The large-scale changes of Russian forests according to Earth observations

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The lecture at Young Scientists' School-Conference on Remote sensing of vegetation at high latitudes in response to climate change and other disturbances

The Space Research Institute of Russian Academy of Sciences
Moscow, November 17, 2020

Carbon Budget in Russian Forests

- **Russian forest is a factor of global importance** for international conventions on climate considering its potential for absorption of the atmospheric carbon
- Considering **Paris agreement on climate** the comprehensive and accurate estimation of Russian forests' carbon budget became a top priority research and development on national agenda
- Existing quantitative estimates of **Russian forests' carbon budget are of significant level of uncertainty**. One of the most obvious reasons for such uncertainty is not sufficiently reliable and up-to-date information on forests and their dynamics
- Information for carbon budget estimation includes data on land cover, forest characteristics (**growing stock, species, age, productivity**) and ecological parameters (NPP). Data on **natural and anthropogenic disturbances, as well as reforestation**, are also vital
- **Remote sensing can provide significant part of missing information** on forest for a country-wide carbon budget estimation. However, the most expedient approach should integrate remote sensing, field measurements and mathematical models of forest dynamics

The Project Objectives

The **Space Research Observatory for Forest Carbon Project** is focused at the following objectives:

- development of a new methodology for forest carbon budget assessment using a multi-sensor EO approach;
- integration of ground based and remote sensing data to improve existing and create new models;
- using the developed methodology to produce new dynamically updated GIS databases of Russian forests' characteristics;
- development of an informational system and technology for the continuous monitoring of Russian forests' carbon budget.

RS data derived essential forest variables for Carbon Budget Assessment

- Forest and non-forest land cover types
- Dominant tree species and their composition
- Forest growing stock volume
- Forest density (relative growing stock, cover fraction)
- Forest Age
- Forest Site Index
- Forest biophysical characteristics (LAI, FAPAR)
- Forest disturbances, including:
  - burnt area and severity
  - other natural and human-induced disturbances
  - logging

Main component of R&D at IKI

(I) Multi-annual of automatic near-real-time update EO data archive

(II) Automated EO data processing chains, including:

a. EO data pre-processing (cloud/shadow screening, image compositing, vegetation indexes generation, data time-series reconstruction and etc)

b. Thematic products generation (land cover/land use, active fires, burnt area and severity, crop masks and etc)

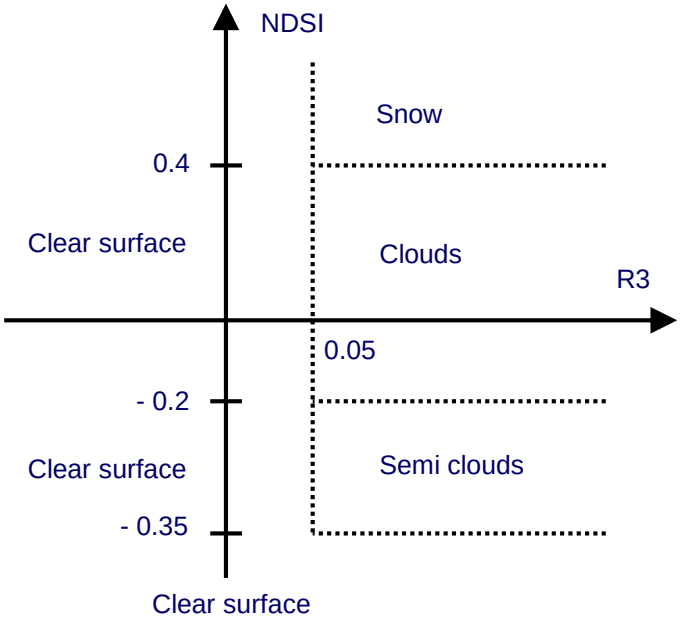
(III) Web-based Users' Interface with data analysis tools

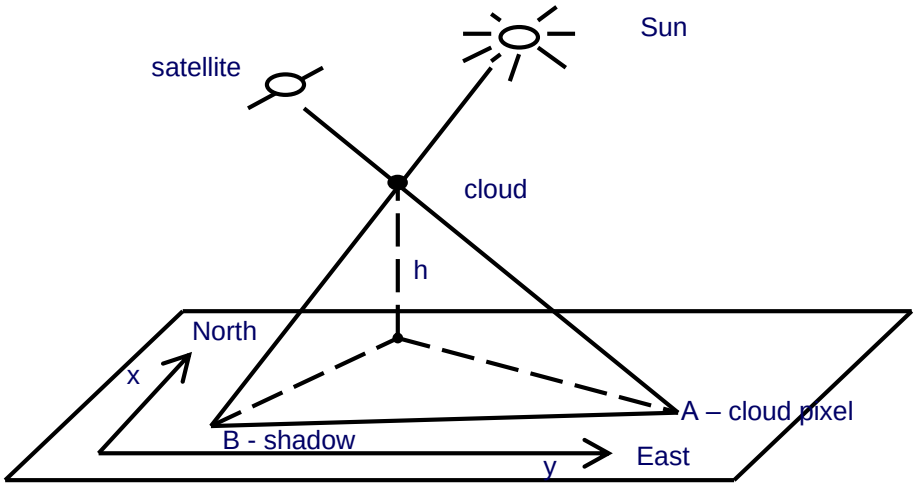
(IV) Terrestrial ecosystems change analysis

Near-real-time update EO data archive at IKI

- **MODIS Surface Reflectance MOD09 from NASA (2000 - ongoing)**
- Landsat data download from USGS and ESA (1984-ongoing)
- Proba-V data download from VITO (2014-ongoing)
- Sentinel-2 data download from ESA (2016-ongoing)
- KMSS Meteor-M data from Russian Hydrometeo Service (2015-ongoing)
- Many other satellite instruments

MODIS data preprocessing

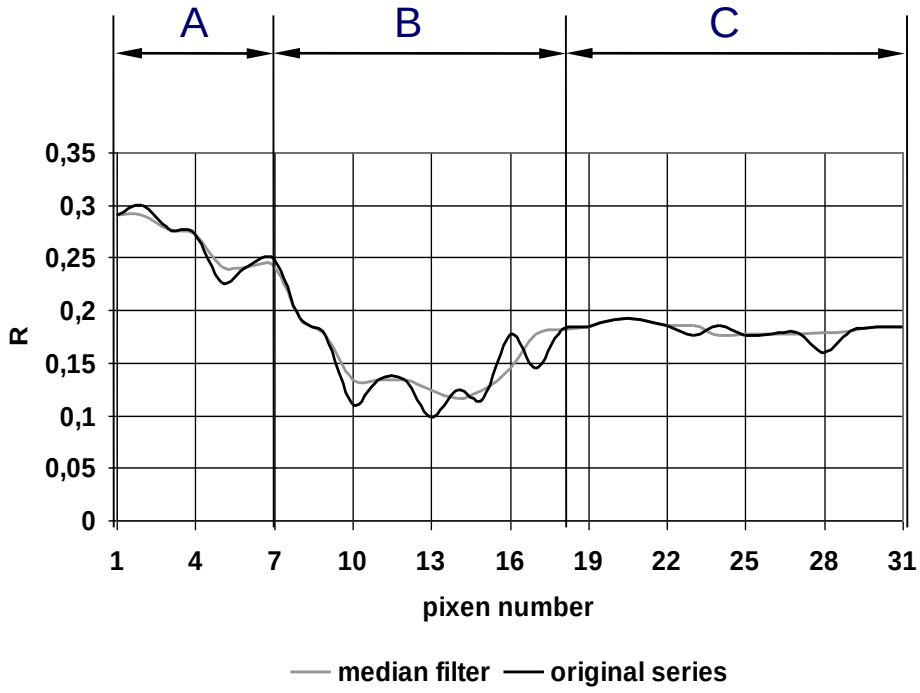




Geometry of shadow line

Daily data masks creation:

1) Snow and clouds detection
2) Shadows detection
3) Statistical filtering



Shadow line analysis

EO data preprocessing

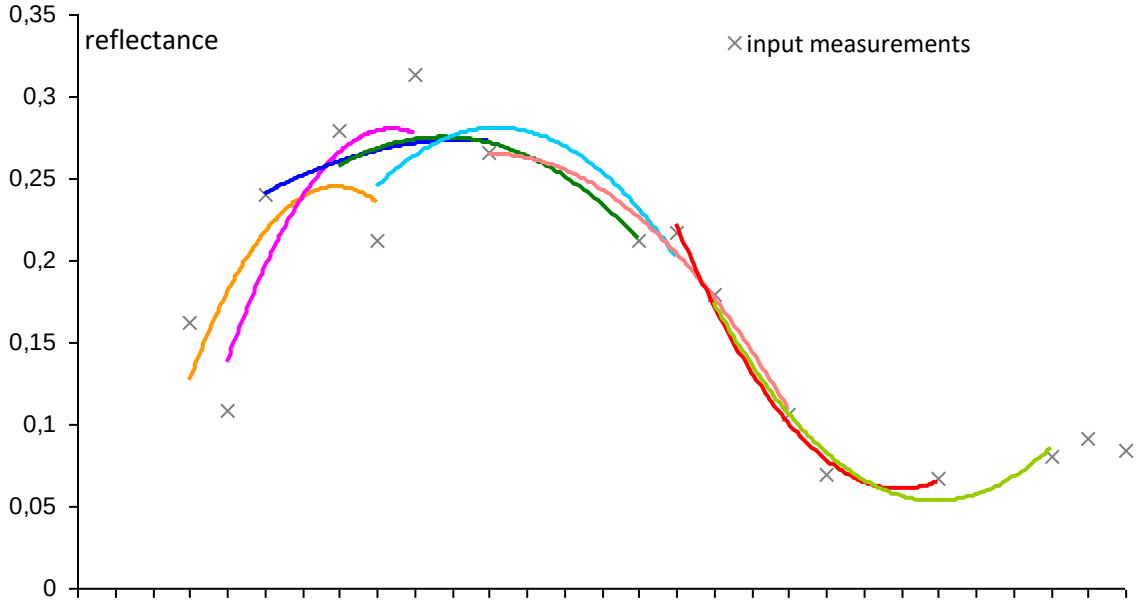
Cloud screening

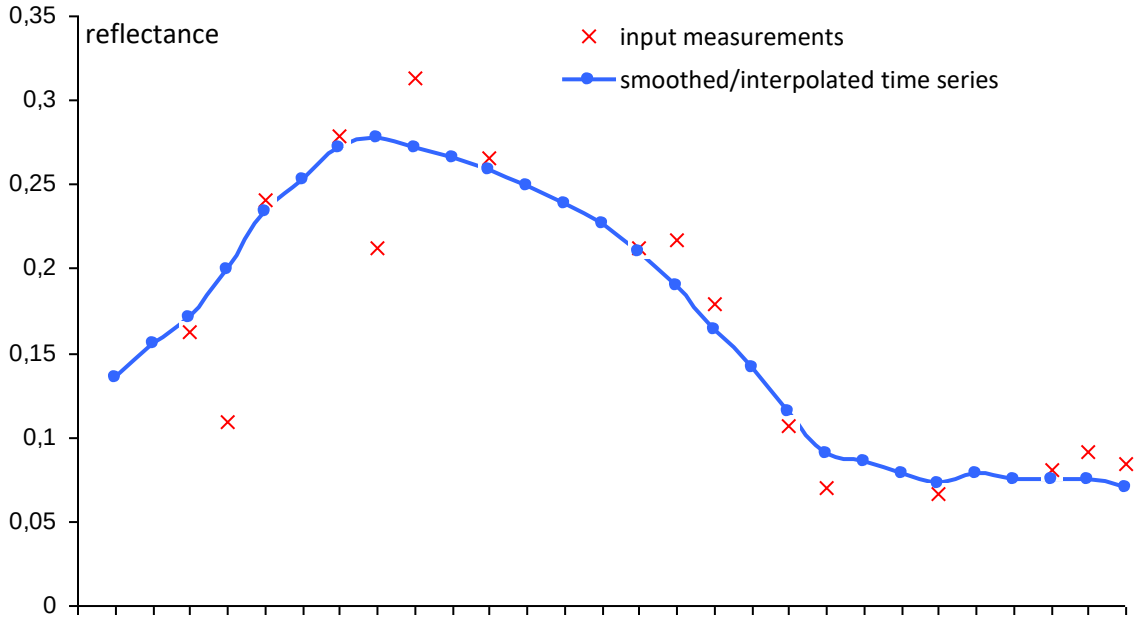
⇩

Time series reconstruction

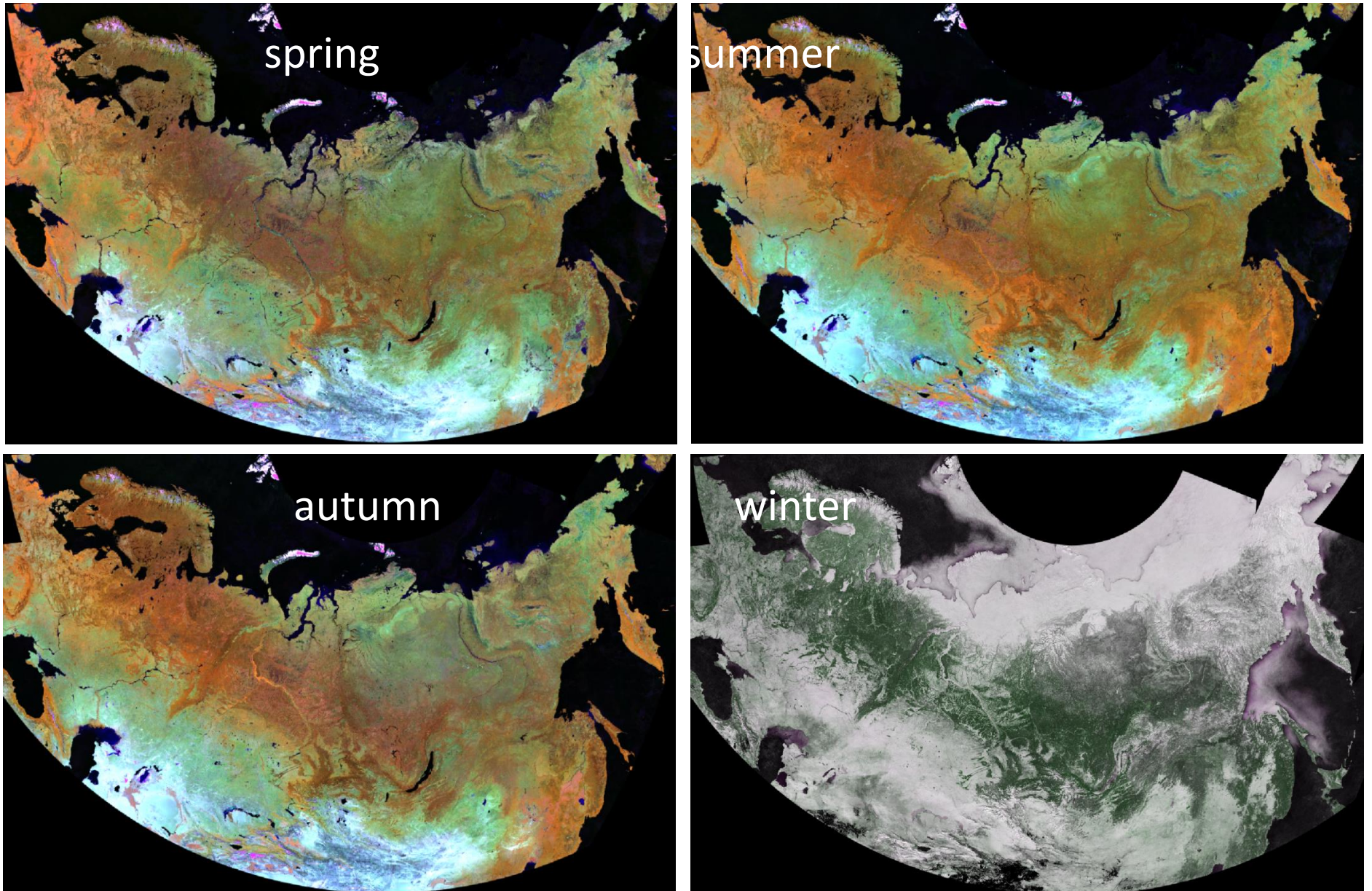
⇩

Images compositing

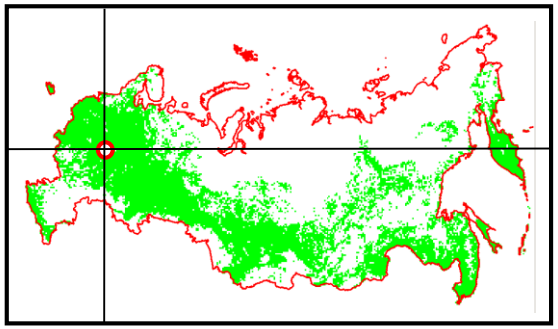




MODIS derived seasonal cloud-free image composites for land cover mapping



LAGMA : Locally Adaptive Global Mapping Algorithm

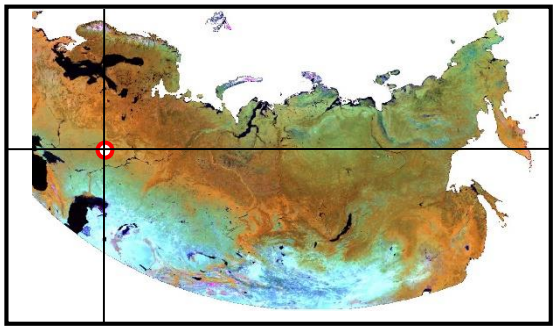


Local spectral-temporal signatures of classes

Σ_i Covariation of metrics

$\bar{a}_i$ Average of metrics

n_i Number of samples



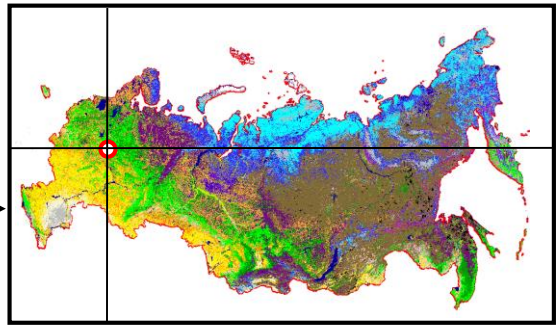
Spectral-temporal MODIS data composites

$\bar{x}$ Metrics for the pixel

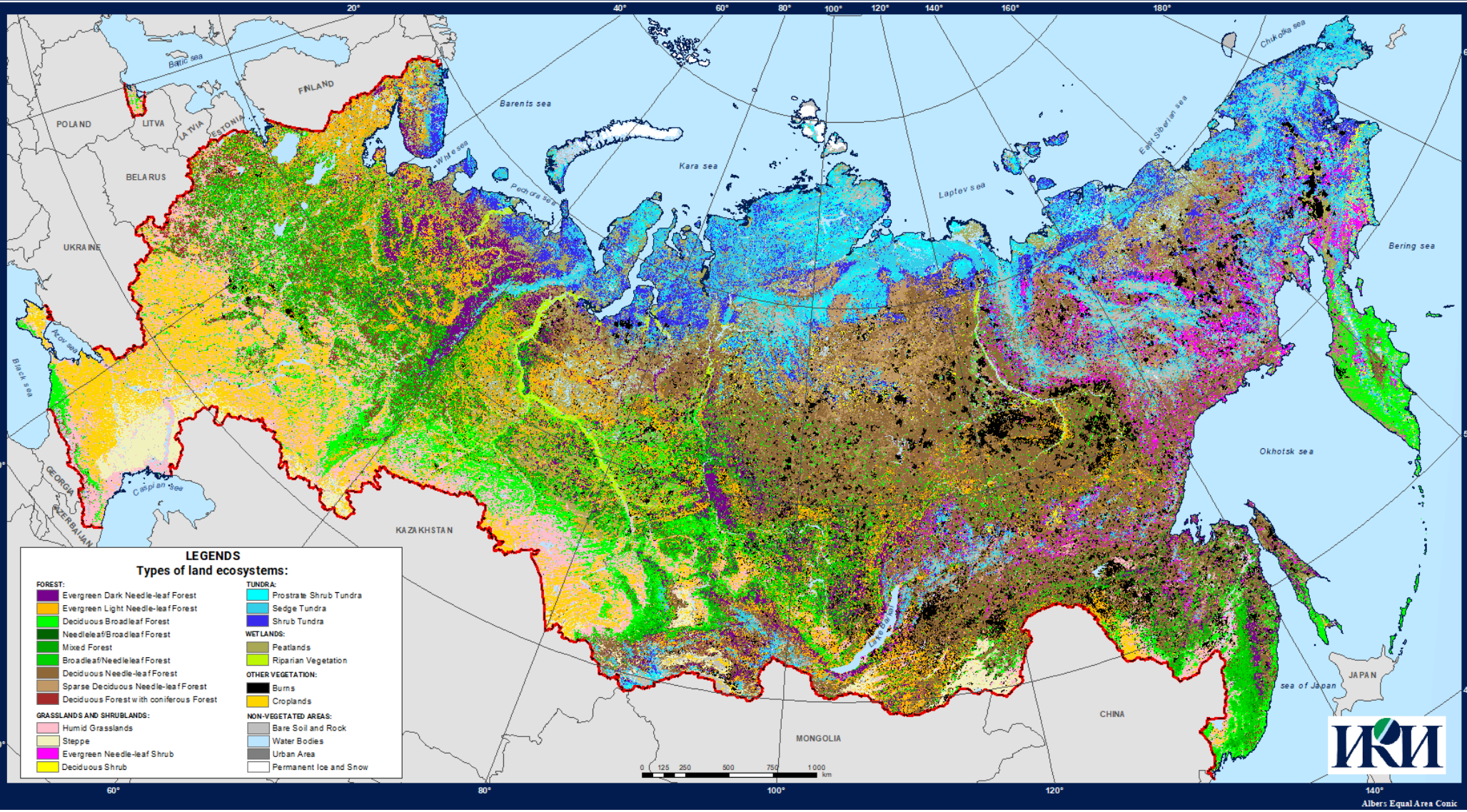
Maximum likelihood classifier

$f_i(\bar{x})$

Probabilities for classes



LAND COVER of RUSSIA



LEGENDS
Types of land ecosystems:

FOREST:
- Evergreen Dark Needle-leaf Forest
- Evergreen Light Needle-leaf Forest
- Deciduous Broadleaf Forest
- Needleleaf/Broadleaf Forest
- Mixed Forest
- Broadleaf/Needleleaf Forest
- Deciduous Needle-leaf Forest
- Sparse Deciduous Needle-leaf Forest
- Deciduous Forest with coniferous Forest

GRASSLANDS AND SHRUBLANDS:
- Humid Grasslands
- Steppe
- Evergreen Needle-leaf Shrub
- Deciduous Shrub

TUNDRA:
- Prostrate Shrub Tundra
- Sedge Tundra
- Shrub Tundra

WETLANDS:
- Peatlands
- Riparian Vegetation

OTHER VEGETATION:
- Burns
- Croplands

NON-VEGETATED AREAS:
- Bare Soil and Rock
- Water Bodies
- Urban Area
- Permanent Ice and Snow

ИКИ

Multi-year land cover dynamics

FOREST

Evergreen Dark Needle-leaf
Forest ecosystems consisting of spruce (picea), fir (abies) and siberian pine (pinus sibirica) for at least 80% of the forest canopy.

Evergreen Light Needle-leaf
Forest ecosystems consisting of pine (pinus sylvestris) for at least 80% of the forest canopy.

Broadleaf
Forest ecosystems consisting of birch (betula), aspen (populus tremula), oak (quercus), tilia, ash (fraxinus), maple (acer), elm (ulmus) for at least 80% of the forest canopy.

Mixed with Needle-leaf Majority
Forest ecosystems consisting of the needle-leaf species for 60% to 80% and the broadleaf species for 20% to 40% of the forest canopy.

Mixed
Proportions of the needle-leaf and the broadleaf species in the forest canopy are approximately equal (40% to 60%).

Mixed with Broadleaf Majority
Forest ecosystems consisting of the broadleaf species for 60% to 80% and the needle-leaf species for 20% to 40% of the forest canopy.

Deciduous Needle-leaf
Forest ecosystems consisting of larch (larix) for at least 80% of the forest canopy.

Sparse Deciduous Needle-leaf
Single trees of sparse tree canopy of larch (larix) having less than 20% density.

GRASSLANDS AND SHRUBLANDS

Humid Grasslands
Grasslands having vegetative season over 5 months long and sufficient humidification. The species composition consists mainly of perennial plant, particularly of cereals and sedges. Forest and shrub canopy area is less than 20%.

Steppe
Herbaceous canopy is mainly composed of drought-resistant perennial bunchgrass, including mat-grass, fescue, mugwort and others. There is also a diversity of steppe shrubs and subshrubs, with short-blooming ephemeral and ephemeroid plants.

Evergreen Needle-leaf Shrubs
Scrublands or low forest of mountain pine (pinus pumila).

Broadleaf Deciduous Shrubs
Scrublands or low forest of deciduous species, including dwarf birch (Betula nana), polar willow (Salix polaris) and others;

TUNDRA

Prostrate Shrub
Dry tundra with sparse vegetation consisting mainly of Alpine and Arctic dwarf-shrub species less than 15 cm high. Moss, lichen and forbs can also be found.

Sedge
Tundra consisting of various herbs and mosses vegetating on wet soil and making up continuous cover. Dwarf-shrubs up to 40 cm high can also be found.

Shrub
Shrubs including dwarf birch (betula nana), willow (salix) over 40 cm high, sometimes mixed with juniperus, высотой более 40 см, иногда с примесью можжевельника, ольхи или кедрового стланика.

WETLANDS

Peatlands
Overhumidified lands covered mainly with moss, lichen, reed and sedge. Sometimes sparse tree canopy (up to 20%) can be found.

Riparian Vegetation
Hydrophilic, periodically flooded herbaceous, shrub and forest vegetation along the coastlines.

OTHER VEGETATION

Recent Burns
Tree cover or tundra seriously damaged by fire or dead.

Croplands
Arable lands regularly cultivated for at least 5 recent years.

NON-VEGETATED AREAS

Permanent Ice and Snow
Land covered by ice or snow for the whole year.

Bare Soil and Rock
Lands having total vegetation canopy less than 20%.

Water Bodies
Open water bodies including seas, lakes, reservoirs and rivers.

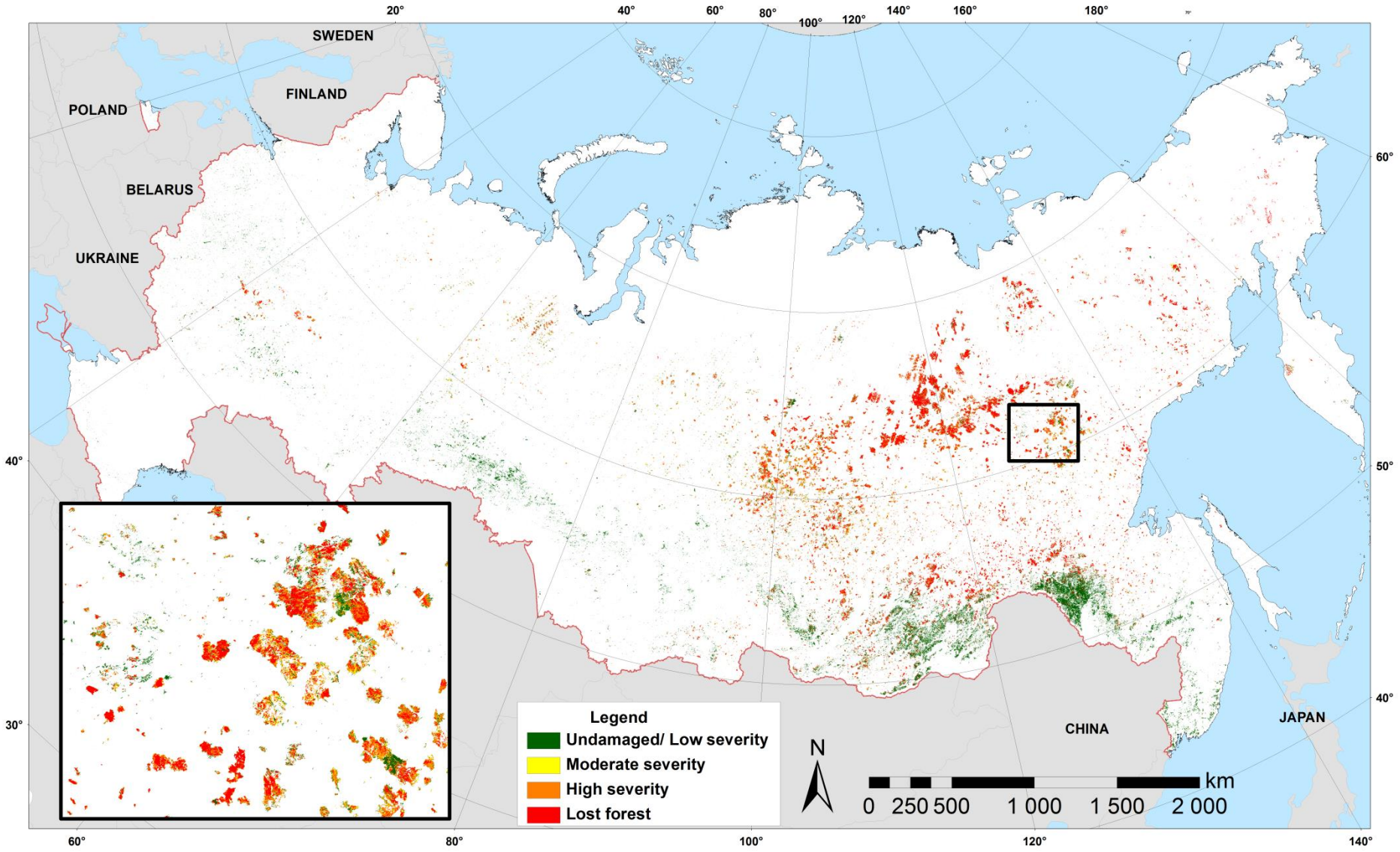
Urban Area
Populated areas, roads, industries and other anthropogenic objects.

Annual mapping of 23 land cover classes since the year 2000 based on 250 m MODIS data

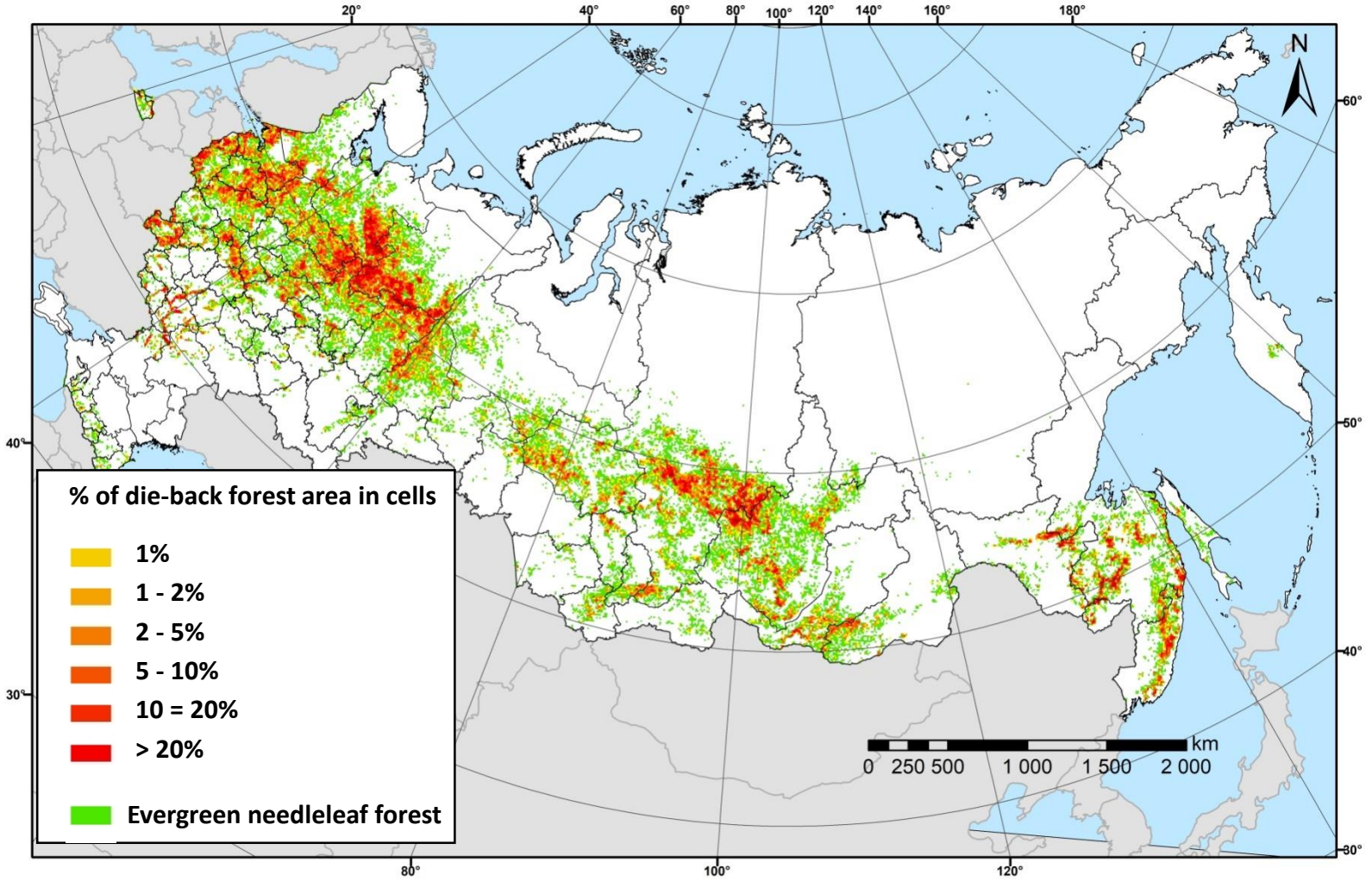
The forest cover is classified considering dominant tree species using seasonal time-series of MODIS data

Annual forest GSV retrieval based on MODIS data

Forest burn severity for years 2006-2019

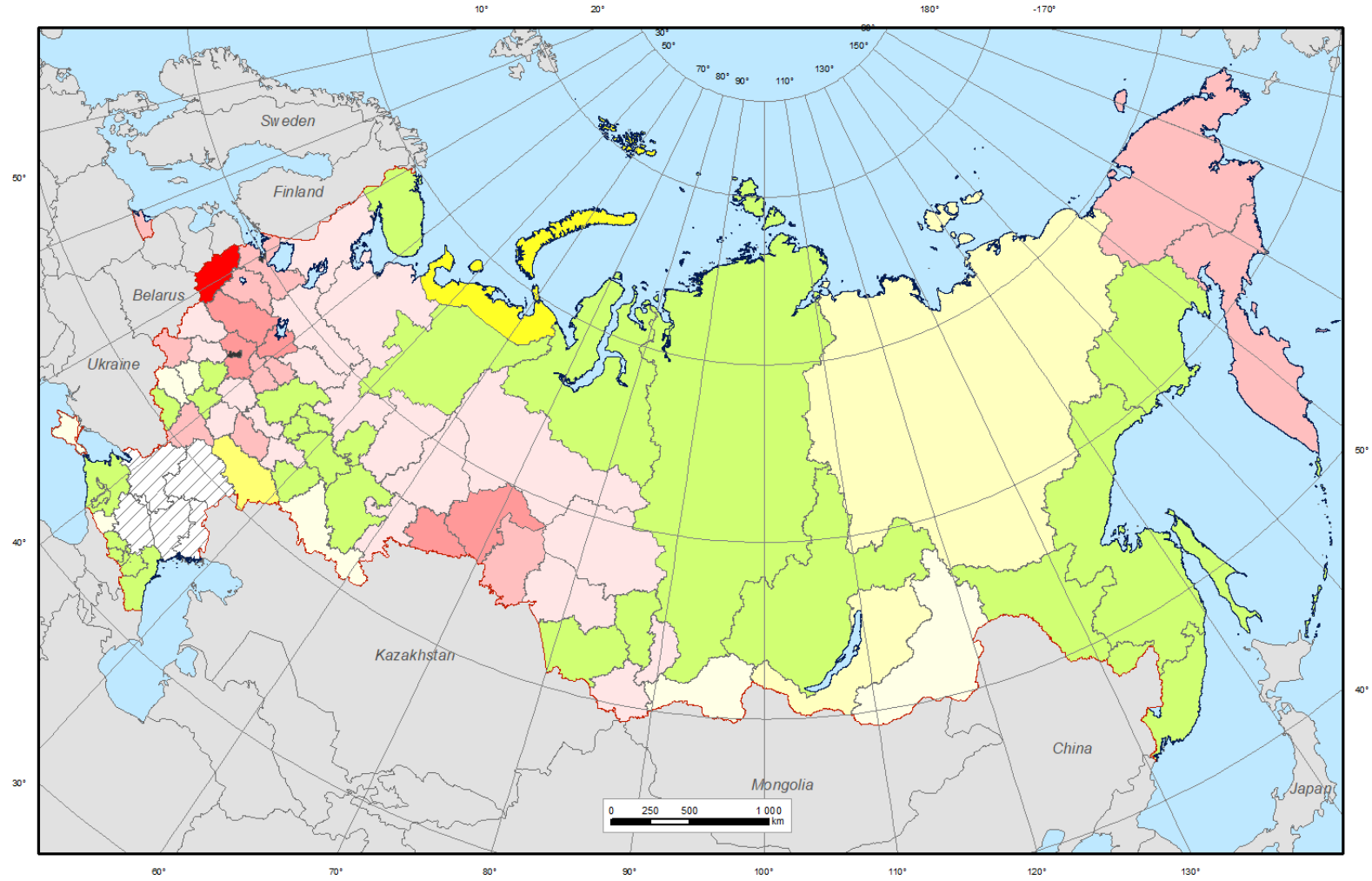


Non-fire caused die-back of evergreen needle-leaf forests



Evergreen needle-leaf forest area of non-fire induced die-back during years 2003-2017 is estimated at $5{,}54 \times 10^6$ ha

The relative difference of forested area according to RS data and official statistics



70-80%
60-70%
50-60%
40-50%
30-40%
20-30%
10-20%
±10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%

$S_{Rosstat} > S_{RSD}$

$S_{RSD} S_{Rosstat}$

Subjects of RF with less than 3% forest cover

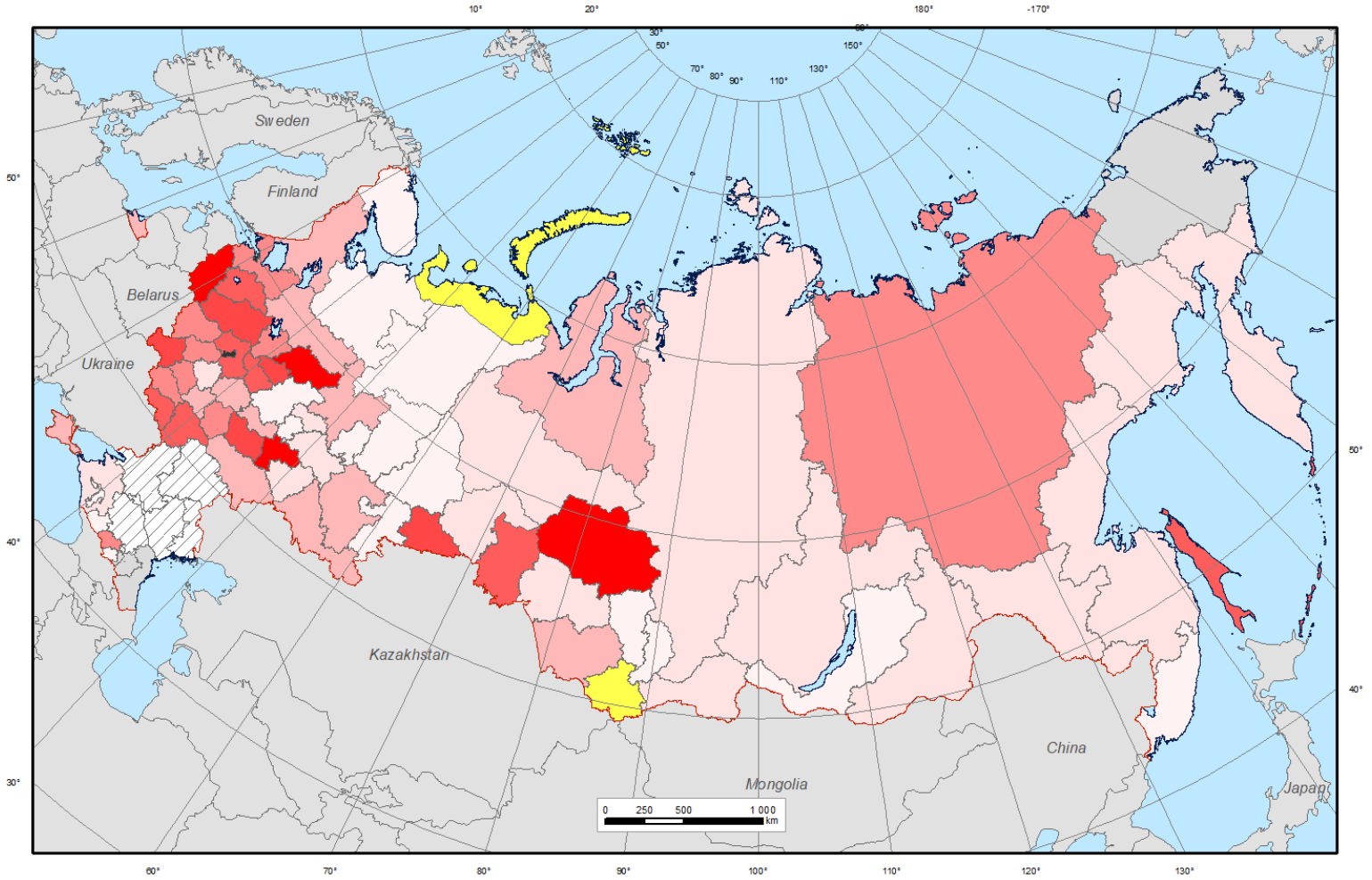
781,5 M ha

Forest area (RSD), 2017 г.

797,6 M ha

Forest area (Rosstat), 2017 г.

The difference of forested area outside forest fund according to RS data and official statistics



$S_{Rosstat} > S_{RSD}$

<2 times

$S_{RSD} > S_{Rosstat}$

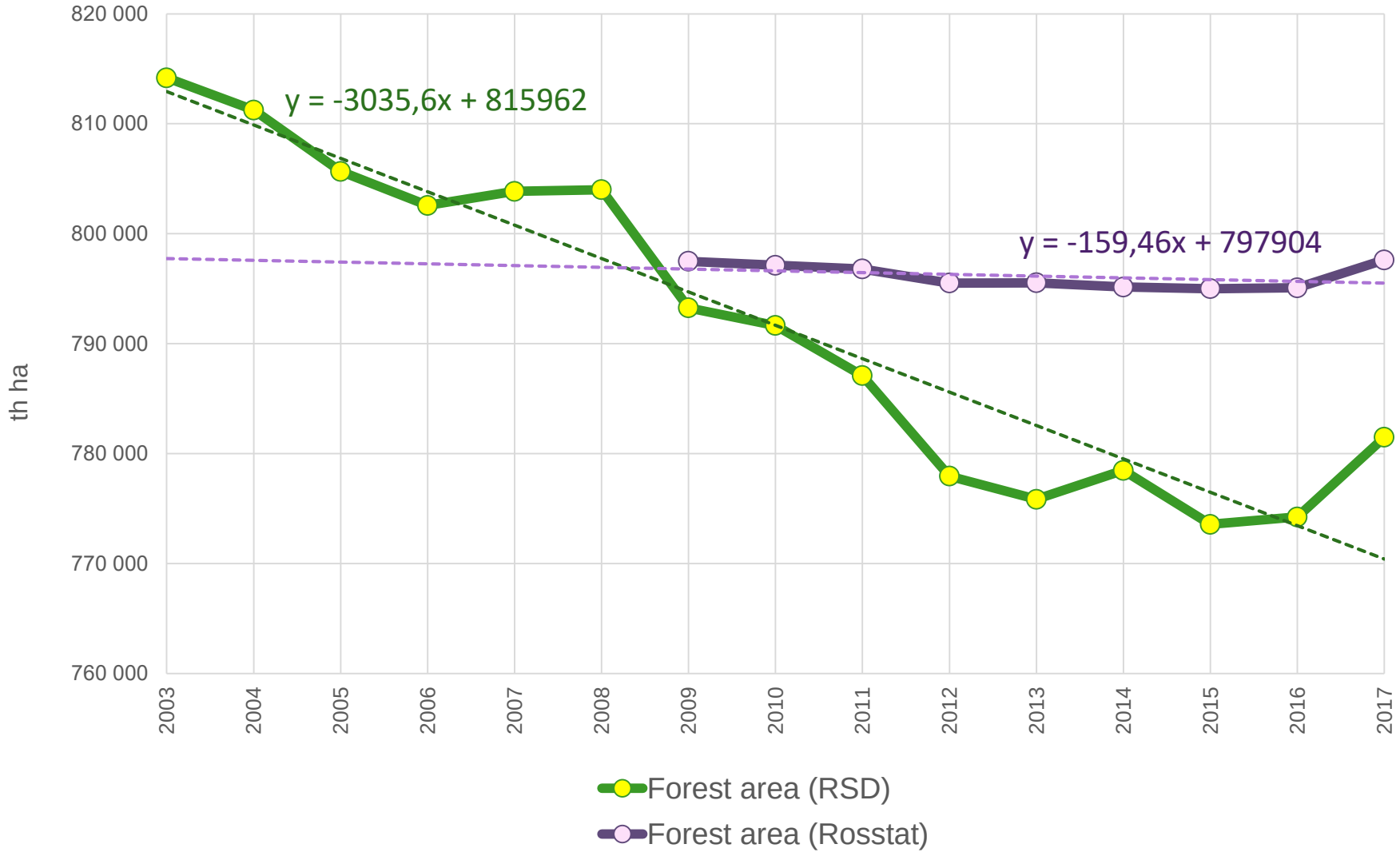
<2 times
2-3
3-5
5-10
10-20
20-30

By Rosstat data there are no forest area outside Forest Fund

Subjects of RF with less than 3% forest cover

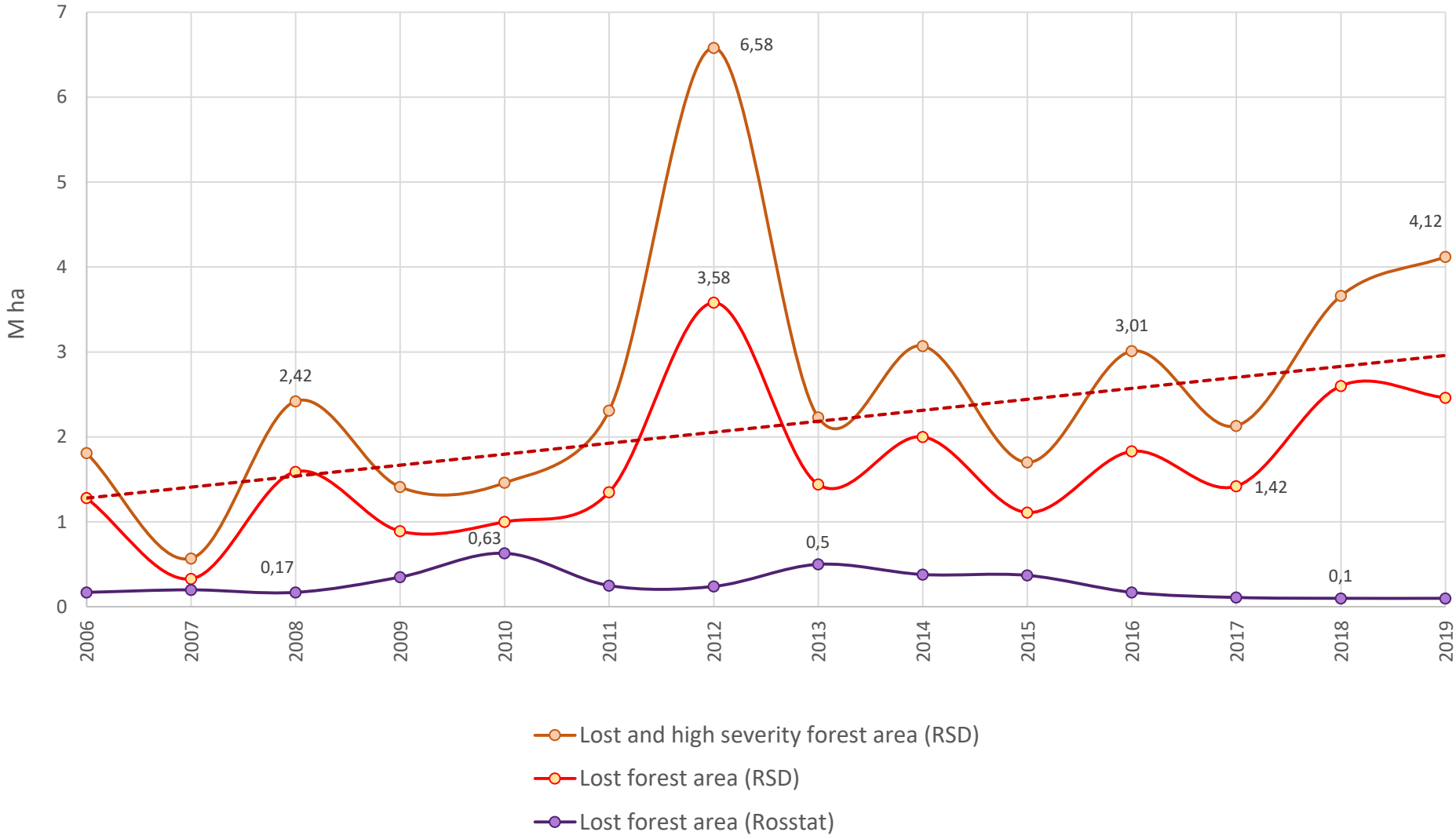
2017 г.	Remote sensing data	Rosstat data	Difference between Rosstat and RSD
Forest area, th ha	781 488,41	797 625,80	**16 137,39**
Forest area inside Forest Fund, th ha	719 873,88	770 172,60	**50 298,72**
Forest area outside Forest Fund, th ha	61 614,53	27 453,20	**-34 161,33**

Russian Forests Area Dynamics

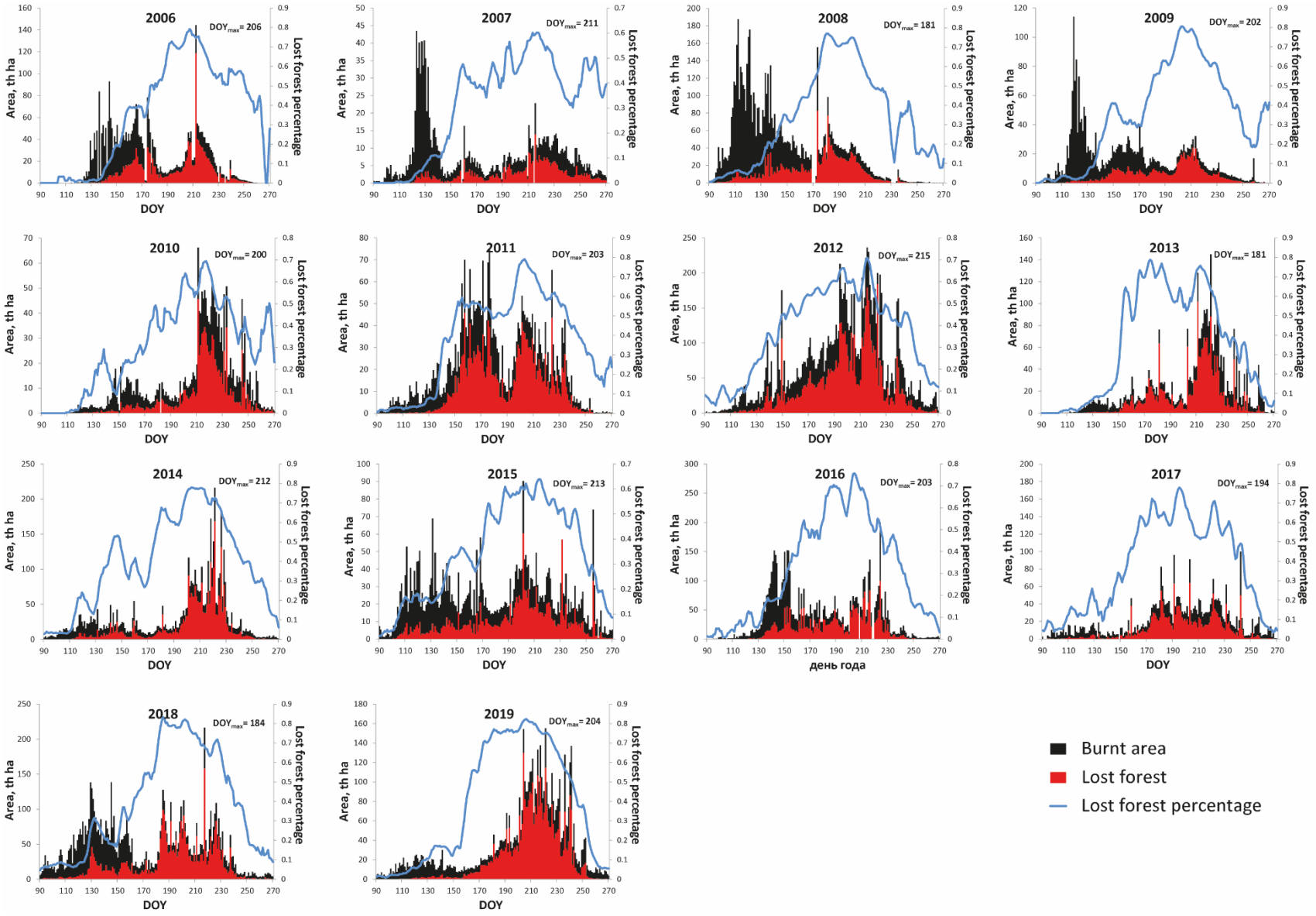


According to remote sensing data forest area reduced by ~3 M ha annually

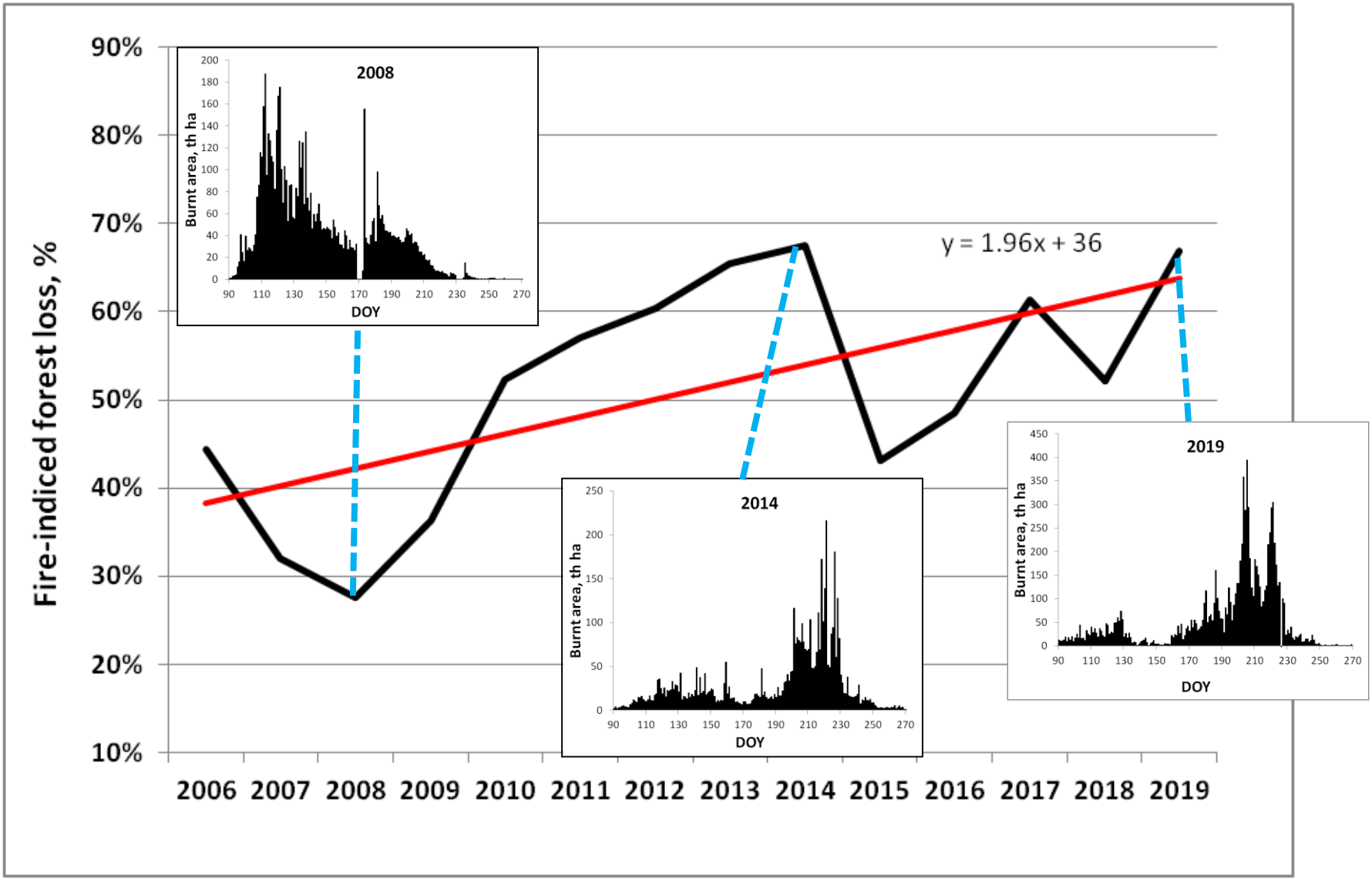
The fire-induced forest die-back area in Russia as estimated by RS data vs official statistics



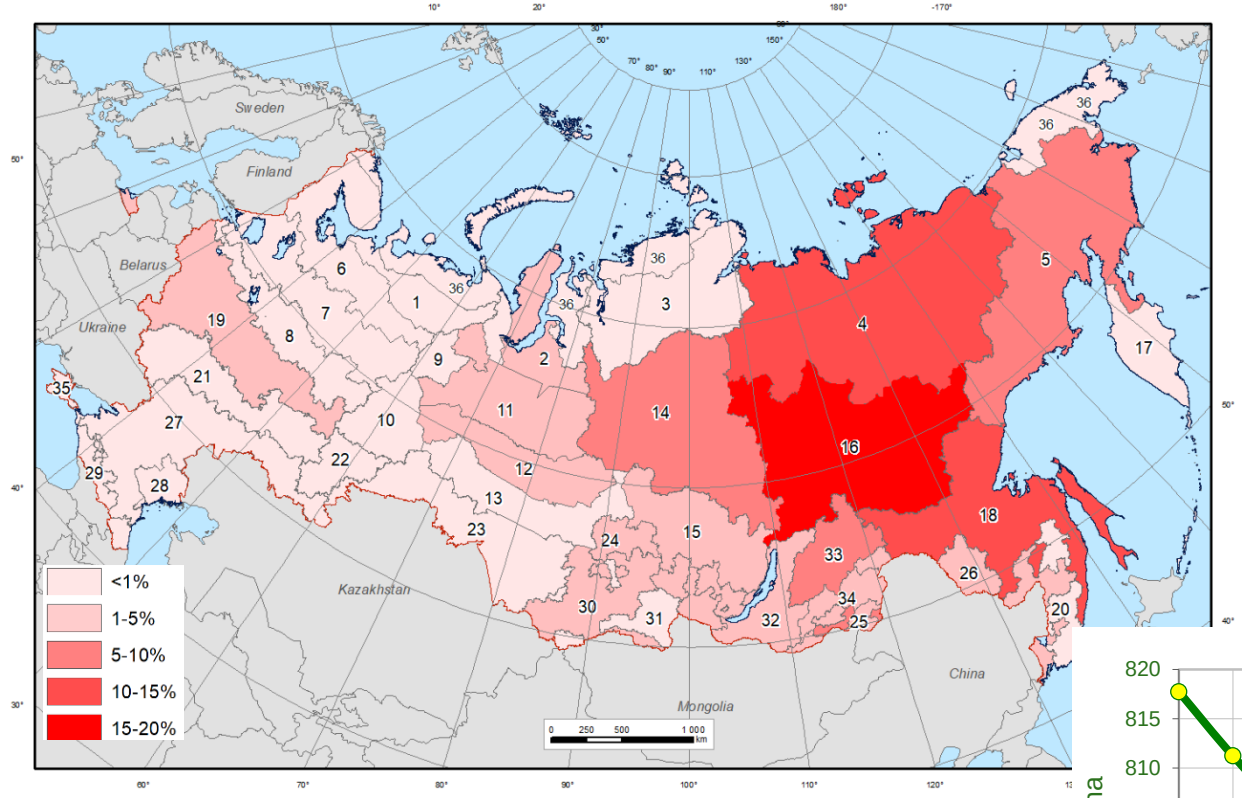
Seasonal distribution of forest burnt and die-back area in Russia



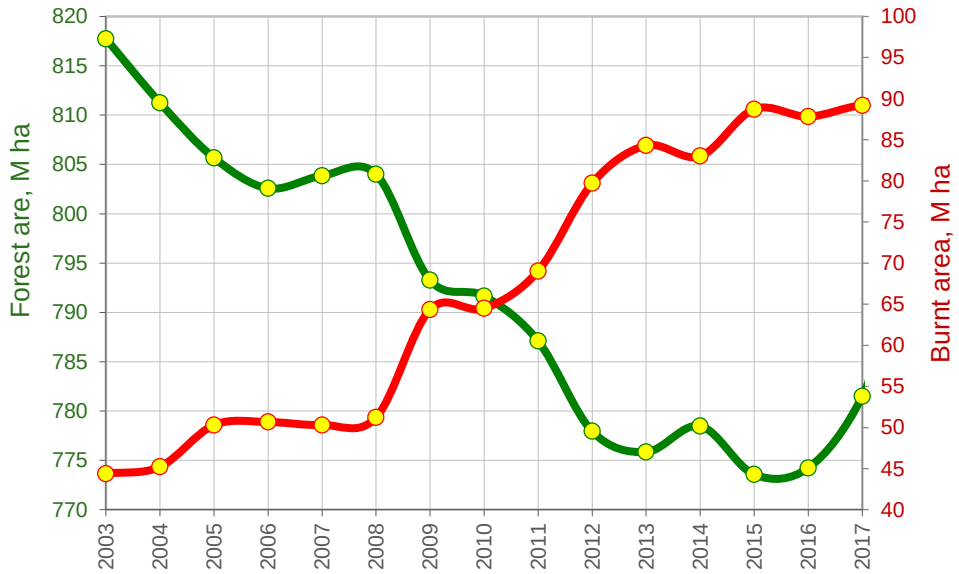
Fire Induced Forest Loss



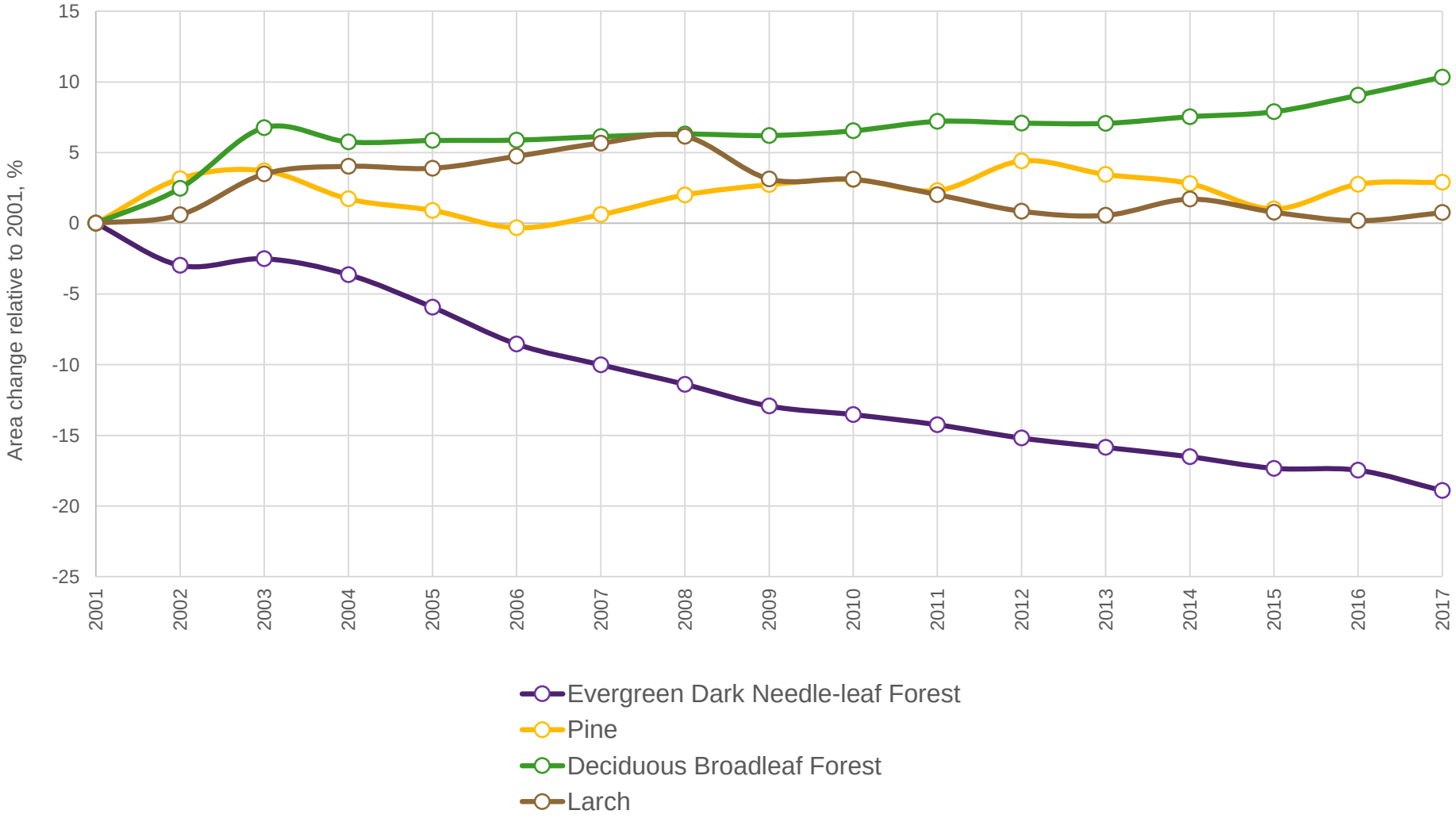
The unforested burnt area in Russia by year 2017



The unforested burnt area accumulated by year 2017 was estimated at about **89,1 M ha**

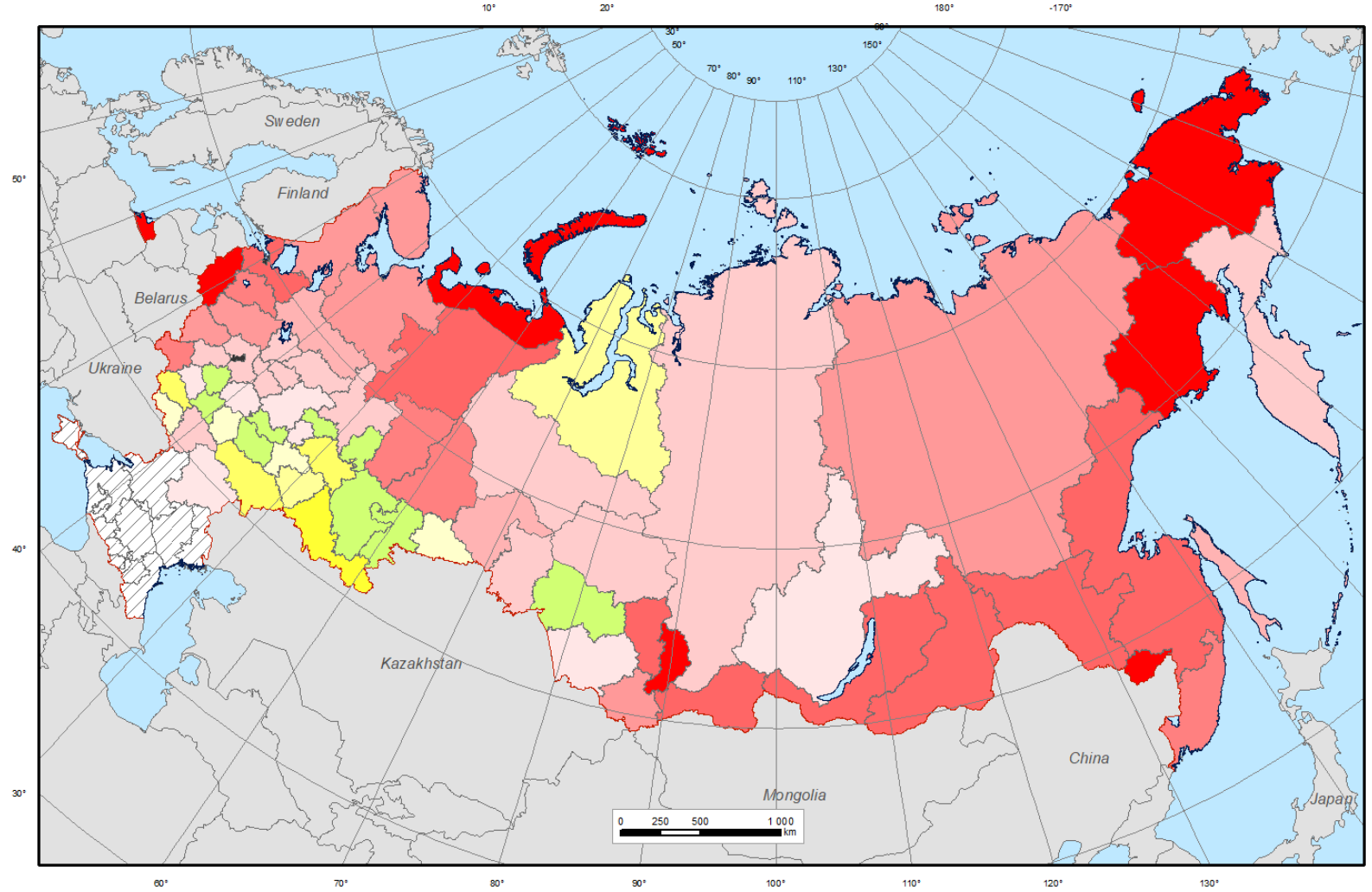


The forest tree species structure change in Russia



Growing Stock Volume of Russian Forests

The relative difference of the total forest GSV estimates based on RS and Rosstat data



40-50%
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±10%
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30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
>100%

$GSV_{Rosstat} > GSV_{RSD}$

$GSV_{RSD} > GSV_{Rosstat}$

Invaluable subjects

116 B m³

Growing stock volume in Russian forests (RSD), 2017 г.

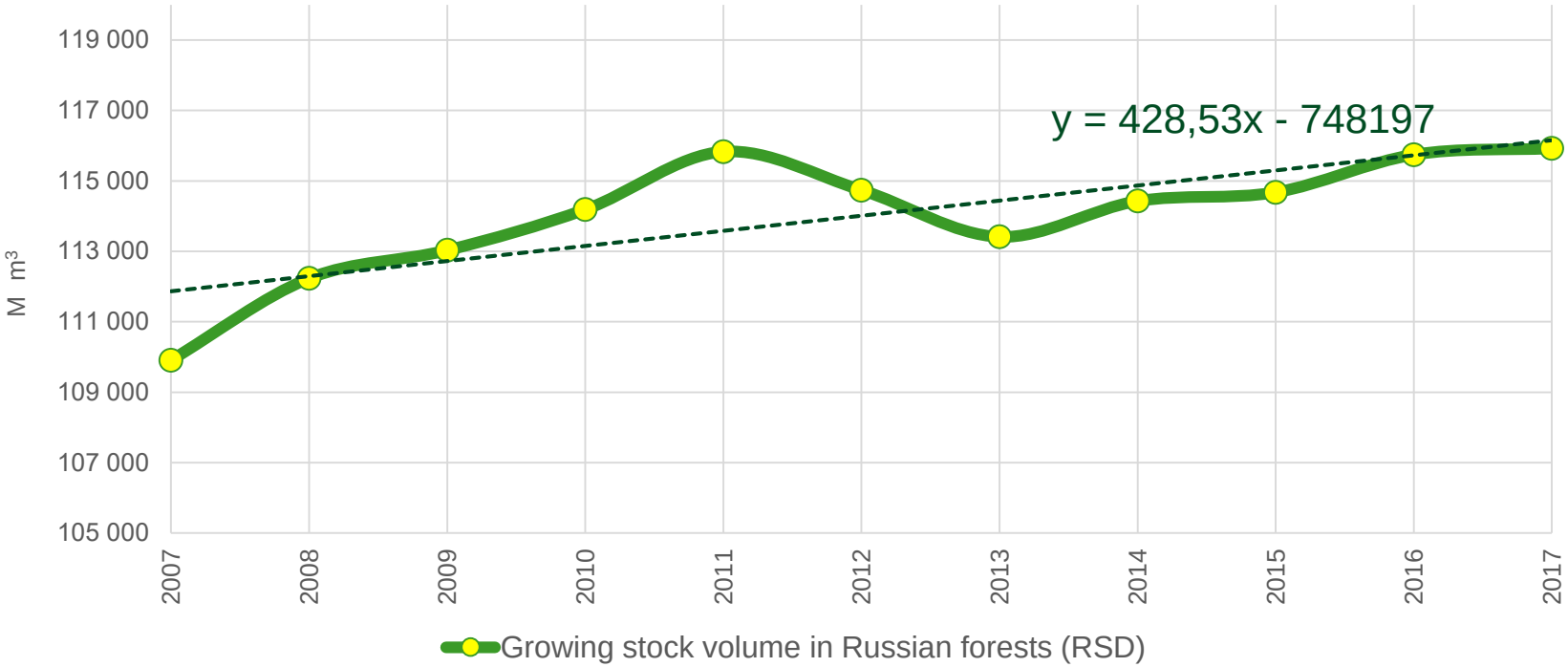
83 B m³

Growing stock volume in Russian forests (Rosstat), 2017 г.

The RS data based estimates include dead wood in the forested area

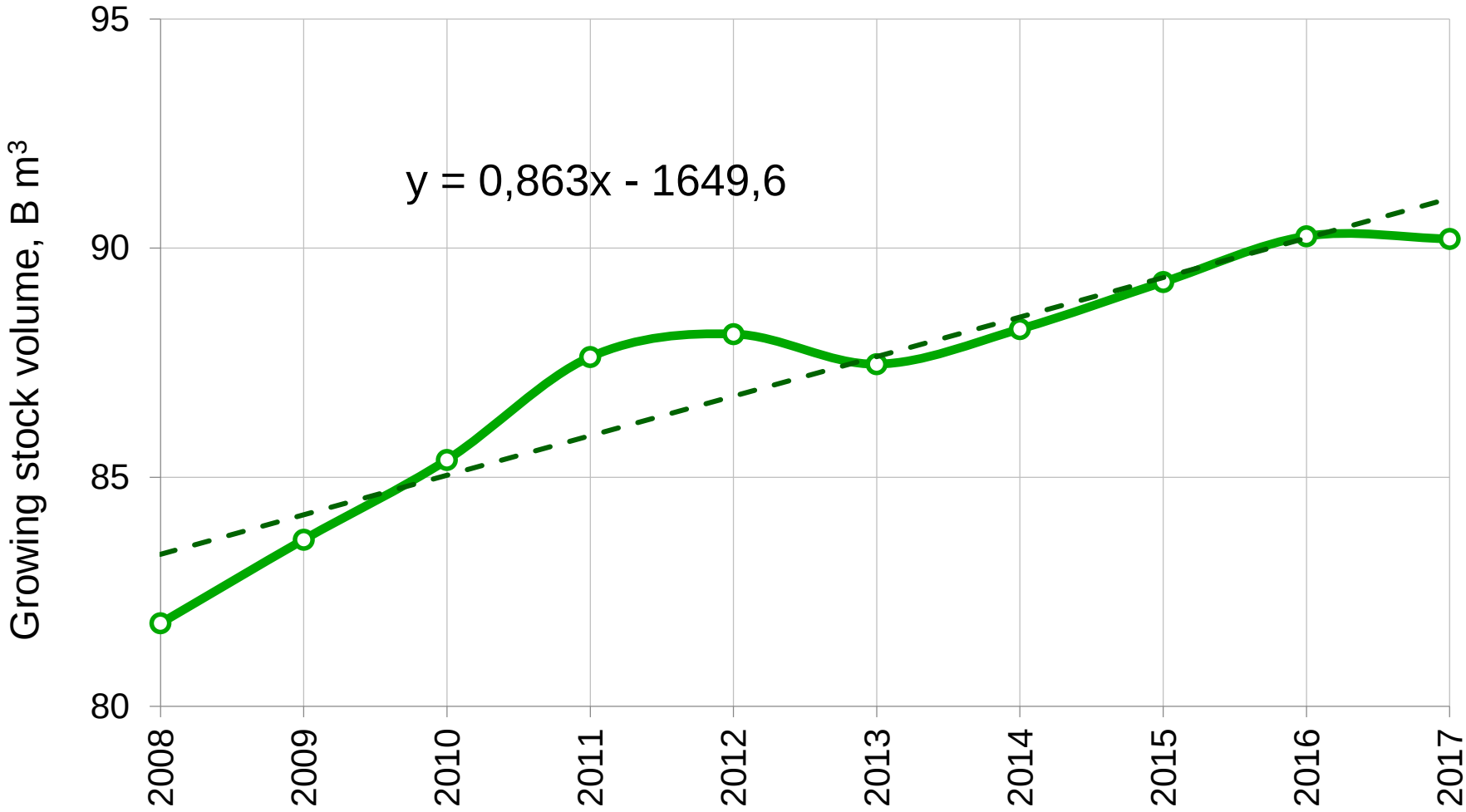
The total GSV dynamics in Russian forets according to RS and Rosstat data

The estimates include dead wood in the forested area



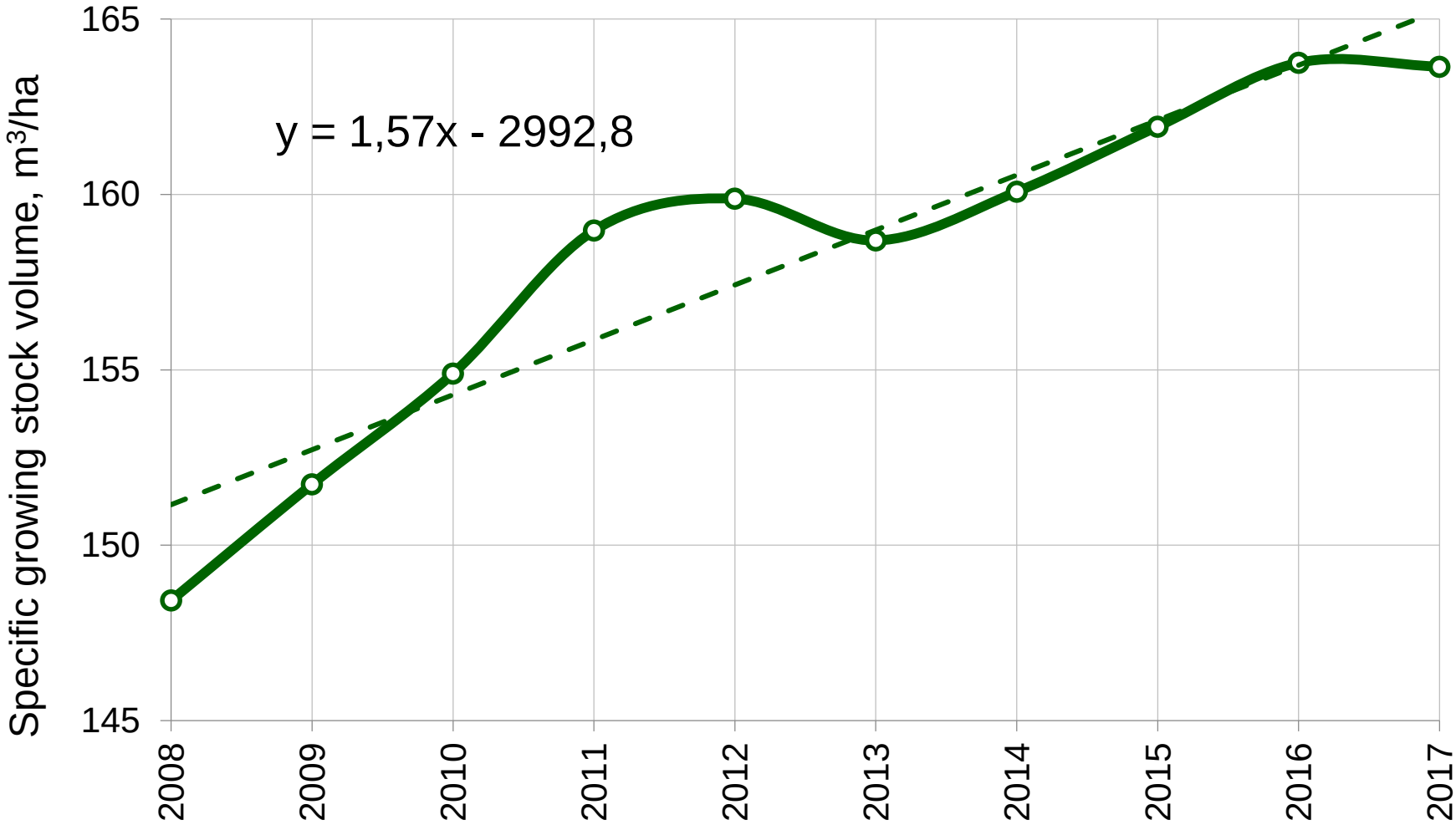
The total GSV dynamics in Russian forests excluding area of changes due to stand replacing disturbances

The estimates include dead wood in the forested area



The GSV dynamics in Russian forests excluding area of changes due to stand replacing disturbances

The estimates include dead wood in the forested area



Thank you for your attention !

This research study was supported by the Russian Science Foundation [grant number 19-77-30015].