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Sustainability of the Northern Eurasia Forest Sector in a Changing World: Ecological, Economic and Social Challenges

(two examples of the inevitability of holistic multi- and interdisciplinary approach)

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Transition to Sustainable, Adaptive and Resilient to Disturbances Forest Management (SFM) – a Basic Paradigm of Co-Evolution of Humanity and Forests

Three pillars of SFM

- Necessity of knowledge of the full set of values of forests – ecosystem functions and services supplied by forests
- Continuously maintaining these values in a reasonable range
- Comprehensive support of the processes of the continuous process of obtaining new knowledge and training of specialists, so that this knowledge is immdediately used in forest management practice: this predetermines new requirements for information about forests – a need of integrated information systems

Three major challenges of SFM

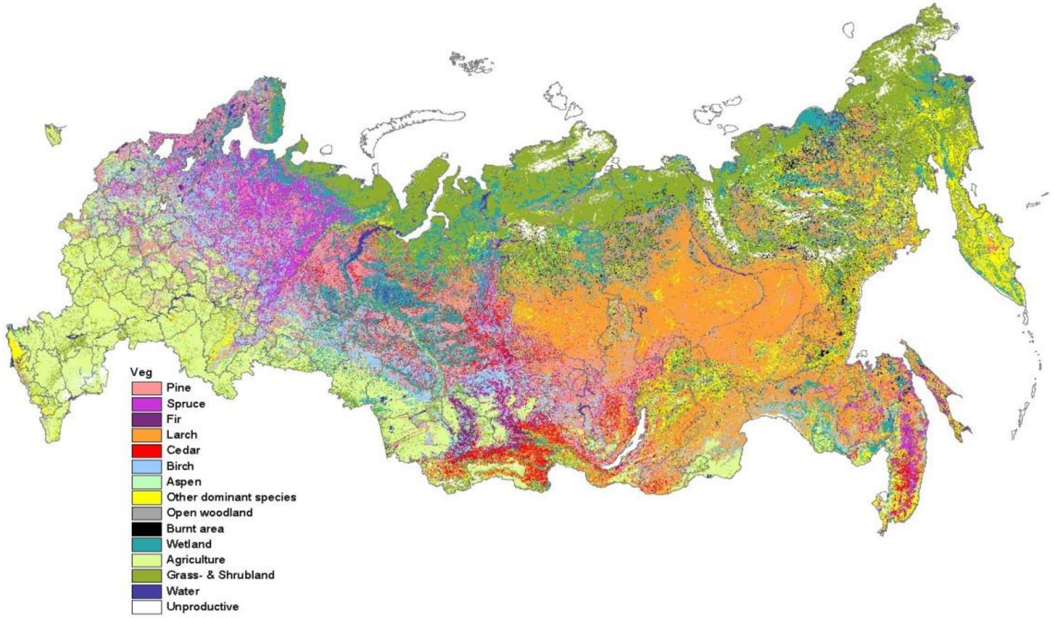
- Making decisions in the face of significant uncertainty in forecasts for situations that have not been observed in the past
- The need for new mentality of all stakeholders
- The need of new methods of understanding: a holistic multi- and interdisciplinary approach. It means the complicated way to understanding "full complexity problems", planning adaptation and mitigation strategies for ill-defined and quasi-manageable tasks etc. etc.

Example 1
Information within the systems approach - What do we know about Russian forests

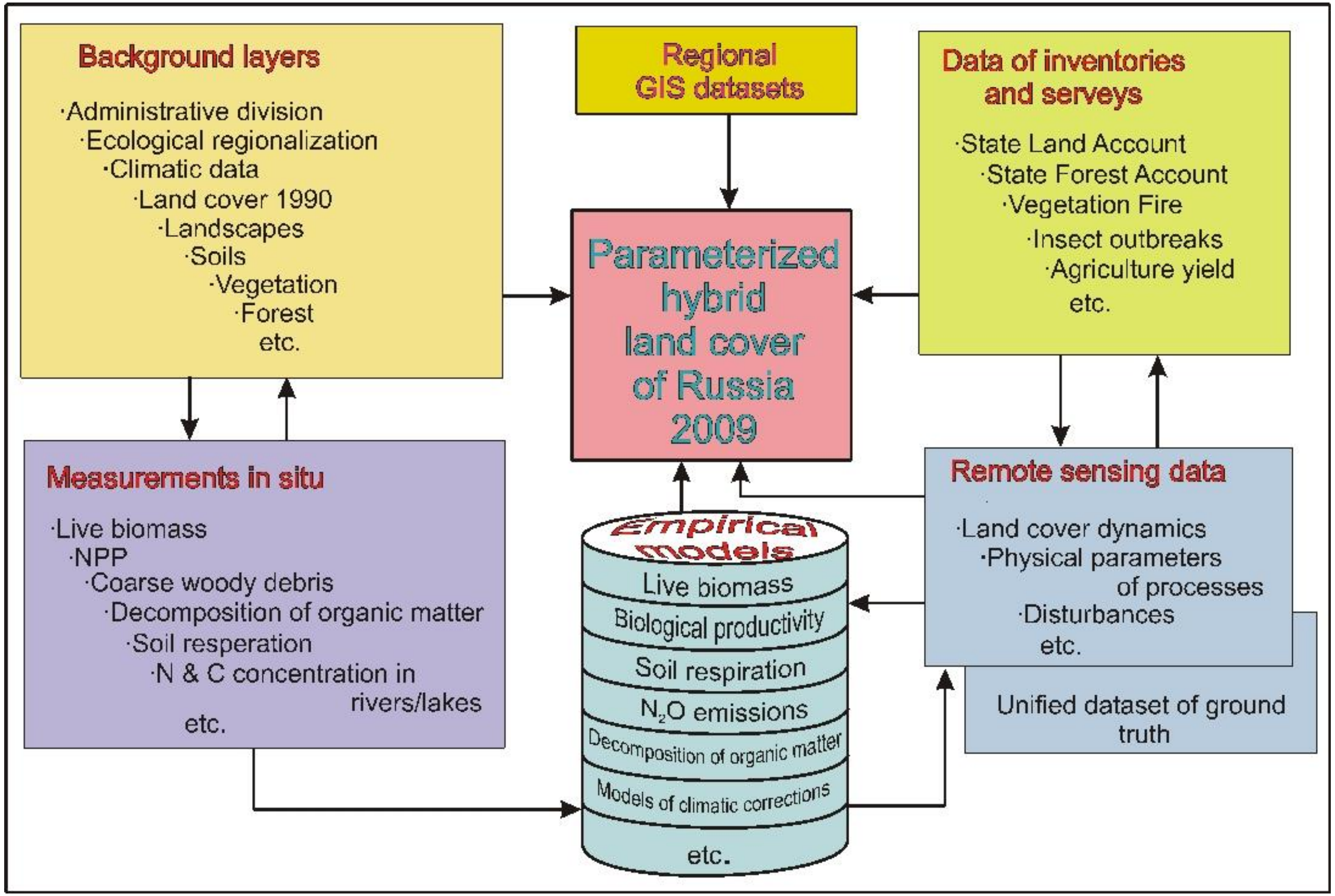
… more than 20% of the global forests but the area and growing stock according

	Area (mln ha)	Growing stock volume (bln m3)
FRA 2020	771	80
State Forest Register (2015)	790	83
National Forest Inventory	na	102
Remote sensing estimates	740-790	100-115

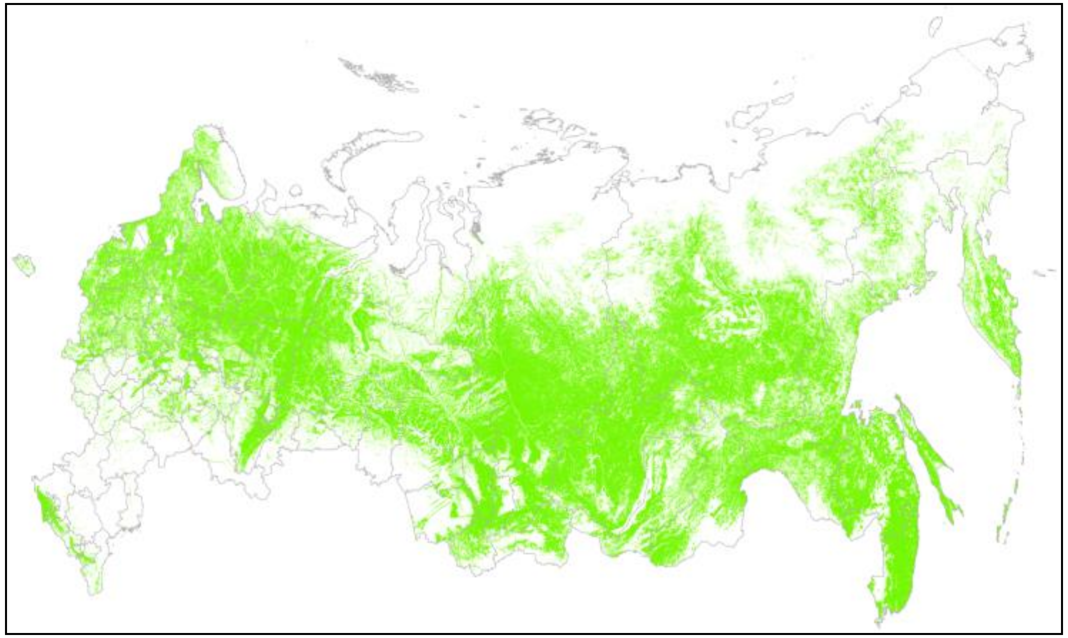
… harvested wood (2018)	218 mln m3
… +illegal harvest (NGO)	+20-30 %%
… forest fire (official data avr. 2001-2019)	2.1 mln ha
… forest fire Space Research Institute	4.5 mln ha
… dead forest official (2006-2018)	0.19 mln ha
… dead forests RS (2006-2018)	2.1-2.5 mln ha



Integral Land Information System of Russia (ILIS)



Hybrid land cover: forest mask



Forest area of Russia in is estimated at (M ha)	2015
Total	757.0
Incl. on abond. agr. land	18.2

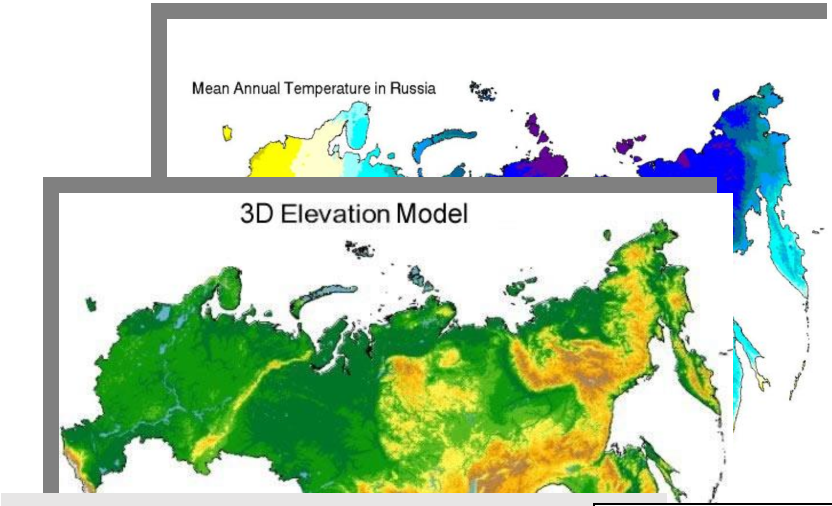
Satellite estimate of forested areas managed by SFA is at 45 M ha less than data of the State Forest Registry

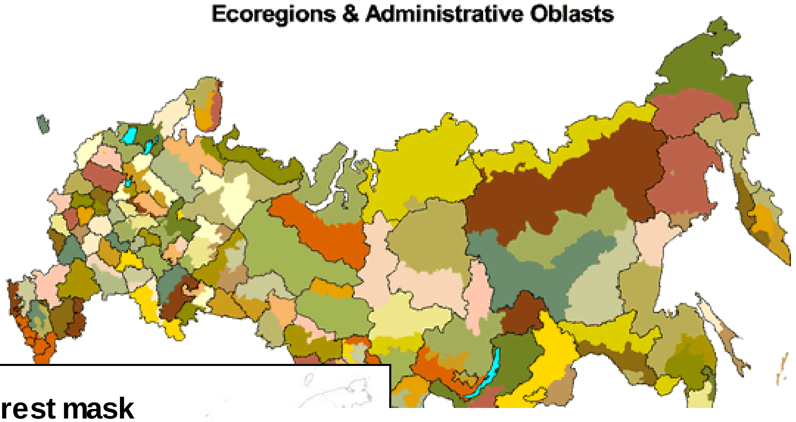
European part	+8%
Asian part	-7%

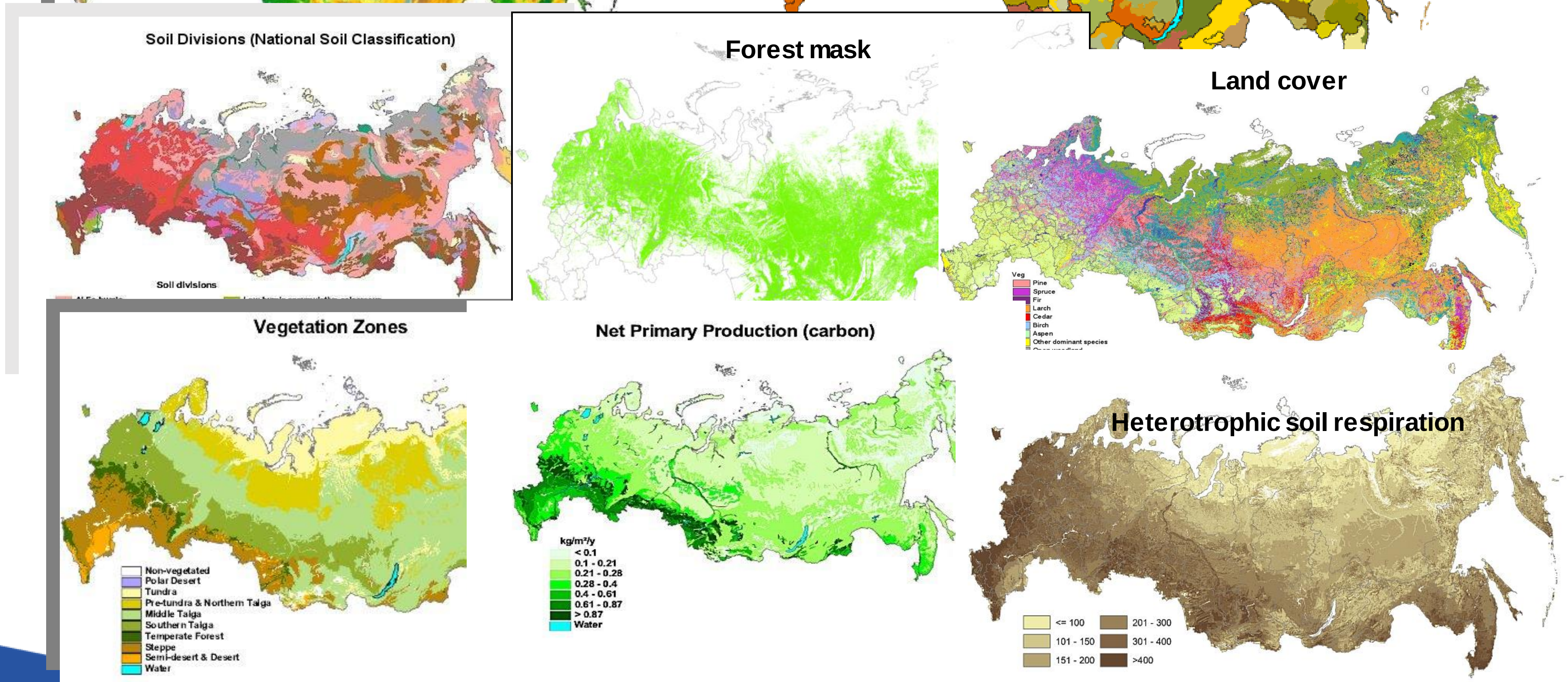
The input RS products include land covers of 12 RS products: GLC2000, 1km, GlobCover 2009, 300m, MODIS land cover 2010, 500m; Landsat based forest masks: by Sexton 2000, 30m and by Hansen 2010, 30m; MODIS Vegetation Continuous Fields 2010, 230m; FAO World's forest 2010, 250m; Radar based datasets: PALSAR forest mask 2010, 50m, ASAR growing stock 2010, 1km. All datasets were converted to 230m resolution.

Source: Schepaschenko et al. 2015

Integrated Land Information System (2009) - examples

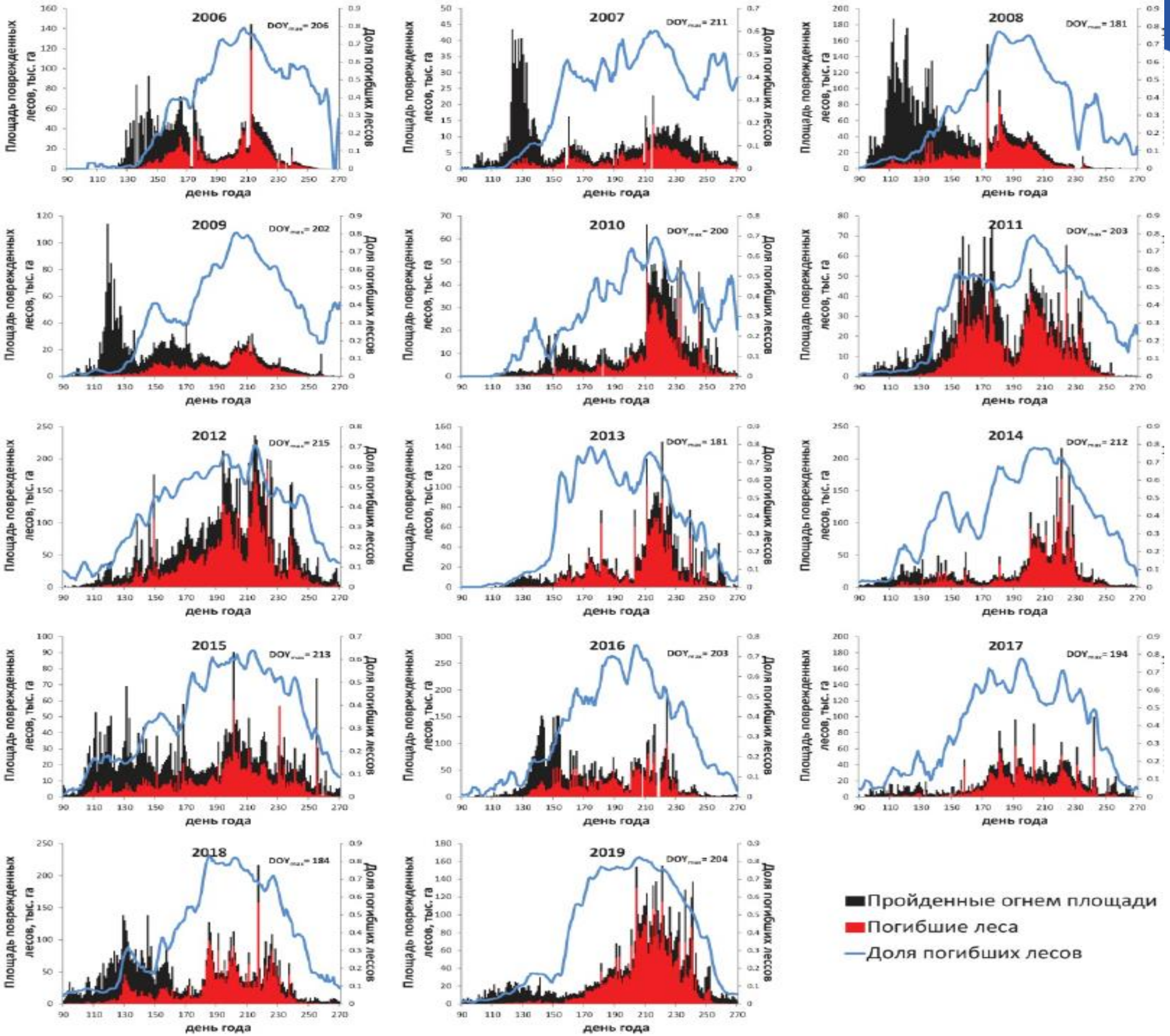






Forest fires in Russia in 2006-2019: area and mortality

Source:
Bartalev, Stezenko 2020 (in press)



Example 2.

Understanding of ecosystem services – Full and verified carbon account

Terrestrial Biota Full Carbon Account (FCA) is a dynamic complicated open stochastic fuzzy system, with some features of a full complexity and wicked problems

Any individually used method of FCA is not able recognize structural uncertainty in a comprehensive way

Major principle: integration, harmonizing and multiple constraints of independent methods and results

Landscape-ecosystem approach
Process-based models
Eddy covariance
Multi-sensor concept of RS
Inverse modelling

Major prerequisites

- Carbon account should be full and verified. It should present unbiased results (NECB, NBP, …) with known uncertainties in explicit spatial and temporal way.
- The carbon account is an underspecified (fuzzy) system. Any individually used method of carbon account is not able to assess structural uncertainty. It defines a necessity to integrate different methods of carbon cycling study.
- The specifics of the account require integrated information background which is realized in form of Integrated Land Information System including Hybrid Land Cover and corresponding DBs.
- Landscape-ecosystem method (= integration of relevant "inventory" approaches) serves for designing systems structure of the account. Other methods are used for mutual constrains of intermediate and final results and their uncertainties.

Two background approaches to FCA

The FCA is presented as a relevant combination of a pool-based approach

$$dC/dt = dPh/dt + dD/dt + dSOC/dt,$$

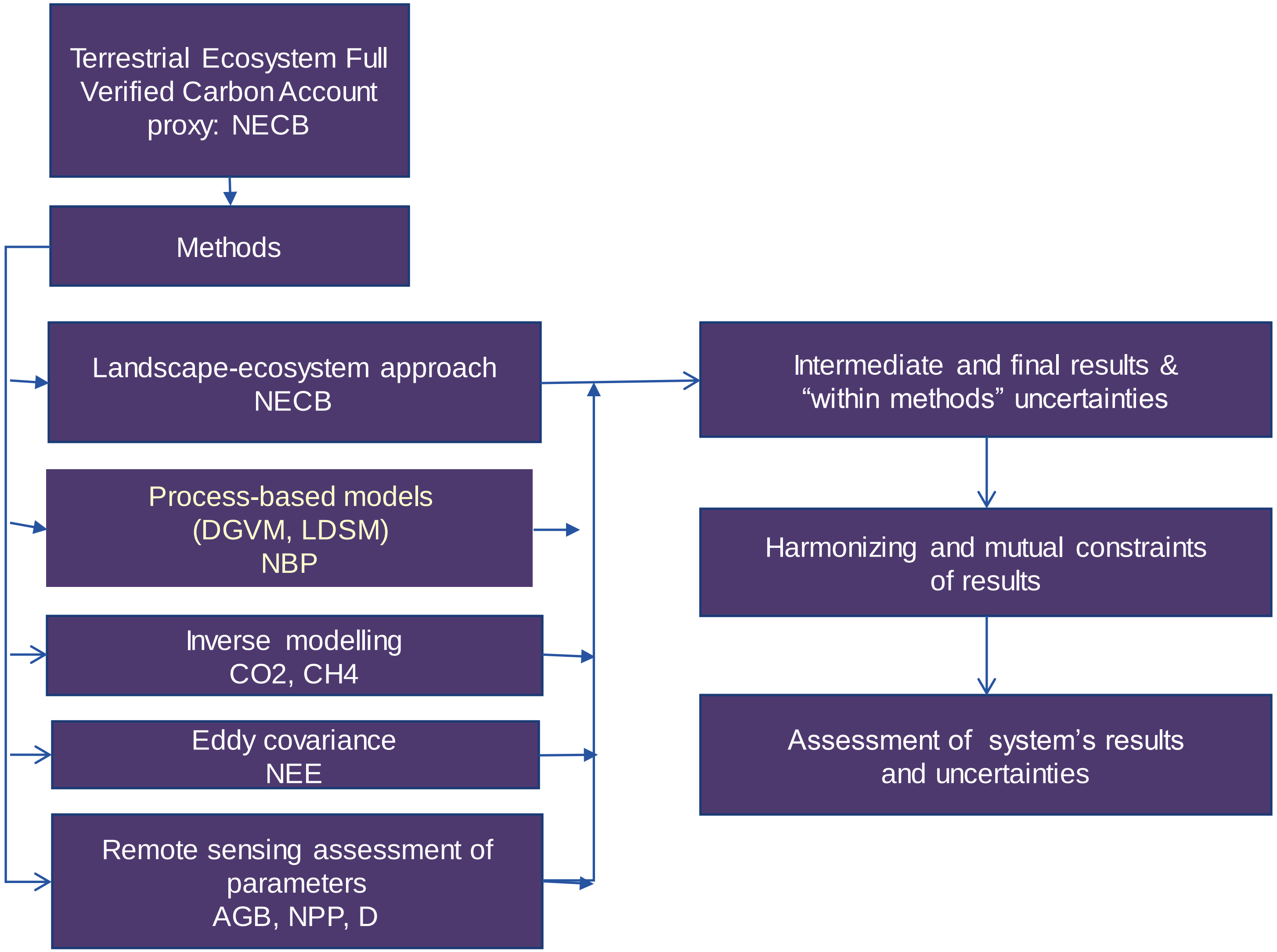
where Ph, D and SOC are pools of live biomss, dead organic matter and soil organic matter,

and a flux-based approach

$$NECB = NPP – HR- ANT – FHYD - FLIT,$$

where NBP and NPP are net biome and net primary production, HR – heterotrophic respiration, ANT – flux caused by disturbances and consumption, FHYD and FLIT- fluxes to hydrosphere and lithosphere, respectively

Structure of full and verified carbon account



Assessment of uncertainties of FCA

- For LEA at each stage - standard error of functional *Y = f (xi)* where variables *xi* are known with standard errors *mxi*

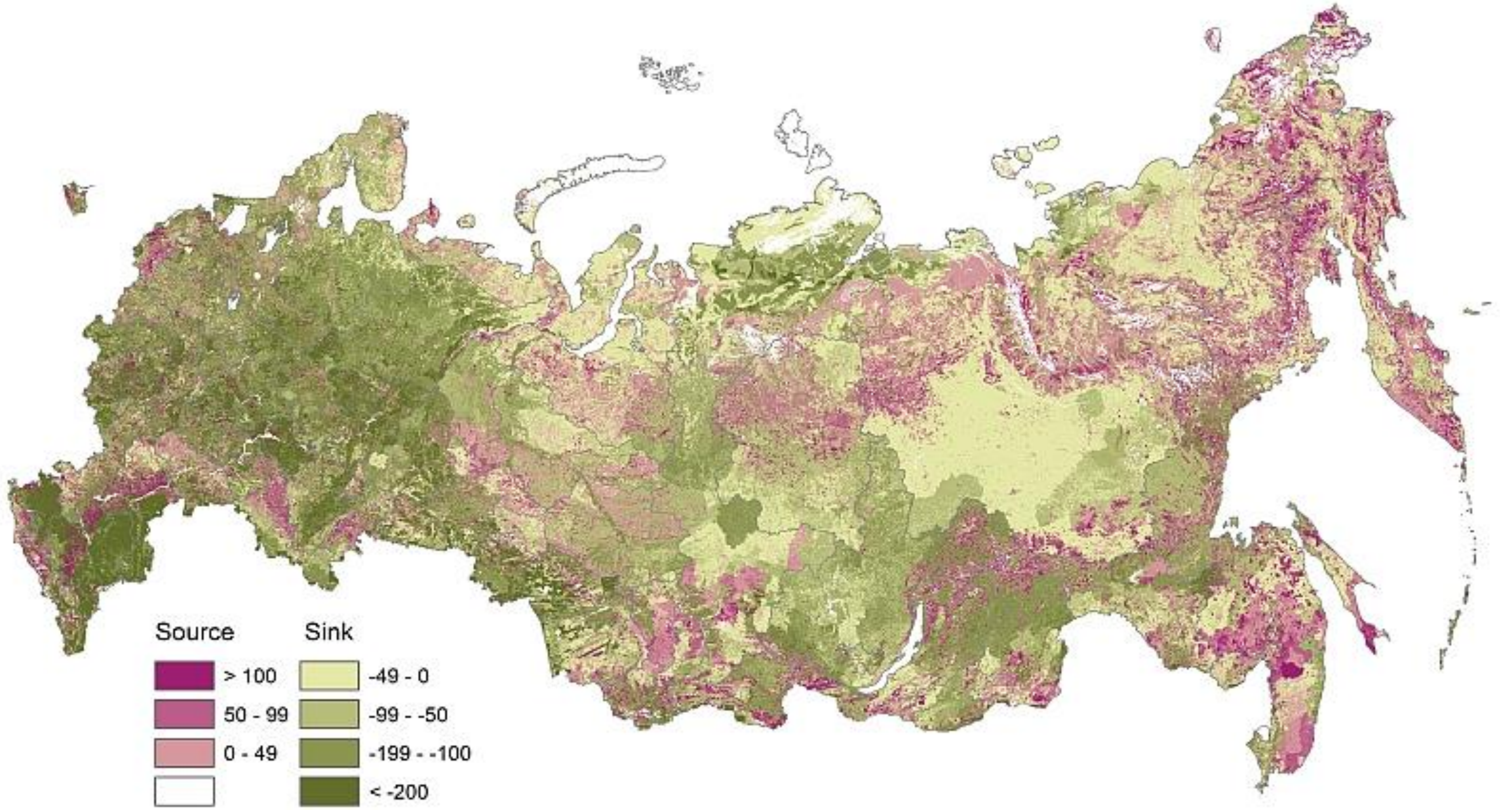
$$m_y = \sum_i \left(\frac{\partial y}{\partial x_i} m_{xi}\right)^2 + 2r_{ij} \sum_{ij} \left(\frac{\partial y}{\partial x_i}\right)\left(\frac{\partial y}{\partial x_j}\right) m_{xi} m_{xj}$$

- *For ensembles of models (inverse modeling, DGVMs) – standard deviation between models is used*
- *For multiple constraints – the Bayesian approach, i.e.*

$$NBP_{Bayes} = \sum_i \frac{NBP_i}{V_i} / \sum_i \frac{1}{V_i}$$

where NBPi is assumed to be unbiased and Gaussian-distributed with variance Vi, i =1, …, n

Full and verified carbon account of Russian terrestrial ecosystems (g C m^{-2} yr^{-1})



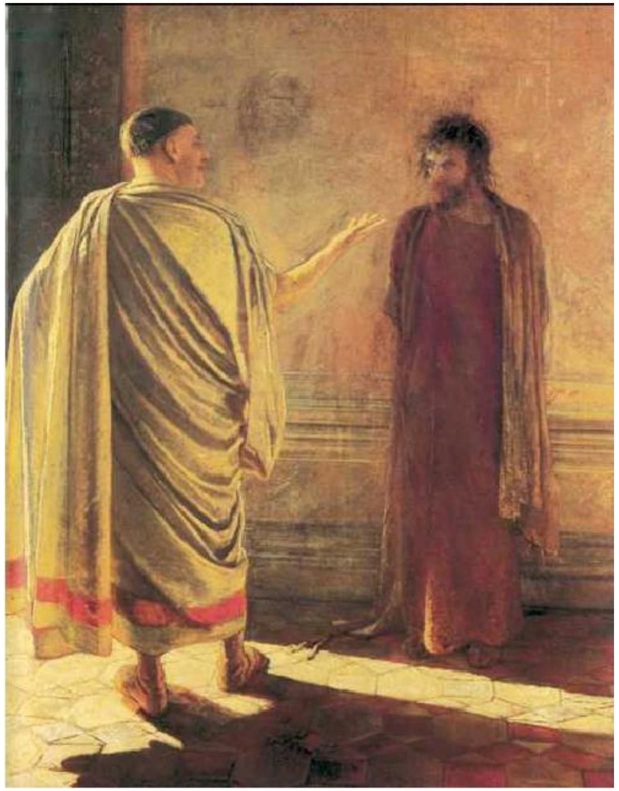
According to IIASA, carbon stock in Russian terrestrial ecosystems was estimated in 2000-2015 at 550-750 Tg C/yr of which 90+ percent is provided by the forest

Source: Shvidenko, Schepaschenko 2014

Current estimates of the FCA of Russian forests: from 150-800+ Tg C / yr

- direct use of official forest inventory data: carbon sink of 400-650 Tg C yr^{-1} (Moiseev, Filipchuk 2012; Filipchuk et al. 2017); 800 Tg C yr^{-1} (Kudejarov et al. 2008); 560±120 Tg C yr^{-1} (Pan et al. 2011); 500-650 (State Report… 2015)
- direct use of official forest inventory data in national communications to IPCC: 150-200 Tg C/yr in 2000-2015 for managed land of the Russian Federation
- aggregation of inventory based estimates: sink of 791 Tg C yr^{-1} and aggregation of flux-based estimates – the sink of 709 Tg C yr^{-1} (Sitch et al. 2015)
- inversions: sink of 580 Tg C yr^{-1} (Gurney et al. 2003); Ciais et al 2010 - 600-700 Tg C yr^{-1}; aggregation of inversions 653 Tg C yr^{-1} (Sitch et al. 2015); results from GOSAT 721±152 Tg C yr^{-1} (Shvidenko, Schepaschenko 2014)
- regional applications of Dynamic Global Vegetation Models: the sink of around 200 Tg C yr^{-1} (Cramer et all. 1999; Dolman et al. 2012), analysis based on 17 DGVMs of the 1st generation resulted at 197 Tg C yr^{-1} (Sitch et al. 2015)
- IIASA system approach: sink in 2000-2012 at 690±246 C yr^{-1} (Dolman et al. 2012); in 2007-2009 (forest) 546±120 Tg C yr^{-1} (forest, Shvidenko, Schepaschenko 2014), average sink for 2000-2015 - 642±141 Tg C yr^{-1} (Shvidenko et al. 2019)
- eddy covariance: sink in 2000-2012 in a range from 760-960 Tg C yr^{-1} (Dolman et al. 2012)
- (recalculated for Russia from results obtained by CARDAMOM data-assimilation model for the circumpolar taiga forests): sink 836 Tg C yr^{-1} (Banko et al. 2018)

Applied systems analysis and integral modelling – a background of understanding of transition to sustainable forest management and development of forest sector on Northern Eurasia



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