5	63.3	32.8	98.6	222.2
Betula	3.5	10.8	67.7	21.5	60.1	163.5
Picea	3.8	9.0	24.9	15.7	41.8	95.2
Pinus sibirica	0.0	4.2	10.4	5.9	16.9	37.3
Populus	0.5	1.3	9.9	2.6	7.7	22.0
Abies	0.3	0.7	2.0	1.1	3.0	7.0
Larix	0.0	0.1	0.4	0.2	0.7	1.3
Tilia	0.0	0.0	0.2	0.0	0.1	0.4
51. Chelyabinsk Oblast						
Betula	0.7	1.5	23.3	14.4	18.1	58.0
Pinus sylvestris	1.4	3.9	12.1	6.3	8.8	32.4
Populus	0.1	0.2	3.2	1.9	2.2	7.6
Picea	0.3	0.9	2.9	1.3	2.1	7.5
Tilia	0.0	0.2	2.5	1.1	1.9	5.6
Abies	0.1	0.4	1.2	0.5	0.7	3.0
Quercus	0.0	0.1	0.7	0.1	1.0	2.0

Continued

Table 19.—Continued

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Maturing	Mature/ overmature	
	Class I[a]	Class II[b]				
Larix	0.1	0.2	0.5	0.3	0.4	1.4
Bushes	--	--	--	--	--	0.0
52. Republic of Bashkortostan						
Betula	0.6	2.2	23.4	11.1	35.3	72.6
Tilia	0.4	2.0	20.7	10.8	33.3	67.2
Pinus sylvestris	2.0	3.4	7.3	11.5	10.6	34.7
Populus	0.3	0.9	10.6	5.3	14.2	31.3
Quercus	0.2	0.5	7.8	4.2	15.5	28.1
Picea	0.8	1.1	2.1	3.9	3.1	11.0
Abies	0.3	0.5	0.9	1.3	1.2	4.2
Larix	0.1	0.2	0.4	0.6	0.6	1.8
Bushes	--	--	--	--	--	0.1
53. Republic of Udmurtia						
Picea	2.7	7.4	11.6	9.8	8.8	40.4
Betula	0.2	1.0	14.5	8.2	6.0	29.9
Pinus sylvestris	0.9	2.6	3.1	3.9	3.6	14.2
Populus	0.1	0.3	4.5	2.4	1.8	9.1
Tilia	0.0	0.0	0.5	0.2	0.1	0.8
Quercus	0.0	0.0	0.1	0.1	0.1	0.3
54. Altai Kray						
Pinus sylvestris	0.5	2.5	26.2	18.0	41.4	88.5
Larix	0.3	1.8	15.9	17.8	31.3	67.0
Betula	0.8	1.7	14.2	12.0	22.8	51.3
Pinus sibirica	0.3	1.2	8.5	10.9	17.8	38.7
Populus tremula	0.5	1.0	8.9	7.4	12.6	30.4
Abies	0.3	1.1	8.8	5.9	12.7	28.8
Picea	0.0	0.1	0.7	0.5	1.3	2.6
Bushes	--	--	--	--	--	0.9
55. Kemerovo Oblast						
Abies	1.3	2.9	16.5	15.9	31.8	68.4
Betula	1.0	1.7	7.8	7.7	18.7	36.8
Populus tremula	0.5	1.5	8.1	8.0	18.3	36.4
Pinus sibirica	0.2	0.5	3.0	2.9	6.1	12.7
Pinus sylvestris	0.1	0.2	1.3	1.5	1.8	5.0
Picea	0.1	0.1	0.5	0.6	1.3	2.5
Larix	0.0	0.0	0.0	0.0	0.0	0.0
Bushes	--	--	--	--	--	0.1
56. Novosibirsk Oblast						
Betula	1.8	3.8	26.1	34.1	31.2	96.9
Pinus sylvestris	0.7	1.8	13.6	5.3	6.6	28.0
Populus tremula	0.4	0.5	5.2	6.5	5.2	17.7
Abies	0.0	0.2	1.0	0.3	0.5	2.0
Pinus sibirica	0.0	0.1	0.3	0.8	0.4	1.6
Picea	0.0	0.1	0.3	0.1	0.2	0.7
Bushes	--	--	--	--	--	0.1
57. Omsk Oblast						
Betula	1.9	3.3	24.8	25.2	62.6	117.8
Populus tremula	0.4	0.7	5.4	5.1	16.4	28.0

Continued

Table 19.—Continued

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Maturing	Mature/ overmature	
	Class I[a]	Class II[b]				
Pinus sylvestris	0.6	1.1	9.6	4.7	5.5	21.6
Pinus sibirica	0.3	0.6	1.9	3.1	3.9	9.8
Picea	0.1	0.2	1.7	0.8	1.0	3.7
Abies	0.1	0.1	0.9	0.4	0.7	2.1
Bushes	--	--	--	--	--	0.0
58. Tomsk Oblast						
Betula	1.3	5.4	34.4	33.7	206.0	280.8
Pinus sibirica	0.1	3.1	27.8	38.1	123.6	192.6
Pinus sylvestris	4.9	2.9	26.3	38.3	115.9	188.2
Populus	0.5	1.5	9.3	8.9	65.0	85.3
Abies	0.2	0.4	3.6	5.0	15.4	24.6
Picea	0.2	0.3	3.2	4.0	15.2	23.0
Bushes	--	--	--	--	--	0.0
59. Tyumen’ Oblast						
Pinus sylvestris	4.4	8.5	84.4	112.9	357.0	567.2
Betula	2.0	5.1	46.0	39.4	260.3	352.8
Pinus sibirica	0.1	1.8	50.9	54.3	189.2	296.3
Larix	1.0	2.3	25.3	28.7	109.7	167.0
Picea	1.2	1.7	25.8	26.8	106.5	162.0
Populus tremula	0.4	1.0	9.8	8.0	45.7	64.9
Abies	0.1	0.1	1.3	1.5	4.9	7.8
Bushes	--	--	--	--	--	1.3
60. Krasnoyarsk Kray						
Larix	2.4	6.0	45.4	131.0	1,597.9	1,782.7
Pinus sylvestris	7.1	14.7	83.2	48.0	456.6	609.4
Pinus sibirica	1.7	10.2	67.0	117.7	381.9	578.4
Betula	3.8	10.7	111.4	103.4	289.1	518.3
Picea	0.4	0.7	12.6	13.7	310.3	337.6
Abies	1.4	4.2	37.0	39.7	244.0	326.3
Populus tremula	1.1	2.4	10.3	10.4	74.0	98.3
Bushes	0.0	0.0	3.5	0.3	0.0	3.9
61. Irkutsk Oblast						
Larix	8.5	27.3	132.5	219.5	578.7	966.5
Pinus sylvestris	9.4	27.2	203.3	134.6	539.4	913.9
Pinus sibirica	4.6	15.4	68.5	112.5	288.3	489.3
Betula	3.3	9.0	48.8	39.2	126.2	226.5
Picea	1.5	4.2	29.6	18.0	87.5	140.8
Abies	0.7	2.6	21.7	11.4	53.6	90.0
Populus tremula	1.2	2.3	14.9	10.6	42.5	71.5
Bushes	--	--	--	--	--	47.6
62. Chita Oblast						
Larix	7.8	34.3	68.8	237.1	276.9	624.9
Pinus sylvestris	1.7	6.1	36.1	20.7	38.9	103.5
Betula	4.4	6.2	39.1	17.2	19.6	86.4
Pinus sibirica	0.0	3.8	11.5	20.8	23.2	59.3
Populus tremula	0.2	0.5	3.2	0.9	1.1	5.9
Picea	0.0	0.0	0.2	0.2	0.3	0.7
Bushes	--	--	--	--	--	23.8

Continued

Table 19.—Continued

Dominant species	Age-class group: Young stands Class I[a]	Class II[b]	Middle-aged	Maturing	Mature/ overmature	Total
63. Republic of Buryatia						
Larix	0.7	17.7	55.3	139.4	181.6	394.7
Pinus sylvestris	2.3	8.4	58.8	26.6	58.0	154.1
Pinus sibirica	0.1	5.2	13.7	32.2	42.1	93.3
Betula	0.4	1.1	12.1	4.6	14.0	32.3
Populus tremula	0.3	0.7	4.9	2.1	4.6	12.4
Abies	0.1	0.5	3.8	1.6	5.3	11.3
Picea	0.1	0.3	1.9	0.7	2.7	5.7
Bushes	--	--	--	--	--	28.4
64. Republic of Tuva						
Larix	0.6	5.5	37.7	60.9	88.9	193.6
Pinus sibirica	0.4	3.1	21.7	30.7	48.5	104.3
Betula	0.0	0.1	2.4	1.4	5.4	9.4
Pinus sylvestris	0.0	0.1	1.8	1.5	2.3	5.7
Picea	0.0	0.1	0.4	0.7	0.9	2.0
Populus tremula	0.0	0.0	0.3	0.2	0.5	1.0
Bushes	--	--	--	--	--	0.6
65. Primor'ye Kray						
Quercus mongolica	2.0	8.6	47.6	22.6	112.8	193.5
Pinus korajensis	0.0	0.5	37.7	28.1	72.3	138.5
Picea	0.4	2.8	39.8	29.8	64.8	137.6
Larix	0.1	0.7	10.7	12.5	34.3	58.3
Betula	0.1	1.1	15.4	6.5	17.4	40.5
Populus tremula	0.1	0.7	10.8	4.3	11.4	27.4
Betula ermanii	0.0	0.0	0.0	0.0	21.2	21.2
Abies	0.0	0.2	2.5	2.6	6.7	12.0
Tilia sp.	0.0	0.1	1.1	0.5	0.2	1.9
Bushes	--	--	--	--	--	0.8
66. Khabarovsk Kray						
Larix	9.3	33.0	146.5	137.0	595.3	921.1
Picea	4.8	14.6	63.8	62.5	230.3	376.0
Betula	1.9	3.3	28.1	13.7	38.1	85.1
Pinus korajensis	0.6	2.0	10.0	8.7	34.8	56.0
Betula ermanii	0.0	0.1	2.7	3.5	45.7	52.0
Populus tremula	1.1	1.7	15.6	5.9	18.4	42.8
Quercus mongolica	0.3	1.4	11.4	13.2	14.6	40.8
Pinus sylvestris	0.4	1.2	7.0	5.3	24.8	38.6
Abies	0.3	0.9	4.6	4.0	14.5	24.3
Bushes	--	--	--	--	--	75.3
67. Amur Oblast						
Larix	4.8	22.8	129.2	77.1	272.5	506.3
Betula	3.3	7.1	55.1	22.1	25.8	113.3
Pinus sylvestris	0.2	0.9	5.0	2.6	10.2	18.8
Picea	0.3	1.0	4.4	2.6	9.2	17.4
Quercus mongolica	2.3	3.1	6.7	2.4	2.5	16.9
Populus tremula	0.2	0.5	3.4	1.2	1.6	6.9
Abies	0.0	0.1	0.6	0.3	1.3	2.4
Bushes	--	--	--	--	--	19.2

Continued

Table 19.—Continued

Dominant species	Age-class group					Total
	Young stands		Middle-aged	Maturing	Mature/ overmature	
	Class I[a]	Class II[b]				
			68. Kamtchatka Oblast			
Betula ermanii	0.0	0.1	6.9	17.5	206.2	230.7
Larix camtchatica	0.4	0.9	2.8	9.4	32.4	45.8
Betula sp.	0.1	0.5	3.8	4.8	9.5	18.7
Populus tremula	0.0	0.0	5.1	0.9	8.9	14.1
Picea	0.1	0.4	1.0	1.6	10.8	13.9
Bushes	--	--	--	--	--	184.5
			69. Magadan Oblast			
Larix	2.7	4.0	8.9	10.5	110.7	136.7
Chozenia arbutifolia	0.0	0.1	4.6	1.0	7.9	13.6
Betula	0.0	0.0	0.3	0.2	0.2	0.6
Bushes	--	--	--	--	--	60.0
			70. Sakhalin Oblast			
Larix	0.6	1.8	14.2	6.2	45.9	68.6
Picea	0.9	2.0	14.7	6.3	39.2	63.0
Abies	0.5	1.3	9.2	3.8	25.7	40.5
Betula ermanii	0.4	3.1	7.1	2.3	10.0	22.8
Populus tremula	0.0	0.1	3.2	1.4	0.7	5.5
Betula sp.	0.0	0.2	2.5	0.9	1.0	4.6
Bushes	--	--	--	--	--	7.2
			71. Republic of Yakutia (Sakha)			
Larix	33.3	95.0	564.7	257.9	1,727.1	2,678.0
Pinus sylvestris	2.1	6.1	56.4	30.9	188.1	283.6
Betula	0.9	2.5	9.7	2.8	4.9	20.8
Pinus sibirica	0.1	1.1	8.2	1.9	4.5	15.9
Picea	0.0	0.1	0.9	1.1	11.8	13.9
Populus tremula	0.1	0.2	0.7	0.7	3.2	4.8
Abies	0.0	0.0	0.0	0.2	1.0	1.3
Bushes	--	--	--	--	--	74.4
Total						26,103.3

[a]Young regeneration.
[b]Advanced regeneration.
[c]no data.

Table 20.—Total and average carbon storage in vegetation of forest ecosystems of Russia, by ecoregion

Ecoregion	Stocked area			Unstocked area	
	Area	Total carbon	Average carbon	Area	Total carbon
	Thousand ha	*Mt*	*t/ha*	*Thousand ha*	*Mt*
Middle European Plain Forest Oblast of Boreal Zone					
1. Baltic forest province	266	15.6	59	18	0.1
Kola-Karelian Tableland Forest Oblast of Boreal Zone					
4. Northern Kola forest province	1,038	12.5	12	59	0.5
5. Kola-Karelian forest province					
5.1. Northern taiga district	9,665	239.8	23	562	3.0
5.2. Middle taiga district	3,622	113.2	31	295	0.9
Dnieper-Baltic Plain Forest Oblast of Boreal and Subboreal Zones					
6. Western Dvina Forest Province					
6.1. Southern taiga district	10,388	551.8	53	339	0.9
6.2. Mixed (subtaiga) forest district	1,899	80.0	42	43	0.1
Caucasian Mountain Forest Oblast of Subboreal Zone					
10. Great Caucasus forest province	3,298	270.6	82	124	0.5
Eastern European Plain Forest Oblast of Boreal and Subboreal Zones					
15. Kaninsk-Pechorsk forest province	2,351	26.9	11	193	1.6
16. Dvina-Pechorsk-Upper-Volga forest province					
16.1. Northern taiga district	26,182	746.9	29	894	4.8
16.2. Middle taiga district	33,642	1,491.6	44	1,127	3.8
16.3. Southern taiga district	25,277	1,149.6	45	1,053	3.1
16.4. Mixed (subtaiga) forest district	10,963	548.3	50	537	1.4
17. Middle Russian forest province (forest -steppe)	9,550	486.9	51	521	1.4
18. Volga-Don Steppe forest province	1,756	63.1	36	319	0.7
Ural Mountain Forest Oblast of Boreal and Subboreal Zones					
19. Northern Ural forest province	330	3.2	10	15	0.1
20. Middle Ural forest province	8,108	373.8	46	433	1.3
21. Southern Ural forest province	5,816	281.6	48	294	0.8
Western Siberian Plain Forest Oblast of Subarctic and Boreal Zones					
22. TransUrals-Enisey forest-tundra forest province	12,247	144.1	12	1,038	7.9
23. TransUrals-Enisey forest province of taiga					
23.1. Northern taiga district	20,771	656.9	32	1,797	11.3
23.2. Middle taiga district	41,221	1,747.2	42	1,998	8.2
23.3 + 25. Southern taiga and subtaiga district	30,196	1,500.1	50	1,622	6.5
24. Irtysh-ObForest steppe forest province	6,833	340.4	50	440	1.1
Altai-Sayan Mountain Forest Oblast of Boreal and Subboreal Zones					
26. Northern Altai-Sayan forest province	5,961	329.9	55	556	3.2
27. Eastern Sayan forest province	10,887	594.5	55	1,231	5.4
28. Central Altay forest province	2,511	109.8	44	211	1.2
29. Westrn Altay forest province	405	19.4	48	37	0.2
30. Eastern Tuva forest province	7,515	313.1	42	537	2.8
31. Khakass-Minusinsk forest province	2,117	92.4	44	122	0.4
32. Salair-Kuznetsk forest province	5,435	178.0	33	247	1.1
Middle Siberian Tableland Forest Oblast of Boreal and Subboreal Zones					
33. Putoran forest province	8,061	125.1	16	1,608	14.7
34. Anabar forest province	152	1.6	11	-	-
Middle Siberian Tableland Forest Oblast of Boreal and Subboreal Zones (continued)					
35. Near-Enisey forest province	23,048	890.7	39	1,528	9.6
36. Khetsk-Kotui-Olenek forest province forest -tundra zone	26,512	407.8	15	7,504	48.8
37. Angara-Tunguska forest province					

Continued

Table 20.—Continued

Ecoregion	Stocked area Area	Stocked area Total carbon	Stocked area Average carbon	Unstocked area Area	Unstocked area Total carbon
	Thousand ha	*Mt*	*t/ha*	*Thousand ha*	*Mt*
37.1. Lower Tunguska northern taiga district	33,472	790.1	24	12,114	92.1
37.2. Stony Tunguska middle taiga district	24,510	1,092.3	45	3,068	16.0
37.3. Angara southern taiga district	25,068	1,548.4	62	2,319	11.0
38. Kansk-Krasnoyarsk Biryusa forest province (forest steppe)	2,175	78.0	36	151	0.4
39. Upper Angara forest province	1,776	91.4	51	222	0.6
40. Upper Lena forest province	10,631	650.4	61	2,331	7.6
Central Yakutian Plain Forest Oblast of Boreal Zone					
41. Lena-Vilyui forest province	47,027	1,291.1	27	10,583	70.9
42. Aldan forest province	20,619	654.5	31	2,163	11.5
Yana-Kolyma Mountain Forest Oblast of Subarctic Zone					
43 + 44 + 45. Yana-Kolyma Subarctic forest province	39,290	670.1	17	20,585	170.9
Northern Transbaikal Mountain Forest Oblast of Boreal Zone					
46. Vitim-Olekma tableland forest province	33,250	1,105.9	33	3,255	20.2
47. Baikal-Stanovoi forest province	19,455	420.9	22	1,919	11.9
48. Uchur-Maisk forest province	9,929	254.1	26	2,241	14.4
Southern Transbaikal Mountain Forest Oblast of Subboreal Zone					
49. Jidin forest province	2,216	106.6	48	137	0.5
50. Selenga forest province	4,433	205.7	46	274	1.1
51. Chikoi-Ingodin forest province	9,533	406.3	43	625	2.4
52. Dahurian forest province	4,911	189.0	38	322	1.2
Baikal Mountain Forest Oblast of Subboreal Zone					
53. Near-Baikal forest province	5,584	236.1	42	469	1.9
Okhotsk-Bering Mountain Forest Oblast of Subarctic Zone					
54 + 55. Magadan and Penzhin-Anadyr forest province	18,435	252.1	14	6,699	59.0
56. Kamtchatka Forest Province	11,883	439.2	37	1,161	7.4
Amur-Sakhalin Mountain Forest Oblast of Boreal and Subboreal Zones					
57. Zeya-Uda forest province	26,035	870.8	33	4,363	21.9
58. Amgun-Selenjin forest province	19,767	794.6	40	4,412	22.9
59. Sikhote-Alin forest province					
59.1. Sikhote-Alin district	21,804	1,024.1	47	3,597	15.7
59.2. Ussuri-Primorye district	5,329	300.3	56	214	0.9
60. Sakhalin-Kurily forest province	5,630	229.3	41	1,133	4.7
61. Near-Amur forest province	5,782	197.6	34	1,010	2.7
Kazakhstan Plain Tableland Forest Oblast of Subarid and Arid Zones					
62. Southern Urals-Mugojar forest province	276	8.9	32	4	0.0
63. Tobol-Ishim forest province	346	14.6	42	-	-
64. Kulunda forest province	1,491	58.1	39	124	0.3
Tura Plain Forest Oblast of Arid Zone					
66. Near-Kaspian forest province	112	4.1	36	25	0.1
Central-Asian Mountain Forest Oblast of Subarid Zone					
73. Southern Altai-Tuva forest province	2,313	89.5	39	158	0.8
Total	771,105	27,980.5	36	112,980	718.3

Table 21.—Carbon density (t/ha) in litter and soils (without accounting for rockiness) in Russian forests (from Shugalei et al. 1994)

Soil type and depth (cm)	Number of samples	Range	Carbon density	Error of mean	σ	Percent variance
		t/ha				*Percent*
			European Part of Russia			
1. Tundra cryogenic soils						
Litter	52	106.7 - 3.7	30.4	2.8	20.6	68
0 - 20	52	196.0 - 24.1	77.9	4.8	34.4	44
0 - 50	52	275.5 - 43.6	125.6	6.4	46.4	37
2. Podsolic sandy soils						
Litter	33	50.8 - 3.6	9.5	1.6	9.4	99
0 - 20	33	58.7 - 8.0	17.9	7.8	10.1	57
0 - 50	33	140.5 - 17.9	30.5	4.3	24.5	80
3. Sod-podsolic sandy soils						
Litter	37	29.3 - 4.4	12.0	0.8	5.0	41
0 - 20	37	31.4 - 7.5	17.8	0.8	4.8	27
0 - 50	37	57.3 - 8.1	28.9	1.6	9.8	34
4. Sod-podsolic loamy soils						
Litter	46	13.6 - 2.9	7.2	0.3	2.1	30
0 - 20	46	48.8 - 12.0	31.4	1.1	7.4	23
0 - 50	46	74.5 - 19.4	46.1	1.6	11.0	24
5. Grey forest soils						
Litter	7	8.5 - 6.4	7.5	0.2	0.5	7
0 - 20	7	75.8 - 59.8	67.8	1.5	4.0	6
0 - 50	7	130.2 - 92.2	111.2	3.5	9.5	8
6. Alluvial soils						
Litter	8	68.8 - 3.1	26.3	5.8	16.4	62
0 - 20	16	56.8 - 18.5	41.9	2.4	9.6	23
0 - 50	16	110.0 - 50.6	86.0	3.7	14.8	17
7. Forest-steppe soils						
Litter	20	8.5 - 0.0	4.3	0.8	3.6	85
0 - 20	20	75.8 - 5.1	40.5	6.8	30.4	43
0 - 50	20	131.4 - 11.7	75.8	11.5	51.5	68
8. Pre-Caucasian forest soils						
Litter	6	6.0 - 0.0	1.6	0.8	2.0	124
0 - 20	6	161.6 - 40.8	70.8	44.1	48.7	69
0 - 50	6	369.6 - 80.5	137.3	38.8	95.4	69
9. Mountain meadow soils						
Litter	5	14.9 - 1.0	7.0	3.1	6.9	99
0 - 20	9	252.1 - 38.6	166.6	23.5	70.4	42
0 - 50	9	535.3 - 70.7	300.7	51.1	153.3	51
			Ural and Asian Part of Russia			
10. Tundra cryogenic soils						
Litter	14	169.3 - 0.4	39.6	13.1	49.0	124
0 - 20	17	236.7 - 13.7	84.8	14.6	60.2	71
0 - 50	17	267.1 - 29.0	125.8	13.3	54.8	44
11. Taiga cryogenic soils						
Litter	35	39.6 - 0.9	12.8	1.8	9.7	75
0 - 20	35	126.5 - 12.1	65.6	3.9	22.9	35
0 - 50	35	160.9 - 31.3	97.7	4.4	25.9	26
12. Podsolic soils						
Litter	18	41.7 - 6.8	15.7	2.0	8.7	55
0 - 20	27	121.0 - 31.9	72.8	3.4	17.8	24
0 - 50	26	225.9 - 44.9	135.3	7.1	36.2	27
13. Sod-podsolic loamy soils						

Continued

Table 21.—Continued

Soil type and depth (cm)	Number of samples	Range	Carbon density	Error of mean	σ	Percent variance
		---------- *t/ha*	----------	----------	----------	*Percent*
Litter	32	47.6 - 1.5	16.3	1.6	9.2	56
0 - 20	47	75.2 - 6.5	75.4	2.0	13.7	18
0 - 50	47	165.4 - 15.4	140.6	4.4	30.0	21
14. Sod forest soils						
Litter	10	116.4 - 1.4	19.9	7.3	23.0	115
0 - 20	27	131.1 - 10.0	91.7	4.6	24.2	27
0 - 50	27	265.6 - 56.0	152.4	8.1	41.9	27
15. Rendzinas						
Litter	11	23.6 - 1.5	8.1	2.7	5.5	68
0 - 20	17	136.1 - 59.2	65.1	3.7	15.4	24
0 - 50	17	321.3 - 90.0	125.7	11.2	46.3	37
16. Brown forest soils						
Litter	53	95.0 - 1.6	20.3	2.8	18.7	92
0 - 20	63	230.7 - 13.1	60.9	5.5	43.5	71
0 - 50	63	340.2 - 32.2	139.5	7.8	61.6	44
17. Alfehumic soils						
Litter	10	27.6 - 2.4	23.1	2.0	6.3	27
0 - 20	10	105.0 - 1.1	53.5	12.9	25.9	68
0 - 50	10	310.0 - 1.4	155.9	29.0	91.7	52
18. Light-grey forest soils						
Litter	5	4.0 - 1.6	12.8	0.3	0.6	47
0 - 20	5	84.0 - 35.0	61.5	10.9	24.5	39
0 - 50	5	179.4 - 94.7	125.5	21.1	42.3	34
19. Grey forest soils						
Litter	15	18.7 - 3.2	7.0	1.1	3.9	55
0 - 20	15	158.1 - 65.4	96.6	6.4	23.2	24
0 - 50	15	246.9 -110.0	169.2	9.5	34.2	20
20. Dark-grey forest soils						
Litter	15	43.8 - 2.0	15.0	2.7	10.4	70
0 - 20	15	171.1 - 43.3	93.7	8.1	31.3	33
0 - 50	15	414.7 -113.5	192.2	19.4	75.3	39
21. Forest volcanic soils						
Litter + Ap	13	92.7 - 7.2	67.8	9.4	34.2	50
0 - 20	13	77.7 - 7.1	34.2	4.9	17.6	51
0 - 50	13	141.4 - 23.8	60.6	8.2	29.4	48
22. Meadow-chernozemic soils						
Litter	5	20.3 - 12.2	16.2	9.1	2.0	12
0 - 20	34	172.2 - 76.3	131.9	4.1	23.9	17
0 - 50	34	396.9 -138.6	263.5	2.2	12.9	49

Glossary

Administrative territory. The Russian Federation (Russia) consists of administrative units or territories (republics, krays, and oblasts) that are "Subjects of the Russian Federation" with more or less equal rights. The statistical collection "Forest Fund of the U.S.S.R." (Goskomles 1990, 1991) includes information about 71 Subjects of Russian Federation (49 Oblasts, 6 Krays, and 16 Republics).

Age-class group. There are five age groups defined for forest stands in stocked areas: young, middle-aged, maturing, mature, and overmature. Young stands include tree communities of two age classes: early regeneration and advanced regeneration. The age class of trees in young stands is dependent on tree species: deciduous softwoods is 10 years; deciduous hardwoods and conifers is 20 years (except Siberian pine is 40 years). Middle-aged stands can include stands of several age classes defined for the Russian inventory depending primarily on the climate conditions of the administrative territory. Maturing stands have only one age class. The mature and the overmature groups can include several age classes depending on the developmental stability and total age of tree species. For example, *Abies sibirica* lives for 100 to 240 years while *Pinus sibirica* lives for about 500 years.

Asian Russia. The part of Russia located east of the Ural mountains. The Asian part of Russia includes several geographic regions: Western Siberia, Middle Siberia, East Siberia and Yakutia, and the Far East.

Basic timber density. Ratio of absolutely dry mass of wood to volume of the same wood in living (fresh, green) condition.

Collective farm ("kolkhos"). One of two types of organization for agricultural production in the former Soviet Union. Although declared as collective property, kolkhoses were under government observation.

European Russia. The part of Russia that includes the Ural Mountains and all territory to the West.

Forest district. Territorial subdivision of a forest farm.

Forest farm ("leskhoz"). A local governmental organization for forest protection and monitoring of the allowable annual cut on the territory of the Forest Fund.

Forest Fund. A designation for all lands included in the government register as forest resources. The Forest Fund includes both forest and nonforest lands.

Forest land. Forest land includes areas stocked with trees (forested areas) and temporarily unstocked areas (woodlands, burnt areas, cutover areas, glades and wastelands).

Growing stock. Volume of all tree stems (including bark) in tree stands.

Kray. An administrative unit and a subject of the Russian Federation.

Lower layers of forest. Bushes, dwarf-shrubs, grasses, mosses, and lichens growing beneath an overstory of trees.

Mortmass. Litter and coarse woody debris.

Nonforest lands. Include peatlands, water, roads, cropland, and other areas that are not suitable for forest or are used for other purposes.

Oblast. The primary administrative unit and subject of the Russian Federation.

Republic. An administrative unit of Russia and a subject of the Russian Federation with significant composition of people with specific nationality.

Site quality class. Stocked land is placed into site-quality classes ranging from I (high productivity) to V (low productivity). There are three gradations within class I: Ia, Ib, and Ic (best quality); and two gradations within class V: Va and Vb (poorest quality).

Species groups. Tree species are aggregated into three groups: coniferous (*Abies* spp., *Picea* spp., *Pinus* spp., *Juniperus* spp.), decidious hardwood (*Quercus* spp., *Fagus* spp., *Betula ermanii*, etc.), and decidious softwood (*Betula* spp., *Populus* spp., *Alnus* spp.).

State farm ("sovkhos"). One of two types of organization for agricultural production in the former Soviet Union. Sovkhoses are under government management.

Stocked area. A category of the Forest Fund that represents "forested area"; includes lands with tree stands with a total basal area more than 0.2 of the standard density. The standard density varies according to site quality class.

Type of forest. According to Russian regulations, type of forest is determined by dominant tree species and dominant species of the lower vegetation layer (bushes, dwarf-shrubs, grasses, mosses, lichens).

Understory. Includes all forest vegetation under the canopy of a tree stand: seedlings, bushes, dwarf-shrubs, grasses, mosses, and lichens (see lower layers of forest).

Unstocked areas. Lands that temporarily are not covered by forests; includes woodlands, burned and cutover areas, glades, and waste grounds.

Woodlands. Unstocked lands with tree groups or individual trees with a total basal area of 0.2 or less of the standard density.

Alexeyev, V.A.; Birdsey, R.A., eds. 1998. **Carbon storage in forests and peatlands of Russia.** Gen. Tech. Rep. NE-244. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 137 p.

Contains information about carbon storage in the vegetation, soils, and peatlands of Russia. Estimates of carbon storage in forests are derived from statistical data from the 1988 national forest inventory of Russia and from other sources. Methods are presented for converting data on timber stock into phytomass of tree stands, and for estimating carbon storage in forest soils and peatlands in Russia's administrative territories and natural ecoregions. Also included is information on the timber stock of Russia's primary tree species and phytomass of forest vegetation, mortmass, and peat.

Keywords: carbon storage, forests, peatlands, forest inventory, Russia, phytomass, ecoregions

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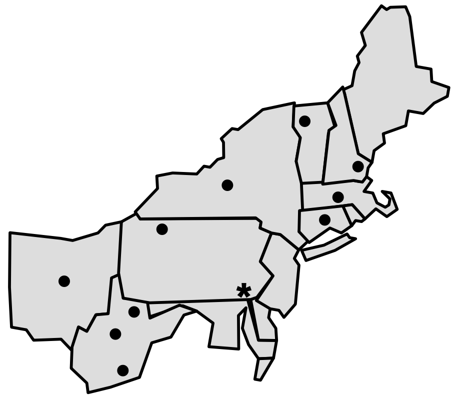

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