Atlas
of Russia's Intact Forest Landscapes

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Front cover inset photos (from the top): forest bog in Karelia by *Alexey Morozov*; Sangpa River valley, Republic of Altay by *P. Kartveli*; mountain forest landscape in the Northern Ural Mountains, Sverdlovsk Oblast by *Alexey Pazhenkov*.
Back cover photo: larch tree in the Sayany Mountains, Republic of Tuva by *Andrey Purekhovskiy*.

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How to use the Atlas

The Atlas has two map sections
The *Main Section* shows the location of Russia's intact forest landscapes. The *Thematic Section* shows their tree species composition in two different ways. A *legend* is placed at the beginning of each set of maps.

If you are looking for an area near a town or village
Go to the *Index* of settlement names on page 152. The Cyrillic name is also given along with the map page number and coordinates (latitude and longitude) where it can be found. Capitals of regions and districts (*raiony*) are listed along with many other settlements, but only if located in the vicinity of intact forest landscapes. The reader should not expect to see a city like Moscow listed. Villages that are insufficiently known or very small are not listed and appear on the map only as nameless dots.

If you are looking for an administrative region
Go to the *Index* of administrative regions on page 183. The numbers refer to the map on the inside back cover. Having found the region on this map, the reader will know which index map to use to search further.

If you are looking for the big picture
Go to the *overview map* on page 35. This map shows all of Russia's Intact Forest Landscapes, along with the borders and Roman numerals of the five *index maps*.

If you are looking for a certain part of Russia
Find the appropriate *index map*. These show the borders of the detailed maps for different parts of the country.

Page I ..... *European Russia* – westwards of the Ural Mountains
Page II ..... *Western Siberia* – eastwards of the Ural Mountains up to the Enisey River
Page III ..... *Eastern Siberia* – eastwards of the Enisey River up to the Lake Baikal, including all regions surrounding the lake
Page IV ..... The Russian *Far East* – the Pacific coast of Russia and westwards up to the vicinity of the Lake Baikal
Page V ..... The Kamchatka Peninsula and the Kuril Islands

Each detailed map has an *ID number* that consists of two letters (e.g., "ES" for the Eastern Siberia index map) and a page number within that index map – Arabic numerals for the finer scale maps (1:1.5 million) and letters for other maps (1:3 million). The ID numbers of neighboring maps are given on each detailed map.

If you are interested in the tree species composition of the remaining Intact Forest Landscapes
The *Thematic Map Section* has two series of maps, each with its own legend. The first one (page 139) shows the tree species composition of the intact forest landscapes according to the *Forests of the USSR* map of 1990. This classification derives from a map of the Russian Forest Service, and is not an original work of Global Forest Watch. The second one (page 147) shows an attempt by Global Forest Watch to classify the composition of apparent areas of closed forest within the intact forest landscapes of Siberia and the Russian Far East.

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NGO Tranparent World (www.transparentworld.ru) has kindly agreed to archive and make widely available, on behalf of Global Forest Watch Russia, satellite images that can be freely copied.

The Atlas in Brief

Results

The romantic notion of the Russian forest as an unbroken band of boundless wilderness is a myth. In reality, the taiga consists of fragments of wilderness, separated by areas affected – either directly or indirectly – by modern land use.

Industrial forest harvesting and the fires that follow logging, agricultural use and road construction are the main causes of fragmentation and transformation in European Russia and the southern parts of Siberia and the Russian Far East. In Western Siberia and the northern parts of Eastern Siberia and the Far East the extraction of mineral resources (including prospecting and construction of transportation infrastructure) and the massive human-induced fires that accompany these activities have also caused fragmentation.

Approximately 289 million hectares (26 percent of the forest zone) remain as large, intact forest landscapes in Russia. Approximately 5 percent of the intact forest landscapes are in areas with special protection at the federal level.

Eastern Siberia is the part of Russia that is least affected by modern land use, with 39 percent of the forest zone still intact, followed by the Russian Far East (31 percent intact) and Western Siberia (25 percent intact). European Russia is the most affected (9 percent intact).

Almost half of all intact forest landscapes are found located in five administrative regions in Siberia: the Republic of Sakha (Yakutiya), the Evenk Autonomous District, Krasnoyarsk Kray, the Khanty-Mansi Autonomous District, and Irkutsk Oblast. Seven regions have more than 50 percent of their area in intact forest landscapes: Nenets Autonomous District (100 percent), Koryak Autonomous District (88 percent), (Kamchatka Oblast (85 percent), the Republic of Altay (63 percent), Yamalo-Nenets Autonomous District (62 percent), Evenk Autonomous District (61 percent), and the Republic of Tuva (57 percent). 98 percent of the total area of intact forest landscapes is in the 29 regions that have at least 10 percent of the area in that category. Intact forest landscapes are completely missing from 49 of 89 administrative regions.

The forest zone of Russia is made up of 6 ecoregions according to the global classification by WWF (Olsson et al, 2001). In half of these, more than 90 percent of the area is affected by modern land use, while only one (montane grasslands) has retained more than half of the area in intact condition. Most of the intact forest landscapes areas are in sparsely wooded and mountainous parts of Russia. More than 80 percent of the intact forest landscapes fall in one ecoregion: boreal forests/taigas.

Most administrative and ecological regions of Russia lack a representative or sufficiently large system of protected areas within the remaining intact forest landscapes. Approximately 5 percent of the intact forest landscapes (14.4 million hectares) have special protection in various forms: *zapovedniks* (strict scientific nature reserves), national parks, federal *zakazniks* (sanctuaries and wildlife refugees), and federal nature monuments. More than half of protected areas (3.6 percent) are in zapovedniks.

Conclusions

Intact forest landscapes are becoming a rarity in many parts of Russia, or have disappeared completely. Such is the case in most parts of European Russia and Western Siberia, and in the southern parts of Eastern Siberia as well as the Russian Far East. Remaining intact forest is broken into fragments, too small to sustain the full array of components and functions characteristic of a natural forest landscape. Important conservation values remain but were outside the scope of this study.

Without decisive action within the next few years, intact forest landscapes may disappear within whole ecological regions and even vegetation zones. The situation is most serious concerning temperate broad-leaf and mixed conifer-broad-leaf forests. Such forests are practically extinct in European Russia. The same fate may befall the forests in the area surrounding the mountain range of Sikhote-Alin, which are Russia's richest in terms of biodiversity.

Decisions about the conservation and use of the remaining intact forest landscapes must reflect a complex range of ecological, social, and economical factors. The forest industry in these areas should observe precautionary measures and make it a priority to preserve large and representative areas of wild nature. This is especially important and urgent in European Russia and the Southern parts of Siberia and the Russian Far East. A reasonable strategy for these areas would be to set aside remaining intact forest landscapes for a limited time period, to allow optimal decision-making for future conservation and land-use.

Next steps

The work needs to be refined in some areas, based on more precise criteria and information. The fire regime classification should be improved and high resolution satellite images (such as Landsat ETM+) used for the entire territory, supported by adequate ground verification. Conservation values within intact forest landscapes should be mapped and described illustrated so that well-informed and balanced decisions can be made without delay about conservation and use. Conservation values must also be mapped outside of the intact forest landscapes, i.e. in the production landscape. Mapping must become more detailed and incorporate the *kvartal* grid of Russian forestry. A retrospective study would add knowledge on the global carbon cycle and form a reference for monitoring future changes. Areas considered as immediate priority for refined mapping of conservation values include the Ural Mountains and Southern taiga belt in European Russia (the Leningrad, Vologda, Kostroma, Kirov and Perm Oblasts), the Altay-Sayan area in Western Siberia, the Angara-Enisey and Baikal Lake areas in Eastern Siberia, and the Sikhote-Alin Range in the Russian Far East.

Purpose

This atlas presents an inventory of intact forest landscapes (i.e. the remaining large, unbroken areas of pristine nature within the forest zone of Russia). This endeavor was carried out by a group of Russian non-governmental conservation and scientific organizations between 1999 and 2002 as part of the Global Forest Watch initiative.

The purpose of the atlas is to provide an accurate picture of remaining intact forest landscapes in Russia, and the boundaries of federally protected areas, to allow decisions about these landscapes to become better informed and more balanced.

In particular, the results are crucial to implementation of Article 4 of the Law of the Russian Federation On Environment Protection, which states that "priority objects for conservation are natural ecosystems, natural landscapes and natural associations, unaffected by anthropogenic influences" (unofficial translation). The atlas will also support the forest industry's effort to exercise precaution in sourcing wood from specific, ecologically sensitive areas.

Definitions and criteria

An intact forest landscape is a landscape in the forest zone that is whole and natural, undivided by infrastructure and almost entirely unaffected by human activities. It is large enough to support viable populations of large predatory vertebrates and keep most of the territory free of edge effects (minimum 50 thousand hectares). It may, and typically does, contain a mosaic of ecosystems (i.e. it is more than a forest). It has a natural fire regime.

Method

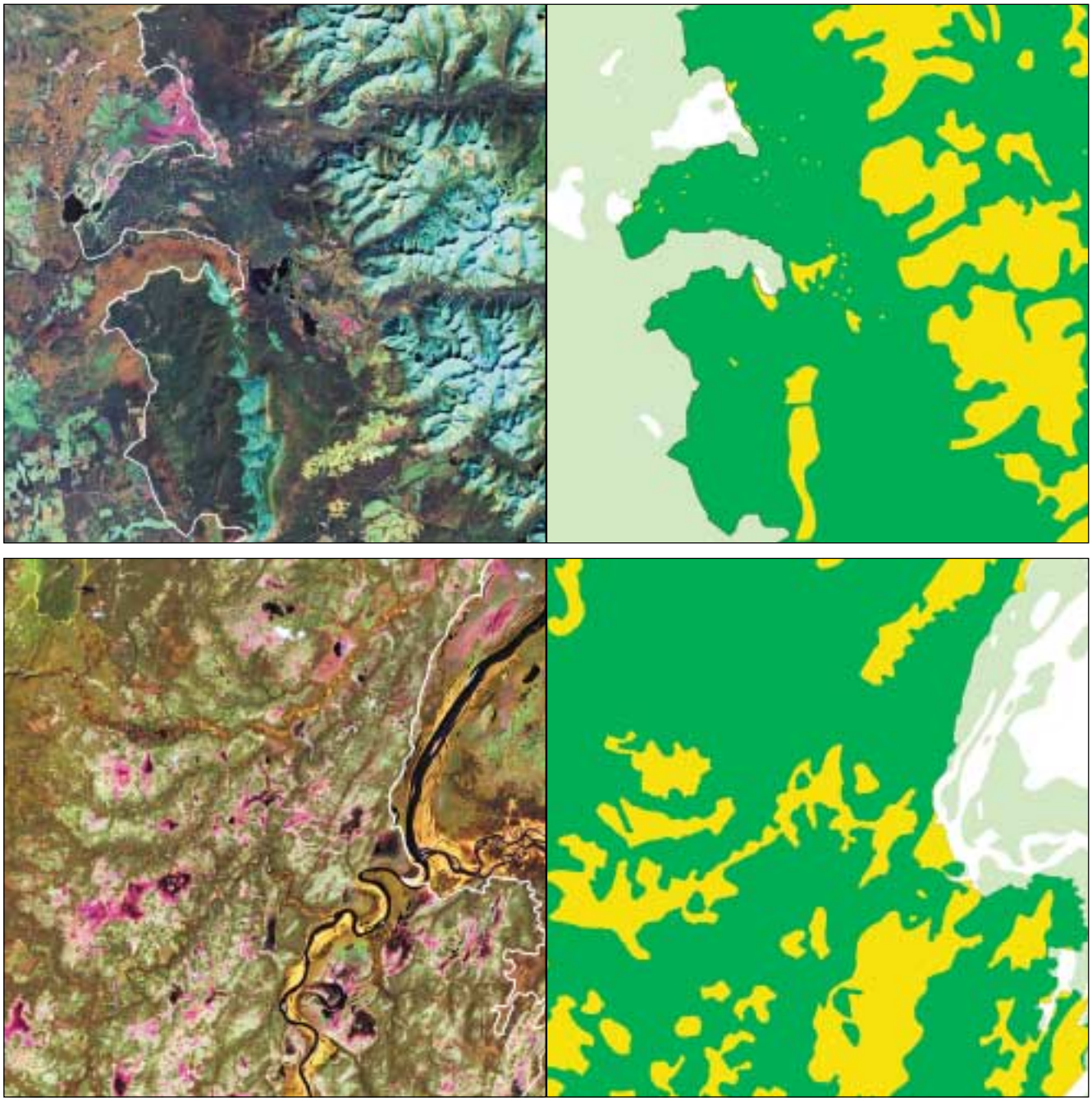
A three-step procedure was used to exclude non-intact areas and delineate remaining intact landscapes:

Areas around human settlements and infrastructure were excluded along with residual fragments smaller than 50,000 ha, based on a 1:500,000 scale topographic map of Russia.

Further exclusion of non-intact areas and residual fragments smaller than 50,000 ha, based on medium resolution satellite images (a country-wide mosaic of Resurs-O1 MSU-SK with 150 m resolution from the summer and winter seasons, and Landsat ETM+ Quicklooks with 300 m resolution). Most agricultural areas and clearcuts of various ages were excluded at this stage.

Further exclusion of non-intact areas and residual fragments smaller than 50,000 ha, followed by fine tuning of boundaries, based on high-resolution satellite images (Landsat-7 ETM+ with a resolution of 30 meters, ASTER with a resolution of 15 meters, and Resurs-O1 MSU-E with a resolution of 35 meters.

Satellite images from 1999 to 2001 were used and reflect the status of the landscape at the middle of year 2000. All satellite images were geo-referenced onto the 1:500,000 or finer scale topographical map. Forest inventory maps at various scales at the level of *leskhoz* (local office of the state forest management agency), other thematic maps and field data on the degree of disturbance were used at all stages of the analysis. In total, approximately 8900 Landsat-7 ETM+ Quicklooks, 1470 TERRA ASTER, 516 Resurs-O1 MSU-E, 771 Resurs-O1 MSU-SK and 262 Landsat-7 ETM+ scenes were used.



Picture 1. An *Intact Forest Landscape*, as the concept is used in this Atlas, is a large natural mosaic of untouched ecosystems located in the forest zone of Russia. The picture shows two different cases – one with mountains (top) and one with bogs (bottom) – of how the landscape is analyzed in a satellite image and represented on the map.

Inside an intact forest landscape the maps use dark colors to show land cover:

Forest areas.

Non-forest areas including bogs and tree-less mountains.

Outside an intact forest area the maps use light colors:

Forest.

Non-forest.

Accuracy

The maps of northern European Russia are most accurate (high resolution images and extensive ground verification - 173 sites). There is an intermediate level of accuracy in the Caucasus, central European Russia, and southern parts of the Ural area, Siberia and the Russian Far East (high-resolution images but insufficient ground verification or medium resolution images with reliable data from previous studies). The least amount of accuracy is in the northern parts of Siberia and the Russian Far East, some areas in the east of European Russia and in the south of Siberia (medium and partly high-resolution images, rare ground verification - 235 sites total for two last categories). The intact area is likely to have been overestimated where only medium-resolution images were used or ground data were insufficient.

Review

The draft atlas was presented in 2002 at review meetings in Krasnoyarsk (at the Sukachev Forest Research Institute), in Khabarovsk (at the Far Eastern Forest Research Institute), and in Moscow (at the International Forest Institute). Russian and international scientists and Russian government agencies were invited to submit written review statements.

Global Forest Watch

Global Forest Watch (GFW) is an international network, consisting of environmental and research organizations in more than 10 countries. The goal of GFW is to improve the conservation and use of the world's forests by providing high-quality information - accurate, timely, relevant and balanced - to decisionmakers in industry and government, and to the general public. No advocacy work is allowed under the GFW name, and all reports must undergo rigorous scientific review. GFW was formally launched in 2000 at the initiative of the World Resources Institute.

Global Forest Watch Russia

Global Forest Watch Russia is an informal, country-wide network of civil society and research organizations from all corners of Russia. The goal of GFW Russia is to provide decisionmakers and the general public with accurate, accessible and practically useful information in the interest of improving the conservation and use of Russia's forest landscapes. GFW Russia was founded in 1999 in Krasnoyarsk. The first report, *called The Intact Forest Landscapes of Northern European Russia*, was published in 2001. The *Atlas of Russia's Forest Landscapes* is the second report of GFW Russia. Both are available in Russian and English editions. Future activities of GFW Russia will include continued mapping of the conservation values of Russian taiga, both within and outside of the remaining intact forest landscapes.

Preface

Intactness, i.e. the absence of human disturbance, is a quality of a natural landscape that cannot be artificially restored. Large intact forest landscapes (also called frontier forests) are quickly becoming a rarity in most parts of the world (Bryant, Nielsen, and Tangley, 1997). Perhaps surprisingly, the extent and boundaries of these areas are poorly known. Myths still abound, such as the widespread romantic notion of the northern taiga forest and the tropical rainforest as virtually endless wilderness areas, intact, unbroken, unpopulated.

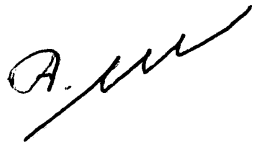
Identifying and describing remaining intact forest landscapes is a difficult but urgent task. It is urgent, because industrial land use is expanding rapidly. It is difficult, because these landscapes are large, inaccessible and poorly known. The work must be sufficiently rapid, accurate, and detailed to allow timely and well-informed decisions about their protection and use.

This atlas is the world's first rigorous attempt at mapping intact forest landscapes to affect decision making. Produced in Russia as part of the Global Forest Watch initiative, it is a pioneer work in many ways. And, as with all pioneer efforts, it has had many problems to overcome. A suitable method had to be designed. People had to be trained to carry out analysis and field work. Satellite images and ancillary information had to be acquired, analyzed, and eventually archived in a broadly accessible way. Finally, the result had to be presented in an informative and user friendly way. Deficiencies no doubt remain. The atlas should not be seen as the last word on this topic, but as the first. It is our hope that the forestry and conservation communities will contribute the necessary resources to refine this work and expand it to mapping of other values that warrant special precaution in forest management.

The emergence of an atlas of this kind in Russia should not come as a surprise. Russia has an older tradition than most countries in forest science, mapping, and remote sensing. Russia has also retained the largest amount of intact forest landscapes in the world. What might be surprising is that the atlas is the result of a country-wide non-governmental initiative. In that sense, too, it is a pioneer work.

We are convinced that this atlas will address several at least two important needs: the need of the public to know the ecological condition of Russia's forest lands, and the need of the decision maker to have accurate, relevant and accessible information at hand.

It is with great pleasure that we recommend this atlas to the reader.



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Introduction

Russia, it is often said, is a country dominated by wild forest, virtually limitless, largely unpopulated, and still unaffected by human development. Even nature conservation experts often espouse this opinion, assessing the extent of "absolutely wild" areas at 2/3 of the forest zone of Russia. Some regions in Siberia and the Russian Far East are even said to be 90 percent wild, or more.

No systematic study that assesses the degree to which the forest zone (or any other zone) of Russia is still intact in a natural state has ever been completed. All verdicts on the remaining amount of "wild nature" in Russia are based solely on purported expert opinion.

Moreover, the areas of intact wilderness that still remain (including forest wilderness) tend to be regarded as a virtually unlimited reserve of exploitable resources.

This work is the first attempt at mapping the large, unbroken wilderness areas that still exist in the forest zone of Russia. The term intact forest landscapes refers to large mosaics of ecosystems in the forest zone, still in their natural state, minimally affected by human activity, and unbroken by infrastructure.

Purpose

The purpose of the atlas is to give an accurate picture of the current status of remaining intact forest landscapes in Russia, and of the boundaries of federally protected areas, using a mapping scale that is relevant to practical land management (approximately 1:1 million). Such information is relevant for at least two reasons:

- To eliminate the uncertainty and myths about the extent to which the forest has been affected by human influence and to record the location of remaining large intact areas.
- To improve decisions about the conservation and sustainable use of the forest landscape. Classical forest inventory information does not, by itself, provide a sufficiently multi-faceted decision base. Complementary information regarding conservation values is therefore needed.

In particular, the results are crucial to implementation of Article 4 of the Law of the Russian Federation *On Environment Protection*, which states, "priority objects for conservation are natural ecosystems, natural landscapes and natural associations, unaffected by anthropogenic influences (unofficial translation)."

The atlas will support the forest industry's effort to exercise precaution in sourcing of wood from specific, ecologically sensitive areas.

Definitions and Criteria

For the purposes of this atlas, an intact forest landscape is an area with the following characteristics: (i) It is situated within the forest zone; (ii) It is large enough (see below); (iii) It contains a contiguous mosaic of natural ecosystems which may or may not be of different types; (iv) It is not broken or fragmented by infrastructure; (v) It does not display signs of significant transformation caused by human activity; and (vi) it has a natural fire regime.

The following set of criteria was used to identify and delineate intact forest landscapes.

1. Smallest viable area of an intact forest landscape

The size of an intact forest landscape is considerably important for its viability and quality. If fragments are too small, they do not allow all essential components of the intact landscape to be conserved in their pure, natural state. For vital populations of large predatory vertebrates to coexist with the full range of natural ecological functions in a boreal landscape (including fires), for example, considerable space is required – upwards of tens of thousands of hectares, sometimes as much as hundreds of thousands of hectares. Nor do small fragments provide sufficient protection against edge effects, i.e. the influence from transformed areas outside the boundary of the intact forest landscape.

The following size criteria were used in this study:

- Smallest area: 50,000 hectares (123,500 acres)
- Smallest width: 10 kilometers (6.2 miles) (i.e. the diameter of the largest circle that can be fit inside the contours of an area)

These minimum dimensions are sufficient to sustain vital populations of most large and medium-size predator species (Sokolov, et al., 1997). They coincide with the recommendations from a number of Russian environmental organizations specified in the document *Principles for Ecologically Responsible Trade with Russian Wood* (Biodiversity Conservation Center, *et al.*, February 14, 2002).

2. Significant kinds of disturbance

There is a notion that the world still contains areas that have never been exposed to human influence. In reality this is not true. Each and every place on Earth has at some time in history been exposed to human influence, either directly or indirectly. Any meaningful definition of intactness must reflect this fact. Intact forest landscapes are not wild in a strict, absolute sense – they are only the most well preserved specimens of wild nature that remain in the forest zone. Delineation of these landscapes involves drawing a line between more or less disturbed areas – between areas having been subject to "significant," as opposed to "non-significant" or "background," human influence. The latter should show no signs of significant transformation by human activity nor should it have been subject to industrial land use for the last six decades. In this study, all ancient types of human activity were considered as background influence and were treated as a factor in the evolution of today's forest landscapes. The following more recent analogous activities were also classified as background influence:

- Shifting cultivation, hunting, fishing, picking of mushrooms and berries, and fires caused by humans engaged in these activities;
- Grazing of domestic and semi-domestic animals (wild reindeer, sheep, cattle, horses, and yaks);
- Harvest of hayfields and floodplains of small rivers, haymaking;
- Selective logging of trees for local, non-industrial needs, and industrial high grading for stone pine (*Pinus sibirica and P. koraiensis*) and other species in mixed stands;
- Activities occurring such a long time ago that their influence is more akin to an evolutionary force than a disturbance (see next section).

The effects of air pollution and climate change could not be properly assessed at this time. They were therefore also treated as background influences.

3. Minimum time since disturbance

Human activity has shaped the forests for millennia. People have been one of the predominant causes of forest fires since the very beginning of colonization. In some cases it is impossible to tell to what extent a structural feature in the forest landscape is the result of natural processes and to what extent it is the result of human influence, such as reindeer grazing or human-set fires. It is therefore reasonable to consider only recent human activities as disturbances along with any activities of ancient times that have radically shifted the balance between natural and anthropogenic influences on the forest.

The beginning of the 1930s marked the beginning of significant disturbances. Earlier human disturbance has not been considered significant with regard to the natural dynamics of the forest landscape. This time was chosen due to some radical changes in the 1930s that had very significant consequences for the forest landscape:

- The GULAG system was established, and an effort was initiated to colonize remote areas in the North and Far East, on the brink of the tundra;
- There was a rapid increase in the export of forest products;
- A large number of pulp mills and other consumers of low-quality wood (railway sleepers, mining timber) were established or reconstructed. This led to rapid growth in the demand for small dimension and low quality wood, and a shift in logging practices towards clear cutting;
- Slash and burn agriculture was abolished, agriculture was collectivized; the area of agricultural lands was initially expanded but later followed by a process of abandoning small and remote villages;
- There was a sharp increase in the intensity of mineral surveying and extraction that extended to remote areas.

In this study all disturbances that were concluded prior to 1930 and whose impact is not evident were considered of no consequence for the identification of intact forest landscapes.

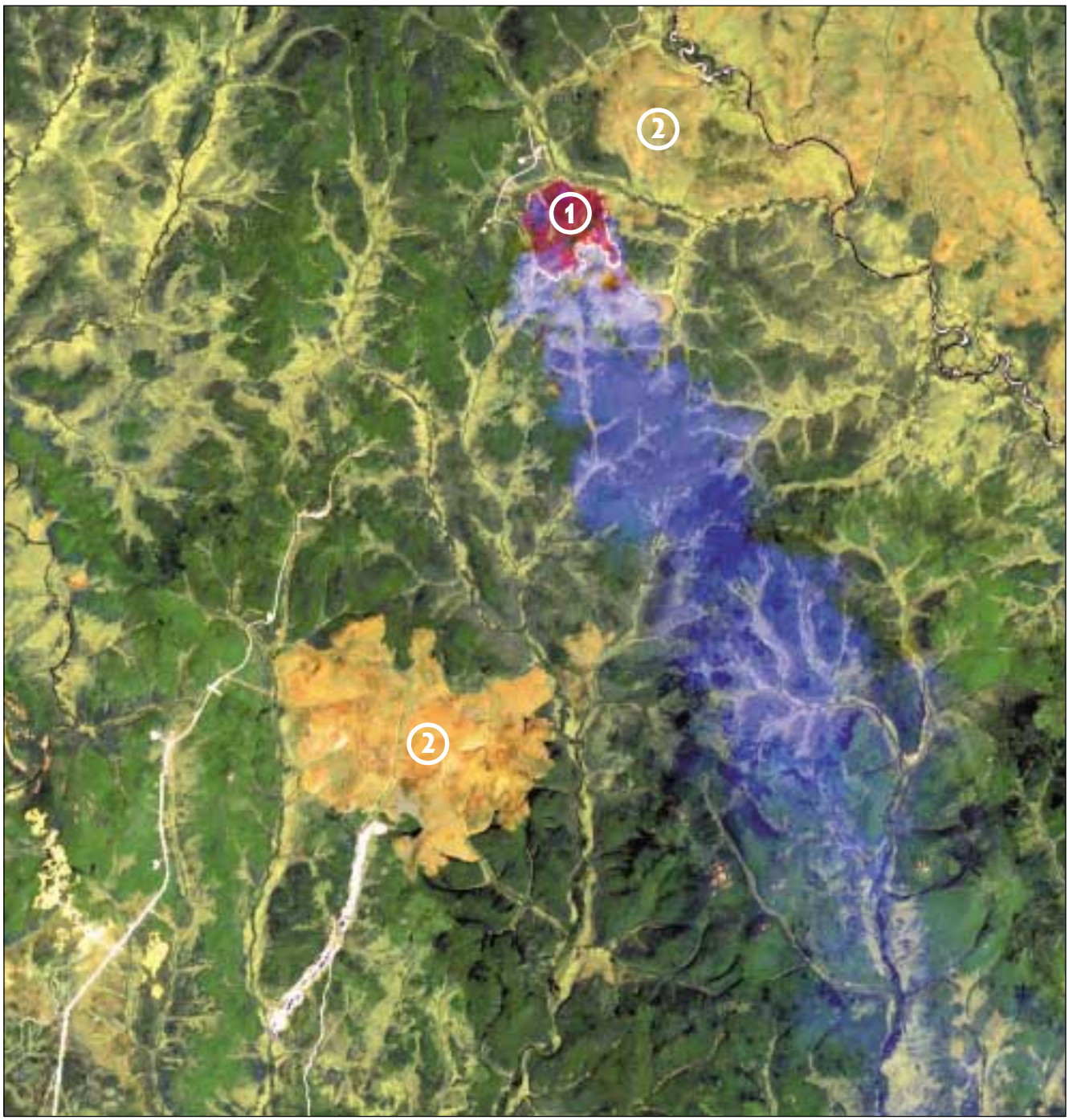
4. Forest fires

Forest fires, if ignited by lightning, are a natural part of the dynamics of boreal forest landscapes. Evidence of naturally occurring fires is available for practically all parts of Russia. Nevertheless, humans are the cause of most forest fires in Russia. The exact proportion of anthropogenic fires is not known. The official statistics contain a "fires of undetermined cause" category. Moreover, the classification of fires as "caused by lightning" is often rather dubious. V.A. Ivanov (1985) writes in his review of forest fires that "as a rule, the analysis of the link between lightning and forest fire is based on visual inspection. Within the next few days after a thunderstorm all fires are classified as caused by lighting, without consideration of possible anthropo-

genic causes. It is likely that the portion of fires caused by lightning is overestimated. As shown by Ivanov, the currently used method does not produce consistently correct information on the cause of fires.

Even though the amount of spontaneous fires is likely to be exaggerated, most authors point to the overwhelming dominance of anthropogenic fires (Zakharov, 1977; Noga, Tikhonov, 1979; Sofronov, Vakurov, 1981; Odintsov, 1995; Furyaev, 1996; Sergienko, 1996, 1999, etc.). The average proportion of anthropogenic fires is estimated to be 80-90 percent for Russia as a whole. The proportion of spontaneous fires is higher only in areas with a pronounced continental climate, such as the area around the Irtysh River and in Evenkia and Yakutia in northern Siberia, where it has been estimated that 33-67 percent of fires are spontaneous, depending on the time period (Noga, Tikhonov, 1979; Ivanov, 1985). However, the occurrence of fires is connected with population density and land use even in these areas (Valendik, Ivanova, 1996).

The published statistical evidence shows that spontaneous fires may dominate in number only in unusual years and in remote regions. Land use is one of the main causes of forest fires. A considerable amount of fires were probably caused by people even in the distant past. Causes range from slash and burn agricul-



Picture 2. Proximity to infrastructure affects the fire regime. The Landsat-7 satellite image shows a ground fire burning in an old fire scar, which is adjacent to infrastructure (1). Similar old fire scars are visible nearby (2).

ture, hunting, reindeer herding, and later logging, mining, charcoal production, and transportation (Ponomarenko, *et al*, 1996).

The influence of a fire on a forest ecosystem does not depend on its origin, everything else being equal. It is not possible to deem by the characteristics of the fire scar if the fire was anthropogenic or natural. An individual fire caused by a tossed burning match or a hunter's fire is fully analogous with a fire caused by a lightning strike at the same spot. Single fires, regardless of their origin, that are not associated with the modern intensification in land use, can therefore reasonably be treated as a component in the natural dynamics of the forest landscape and a factor in its historical formation.

The situation is different, however, for an entire forest landscape. Here it is the fire regime that is important, especially the frequency and typical site location of individual fires. These factors are associated with characteristics of the fire regime, such as fire intensity, pattern of distribution, and type (ground or crown fire).

A fire regime at equilibrium (more or less) over a long period of time will produce a pronounced structure in the boreal landscape. There will be areas shaped by frequent fires, but also fire refuges – spots, which for various reasons escape fires for long periods (such as wet sites along rivers and creeks). Together, such areas form a mosaic that influences the biological diversity and the sustainability of the landscape as a whole.

The increase in fire frequency caused by modern land use affect the fire mosaic of the landscape. The area of forest in an early succession stage will increase, fire refuges will decrease in numbers and may even disappear, the water balance will change along with the soil permafrost horizon, and the intensity of erosion, etc.

Although the effect of individual fires does not depend on their origin, the combined effect on the landscape of all anthropogenic and natural fires is very different from that of a natural fire regime. The increase in fire frequency (or frequency of ignitions) caused by modern, intensive land use has caused abrupt changes in the affected landscapes. These changes are the result of significant human disturbance.

A typical case is the abundance of fire in areas where oil, gas or gold is extracted, where geological surveying is conducted, and along transportation corridors. Intensified land use and expansion of infrastructure increase the fire activity in a landscape. The post-fire succession of burned areas may also be affected. If a fire scar, whether from a natural or anthropogenic fire, reaches a road or other piece of infrastructure, the regeneration on this site is likely to develop differently than it would without that influence. The probability of non-natural disturbance is greater, such as another fire, the introduction of non-indigenous (to the site) species, etc.

Picture 3. Forest fire. Primorskiy Kray. Photo by Vadim Kantor.

In this study, fire scars were identified directly in the satellite images. The cause of a fire scar could not be determined, however. A decision rule therefore had to be constructed, so that the fire regime associated with each fire scar could be classified in a consistent way as either "natural" or "anthropogenic" (the latter were considered disturbed landscape). The following rule was created:

All areas in which fire scars or fire mosaics (including areas with young forest vegetation) occur directly adjacent to a source of disturbance such as infrastructure or some other conduit of human activity were assumed to have an "anthropogenic" fire regime. They were therefore classified as disturbed landscape, even though some of these fires most likely were of natural origin. Such sources of disturbance include settlements, roads, clear cuts, industrial facilities, and rivers wider than 60 meters.

Areas of otherwise intact forest landscapes, in which fire scars or fire mosaics do not reach any of the sources of disturbance mentioned above, were considered as having a "natural" fire regime. They were therefore classified as intact (even though many of these fires probably were caused by careless hunters, tourists, etc.).

The authors are aware of the artificial nature of this classification of fire regimes. A consistent rule was needed, however, and this necessitated a pragmatic approach. All radical options were less attractive. Excluding all fire scars from intact forest landscapes was problematic. Fires are a natural element in the dynamics of a boreal forest landscape, and many typical forest landscapes owe their appearance to past fires. On the other hand, it would also be a mistake to include all fires in intact forest landscapes. There are gigantic areas of fire-affected landscapes around current sites of "development activities" that differ fundamentally from the structure of an intact landscape. A schematic decision rule had to be used because there is no credible method for separating natural and human induced forest fires.

Picture 4. Examples of forest fires classified as intact and non-intact. The yellow line plased over Landsat-7 satellite image indicates the boundary of an intact forest landscape. The fire scars in the upper part of the image (indicated by a box) are classified as human disturbance as they are adjacent to roads and other infrastructure visible in the image.

5. The northern boundary of intact forest landscapes

The northern edge of the forest can be very diffuse in northern Russia. Moving north, the trees get successively smaller and sparser. Thus, a genuine intact forest landscape often changes gradually into an equally intact tundra landscape. Drawing the northern boundary of a forest landscape is a delicate task under such circumstances. The outcome depends totally on the forest definition used and does not reflect any change in the degree of intactness.

The boundary of so-called "high dense" forests given on topographical maps (and also indicated in this Atlas) was deemed not suitable to represent the northern boundary of closed forests (further referred to as the northern forest boundary). An analysis of medium resolution satellite images suggests that the topographical maps for these areas are partly out of date and include significant areas of southern tundra shrubs that are classified as forest.

The northern forest boundary in European Russia and Western Siberia was drawn based on medium resolution winter images, using data from model sites with known characteristics. A tree covered area needed to exceed 20 percent canopy density and be more than 20 kilometers (12.4 miles) wide to qualify. More narrow strips of forest, (e.g., along river valleys) were thus considered part of the treeless tundra zone (and consequently not considered intact forest landscape) along with tree-covered areas of lesser canopy density. Directly adjacent treeless areas of other kinds, such as alpine areas and bogs, were also excluded from the forest zone.

This method allows for the separation of forest tundra from forest in flat watersheds. It is not directly suitable for the rest of the country, however, because the lack of model sites and dramatic variation in illumination and snow depth, caused by the mountainous topography, make it difficult to interpret satellite images.

A landscape approach was therefore used in Eastern Siberia and the Russian Far East. Proposed by Zvorykin and Parmuzin (1956), it takes into account a whole complex of abiotic factors (e.g., occurrence of permafrost) that influence the composition and structure of forest ecosystems. Here, the boundary of the forest zone was drawn along the boundary of closed high forests (i.e., typically consisting of trees with more or less straight, main trunks). Besides satellite images and topographical maps, a number of thematic maps (climatic, hydrological, geological, vegetation, and soil, along with the percent tree-cover map by the University of Maryland (DeFries, *et al.*, 2000)) were used. In some regions, a high degree of transformation by land use has resulted in a significant shift of the forest boundary to the south (e.g., in the vicinity of Salekhard and the Viluy reservoir, and the area between the Lena and Viluy rivers).

The natural fragments of forest that exist north of this line were not assessed for intactness due to insufficient information. These areas' boundaries are shown on the final map as a separate category without any division into classes of intactness, in the same way as they appear on the 1:500,000 topographic map.

6. The southern boundary of intact forest landscapes

In the vast majority of cases, the intact forest landscapes identified in this study have a distinct southern edge of a clearly anthropogenic character. Often it is formed either by infrastructure or by agricultural land. Some areas in southern Siberia and the Caucasus Mountains are an exception to this rule. Here, moving south, the forest gradually changes into forest steppe or treeless steppe, or in some cases into treeless alpine areas, without any noticeable change in intactness. No boundary was drawn in these cases. Instead, all contiguous intact areas were unified into one landscape all the way to the southern boundary of the Russian Federation. The identification of intact landscapes outside the forest zone of Russia is a special task, which requires individual approach and additional research.

7. Intact forest landscapes that go beyond the boundary of the Russian Federation

Some intact forest landscapes continue beyond Russian borders into neighboring countries. Such landscapes were delineated if their total area exceeded 50,000 hectares (123,500 acres), regardless of the political boundary. The part located in Russia may thus be smaller than 50,000 hectares.

Method for delineation of intact forest landscapes

A three-step procedure was used to exclude non-intact areas and delineate remaining intact landscapes:

1. Exclusion of areas around human settlements and infrastructure and residual fragments of landscape smaller than 50,000 ha, based on the 1:500,000 scale topographic map of Russia, and of residual fragments smaller than 50,000 ha. The result was a candidate set of landscape fragments without roads.
2. Further exclusion of non-intact areas and residual fragments of landscape smaller than 50,000 ha, based on medium resolution satellite images (a country-wide mosaic of Resurs-O1 MSU-SK (scenes' size is 600x600 km) with 150 m resolution from the summer and winter seasons, and Landsat-7 ETM+ Quicklooks (183x183 km) with 300 m resolution. Most of the old and recent agricultural areas and clear cuts were excluded at this stage.
3. Further exclusion of non-intact areas and residual fragments of landscape smaller than 50,000 ha followed by fine tuning of boundaries, based on high-resolution satellite images (Landsat-7 ETM+ (45x45 km) with a resolution of 30 meters), TERRA ASTER (60x60 km) with a resolution of 15 meters, and Resurs MSU-E with a resolution of 35 meters).

Satellite images taken between 1999 and 2001 were used, reflecting for the most part the status of the landscape around mid 2000). All satellite images were geo-referenced onto topographical maps of 1:500,000 or finer scale.

Additional information, such as forest inventory maps at the level of *leskhoz* (local office of the state forest management agency) and other thematic maps, were used at all stages of the analysis. Verification was done through a number of field expeditions, mostly in European Russia, and by using high-resolution images for spot checking the interpretation of medium-resolution images.

Picture 5. A step-wise approach was used to eliminate disturbed areas and identify remaining intact forest landscapes.

Area outside the area of investigation (excluded due to insufficient information)

Area eliminated in step 1 of the analysis, using topographical maps to exclude areas influenced by infrastructure and area fragments smaller than 50,000 hectares

Area eliminated in step 2, using medium resolution satellite images to identify agricultural lands, clearcuts, urban areas, and other clearly disturbed

Area eliminated in step 3, using high resolution images to eliminate additional disturbances and draw precise boundaries

The remaining area of intact forest landscapes

This approach was adopted because of information constraints associated with both cost and availability. The step-wise approach made it possible to exclude large areas from further analysis on the basis of readily available and affordable information. This led to significant savings in working time and data cost.

The most important elements of each step of the analysis are described below. A more detailed description is given in the book *The Last Intact Forest Landscapes of Northern European Russia* (Yaroshenko *et al.*, 2001).

Step 1. Reduction of the initial candidate area (the total area of the forest zone) by elimination of areas in the vicinity (i.e. within buffer zones) of infrastructure as well as landscape fragments smaller than 50,000 hectares

The main source of information at this stage was topographical maps at the scale of 1:500,000.

The quality of these maps can be rather low. Therefore, only major elements of infrastructure (i.e. that could, within reason, be assumed to be reliably depicted on a general map) were taken into account. A list of such elements and the width of their maximum zone of disturbance (buffer zone) is provided in Table 1. Occasionally, these maps show elements of infrastructure that do not exist on the ground or which are incorrectly classified. Such errors were corrected at subsequent stages of analysis with the aid of satellite images.

The goal at this first stage was to reduce the initial candidate areas under examination (the forest zone of Russia) by excluding obviously disturbed areas from further analysis. Major elements of infrastructure were excluded at this stage, together with a buffer zone surrounding them. Remaining landscape fragments were also excluded if their size was smaller than the minimum viable size for an intact forest landscape, i.e. 50,000 hectares (123,500 acres).

The first stage of the analysis produced a map of landscapes without roads greater than 50,000 hectares in size (Picture 5). Smaller roads and other linear objects, such as geological survey lines, forest roads, and winter roads, were not taken into account at this stage.

Table 1. Types of infrastructure considered in the analysis of landscape fragments undivided by constantly used roads and settlements, and the width of their assumed area of disturbance on each side of the object

Type of infrastructure:	Width of buffer zone on each side of the object (meters):
Settlements	
Big cities (over 100 thousand inhabitants)	10,000
Cities (50-100 thousand inhabitants)	5,000
Small cities (less than 50 thousand inhabitants) and towns	1,000
Villages	500
Summer houses and gardens settlements	500
Separate houses, buildings and facilities	500
Regular places for temporary cabins	500
Churches, monasteries etc.	500
Industrial and military objects	
Power plants, power stations, service points for power lines and pipelines	1,000
Military bases and objects	1,000
Sea and river ports	1,000
Radio and TV centers, TV-towers	1,000
Railway stations	1,000
Sedimentation pools	1,000
Airports, airfields	1,000
Storages, tanks etc.	500
Meteorological stations	500
Mining and drilling	
Mines	1,000
Mining dumps, mining waste piles, reservoirs with waste water	1,000
Facilities on oil and gas fields	1,000
Wells	1,000
Open mines and quarries	500
Pit mines	500
Open salt mines	500

Pipe lines, power lines	
Oil and gas pipelines	1,000
Power lines higher than 14 meters	500
Automobile roads	
Highways	1,000
Improved hard surface roads	1,000
Hard surface roads	1,000
Improved earth roads	500
Country earth roads	500
Railroads	
Railroads	1,000
Narrow-gauge railroads	500
Local railways	500
Navigable rivers, lakes, canals, reservoirs, seas and oceans	
Canals	1,000
Parts of rivers wider than 300 meters	1,000
Reservoirs	1,000
Lakes larger than 75 square kilometers	1,000
Seas and oceans	1,000

Step 2. Reduction of the remaining candidate area (roadless landscapes greater than 50,000 hectares) by elimination of areas with larger surface disturbances, visible in satellite images with a resolution of 150-300 meters

The main source of information at this stage was satellite images from two different sources: summer and winter images from Resurs-O1 MSU-SK (resolution 150 meters, 771 scenes), and Landsat ETM+ Quicklooks (resolution approximately 300 meters, 8900 scenes).

The goal at this second stage was to further reduce the candidate area (the map of roadless areas produced in step 1 by excluding large areas disturbed by contemporary land-use practices that could be positively identified in images of medium resolution, including typically large agricultural fields, clear cuts, and quarries (see Table 2). Burned areas adjacent to infrastructure were also excluded (see the section on forest fires above).

The individual disturbed areas that were excluded at this stage varied in size between 30-50 hectares (74-124 acres) and 150-200 hectares (370-494 acres), approximately. Smaller disturbed areas and other areas not positively identifiable in these images were not taken into account at this stage (i.e. were retained until the next stage).

The disturbed areas were removed from the roadless landscapes. Remaining landscape fragments were then excluded if their size was less than 50,000 hectares, or their width less than 10 kilometers (6 miles).

High-resolution satellite imagery was not available at this stage for a considerable part of the studied landscape (the northern parts of Siberia and the Russian Far East). The analysis of these areas therefore had to be concluded at this stage (accuracy zone 3).

The result of the second stage of the analysis was a map of candidate intact forest landscapes.

Step 3. Reduction of the remaining area (candidate intact forest landscapes) by elimination of smaller linear and surface disturbances, visible in satellite images of high resolution (15-35 meters)

Satellite images from three different sources were used at this stage of the analysis: Landsat-7 ETM+ (262 scenes), ASTER (1470 scenes), and Resurs-O1 MSU-E (516 scenes). In addition, images from SPOT-HVR (15 scenes) were used for a small part of the Murmansk region. Summer images were mainly used, but in their absence images from the winter, spring and fall seasons were also used.

In the third and final stage of the analysis, the remaining set of candidate intact landscapes was reduced further by elimination of areas with surface disturbances that were either too small or too unclear to have been eliminated at earlier stages (see Table 2). Elongated, less than 2-kilometer wide, parts of intact forest landscapes were eliminated. Areas with smaller linear disturbances were also eliminated, along with remaining landscape fragments, which did not meet the requirements for minimum size or width.

Table 2. Additional types of human disturbance detectable in medium and high resolution images.
None of these disturbances are allowed in intact forest landscapes (step 2 and step 3 in the analysis)

- Reclaimed areas
- Arable and hay fields, including agricultural fields abandoned 25-30 years ago (in the zone of dry steppes)
- Zones of intensive geological prospecting using geophysical methods
- Areas with evident signs of overgrazing by domesticated and semi-domesticated animals (wild reindeer, sheep, cattle, horses, and yaks)
- Fire scars next to areas that are or have been subject to exploration and mining of mineral resources (oil, gas, coal, diamonds, bauxites, gold, platinum, polymetallic ores, chemical raw materials)
- Areas within the zone of permafrost where high population density has caused woody vegetation to disappear
- Public roads and service roads that are used as public roads (connecting settlements and/or public roads)
- Areas suffered from catastroptic mass outbreaks of pest
- Human disturbances in the vicinity of navigable rivers (at least 60 m wide) and rivers suitable for log driving

Individual disturbed areas that were eliminated at this stage varied in size between 1-2 hectares (2.5-4.9 acres) and 10-20 hectares (25-49 acres), depending on the kind and age of the disturbance. The high-resolution images also made it possible to verify or correct the location of most linear elements of infrastructure.

The result of this last phase of the analysis was a selection of internally un-fragmented forest landscapes without detectable signs of significant disturbance, larger than the minimum dimensions of 50,000 in size and 10 km in minimum width. The final map of intact forest landscapes was drawn based on the results of step 3 with the exception of the areas for which satellite images of high resolution were not available (accuracy zone 3).

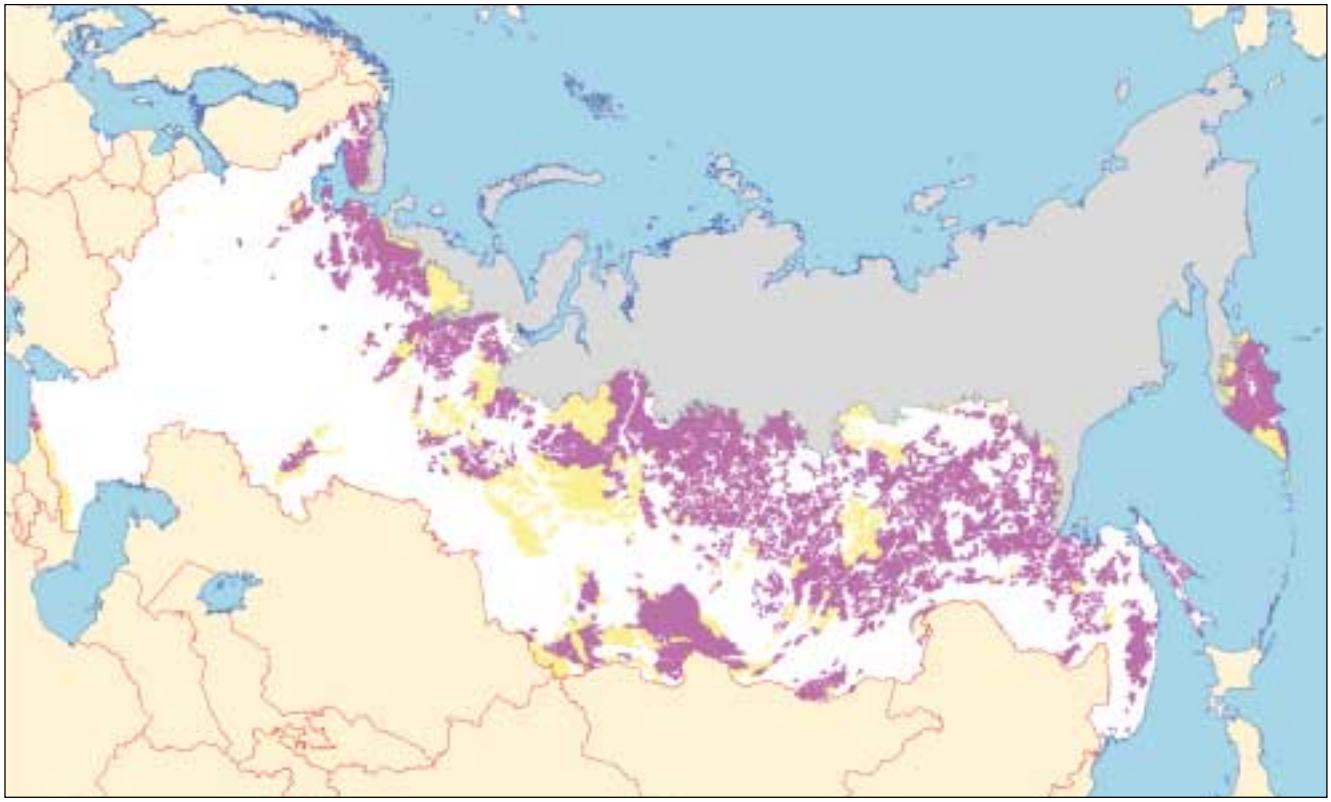
Picture 6. Availability of high resolution satellite images for continued analysis of candidate areas remaining after step 2 (i.e., after the analysis with medium resolution images).

Candidate area covered by high resolution images

Candidate area covered by medium resolution images only (and therefore not further analyzed in step 3)

Area outside the area of investigation

Forest inventory information was used to support the interpretation of the high resolution images in step 3 (and were also used to some extent in step 2). Most of this information was in the form of generalized forest maps of *leskhozes* (local offices of the state forest management agency) at scales typically between 1:150,000 and 1:300,000. More detailed maps do exist in many cases but were not available to the study for reasons of price and limited public access. Even the less detailed maps were not available for some areas due to constraints in public access in combination with the physical dispersal of these maps (there is no central library with materials for the whole country).



Picture 7. Availability of official forest inventory information for continued analysis of candidate areas remaining after step 2 (i.e., after the analysis with medium resolution images).

Generalized official forest inventory information used to support interpretation of satellite imagery

Official forest inventory data not used (due to lack of availability)

Accuracy

The map's accuracy varies for different parts of Russia, largely depending on the amount and quality of available information. Field expeditions were organized as part of this mapping project to verify the accuracy of the result. External researchers kindly shared data that was used for the same purpose.

In most of northern European Russia (accuracy zone 1, Picture 8), high resolution images (15-30 meters) were used along with information from ground observations from a large number of sites (173 inventoried key areas). A big share of the southern parts of European Russia and Western Siberia were excluded either in step 1 or on the basis of reliable ground data along with scattered satellite images (zone 0).

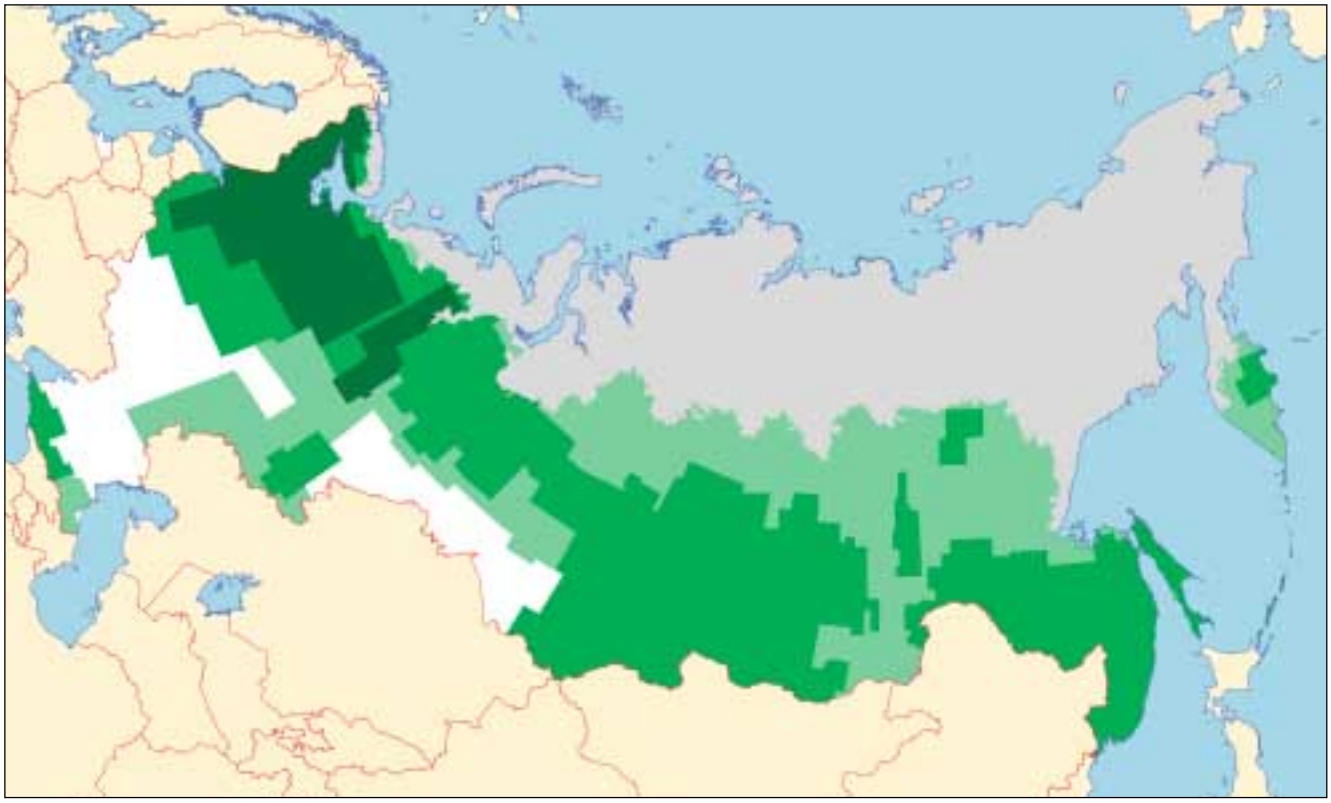
In the Caucasus and central European Russia, and in the southern parts of the Ural area, Siberia, and the Russian Far East (accuracy zone 2), the work was mainly based on high resolution images, but with a smaller number of ground observations. For some areas not covered by high resolution imagery reliable data were available from previous studies by project participants and external researchers. It is possible in this zone that individual areas may have been incorrectly classified, making an intact area out of a non-intact, or vice versa. Information from a total of 235 sites was used to verify the map within accuracy zones 2 and 3 together.

In the remaining regions (the central and northern parts of Siberia and the Russian Far East, some areas in the east of European Russia and in the south of Siberia, accuracy zone 3) the work was mostly based on medium-resolution images (150-300 meters) and ground observations were rare. Instead, high resolution images were used to verify the interpretation of selected areas. Additional analysis, using ground observations and high-resolution images, is recommended before any management decisions are made concerning these areas.

In the naturally highly fragmented tundra forests in the northernmost regions of Siberia and the Russian Far East (accuracy zone 4), the available information (low-resolution images and fragmented ground observations) was not sufficient to assess the degree of human transformation of the landscape accurately. A large portion of this area has nevertheless been processed as part of the analysis (see The northern boundary of intact forest landscapes section in the page 15).

Forests at the northern tree limit are extremely vulnerable to any disturbances, even those that are only indirectly related to humans. It would not be correct to assume that they are totally undisturbed, despite their remote location. These forests are shown as forested areas outside of the studied territory, and their boundaries are given in accordance with the Russian topographical maps at 1:500,000 scale of the Main Department of Geodesy and Mapping, most of which reflect the state of the area in the 1970 and 1980s.

The analysis is more likely to overestimate the remaining intact area than to underestimate it. This is inherent in the very approach of the study, which assumes land to be intact unless signs of disturbance can be detected. Signs of disturbance are much more likely to have been missed than to have been mistakenly found where none exist, although this possibility can not be ignored. A sparse larch forest without needles in rocky terrain can be difficult to distinguish from fire scar. Ancillary information was used to decrease the risk of such mistakes, but a few may have occurred. The more likely mistake, however, is that signs of disturbance were not seen, particularly in those areas where high-resolution images were not available. Some types of intensive disturbance cannot be detected without such images.



Picture 8. Accuracy zones of the analysis.

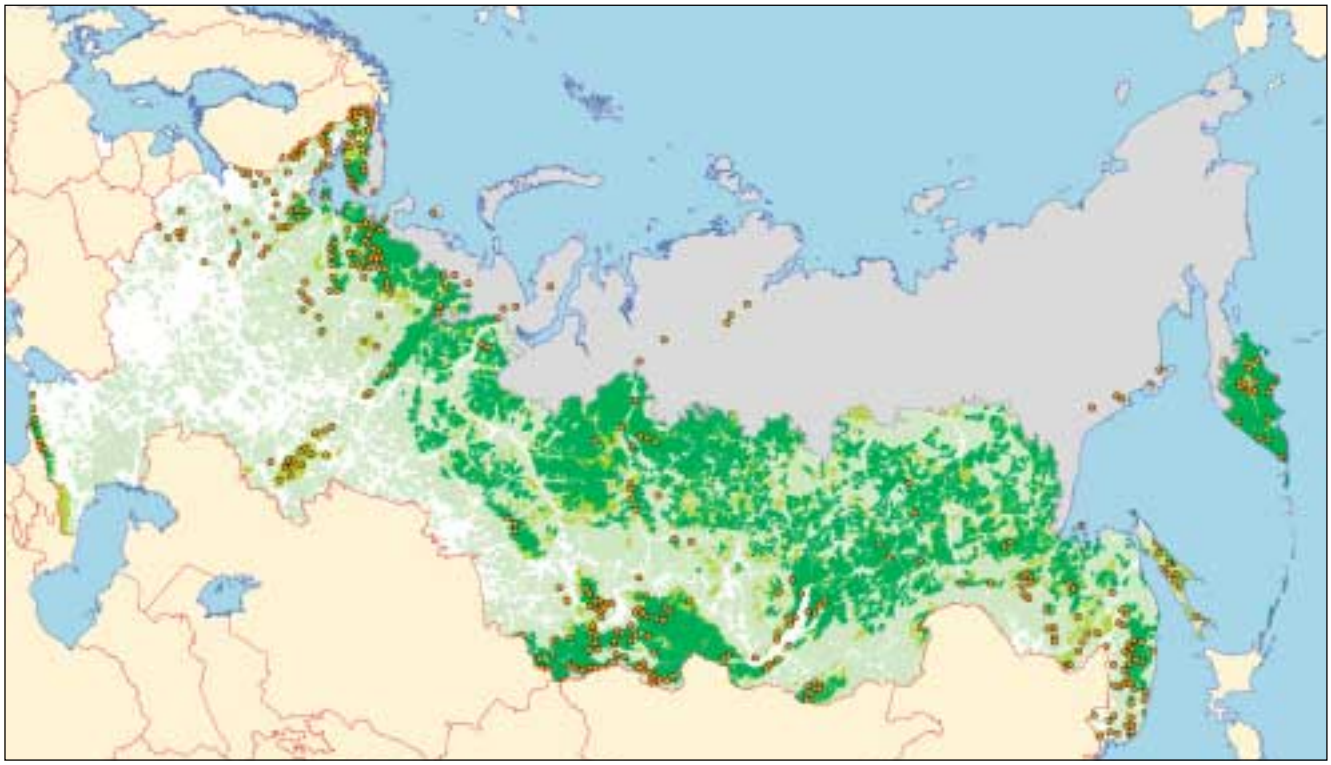
Highly developed areas classified as disturbed either in step 1 of the analysis or on the basis of reliable ground data along with scattered satellite images (zone 0)

The highest level of accuracy (zone 1). High resolution satellite images were mostly available, along with good ground information

Medium level of accuracy (zone 2). High resolution images were mostly available, but the ground information was insufficient for some areas. For some areas not covered by high resolution images reliable data from previous studies by project participants and external researchers were used

Low level of accuracy (zone 3). Fragmented coverage of high resolution images, ground information insufficient or fragmented

Area outside the area of investigation (zone 4)



Picture 9. Sites of ground observation used to verify the accuracy of map.
Orange dots indicate sites of ground observations. These include sites inspected by Global Forest Watch Russia field expeditions, as well as sites for which data were contributed by external researchers. *Other colors:* same as in Picture 5.

Preliminary identification of large intact forest-dominated areas and classification of their tree species composition

In a special study for Global Forest Watch, R&D Center ScanEx has tested a method for identification of large blocks of intact, forest-dominated areas. In the process of this study, the tree composition of these forests was classified according to the criteria used in the map *Vegetation of the USSR* edited by B. V. Sochava (1957). These criteria were selected because they have been used to develop other systems for country-wide classification of vegetation and have been found well suited for this purpose.

The purpose of the study was to test a method for direct identification of large intact forest-dominated areas (landscape mosaics with a minimum of 50 percent in forest). The approach was to first identify a set of "typical" intact forests of different composition and then use an automatic algorithm to search for identical forests across the landscape. Medium-resolution imagery was used. The result shows that this approach is sensitive to small differences in forest composition and to the quality of the satellite images used. Primarily closed forests tend to be identified.

The study has produced maps that shows the location and tree species composition of large blocks of apparently closed forest that fitted the search criteria (i.e. the legend of the map). These maps are shown in the thematic section of this Atlas, beginning on page 147. A more technical description of the work is given below.

Medium-resolution satellite images from the Russian satellites Resurs-O1 series from different seasons were used. The images were geometrically transformed with the ScanEx Transformer software, then arranged into a mosaic with 6-degree zones in the Gauss-Kruger projection. The images were brought into a uniform resolution of 150x150 meters, and geo-referenced to the 1:1 million scale topographical map.

The thematical analysis was conducted in the ScanEx NeRis software, using the Kohonen algorithm for self-organizing nets. Blocks of closed forest assumed to be typical of intact forest were selected and used for training of the neural nets employed by this software. The quality and characteristics of the representation of these forests in medium resolution imagery was assessed with high-resolution Resurs-O1 MSU-E images (35x45 meter resolution). The trained neural nets were used to perform a multi-channel spectral analysis and the resulting layer was then analyzed for contextual features.

The classification of textural and contextual characteristics resulted in an 8-bit raster layer. Based on expert decision, a color coding table was designed and used to vectorize the result. The vector layers were then overlayed with the original imagery and with fragments of high resolution imagery for visual control.

Results

The Russian forest is no longer a boundless belt of unbroken wilderness. It is better described as a belt of intact fragments that are separated from each other by areas affected either by land use or its side effect. Exceptions to this pattern exist, primarily in Kamchatka in the northern parts of Eastern Siberia and the Russian Far East and in the mountainous areas of Altay and Tuva in Southern Siberia.

In European Russia, the southern parts of Siberia, and the Russian Far East, the main causes of fragmentation and disturbance are industrial forest harvesting and the fires that follow logging, agricultural use and road construction. In Western Siberia, the northern parts of Eastern Siberia and the Far East, the major causes of fragmentation and disturbance are extraction of mineral resources (including prospecting and construction of transportation infrastructure) and the massive human-induced fires, which accompany these activities.

Approximately 289 million hectares of large, intact forest landscapes remain in Russia (see Table 3). This is 26 percent of the forest zone of Russia (not counting tundra and forest tundra). Around 75 percent of the area of intact forest landscapes are in forest land, a category that includes both wooded and regenerating areas (e.g. after a fire or other natural catastrophe). The remaining 25 percent are made up of non-forest natural ecosystems (bogs, tundra and mountainous grasslands). Approximately 14 million hectares (5 percent) of the intact forest landscapes are in areas with special protection at the federal level.

Table 3. Areas of different land categories in Russia (million hectares).

Land category	Russia	European Russia	Western Siberia	Eastern Siberia	Russian Far East	Source of information
Area of Russia	1,707.5	383.2	290.5	722.6	311.3	Russian Encyclopedic Dictionary (2001)
Area of investigation – the forest zone of Russia	1,118.4	345.9	234.1	397.3	141.1	This study
Forest land within the area of investigation	876.9	198.4	160.5	375.5	142.5	This study and the topographical map of Russia, 1:500,000
Intact forest landscapes	288.5	31.8	58.4	153.9	44.4	This study
Intact forests within intact forest landscapes	216.4	24.0	36.7	125.9	29.8	This study and the topographical map of Russia, 1:500,000
Intact forest landscapes with special protection within *zapovedniks,* national parks, federal *zakazniks* and nature monuments	14.4	-	-	-	-	This study

Large areas of the forest landscape (i.e. the mosaic of forest and non-forest ecosystems) of Russia have been substantially affected by modern land use (see Table 4 and Figure 1). The least affected part is Eastern Siberia, where 39 percent of the forest zone remains in intact forest landscapes, followed by the Russian Far East (32 percent intact) and Western Siberia (25 percent intact). European Russia is by far the most transformed part (9 percent intact). Of Russia as a whole, about 26 percent of the forest zone remain in intact forest landscapes.

The picture is slightly different if only the forest area of the landscape is considered. The forest area within remaining intact forest landscapes was compared to the total forest area within the territory of investigation. The land cover classification of the 1:500,000 scale topographical map of Russia was used in both cases. Eastern Siberia has the greatest portion of forest in intact landscapes, with 34 percent, followed by Western Siberia (23 percent), the Russian Far East (21 percent), and European Russia (12 percent). About 25 percent of the forest area of Russia as a whole fall within intact forest landscapes.

Table 4. Portion of the landscape that remains in intact forest landscapes and in intact forest (percent).

	Russia	European Russia	Western Siberia	Eastern Siberia	Far East
Portion of the entire forest zone (all ecosystems) that remains in intact forest landscapes	26%	9%	25%	39%	31%
Portion of the forest within the forest zone that remains in intact forest landscapes	25%	12%	23%	34%	21%

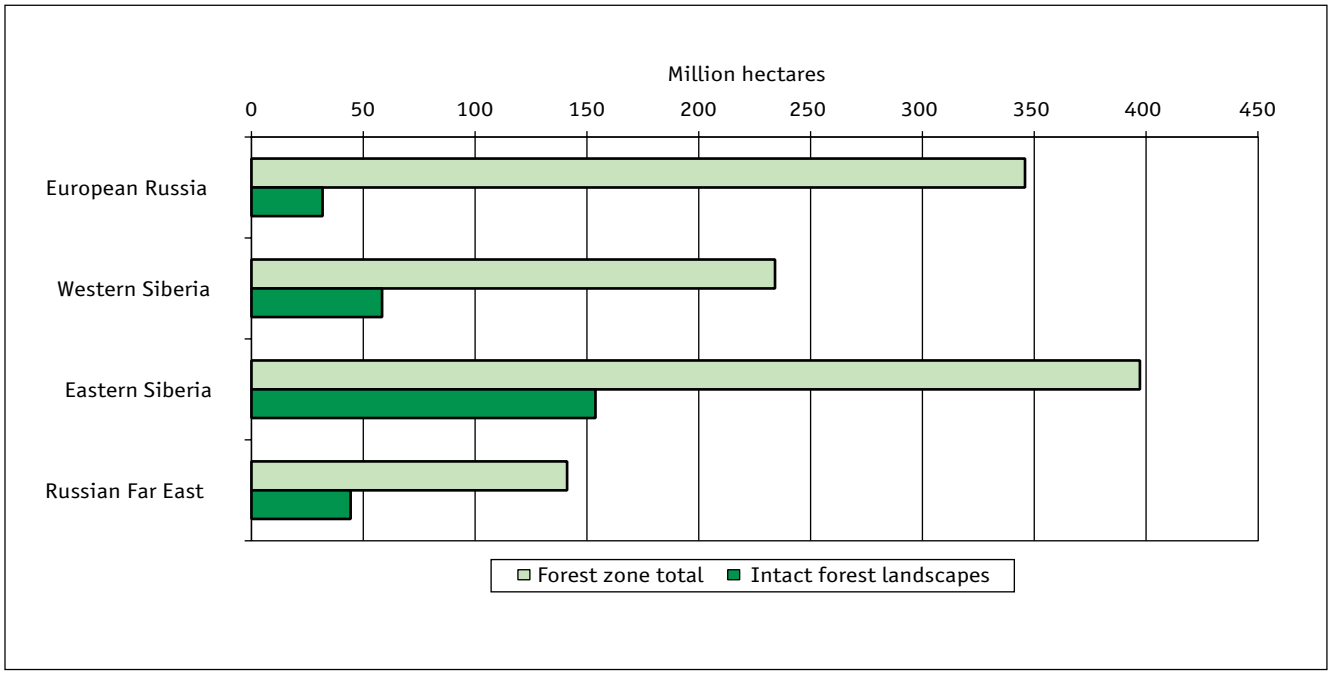


Figure 1. Total area within the forest zone and within intact forest landscapes for different parts of Russia, million hectares.

Russia has 6 ecoregions according to the global classification proposed by Olsson *et al* (2001). These fall mostly within the forest zone (the other two ecoregions, tundra, and desert and xeric shrublands, lie mostly outside the forest zone). Three of these have had more than 90 percent of their area affected by modern land use, while only one (montane grasslands) has retained more than half of the area in intact condition. More than 80 percent of the intact forest landscapes fall in one ecoregion: boreal forests/taiga (Figure 2).

The remaining intact forest landscapes are highly concentrated among a few large administrative regions. Five regions, all in Siberia, contain almost half of the intact forest landscapes in Russia: the Republic of Sakha (Yakutia), the Evenk Autonomous District, Krasnoyarsk Kray, the Khanty-Mansi Autonomous District, and Irkutsk Oblast. In Eastern Siberia the five regions with the most intact forest landscapes make up 85 percent of the total area. The corresponding number is 90 percent for European Russia and Western Siberia, and as

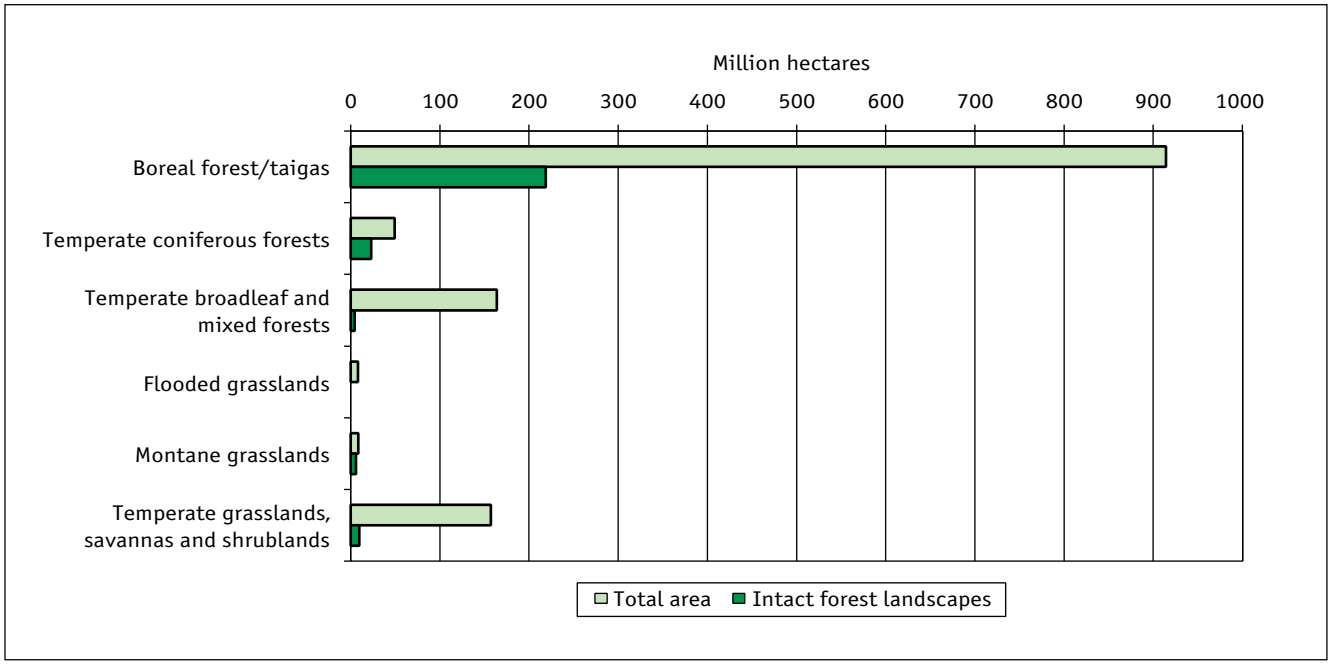


Figure 2. Area of ecoregions, according to the global classification proposed by Olsson, *et al* (2001), within the forest zone of Russia and the area of the intact forest landscapes contained within them.

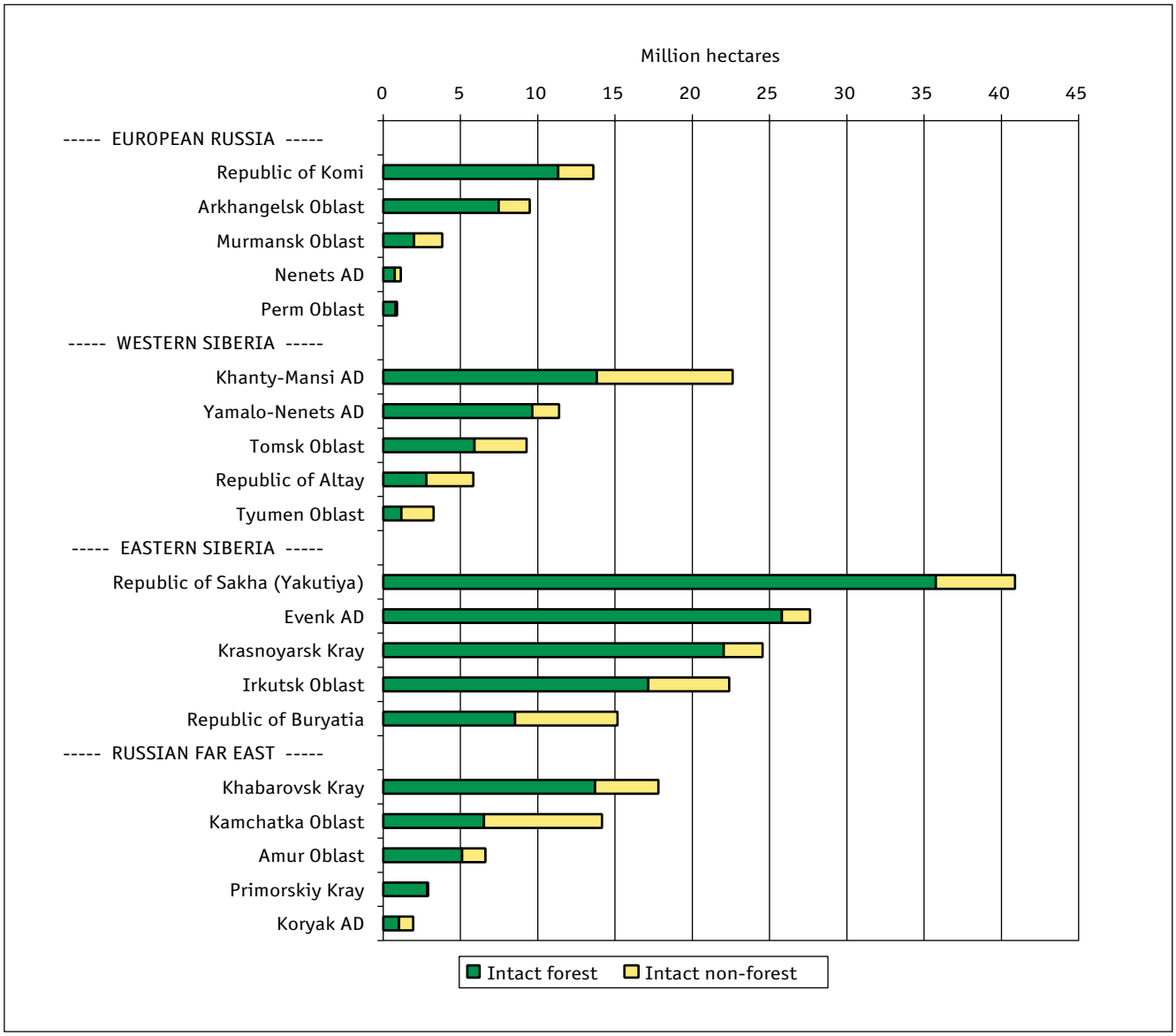


Figure 3. The five administrative regions in each macro-region of Russia that have the largest areas of intact forest landscapes. The land-cover type distribution within each of these is also shown.

much as 98 percent in the Russian Far East (see Figure 3). Seven regions have more than 50 percent of their area in intact forest landscapes: Nenets Autonomous District (100 percent), Koryak Autonomous District (88 percent), (Kamchatka Oblast (85 percent), the Republic of Altay (63 percent), Yamalo-Nenets Autonomous District (62 percent), Evenk Autonomous District (61 percent), and the Republic of Tuva (57 percent). 98 percent of the total area of intact forest landscapes is in the 29 regions that have at least 10 percent of the area in that category. Intact forest landscapes are completely missing from 49 of 89 administrative regions.

Most of the intact forest landscapes areas are in sparsely wooded and mountainous parts of Russia. The following administrative regions have a comparatively high proportion of intact forest landscapes:

- European Russia: the Republic of Komi and Murmansk Oblast.
- Northern Siberia: the Yamal-Nenets, Khanty-Mansi, and Evenki autonomous districts.
- Southern Siberia: the republics of Burytia, Tuva and Khakassia, Altay Kray, Krasnoyarsk Kray and Chita Oblast.
- The Russian Far East: Kamchatka Oblast and the Koryak Autonomous District.

Most administrative and ecological regions of Russia lack a representative or sufficiently large system of protected areas within the remaining intact forest landscapes. Only 5 percent of all intact forest landscapes (14.4 million hectares) currently have special protection in various forms: *zapovedniks* (strict scientific nature reserves), national parks, federal *zakazniks* (sanctuaries and wildlife refugees), and nature monuments. More than half of protected areas (3.6 percent) are in zapovedniks.

Conclusions

These findings refute the myth that ancient or virgin forests still dominate Russia. Such forests now dominate only the northern parts of Eastern Siberia and the Russian Far East, and even here, human influence, especially as a cause of forest fires, has become the leading factor affecting vegetation dynamics. In most parts of European Russia and Western Siberia, and the southern parts of Eastern Siberia and the Russian Far East, the forest vegetation has been fundamentally transformed by human activity. No large intact landscapes remain in many of these western and southern areas, while the intact forests that remain are broken up into fragments, too small to sustain the full array of components and functions characteristic of a natural forest landscape.

Without decisive action within the next few years, intact forest landscapes may disappear within whole ecological regions and even vegetation zones.

This picture raises serious concerns. The most biodiversity-rich and productive forest landscapes of southern Siberia, the Russian Far East, and of European Russia are also the most transformed. These areas are steadily diminishing due to continued extensive "development" of natural resources. The situation is most serious concerning temperate broad-leaf and mixed conifer-broad-leaf forests. Such forests are practically extinct in European Russia. The same fate may befall the forests in the area surrounding the mountain range of Sikhote-Alin, which contain the richest biodiversity in Russia. Intact landscapes remain, but only in the most inaccessible mountainous locations. Almost all of the unique, far-eastern broad-leaf and mixed conifer-broad-leaf forests have been affected by industrial logging during the last decade.

Decisions about the conservation and use of the remaining intact forest landscapes must no doubt reflect a complex range of ecological, social, and economical factors. At this stage it is reasonable to suggest only that forestry practices observe all possible precautionary measures and make it a concrete goal to preserve sufficiently large and representative reference areas of wild nature. This is especially important and urgent in European Russia and the Southern parts of Siberia and the Russian Far East, where intact forest landscapes are particularly rare and threatened. A reasonable strategy for these areas would be to set aside remaining intact forest landscapes for a limited time, to allow optimal decision-making regarding future conservation and land-use.

Next steps

This atlas represents the first attempt to map the extent and boundaries of intact forest landscapes across a continental-size country. The goal has been to produce maps that are accurate and detailed enough to inform decisions concerning practical conservation and management. Such a big undertaking would surely have benefited from additional time and resources. Thus it would be desirable to both refine and extend the work.

An obvious way to refine the work would be to use better information. This would create two important advantages: additional accuracy in the classification and delineation of areas with conservation and other values, and greater usefulness to practical land management.

Access to high-resolution satellite images for the whole territory would increase the accuracy, as would access to more ancillary information and additional ground verification. In the north of Russia, lack of information prevented classification of large forest areas as well as the tundra. More information was available in the South, but here the needs are much greater, due to the greater biodiversity values and smaller remaining intact areas, as well as the faster rate of change caused by intensified land use, both legal and illegal. The need for accurate and frequent monitoring is significant in the South, and poses great (and costly) information needs.

Another way to refine the work would be to elaborate the criteria used to separate intact and non-intact areas. A particularly difficult problem was posed by the classification of fire regimes. In this study, all fires occurring in the vicinity of infrastructure and big rivers (wider than 60 meters) were considered anthropogenic. The associated fire scars and mosaics, including those with regenerating young forests, were therefore classified as non-intact. This schematic approach has obvious weaknesses. No better alternative was available, however, given the need for a decision rule that can be consistently applied across Russia. It is hoped that future research will produce a more reliable and accurate algorithm.

A third approach to refinement would be to map additional characteristics of the forest landscape. The Atlas does not distinguish any differences in conservation value within intact forest landscapes. This does not mean that such differences do not exist, only that it was beyond the scope of this work to study them. A study of this kind is urgent, as optimal decisions concerning the conservation and use of these landscapes require such information.

There is also an urgent need to expand the mapping to areas outside of the large intact forest landscapes. It must be emphasized that there are important conservation values outside of the intact forest landscapes that are not captured by this Atlas. Intactness is only one of many such values. There is currently an almost

total lack of conservation value maps that are detailed enough to function as on-the-ground decision support tools to practical land management. The mapping scale needs to be 1:500,000 or even 1:200,000. All forest values need to be placed within the network of quadrants (*kvartals*) which is used for forest inventory and management purposes in Russia. Such information is needed by many users, including government authorities, the forest industry, and environmental protection groups. Unfortunately, they do not produce it.

Priority areas for refined mapping of conservation values include the Ural Mountains and the Southern taiga belt of European Russia (Leningrad, Vologda, Kostroma, Kirov and Perm Oblasts), the Altay-Sayany area in Western Siberia, the Angara-Enisey and Baikal Lake areas in Eastern Siberia, and the Sikhote-Alin Range in the Russian Far East.

From a scientific point of view, a highly desirable extension of the work would be a retrospective analysis of the landscape. Access to old satellite images would be of tremendous value and would make it possible to analyze the rate of transformation of different parts of the landscape. Besides the obvious ecological interest, such a study would advance the knowledge of the role that the Russian forest plays in the global carbon budget.

The partners within the Global Forest Watch initiative would welcome any support that would make it possible to continue and expand the work as outlined above.

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Annex 1. Data on intact forest landscapes at the level of administrative regions (subjects of the Russian Federation)

Region's name	Total area within the region	Total area within territory of study (the forest zone of Russia)			Forest area within the territory of study (according to the 1:500,000 topographical map)		
	Total area	Total area	Intact Area (Intact forest landscapes)	Intact portion of total area	Total forest area	Forest area within intact forest landscapes	Intact portion of total area
	Thousand ha	Thousand ha	Thousand ha	Percent	Thousand ha	Thousand ha	Percent
1	2	3	4	5	6	7	8
European Russia							
Adygea, Republic of	760	760	101	13	357	75	21
Arkhangelsk Oblast	41,070	30,484	9,482	31	29,217	7,477	26
Astrakhan Oblast	4,410	4,410			46		
Bashkortostan, Republic of	14,360	14,360	415	3	6,792	414	6
Belgorod Oblast	2,710	2,710			246		
Bryansk Oblast	3,490	3,490			1,302		
Chuvashia, Republic of	1,830	1,830			702		
Dagestan, Republic of	5,030	5,030			552		
Ingushetia and Chechnia (Chechnya), Republics of*	1,930	1,930			477		
Ivanovo Oblast	2,390	2,390			1,597		
Kabardino-Balkaria, Republic of	1,250	1,250	338	27	209	33	16
Kaliningrad Oblast	1,510	1,510			238		
Kalmykia (Khalmg Tangch), Republic of	7,590	7,590			9		
Kaluga Oblast	2,990	2,990			1,684		
Karachay-Cherkessia, Republic of	1,410	1,410	503	36	521	165	32
Karelia, Republic of	17,240	17,240	864	5	14,880	678	5
Kirov Oblast	12,080	12,080	21	<1	9,867	21	<1
Komi, Republic of	41,590	36,908	13,599	37	35,752	11,322	32
Komi-Permyak Autonomous District	3,290	3,290			3,282		
Kostroma Oblast	6,010	6,010			5,692		
Krasnodar Kray	7,600	7,600	314	4	1,748	235	13
Kursk Oblast	2,980	2,980			237		
Leningrad Oblast**	8,590	8,590			6,916		
Lipetsk Oblast	2,410	2,410			172		
Mari-El, Republic of	2,320	2,320			1,569		
Mordvinia, Republic of	2,620	2,620			829		
Moscow Oblast***	4,700	4,700			2,792		
Murmansk Oblast	14,490	9,046	3,821	42	6,574	1,990	30
Nenets Autonomous District	17,670	1,134	1,134	100	1,006	741	74
Nizhniy Novgorod Oblast	7,480	7,480			4,852		
North Ossetia (Alania), Republic of	800	800	135	17	220	13	6
Novgorod Oblast	5,530	5,530	43	1	5,031	6	<1
Orel Oblast	2,470	2,470			161		
Penza Oblast	4,320	4,320			1,057		
Perm Oblast	12,770	12,770	892	7	10,508	803	8
Pskov Oblast	5,530	5,530	39	1	3,597	9	<1
Rostov Oblast	10,080	10,080			195		
Ryazan Oblast	3,960	3,960			1,131		
Samara Oblast	5,360	5,360			736		
Saratov Oblast	10,020	10,020			563		
Smolensk Oblast	4,980	4,980			2,419		

*, **, *** - See footnotes in Annex 2 (page 32)

1	2	3	4	5	6	7	8
Stavropol Kray	6,650	6,650			100		
Tambov Oblast	3,430	3,430			386		
Tatarstan, Republic of	6,800	6,800			1,260		
Tula Oblast	2,570	2,570			349		
Tver Oblast	8,410	8,410			7,048		
Udmurtia, Republic of	4,210	4,210			2,536		
Ulyanovsk Oblast	3,730	3,730			1,176		
Vladimir Oblast	2,900	2,900			2,598		
Volgograd Oblast	11,410	11,410			398		
Vologda Oblast	14,570	14,570	103	1	13,750	24	<1
Voronezh Oblast	5,240	5,240			481		
Yaroslavl Oblast	3,640	3,640			2,549		
Total European Russia	**383,180**	**345,880**	**31,804**	**9**	**198,366**	**24,006**	**12**
Western Siberia							
Altay Kray	16,910	16,910	359	2	4,819	218	5
Altay, Republic of	9,260	9,260	5,837	63	5,290	2,799	53
Chelyabinsk Oblast	8,790	8,790			3,128		
Kemerovo Oblast	9,550	9,550	1418	15	6,851	1,290	19
Khanty-Mansi Autonomous District	52,310	52,740	22,619	43	47,451	13,812	29
Kurgan Oblast	7,100	7,100			2,772		
Novosibirsk Oblast	17,820	17,820	2,429	14	6,234	920	15
Omsk Oblast	13,970	13,970	934	7	7,202	369	5
Orenburg Oblast	12,400	12,400			498		
Sverdlovsk Oblast	19,480	19,480	906	5	18,506	538	3
Tomsk Oblast	31,690	31,690	9,271	29	28,814	5,897	21
Tyumen Oblast	16,180	16,180	3,262	20	12,216	1,179	10
Yamalo-Nenets Autonomous District	75,030	18,469	11,385	62	16,712	9,646	58
Total Western Siberia	**290,490**	**234,145**	**58,420**	**25**	**160,493**	**36,668**	**23**
Eastern Siberia							
Aga-Buryat Autonomous District	1,900	1,900			735		
Buryatia, Republic of	35,130	35,130	15,155	43	29,595	8,535	29
Chita Oblast	41,250	41,250	11,958	29	34,673	8,690	25
Evenk Autonomous District	76,760	45,176	27,616	61	45,162	25,803	57
Irkutsk Oblast	74,560	74,560	22,388	30	71,705	17,148	24
Khakassia, Republic of	6,190	6,190	1,582	26	3,830	1,157	30
Krasnoyarsk Kray	71,000	68,053	24,555	36	63,416	22,033	35
Sakha (Yakutia), Republic of	310,320	105,158	40,882	39	101,231	35,756	35
Taymyr Autonomous District	86,210	86,210			13,005		
Tuva (Tyva), Republic of	17,050	17,050	9,740	57	10,849	6,778	63
Ust-Orda Buryat Autonomous District	2,230	2,230			1,321		
Total Eastern Siberia	**722,600**	**397,266**	**153,876**	**39**	**375,522**	**125,900**	**34**
Russian Far East							
Amur Oblast	36,370	36,370	6,611	18	30,915	5,106	17
Chukchi (Chukotka) Autonomous District	73,770	73,770			6,443		
Kamchatka Oblast	17,080	16,599	14,163	85	9,434	6,515	69
Khabarovsk Kray	78,860	59,530	17,800	30	51,046	13,709	27
Koryak Autonomous District	30,150	2,196	1,933	88	1,333	1,019	76
Magadan Oblast	46,140	46,140			21,568		
Primorskiy Kray	16,590	16,590	2,902	18	13,799	2,844	21
Sakhalin Oblast	8,710	8,710	905	10	6,107	494	8
Yevreyskaya (Jewish) Autonomous Region	3,600	3,600	101	3	1,900	101	5
Total Russian Far East	**311,270**	**141,113**	**44,415**	**32**	**142,545**	**29,788**	**21**
Total Russia	**1,707,540**	**1,118,404**	**288,515**	**26**	**876,926**	**216,362**	**25**

Annex 2. Data on forest area at the level of administrative region (subject of the Russian Federation)

Name of region	Total area of region	Forest area according to the State Forest Account as for January 1 1998 (Federal Forest Service, 1999)****	Forest area according to the 1:500,000 topographical map*****
	Thousand ha	Thousand ha	Thousand ha
1	2	3	4
European Russia			
Adygea, Republic of	760	246	357
Arkhangelsk Oblast	41,070	22,086	29,273
Astrakhan Oblast	4,410	24	46
Bashkortostan, Republic of	14,360	5,406	6,792
Belgorod Oblast	2,710	228	246
Bryansk Oblast	3,490	1,128	1,302
Chuvashia, Republic of	1,830	568	702
Dagestan, Republic of	5,030	367	552
Ingushetia and Chechnia (Chechnya), Republics of*	1,930	346	477
Ivanovo Oblast	2,390	977	1,597
Kabardino-Balkaria, Republic of	1,250	155	209
Kaliningrad Oblast	1,510	292	238
Kalmykia (Khalmg Tangch), Republic of	7,590	5	9
Kaluga Oblast	2,990	1,328	1,684
Karachay-Cherkessia, Republic of	1,410	408	521
Karelia, Republic of	17,240	9,390	14,880
Kirov Oblast	12,080	7,552	9,867
Komi, Republic of	41,590	29,750	36,763
Komi-Permyak Autonomous District	3,290	2,626	3,282
Kostroma Oblast	6,010	4,426	5,692
Krasnodar Kray	7,600	1,337	1,748
Kursk Oblast	2,980	230	237
Leningrad Oblast**	8,590	4,772	6,916
Lipetsk Oblast	2,410	191	172
Mari-El, Republic of	2,320	1,288	1,569
Mordvinia, Republic of	2,620	690	829
Moscow Oblast***	4,700	1,913	2,792
Murmansk Oblast	14,490	5,253	7,090
Nenets Autonomous District	17,670	191	1,661
Nizhniy Novgorod Oblast	7,480	3,619	4,852
North Ossetia (Alania), Republic of	800	171	220
Novgorod Oblast	5,530	3,485	5,031
Orel Oblast	2,470	190	161
Penza Oblast	4,320	918	1,057
Perm Oblast	12,770	8,479	10,508
Pskov Oblast	5,530	2,108	3,597
Rostov Oblast	10,080	197	195
Ryazan Oblast	3,960	1,002	1,131
Samara Oblast	5,360	647	736
Saratov Oblast	10,020	534	563
Smolensk Oblast	4,980	2,047	2,419
Stavropol Kray	6,650	69	100
Tambov Oblast	3,430	349	386
Tatarstan, Republic of	6,800	1,131	1,260
Tula Oblast	2,570	346	349

1	2	3	4
Tver Oblast	8,410	4,518	7,048
Udmurtia, Republic of	4,210	1,926	2,536
Ulyanovsk Oblast	3,730	978	1,176
Vladimir Oblast	2,900	1,467	2,598
Volgograd Oblast	11,410	399	398
Vologda Oblast	14,570	10,019	13,750
Voronezh Oblast	5,240	415	481
Yaroslavl Oblast	3,640	1,637	2,549
Total European Russia	**383,180**	**149,824**	**200,604**
Western Siberia			
Altay Kray	16,910	3,499	4,819
Altay, Republic of	9,260	3,836	5,290
Chelyabinsk Oblast	8,790	2,503	3,128
Kemerovo Oblast	9,550	5,589	6,851
Khanty-Mansi Autonomous District	52,310	27,800	47,651
Kurgan Oblast	7,100	1,589	2,772
Novosibirsk Oblast	17,820	4,611	6,234
Omsk Oblast	13,970	4,471	7,202
Orenburg Oblast	12,400	444	498
Sverdlovsk Oblast	19,480	12,998	18,506
Tomsk Oblast	31,690	18,651	28,814
Tyumen Oblast	16,180	6,497	12,216
Yamalo-Nenets Autonomous District	75,030	15,376	29,657
Total Western Siberia	**290,490**	**107,864**	**173,638**
Eastern Siberia			
Aga-Buryat Autonomous District	1,900	625	735
Buryatia, Republic of	35,130	18,978	29,595
Chita Oblast	41,250	25,379	34,673
Evenk Autonomous District	76,760	45,816	72,764
Irkutsk Oblast	74,560	56,812	71,705
Khakassia, Republic of	6,190	2,945	3,830
Krasnoyarsk Kray	71,000	51,590	66,083
Sakha (Yakutia), Republic of	310,320	122,293	209,106
Taymyr Autonomous District	86,210	1,858	13,005
Tuva (Tyva), Republic of	17,050	7,855	10,849
Ust-Orda Buryat Autonomous District	2,230	1,085	1,321
Total Eastern Siberia	**722,600**	**335,236**	**513,666**
Russian Far East			
Amur Oblast	36,370	20,903	30,915
Chukchi (Chukotka) Autonomous District	73,770	1,804	6,443
Kamchatka Oblast	17,080	6,133	9,525
Khabarovsk Kray	78,860	46,995	60,616
Koryak Autonomous District	30,150	2,541	3,925
Magadan Oblast	46,140	8,353	21,568
Primorskiy Kray	16,590	12,294	13,799
Sakhalin Oblast	8,710	5,282	6,107
Yevreyskaya (Jewish) Autonomous Region	3,600	1,629	1,900
Total Russian Far East	**311,270**	**105,934**	**154,798**
Total Russia	**1,707,540**	**698,858**	**1,042,706**

* The borders are not marked.

** Includes the area of the city of Saint Petersburg.

*** Includes the area of the city of Moscow.

**** Area covered by forest (does not includes sparse and unstocked forests). Forests dominated by minor forest-forming species (e.g., elfin birch and willow woods and creeping stone pine (*Pinus pumila*) and alder) were excluded based on data on them for lands managed by the Federal Forest Service as of 1998; some forests outside the State Forest Fund (e.g., found on the Lands of State Reserve) can be missed (see data for Nenets Autonomous District).

***** Category of high dense forests.