Can the level of uncertainties of a regional terrestrial biota full carbon account be made acceptable for policy makers?

Anatoly Shvidenko
Sten Nilsson

Forestry Program
International Institute for Applied Systems Analysis
Laxenburg, Austria

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A system statement

Only a verified regional (national, continental) Full Carbon Account (FCA) corresponds to the eventual goals of the UN FCCC and Kyoto Protocol

"Full" means all (recognized) sources and removals of the biosphere and technosphere applied continuously in time

"Verified" means: (1) uncertainties of a FCA are defined reliably and comprehensively; (2) they should be below preliminary settled levels; (3) the methodology of FCA allows to explicitly manage uncertainties

Uncertainty is an aggregation of insufficiencies of accounting system output, regardless of whether those insufficiencies result from a lack of knowledge, the intricacies of the system or other causes (Nilsson et al., 2000)

Why "full" and why "verified"?

"Full" because a partial account does not allow

(1) to know a real pictures about emissions and removals
(2) to attract "climate friendly" investments in perspective fields of biosphere
(3) to comprehensively involve developing countries in efforts on climate change mitigation
(4) to avoid of ambiguities with "managed biosphere", "base-line", "additionality", etc.
(5) To estimate uncertainty "reliably and comprehensively"

"Verified" because uncertainties of FCA are very high and – as a rule – are not known

Do we know required/optimal levels of uncertainty?

- We know an overall answer

Min [C(N) + L(N)], where

C(N) - cost of realization of methodology *N*,

L(N) - expected loss due to uncertainties of *N*,

$L(N) = \int l(U) f(U,N) dU$,

l(U) - estimate of loss caused by *U*, and

f(U,N) – distribution of *U* dependently on variation of *N*

And we have two thresholds…

…following from two major approaches of the FCA

(1) from pool based approach

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

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

dC/dt has to have at least one significant figure,

(2) and from flux based approach

NBP = 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, and

uncertainties of NBP >100% do not have any sense

+ we have expert opinions

Background philosophy:
FCA is a fuzzy system

- Membership function of elements/ modules of any FCA is stochastic by nature
- Completeness of any FCA, particularly for large territories, can be estimated only in an expert way
- Formal validation/ verification of FCA's results cannot be provided directly
- Structural uncertainties cannot be estimated inside of any individual methods of carbon accounting (i.e., landscape-ecosystem approach; process-based vegetation models; flux measurements; inverse modeling)
- Any individually used method of FCA cannot present information would be sufficient for reliable and comprehensive assessment of uncertainties
- Only system integrity of information sources and different methods is able to make a step toward a verified FCA

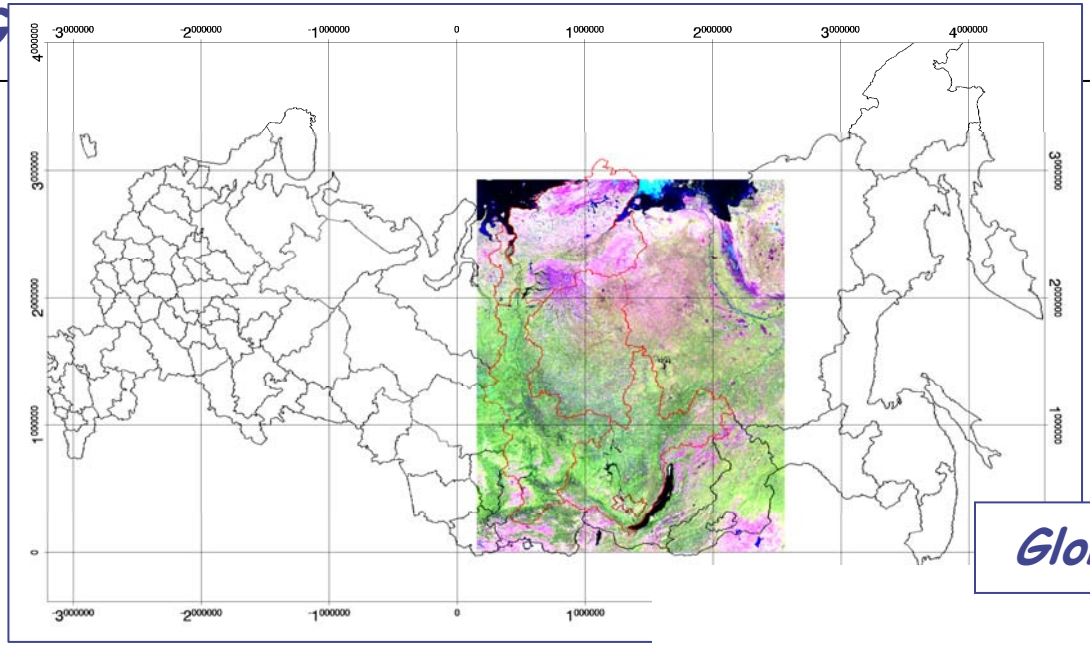
Landscape-ecosystem approach: major requirements to the FCA

- Need for a systems (holistic) approach in all ramifications - goals; expedience; integrity; causal relationships; hierarchy; management; selforganization; optimality; …
- Use of strict monosemantic definitions and proper classification schemes; harmonization of these with other approaches
- Explicit intra- and intersystem structuring
- Optimization of input data and availability of numerous empirical and semi-empirical models
- Accounting schemes, models and assumptions should be presented in an explicit algorithmic form
- Spatially explicit distribution of pools and fluxes
- Clearly defined temporal dimensions
- Assessment of uncertainties at all stages and for all modules of the account

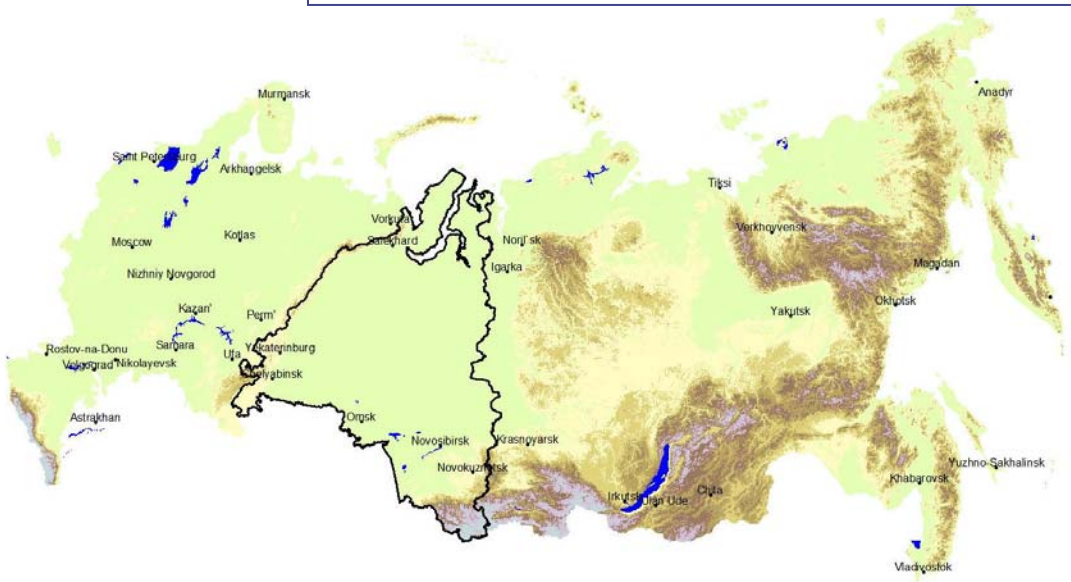
Uncertainty Estimation Scheme

- Estimation of precision using "summarized" errors
- (Limited) use of expert estimates and personal probabilities
- Sensitivity analysis
- Expert modification of precision
- Considering the closed balance
- Harmonizing and multiple constraints of the results using independent sources
- "Transfer" of precision in uncertainties

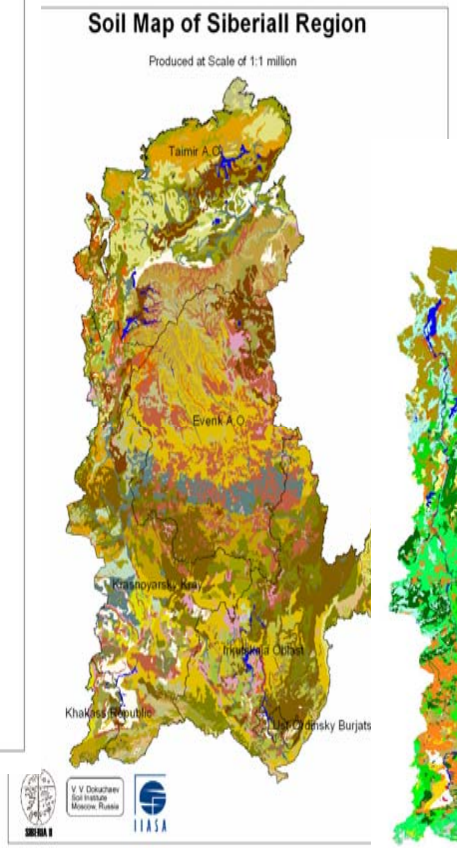
SIBERIA-II: Multi-Sensor Concepts for Greenhouse G



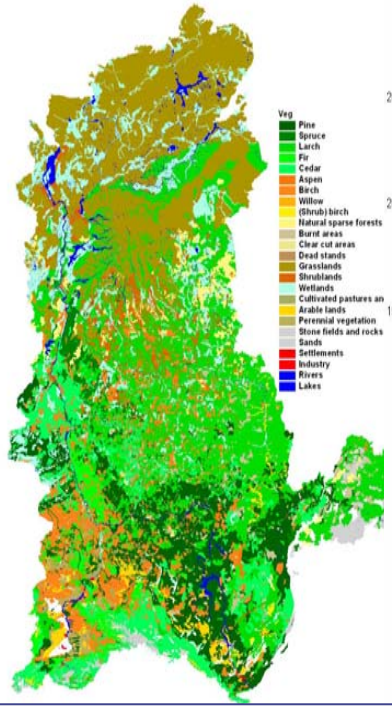
Global Change in West Siberia



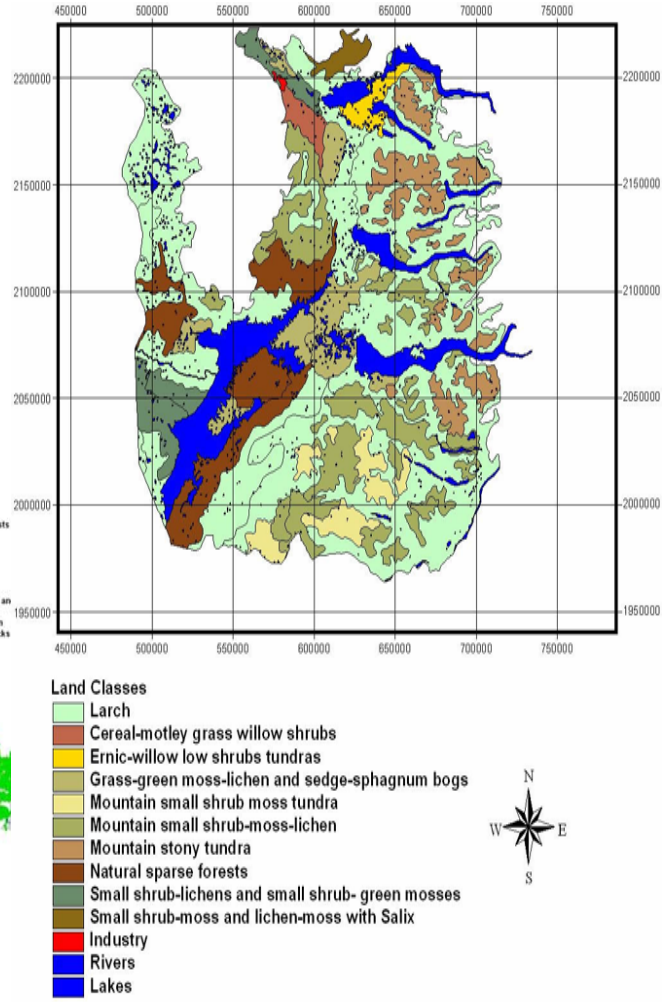
Synergetic use of different information sources and methods -examples from SIBERIA-II



Land Cover / Vegetation



A tundra ecoregion



Different maps + 12 RS instruments + forest inventory + land inventory => more 30,000 polygons
Landscape-ecosystem method + 2 Dynamic vegetation model (LPJ and Sheffield DGVM)

Major "uncertainty players"
SIBERIA-II: FCA for 2003, Mg C $ha^{-1}yr^{-1}$

Land class	NPP	HR	FHYD + LIT	NEP	ANT	NBP
Forest	3.06	2.38	0.066	0.615	0.334	0.28
Disturbed forest	2.07	2.03	0.083	-0.044	0.187	-0.19
Agricultural land	4.78	2.72	0.046	2.013	1.873	0.14
Grassland	1.04	0.74	0.081	0.219	0.072	0.15
Wetland	1.96	1.36	0.083	0.487	0.253	0.23
All land classes	**2.51**	**1.91**	0.071	0.527	**0.297**	0.23

Uncertainty of FCA for SIBERIA-II, % (CI 0.9)

Pool of live biomass	3-4
Pool of phytodetritus	15-25
Soil carbon pool	15-20
Net Primary Production	5-7
Heterotrophic Respiration	8-10
Decomposition of CWD	20-25
FHYD and FLIT	20-30
Disturbances	20-25
Net Ecosystem Production	35-40
Net Biome Production	60-80

… assuming that the data and models have no unrecognized biases

Interannual variability: Impact of climatic indicators

- T - annual temperature, ^{o}C
- D>0, D>5, D>10 - period with t>0,5,10^{o}C, days
- ST>0, ST>5, ST>10 – sum of degree-days
- P - annual precipitation, mm
- SP>0,SP>5, SP>10 - amount of precipitation during period with t>0,5,10^{o}C, mm
- GTK>0,GTK>5,GTK>10 - hydrothermal coefficient during period with t>0, 5,10^{o}C, mm/^{o}C

Impact of weather indicators: examples of linear regressions

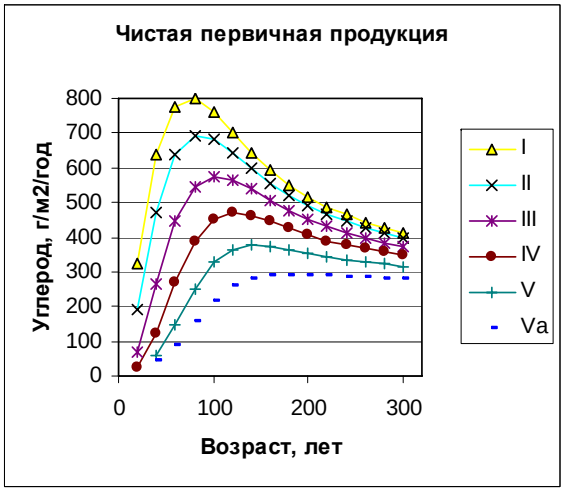
- Constants of decomposition could be estimated quite accurately if a number of measurements exceed ~100, e.g., for litter of coniferous (R=0.86, n=131), included D>10,5,0; ST>0,5; P; P>0; SP>0,5,10; GTK>10, 5
- Heterotrophic soil respiration is defined based on weather indicators with R=0.6-0.7, e.g., for forests R=0.66 (n=310), included min T, maxT, D>0, ST>10, Ln (GTK>10)
- Net Primary Production is estimated less reliable, R = 0.4-0.5
- Examined approach allows to decrease uncertainties for an individual year for about 30-40%

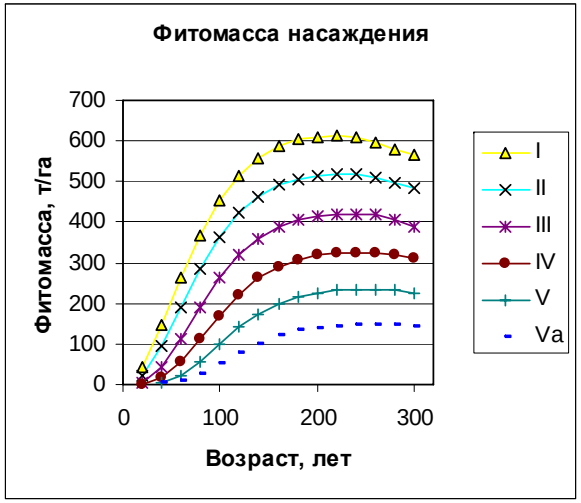
Processes and biases: assessing NPP of Northern Eurasian forests

NPP = GPP – AR

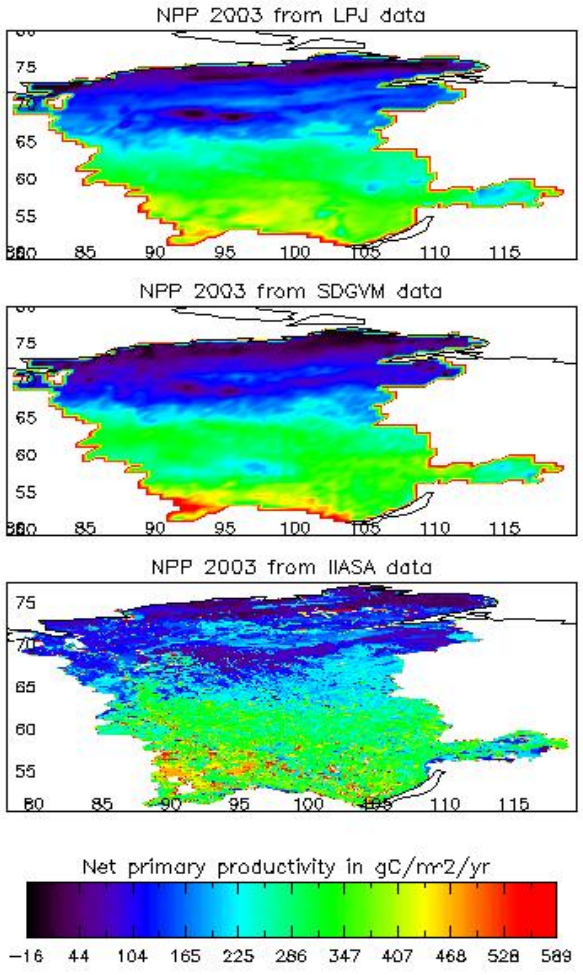
Destructive method historically used for NPP measurements did not account some components (root exudates, VOC, green forest floor) that resulted in systematic errors in range 15-30%

The estimate of NPP of Russian forests
(1) based on ~1500 sample plots is
225 g C m^{-2} yr^{-1} (Nilsson, Shvidenko et al. 2000)
(2) using a new “semi-empirical” modeling system is 307 g C m^{-2} yr^{-1} (Shvidenko, Nilsson et al. 2007,Ecological Modelling, 204,163-179)

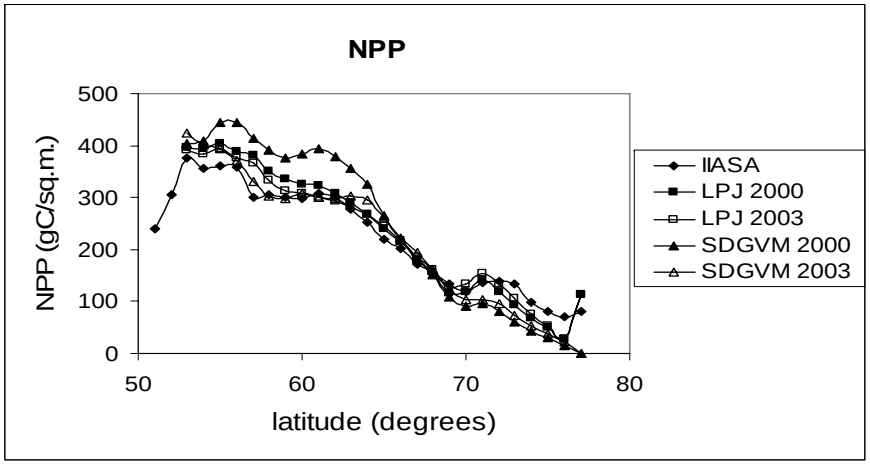




Process-based models as a tool of the FCA at regional and continental level



Source: Quegan et al., 2007



- **Average of 17 DGVMs (Cramer et al. 1998) for all Russian forests is estimated to be 338 g C m^{-2} yr^{-1} (+11% to inventory-based estimate) but variability of individual models is high**
- **Regionalized LPJ model ("real" remotely sensed land-cover and a new hydrological-permafrost model) estimated NPP for Russian forests as almost-identical derived from landscape-ecosystem approach (Beer et al., 2006)**
- **Application of two regionalized DGVMs to SIBERIA-II region (SDGVM and PLJ shows substantial potential of the approach (Quegan et al., 2007, submitted)**

Comparison with inverse modeling results

† Inverse modeling – Results for Eurasia, Pg C year^{-1}

Fan *et al.*,1999, *Science*	+0.1±0.7
Bousquet *et al.*, 1999, *JGR*	-1.8±1.0
Rodenback *et al.*, 2003, *AChPh*	+0.2±0.3
Gurney *et al.*, 2004, *GChB*	-0.7±1.0

† Inverse modeling – Recent estimates for boreal Asia, Pg C year^{-1}

Maksyutov et al., 2003 (1992-1996)	-0.63±0.36
Gurney et al.,2003 (1992-1996)	-0.58±0.56
Baker et al. (1988-2003)	-0.37±0.24
Patra et al., 2006 (1999-2001)	-0.33±0.78
Appr. estimate (2003), SIBERIA-II	-0.27±??
Appr.estimate (1999-2001), SIBERIA-II	-0.38±??

Eddy covariance in a FCA-some questions

- † What is a reliable background for upscaling?
- † What is real uncertainties of a “point measurement”?

  Oren *et al*., 2006, *GChB*

  In a uniform pine plantation spatial variability can contribute ~50% of the uncertainty in annual NEE estimates … variability of night fluxes up to 160% ... adjusted and combined variability from 79 to 127 g Cm^{-2} yr^{-1}

- † Why almost everywhere forest sink?

The regional FCA – some conclusions

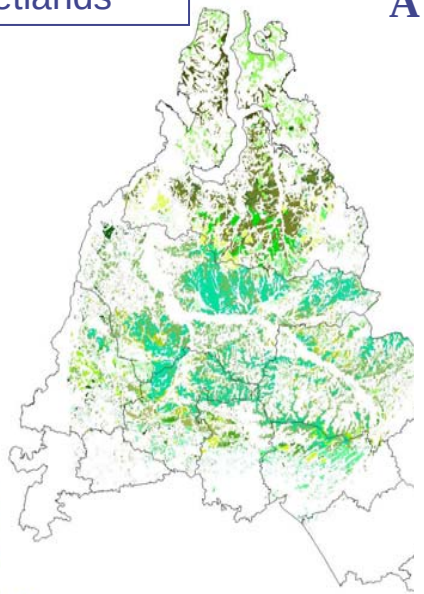
- There is a significant synergism in combining remotely sensed data, GIS description of landscapes and ecosystems, and regionalized ecological models
- The approach allows production of a number of intermediate products (land cover, forests, etc.) with satisfactory details and accuracy for users in the post Kyoto world
- Net Biome Production for large regions is expected to have an uncertainty in limits of 15-25% (confidential interval 0.9) mostly depending on availability/ resolution/ technical ability of RS data but not only
- Soil processes remain the most uncertain component of the FCA
- Substantial seasonal variability of carbon sink (25-40%) is mostly driven by natural disturbances

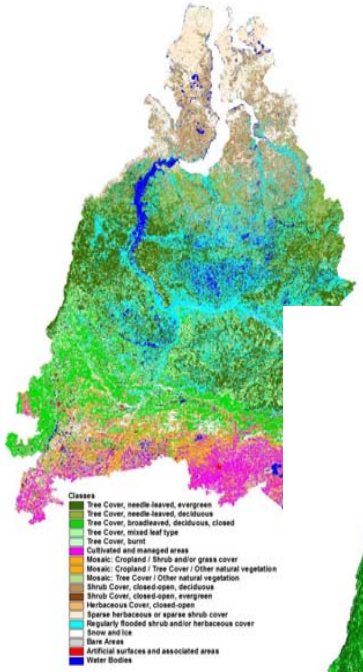
The regional FCA – research questions

- Specialized RS tools for assessing important ecological parameters (biomass, above ground NPP etc.)
- Specialized RS tools for assessing extent and severity of disturbances
- Tools for multiple constraints of results from independent sources
- "Regionalization" of DGVM
- Gradients for upscaling of NEE measurements
- Introduction of multiple anthropogenic impacts
- Regional empirical models for assessing "hidden" ecological parameters
- Numerous problems with soil carbon…

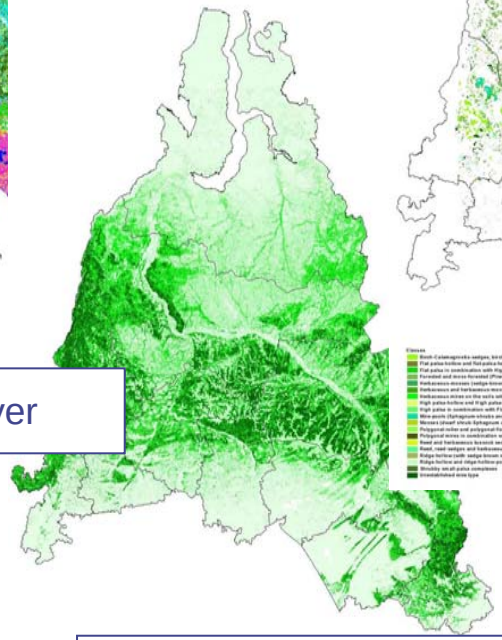
How to harmonize the results and uncertainties of different approaches?

Wetlands



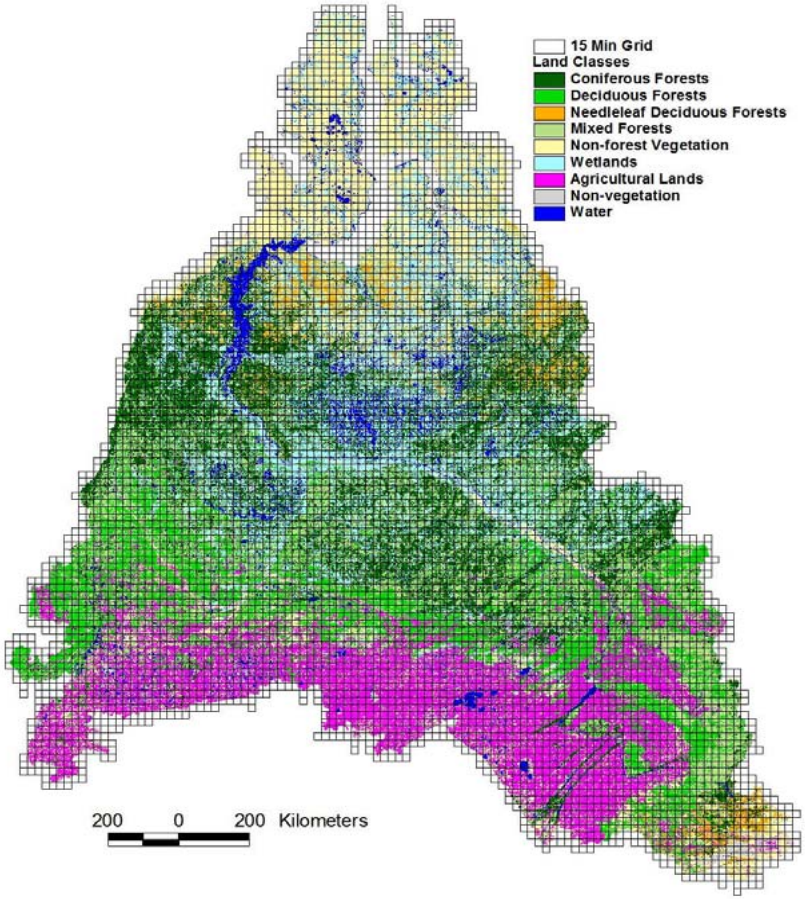


Land cover



Percent forest

A unified background for harmonizing ?



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