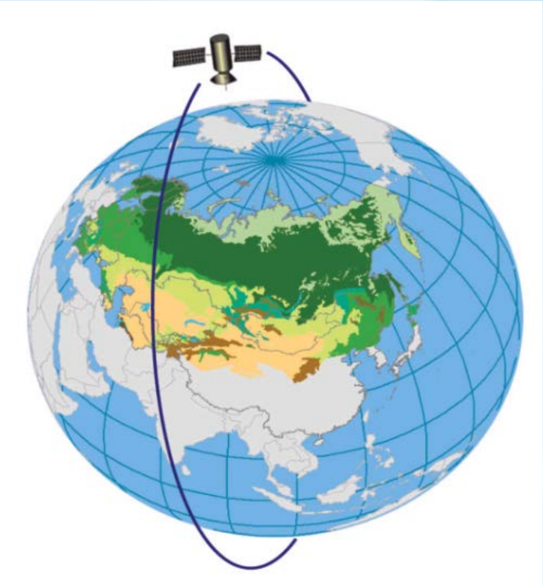

Forest Biomass Assessment: Glance of a forester and modeler

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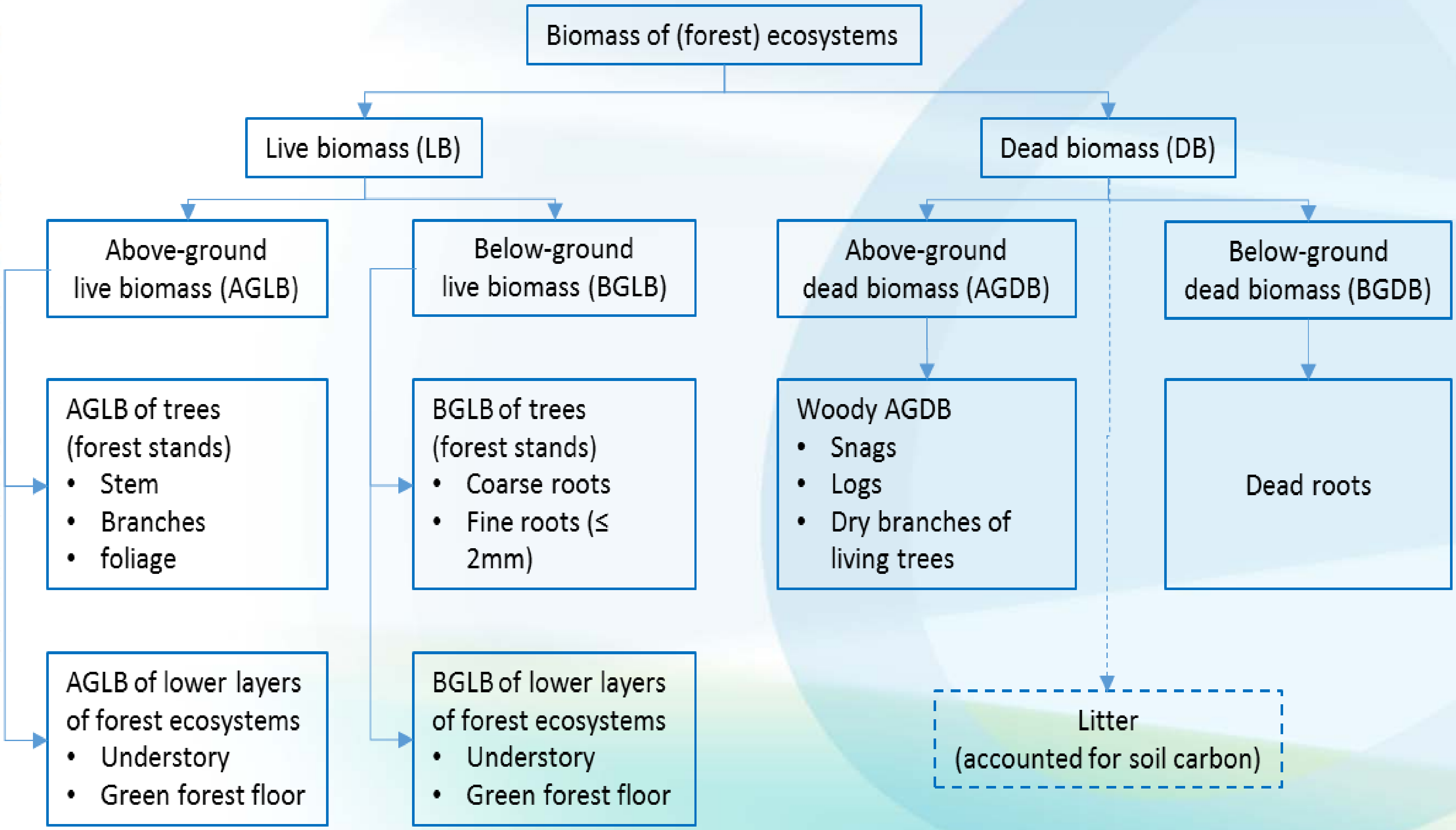
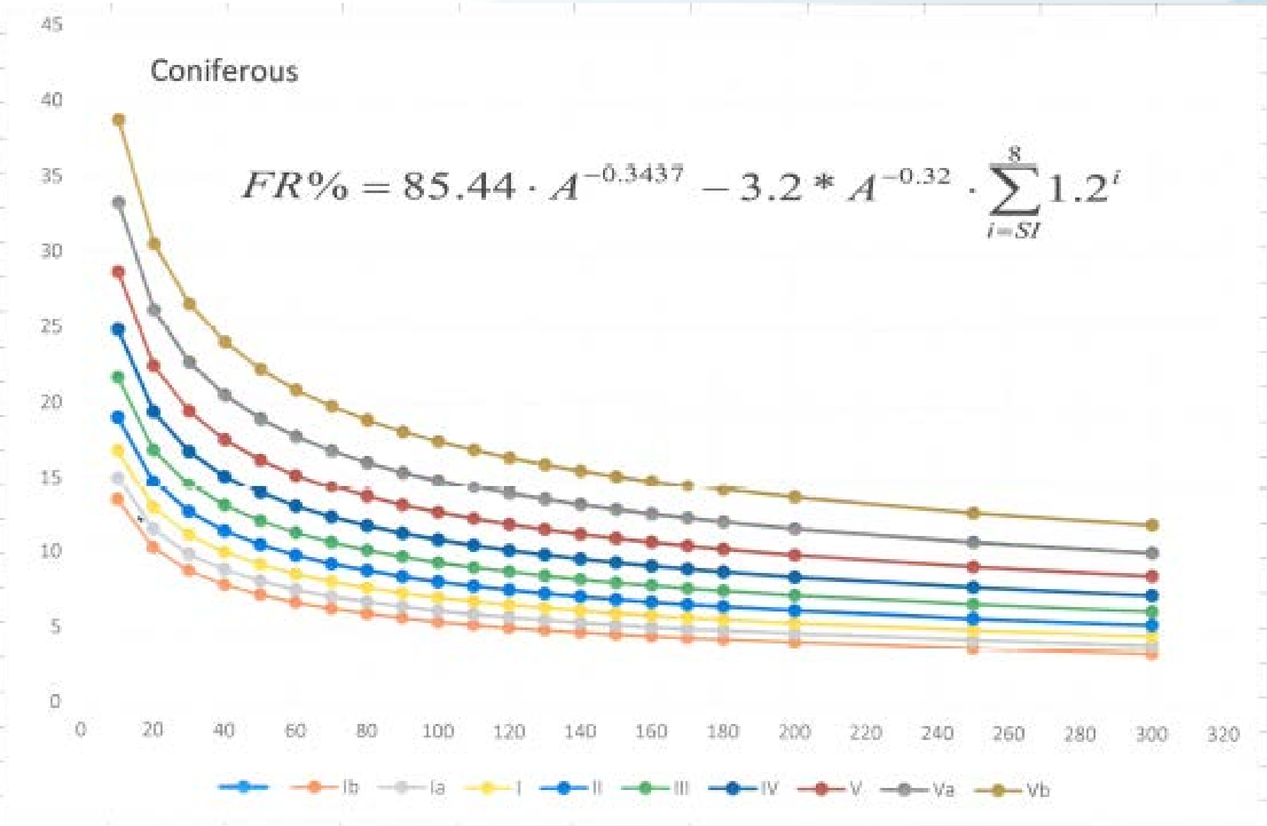
Final GlobBiomass User Consultation Meeting, FAO-Rome, 11-13 September 2017

Forest biomass which we have to know



An Example: Mysterious fine roots



Fine roots comprise from 3 to 5% of forest LB, but provide from 25 to 60% of NPP

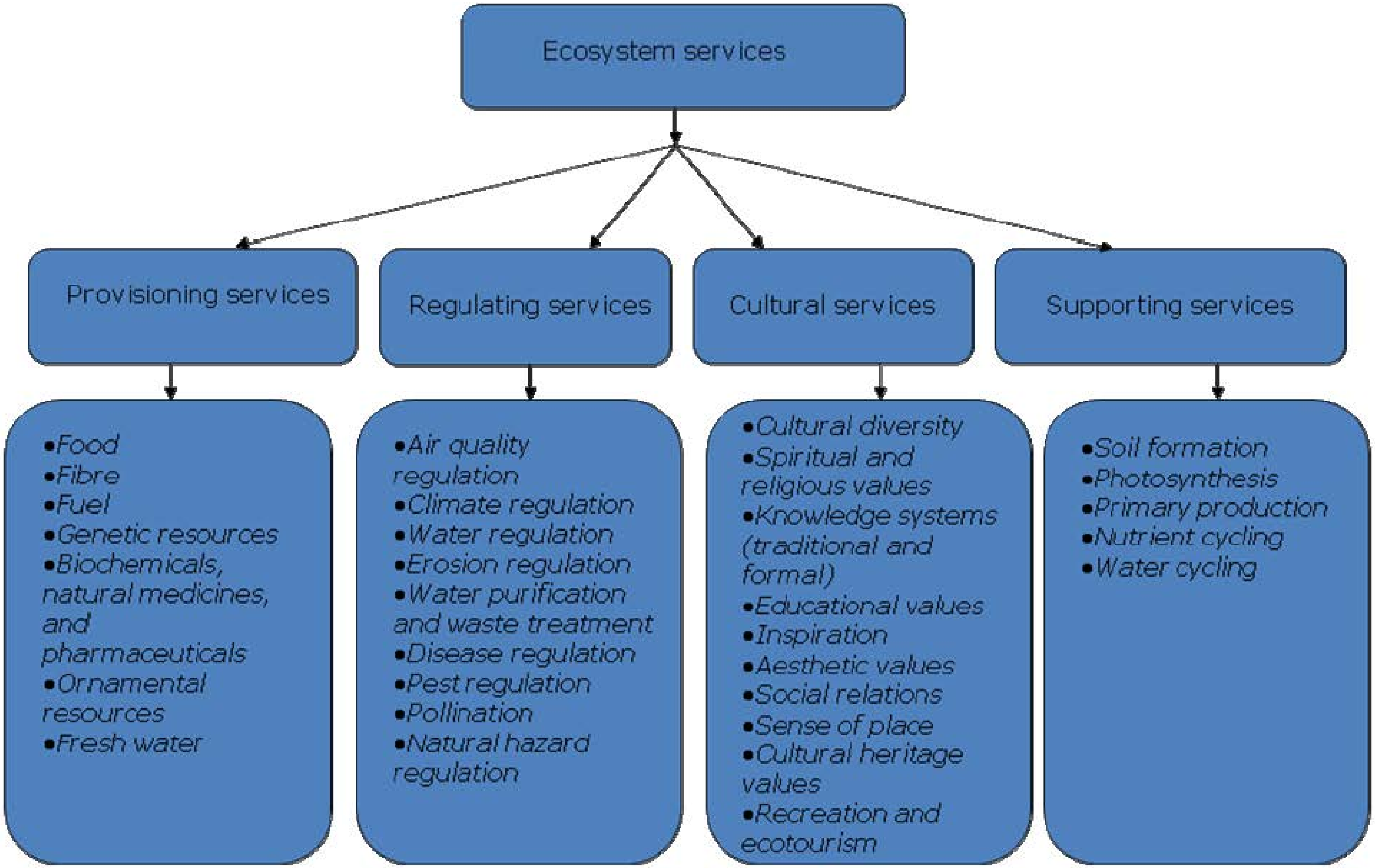
Far better an approximate answer to the right question, which is often vague, than the exact answer to the wrong question, which can always be made precise

Tukey 1962

Prerequisites

- Biomass is a crucial Essential Variable for forest management and forest ecology
- Forest practice: Transition to sustainable forest management (SFM): Sustainable forest management means the environmentally appropriate, socially beneficial, and economically viable management of forests for present and future generations
- In a changing world SFM means Adaptive Sustainable Forest Management (ASFM) based on principles of Risk Resilient Forest Management
- Transition to ASFM requires new information background which allows assessing all current and future forest ecosystem functions and services based on a principle of their equivalence but different values

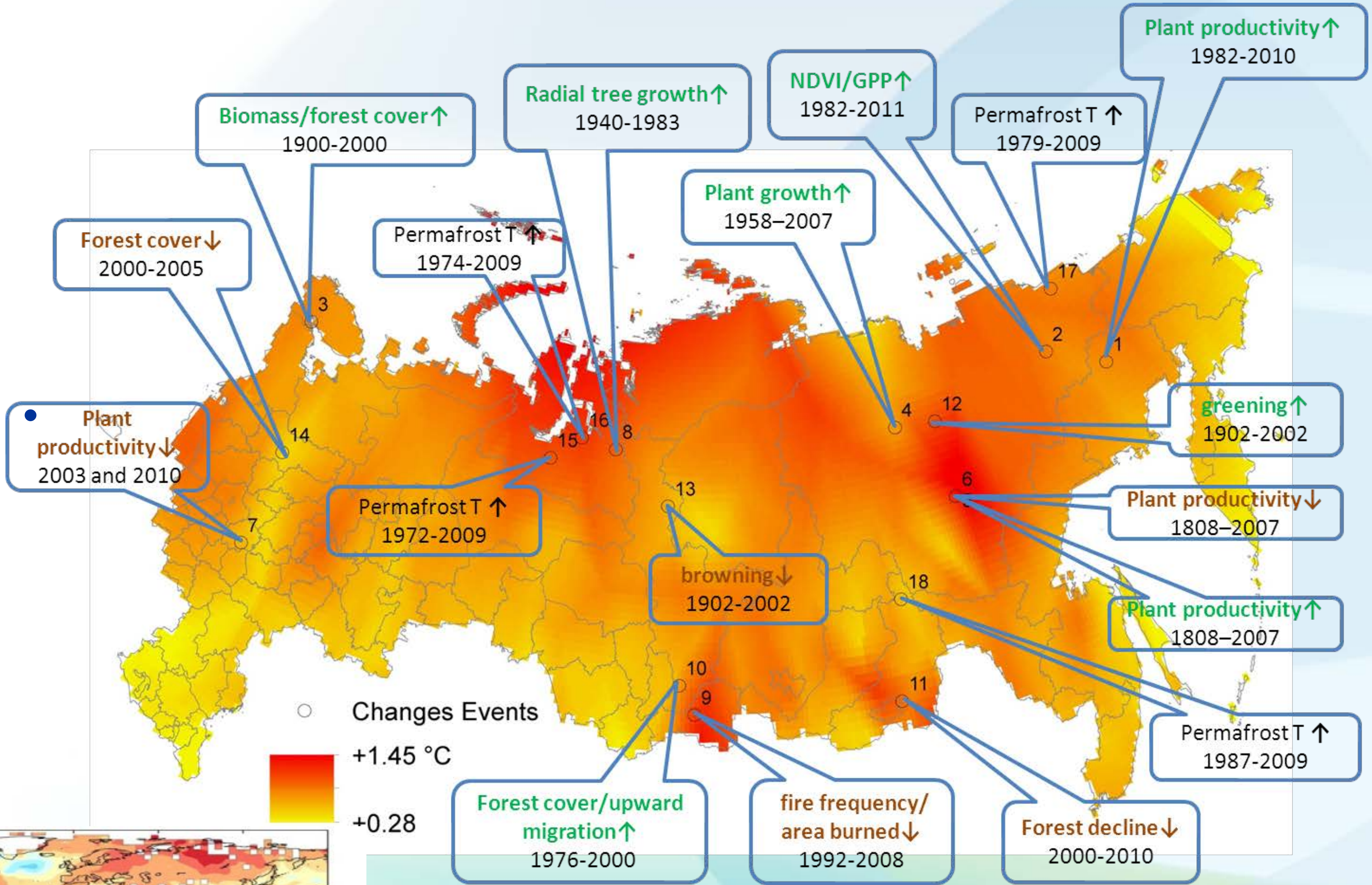
Classification of ecosystem functions (MA, 2005)

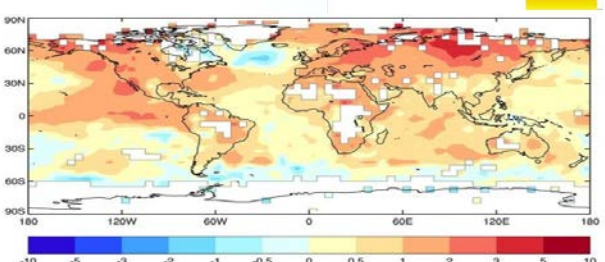


Of 75 forest ecosystem functions (classification by Sheingauz 1983), >90% are directly tied with biomass

IIASA

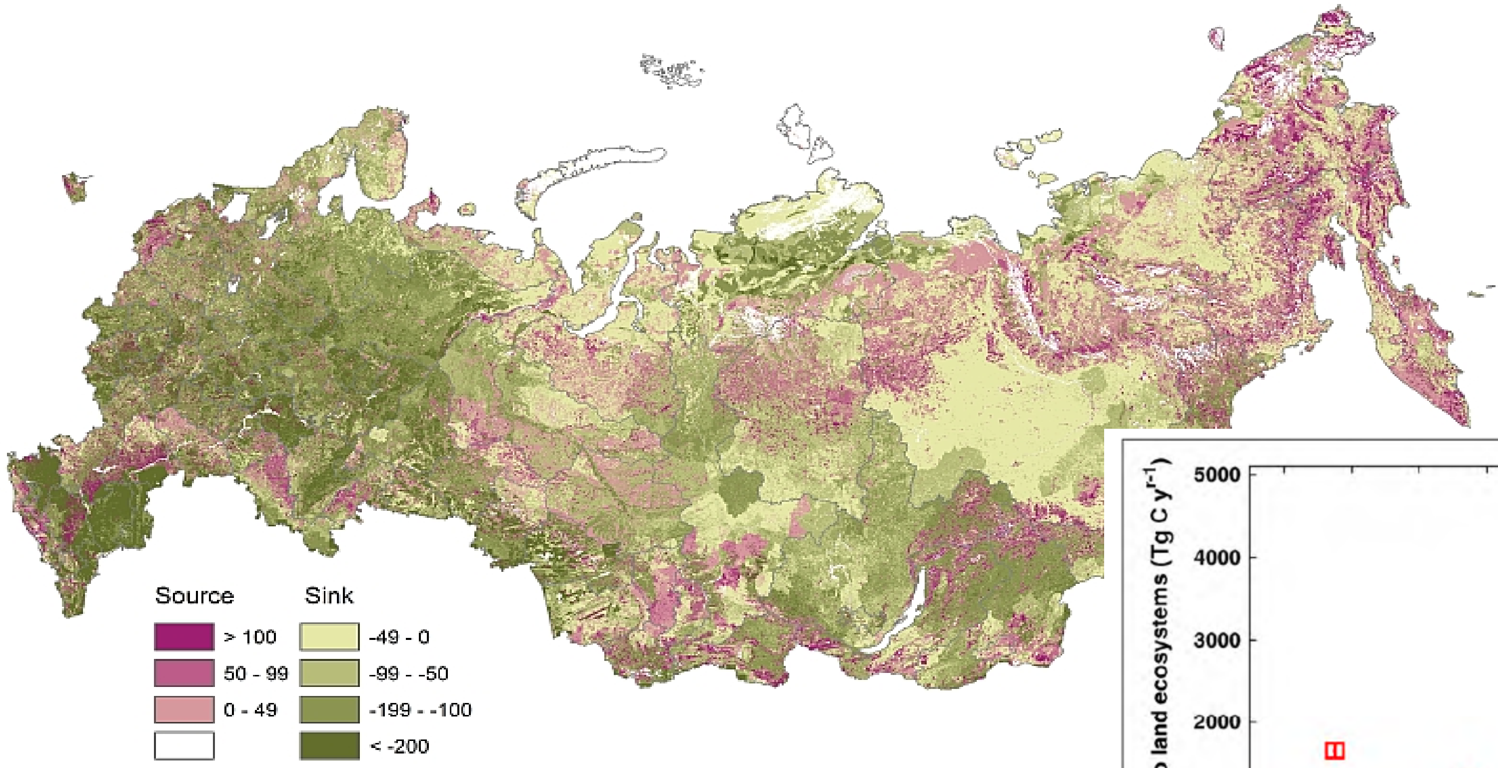
Climate change: Impacts on Russian forest

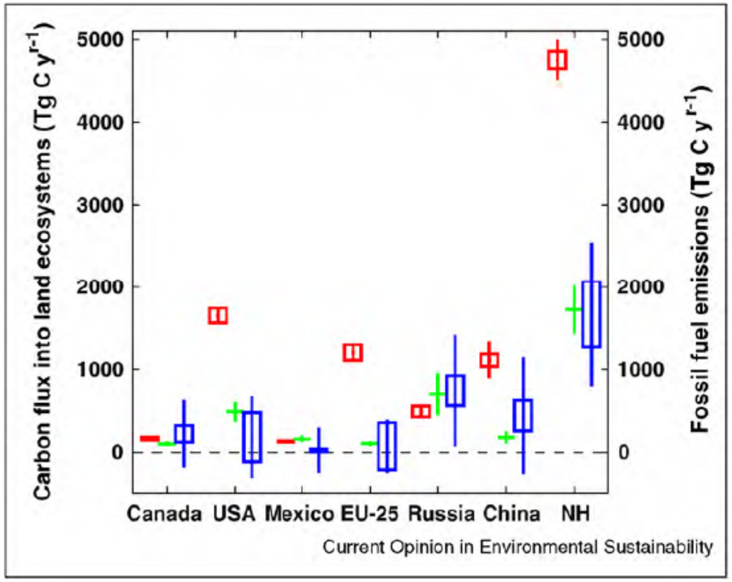




Source: Schaphoff et al.2016

Full carbon account for Russia in 2010 – Bayesian aggregation





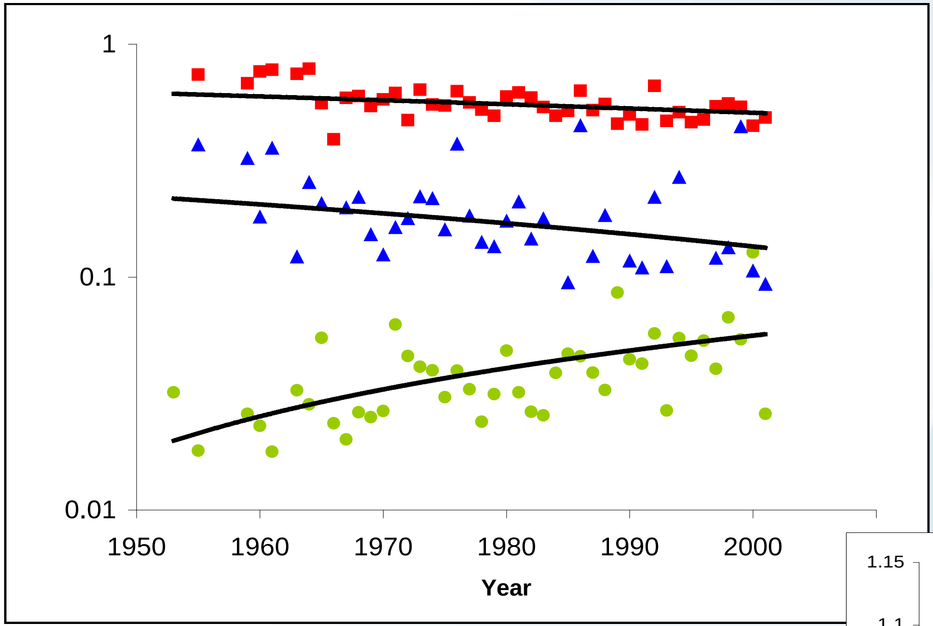
All ecosystems of Russia in 2000-2010 served as a net carbon sink at 0.5-0.7 PgC per year

Of this sink ~95% was provided by forests

Source: Shvidenko et al. 2011, Pan et al. 2011

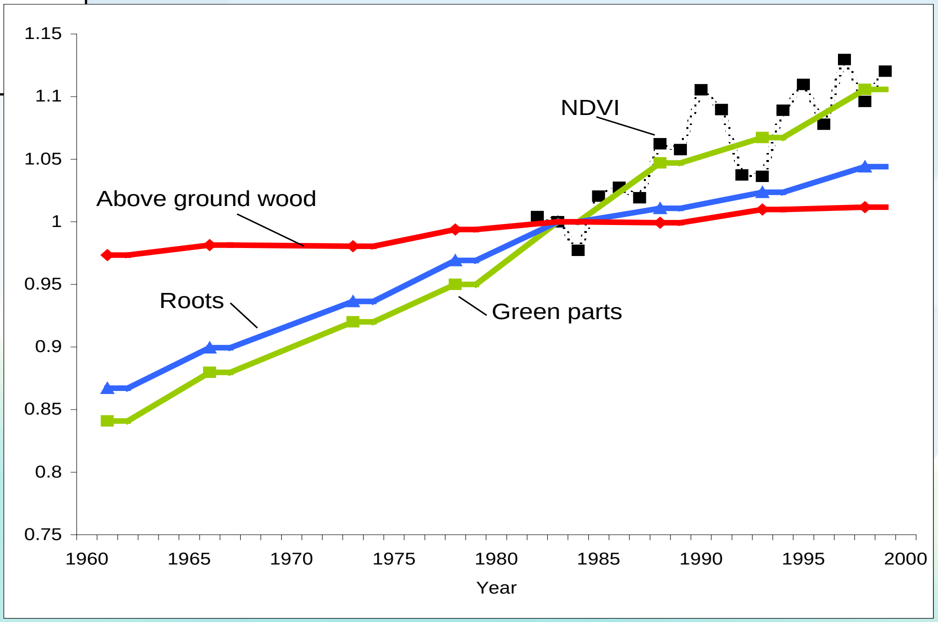
Source: Ciais et al. 2010

Acclimation of Russian forests to Climate Change



Temporal dynamics of BEF:
above ground wood (red)
roots (blue)
foliage (green)

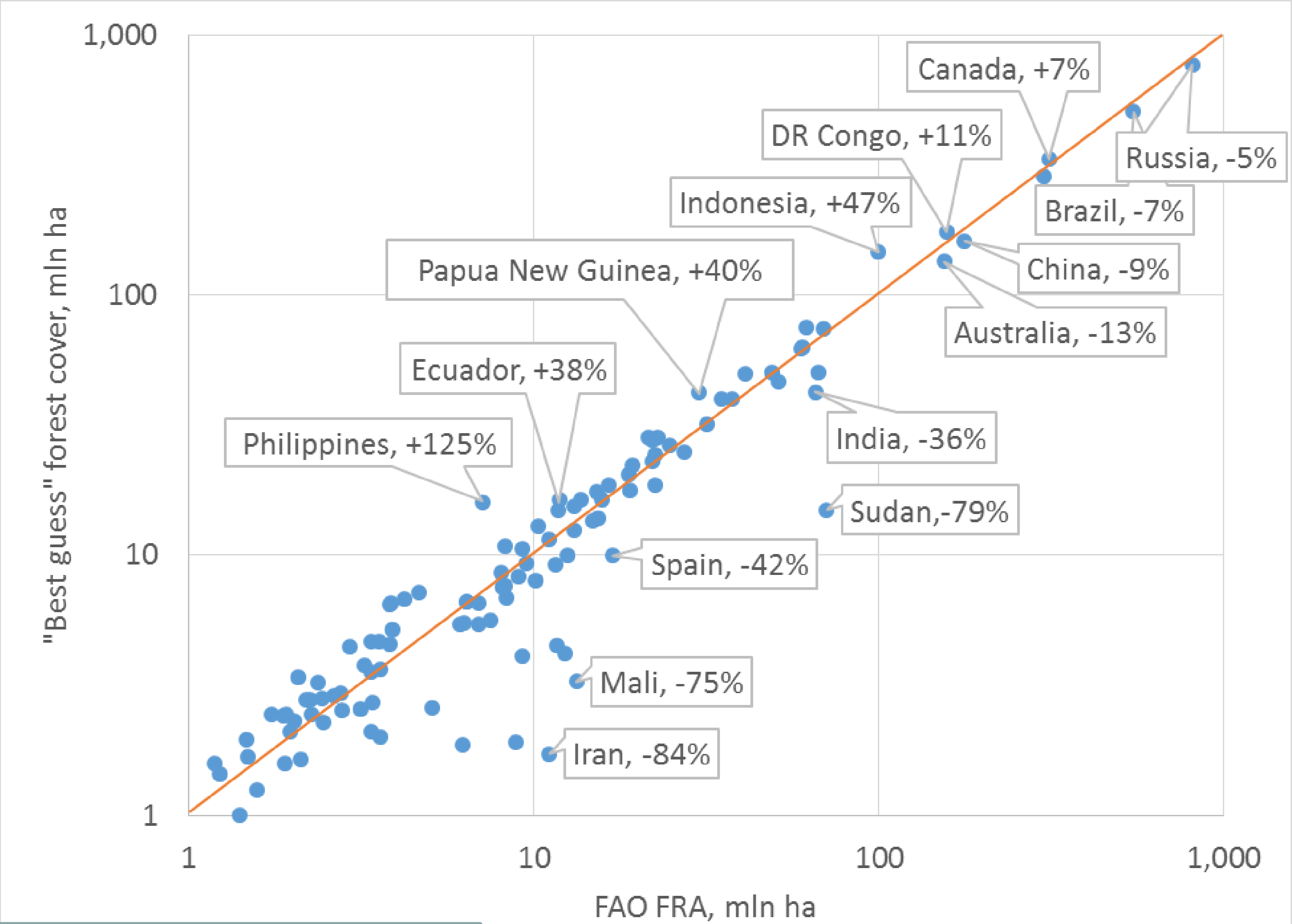
Dynamics of structure of live biomass of Russian forests in 1961- 2003 (normalized to 1983)



Consistency of terminology, definitions and classifications

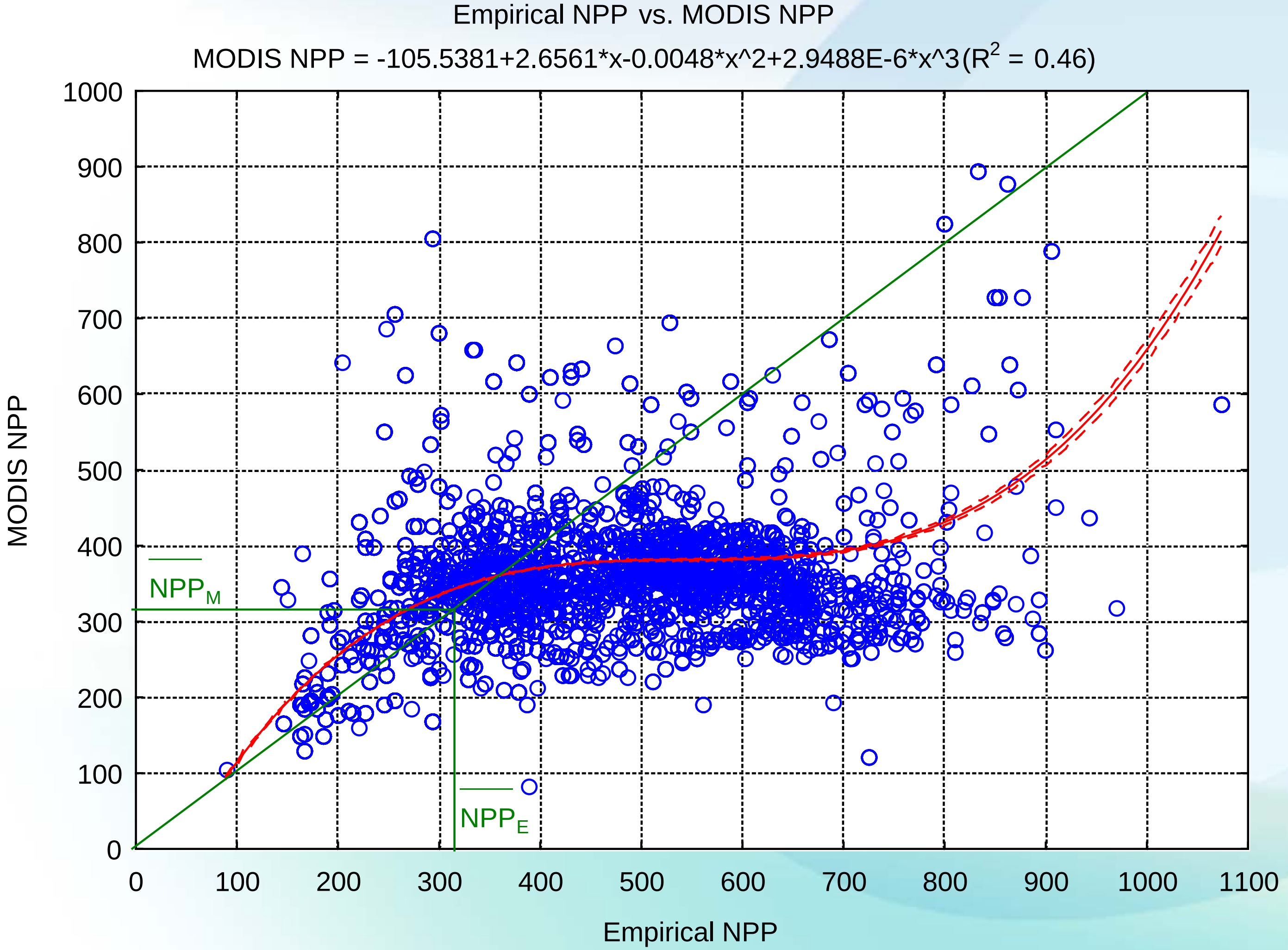
- There are >200 definitions of forest worldwide (FAO 2000-2002)
- The globally accepted definition of forests (FRA 2010, FRA 2015) is not optimal for RS application
- Is IPCC "democracy" really productive?
- Live biomass of trees *vs* live biomass of forest ecosystems
- Biomass of live trees vs total standing biomass
- We measure canopy closure but use it as a surrogate of relative stocking
- …

Comparison of forest area estimated based on the RS data and FAO FRA estimates

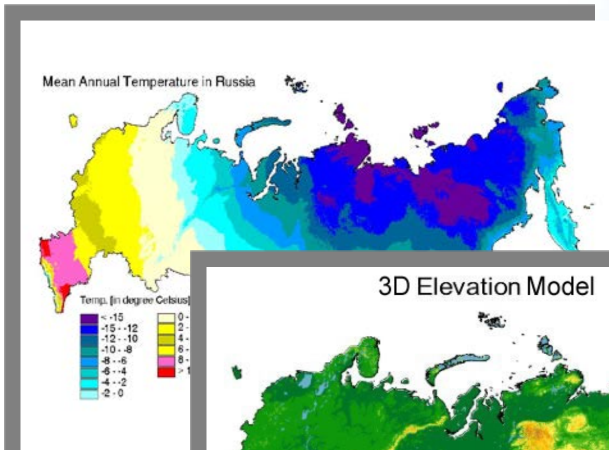


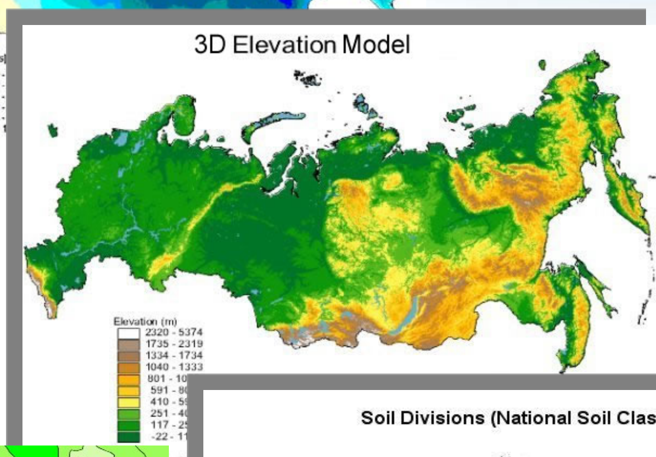
Source: Schepaschenko et al. 2015

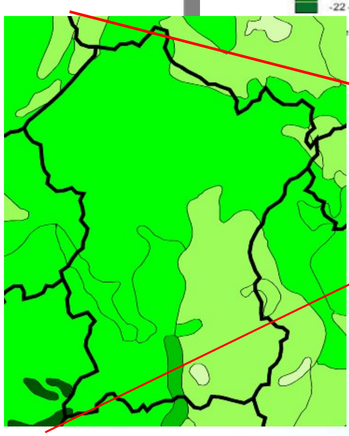
Spatial *vs* “real” user’s resolution: need of systems consistence of RS data and ground knowledge (an example - validation of MODIS forest NPP)

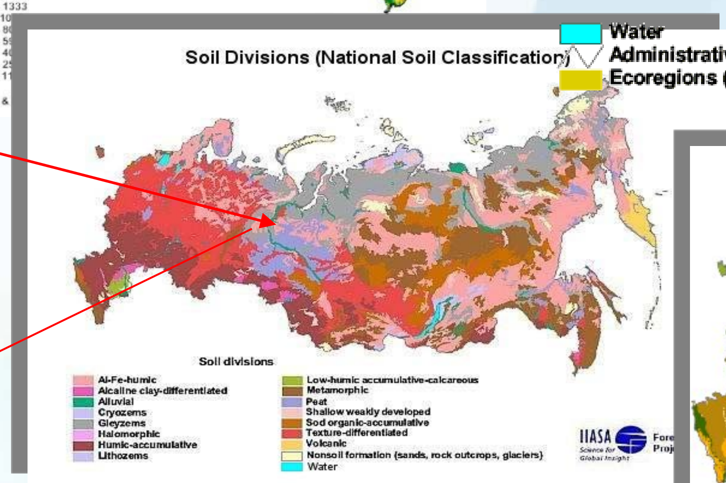


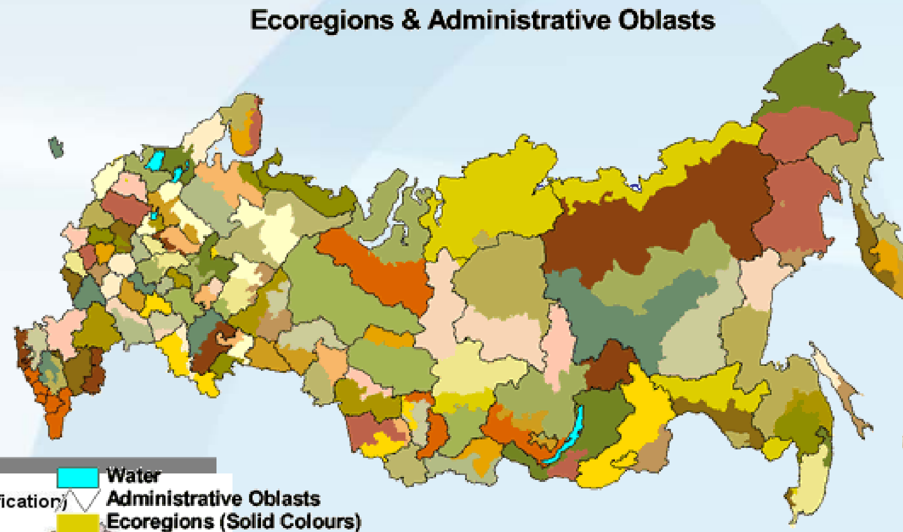
Hybrid Land Cover – an information basis of Integrated Land Information System



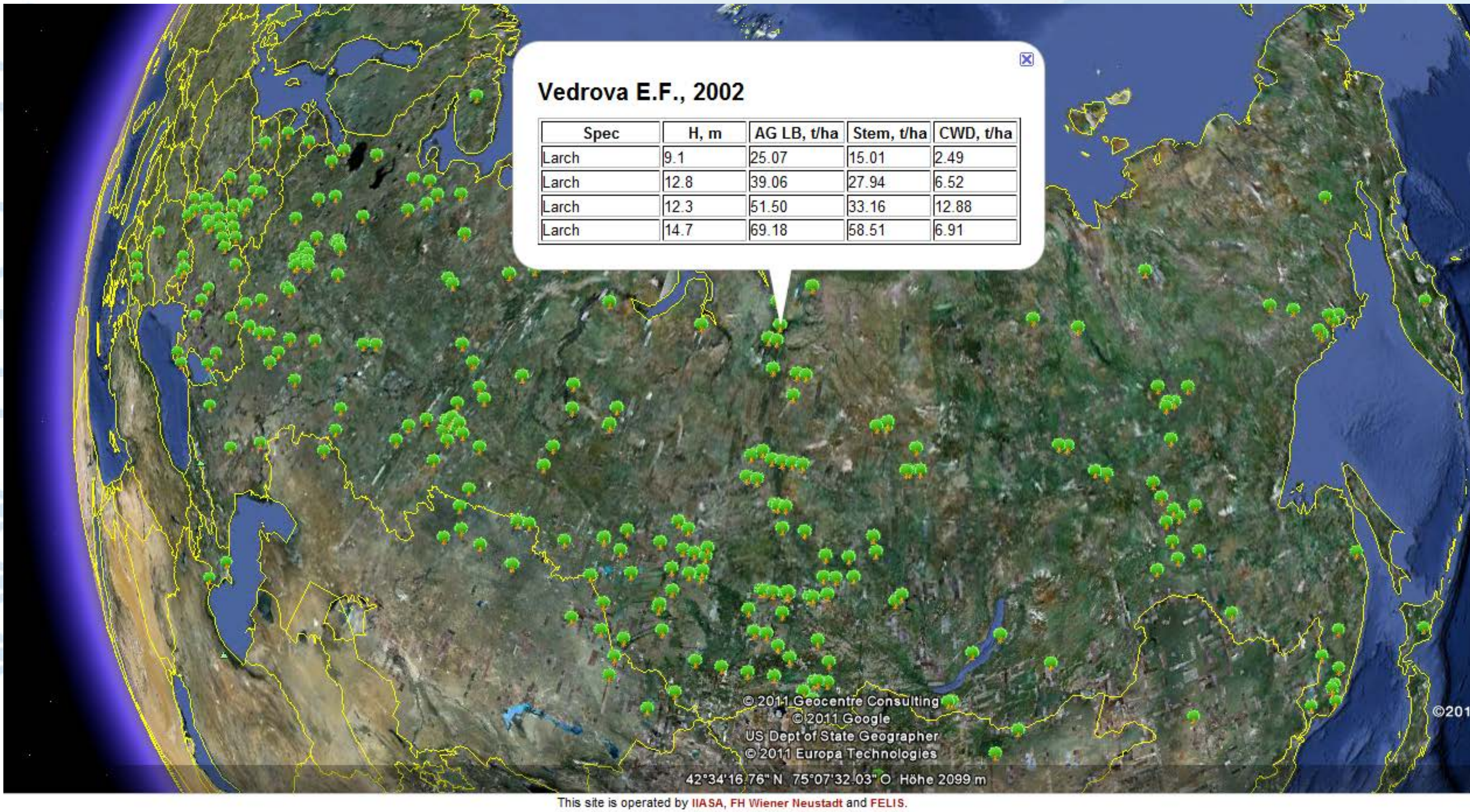








Database of *in situ* biomass measurements (over 10300 records for Eurasia)



Schepaschenko, Shvidenko et al., 2017

Transition from biometric (inventory) characteristics of stands to LB components : allometry vs multi-dimensional models of BEF

Minimal informative combination of Live Biomass components:

- stem wood over bark;
- bark;
- branches (over bark);
- foliage;
- roots (coarse and fine);
- understory (shrubs and undergrowth);
- green forest floor.

$$BEF_{fr} = M_{fr} / GS = c_0 \cdot A^{C_1} \cdot SI^{C_2} \cdot RS^{C_3} \cdot EXP(C_4 \cdot A + C_5 \cdot RS)$$

where BEF_{fr} – mass of phytomass by components (fractions), t m^{-3};

GS – growing stock, m^3 ha^{-1};

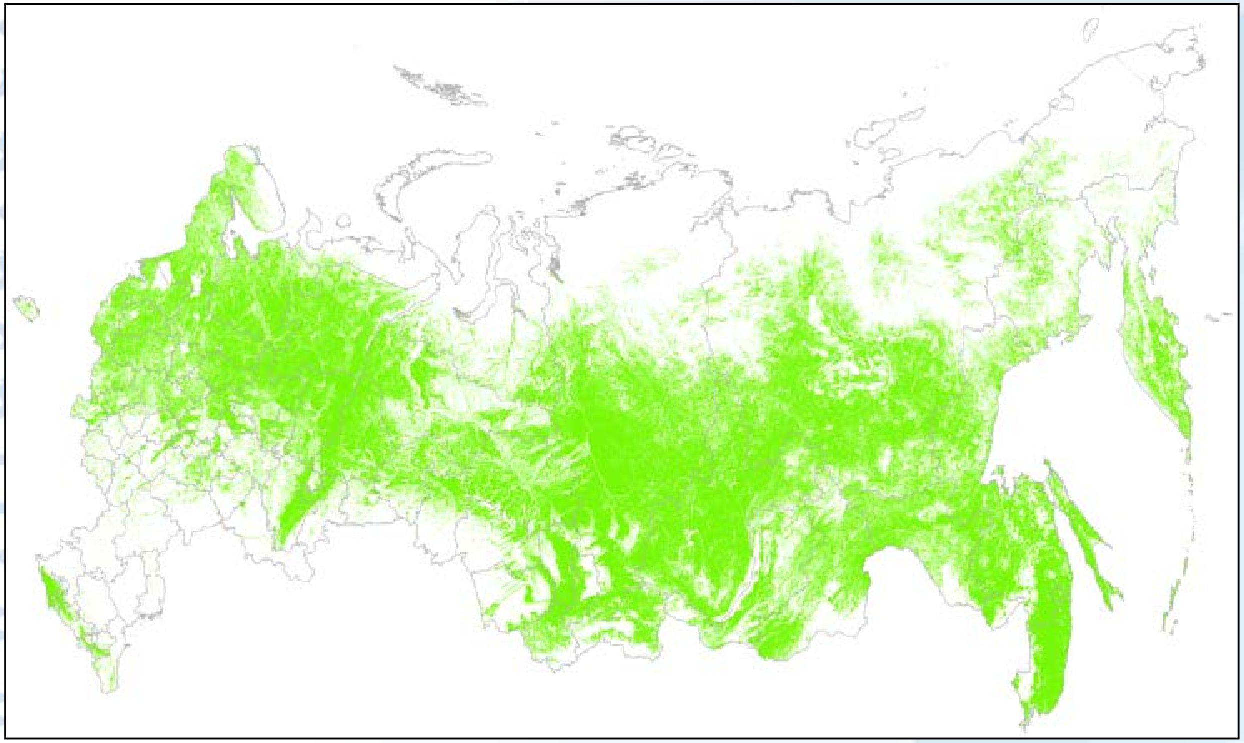
A – average forest stand age, years;

SI – level of productivity (site index);

RS – relative stocking;

$c_0, c_1, \ldots, c_5$ – model parameters.

Forest mask: 12 RS products, resolution 230 m



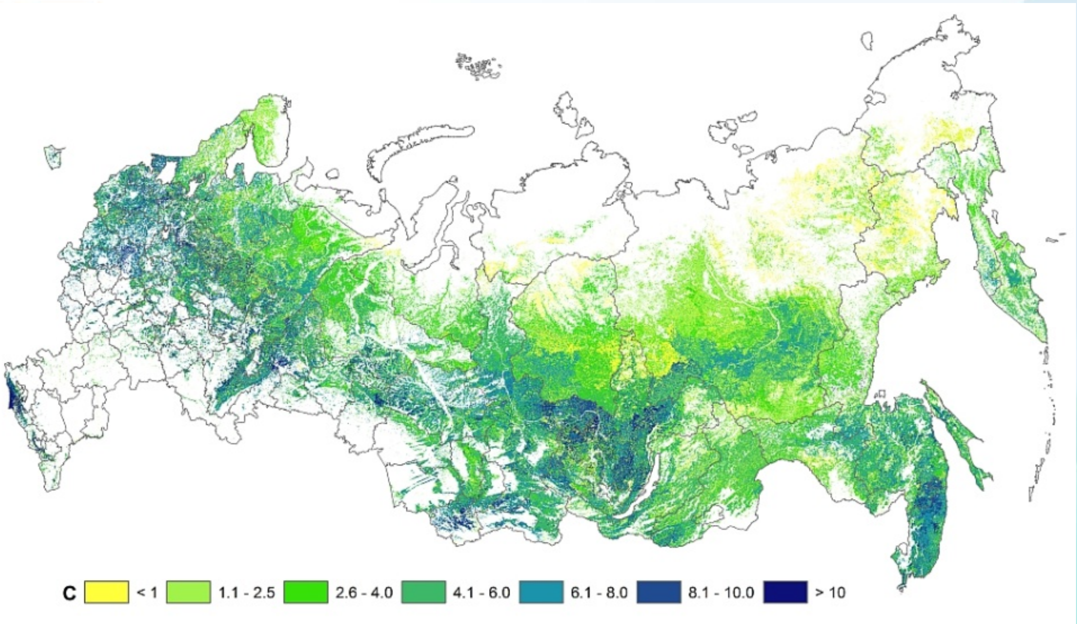
The input RS products include land covers: GLC2000, 1km, GlobCover 2009, 300m, MODIS land cover 2010, 500m; Landsat based forest masks: by Sexton 2000, 30m and by Hansen 2010, 30m; MODIS Vegetation Continuous Fields 2010, 230m; FAO World's forest 2010, 250m; Radar based datasets: PALSAR forest mask 2010,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

Schepaschenko et al. 2014

Assessment of LB is underspecified (fuzzy) system

LB of Russian forests (Pg C)

Alexeyev & Birdsey (1998)	28.7
Houghton et al. (2007)	39.5-43.0
Shvidenko et al. (2010)	37.5
Turner et al. (2013)	49.7



Any research method applied individually to an underspecified system does not allow assessing structural uncertainty

Assessment of uncertainties: mutual constraints

- For empirical approaches - assessing 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*

- *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

New applications of live biomass: NPP as an example

$TPF_A = TPF_A^{st} + TPF_A^{br} + TPF_A^{fol} + TPF_A^{root} + TPF_A^{under} + TPF_A^{gff}$

$NPP = TPF_A - TPF_{A-1}$

TPF_A – total production, kg C m^{-2} or Mg C ha^{-1}
A – forest stand age ;
st – stem;
br – branches;
fol – foliage;
root – roots;
under – shrubs and undergrowth;
gff – green forest floor.

Source: Shvidenko et al. 2007

Examples of calculation of total forest production by fractions

- Total production for stem wood

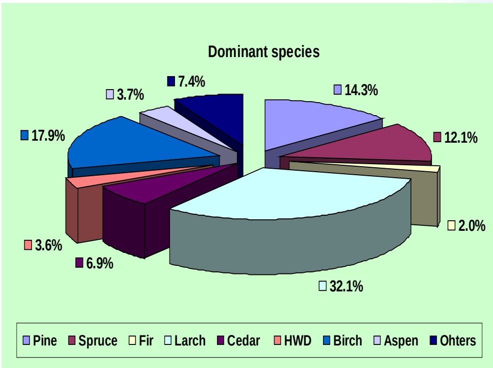
$$TPF_A^{st} = \sum_{A=1}^{A} \left[\left(TV_A - TV_{A-1} \right) R^{st} \right]$$

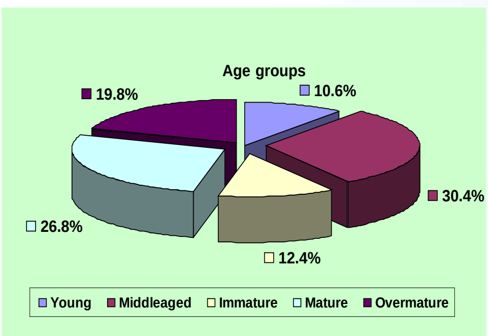
- Total production for foliage

$$\mathrm{TP}F_A^{fol} = \sum_{A=1}^{A} \left[\begin{array}{l} \left(F_A^{fol} - F_{A-1}^{fol} \right) + \left(TPF_{A-l}^{fol} - TPF_{A-l-1}^{fol} \right) + \left(1 + \frac{\upsilon}{q} \right) F_{A-1}^{fol} + \\ \frac{\eta}{2k} \left[\left(TV_A - GS_A \right) - \left(TV_{A-1} - GS_{A-1} \right) \right] R_{A-1}^{fol} \end{array} \right]$$

NPP as a function of live biomass - results

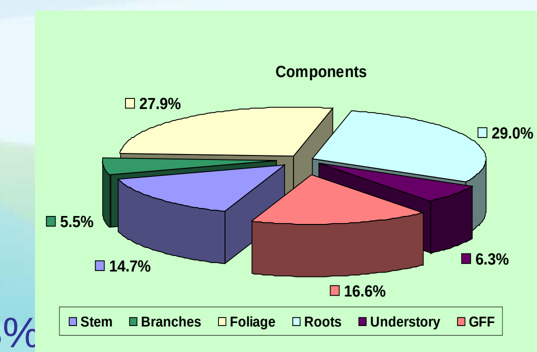
Net Primary Production (2010) 2.7±0.25 Pg C $year^{-1}$





Other methods

DGVMs (ensemble of 17 inv. models, Cramer et al. 1999)	-8.7%
DGVMs (ensemble of 8 models, Dolman et al. 2012)	-5.8%
Chlorophyll index by Voronin (1999)	+1.5%
MODIS (2005-2007)	<1.0%
Different inventories	from -36% to +93%



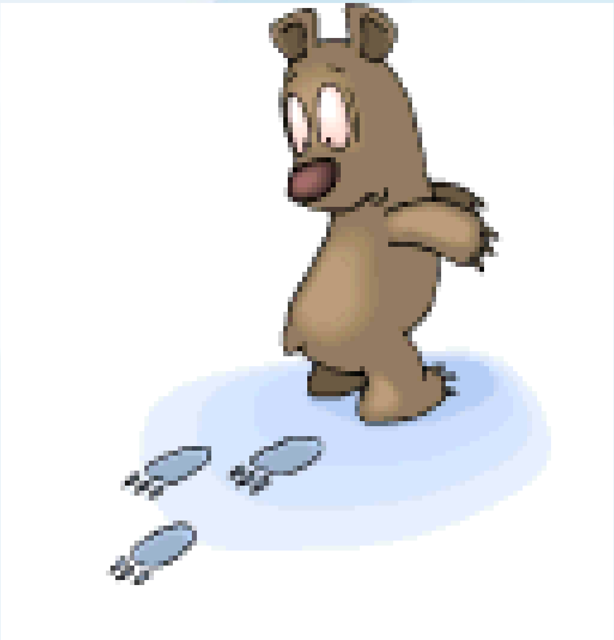
Lessons and potential tasks (1)

- Transition to Adaptive Sustainable Forest Measurement (ASFM) is impossible without availability of Integrated Information Systems of which remote sensing component is one of two of the most important pillars
- There is a need of improvement of professional languages of different sciences – with respect to compatibility and logical consistency of terminology, definitions and classifications
- "Multi-RS" concept is a background of all application
- Optimal spatial resolution for regional/ national modelling and prospective forest management planning is 100-200 m and for realization of local ASFM – (3)-5 (10) m
- Lack of ground-based knowledge becomes a major limitation for assessing forest ecosystem functions/services

Lessons and potential tasks (2)

- “Adaptive” application of different radar bands to multi-dimensional models of forest ecosystems
- New methodology of mutual constraints of results obtained by independent methods for underspecified (fuzzy) systems
- Development/improvement of empirical models for regional correction of remotely sensed biophysical indicators
- Further improvements of ecological models which combine remotely sensed and “hidden” components of ecosystems (e.g. roots)
- Development of multi-dimensional models of morphological structure of forest ecosystems (assessment of “hidden” components of biomass)
- Development of models of grows and dynamics of forests under global change

A bottleneck of current assessment of forest biomass: the lack of satisfactory knowledge of forest ecosystems



Thank you