REMOTE SENSING APPROACHES FOR MONITORING OF EMISSIONS FROM LAND COVER CHANGE

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BioCarbon Fund Initiative for Sustainable Forest Landscapes
Landscape-level carbon accounting
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Outline

Monitoring of emissions :

- Aboveground carbon pool monitoring
  - Remote Sensing/IPCC approaches
  - “Direct” measurements of carbon density changes
    (Deforestation, Degradation, Gain)

- Trees Outside Forest
- Changes in Soil Carbon

IPCC guidelines

Gross carbon emissions

Deforestation

Degradation

$$C_{gr\_em} = \left(\sum_{i=1}^{m} A_{loss(i)} \cdot C_{loss(i)} \right) + \left(\sum_{i,j=1}^{n,m} A_{dgr(ij)} \cdot C_{dgr(ij)} \right)$$

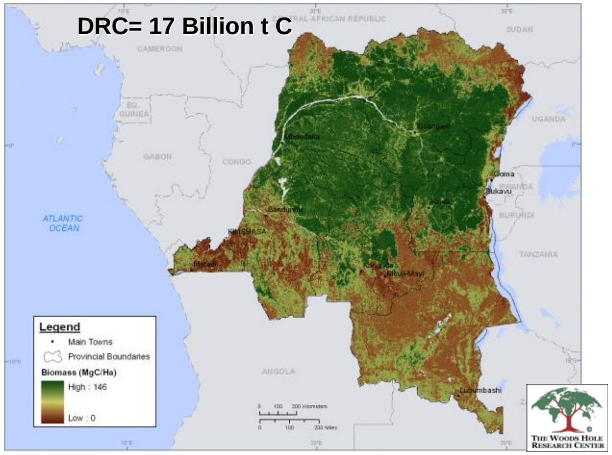
A_{loss} = Area of deforestation (ha)
C_{loss} = Carbon emission from deforestation (t/ha)

for forest types i … m

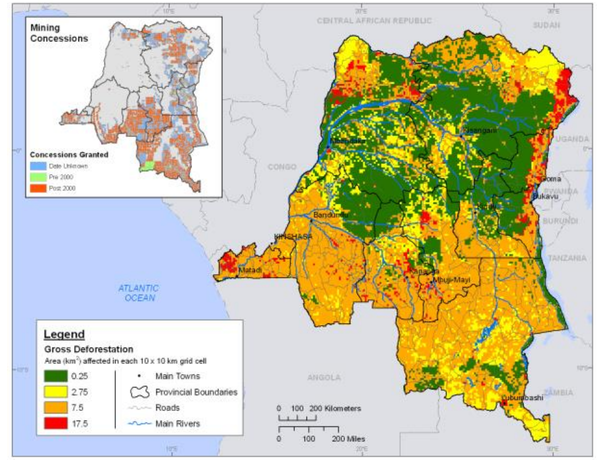
A_{dgr} = Area affected by degradation (ha)
C_{dgr} = Carbon emission from degradation (t/ha)

for degradation types j … n
for forest types i … m

Biomass

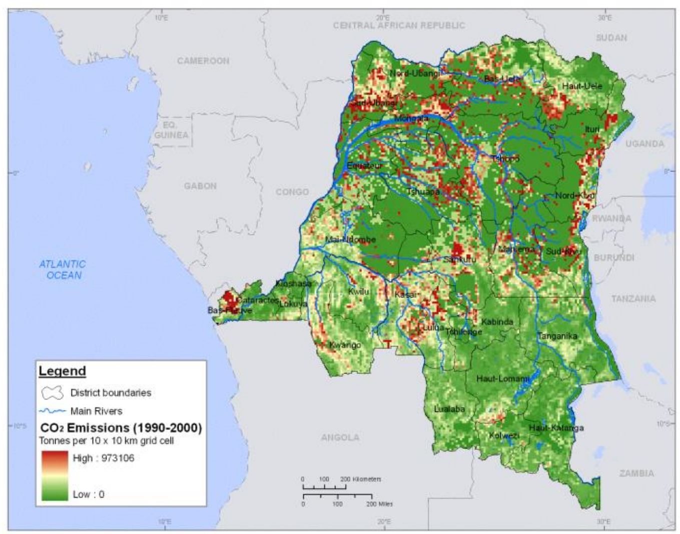


Deforestation



(tC/ha)

(tC/ha)



Reduce uncertainty in carbon cycle studies

Input for REDD/carbon Market

Stock Flow Approach

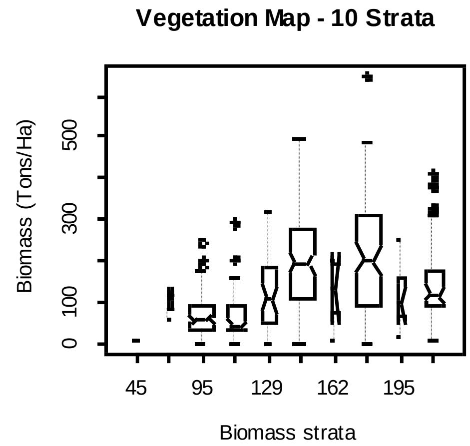
CO_2 Emissions 1990/2000

Large Area Carbon Estimation

- **Forest Inventories**
- **Stratify & Multiply (SM) Approach**
  - Assign an average biomass value to land cover/vegetation type map (Asner et Al. 2010)
- ***Combine & Assign (CA) Approach***
  - Extension of SM, GIS and multi-layers information (Gibbs et al. 2007, Tyukavina et al. 2015)
- ***Ecological Models (EM) Approach***
  - Remote sensing to parameterize the model (Hurtt et al. 2004)
- ***Direct Remote Sensing (DR) Approach***
  - Empirical Models where RS data is calibrated to field estimates (Baccini et al. 2004, 2008, 2012, Saatchi et al. 2007, 2011, Blackard et al. 2008)

Goetz, Baccini et al. 2009

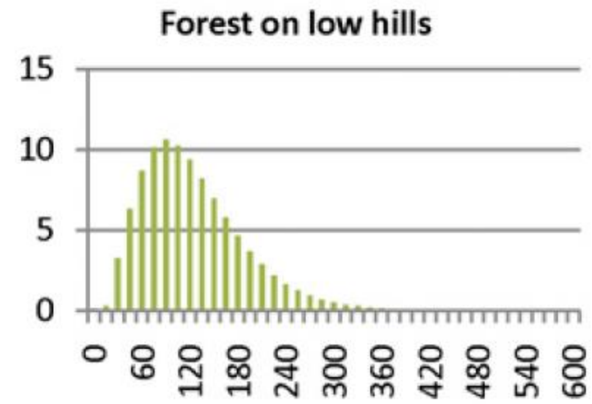
Stratify & Multiply (SM)

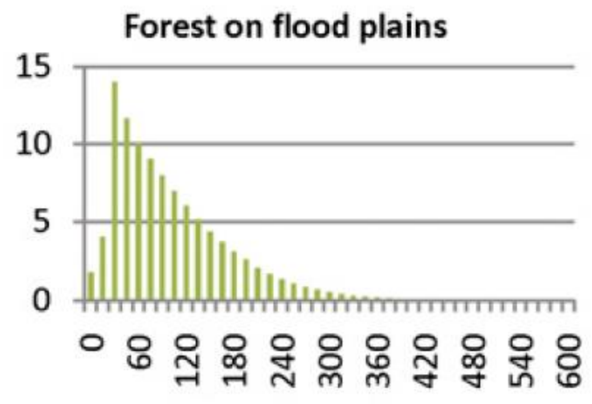


- Adequate number of samples required in each class

- Errors in thematic map

- Land cover only partially related to biomass (e.g. within class variability)



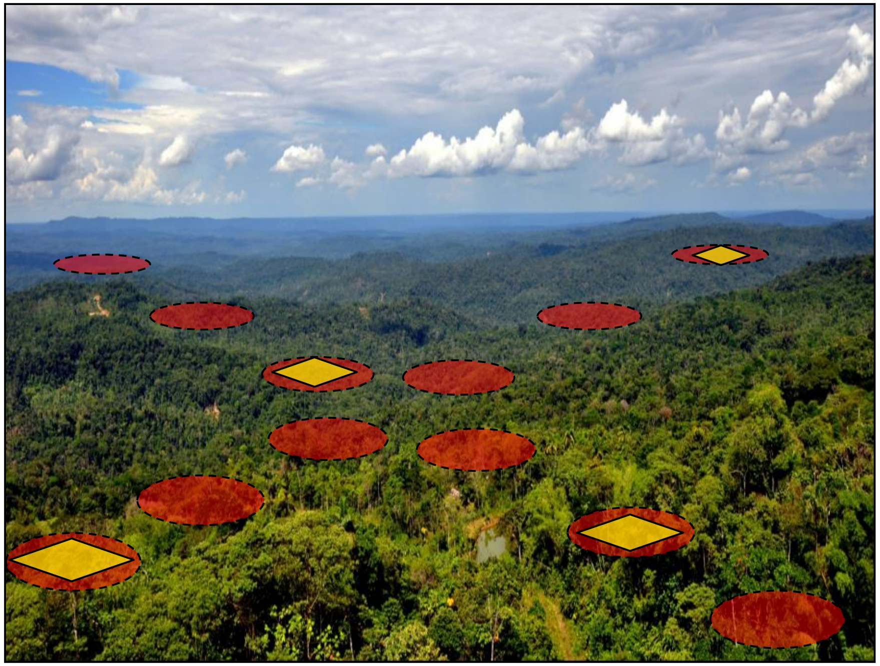


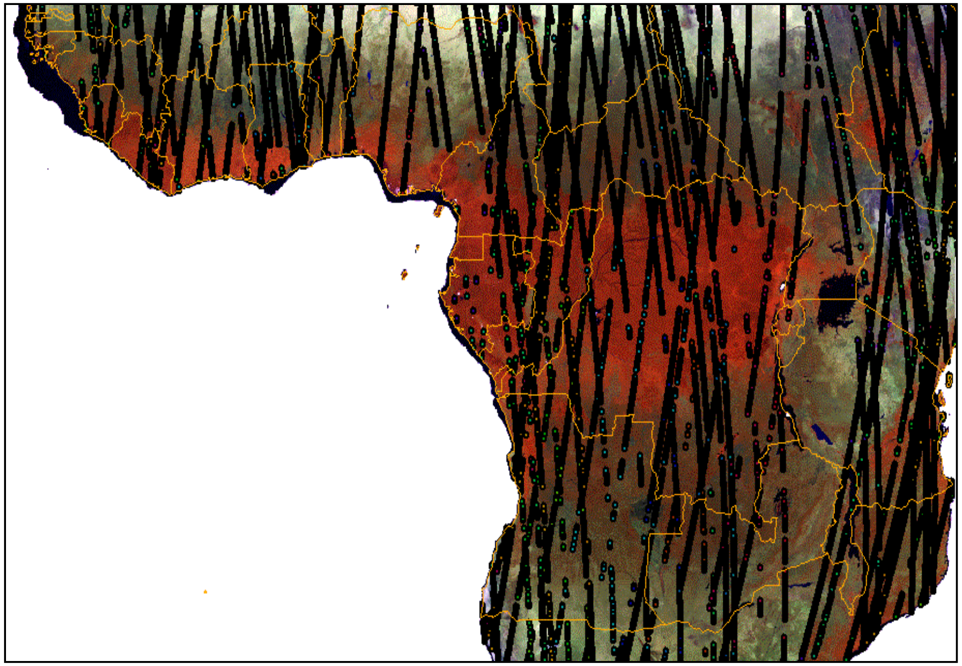
Baccini and Friedl 2007, Asner et al. 2010

Satellite Information

Two types of information: Point data and Image data

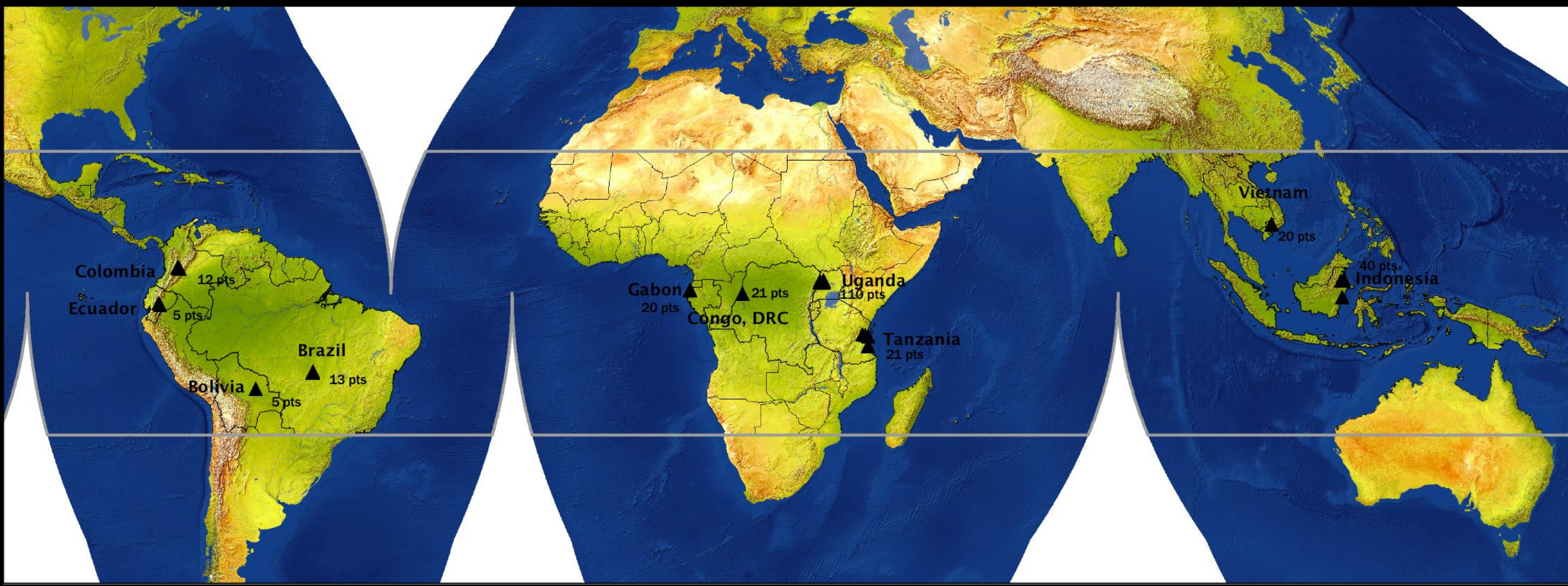
ICESat GLAS (Points)





Field observation network & calibration

>300 locations > 30,000 trees measured



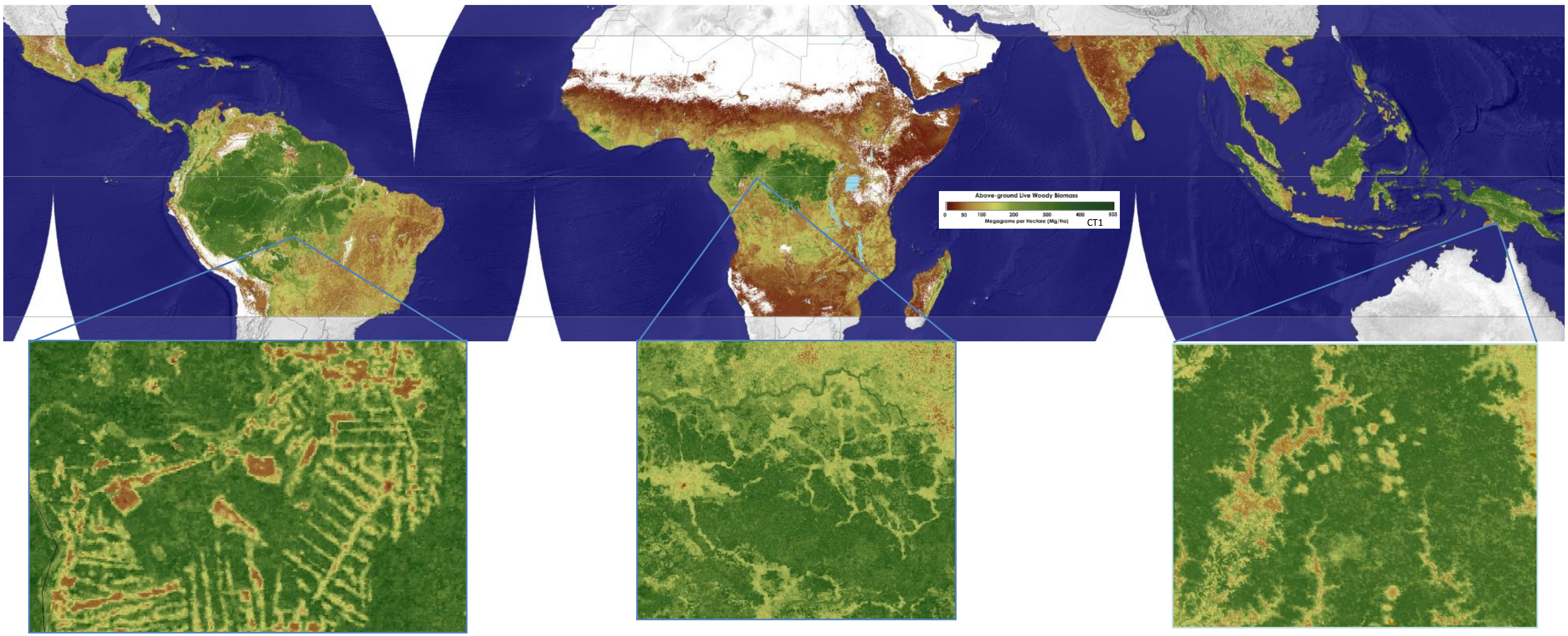
- Columbia
- Ecuador
- Bolivia
- Brazil

- Gabon
- DRC
- Uganda
- Tanzania

- Vietnam
- Cambodia
- Indonesia

Pantropical Forest Carbon Mapped with Satellite and Field Observations

Baccini et al. 2012



Amazon Basin detail from the map

Error 25 Mg C ha^{-1}

DRC detail from the map

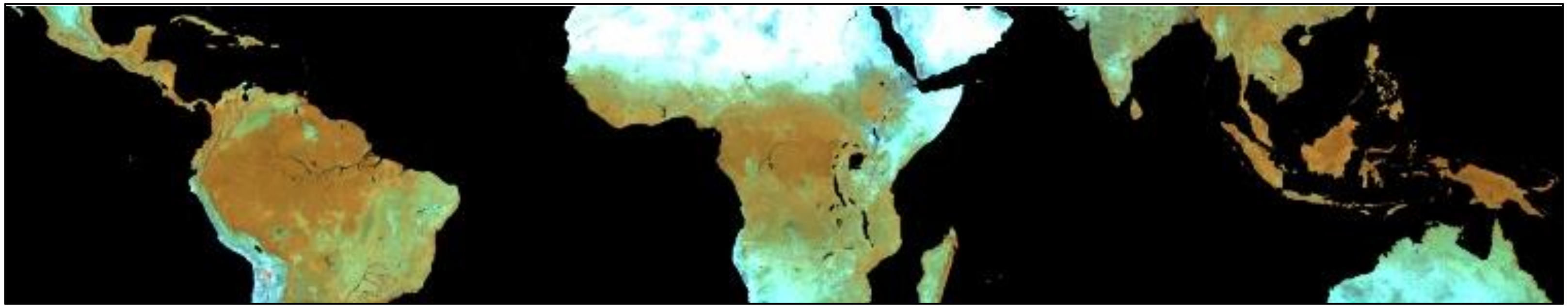
Error 19 Mg C ha^{-1}

PNG detail from the map

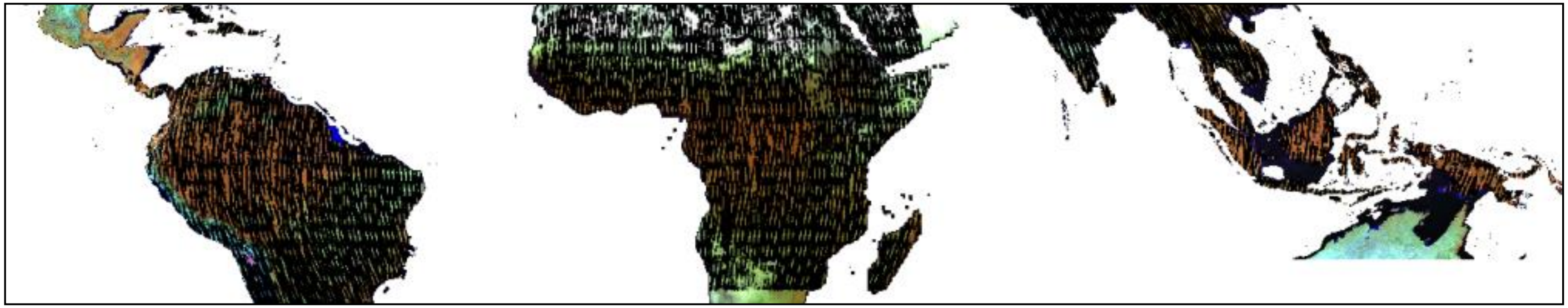
Error 24 Mg C ha^{-1}

Recent work

Landsat circa year 2000 RGB: 4,5,7 (Hansen et al. 2013)

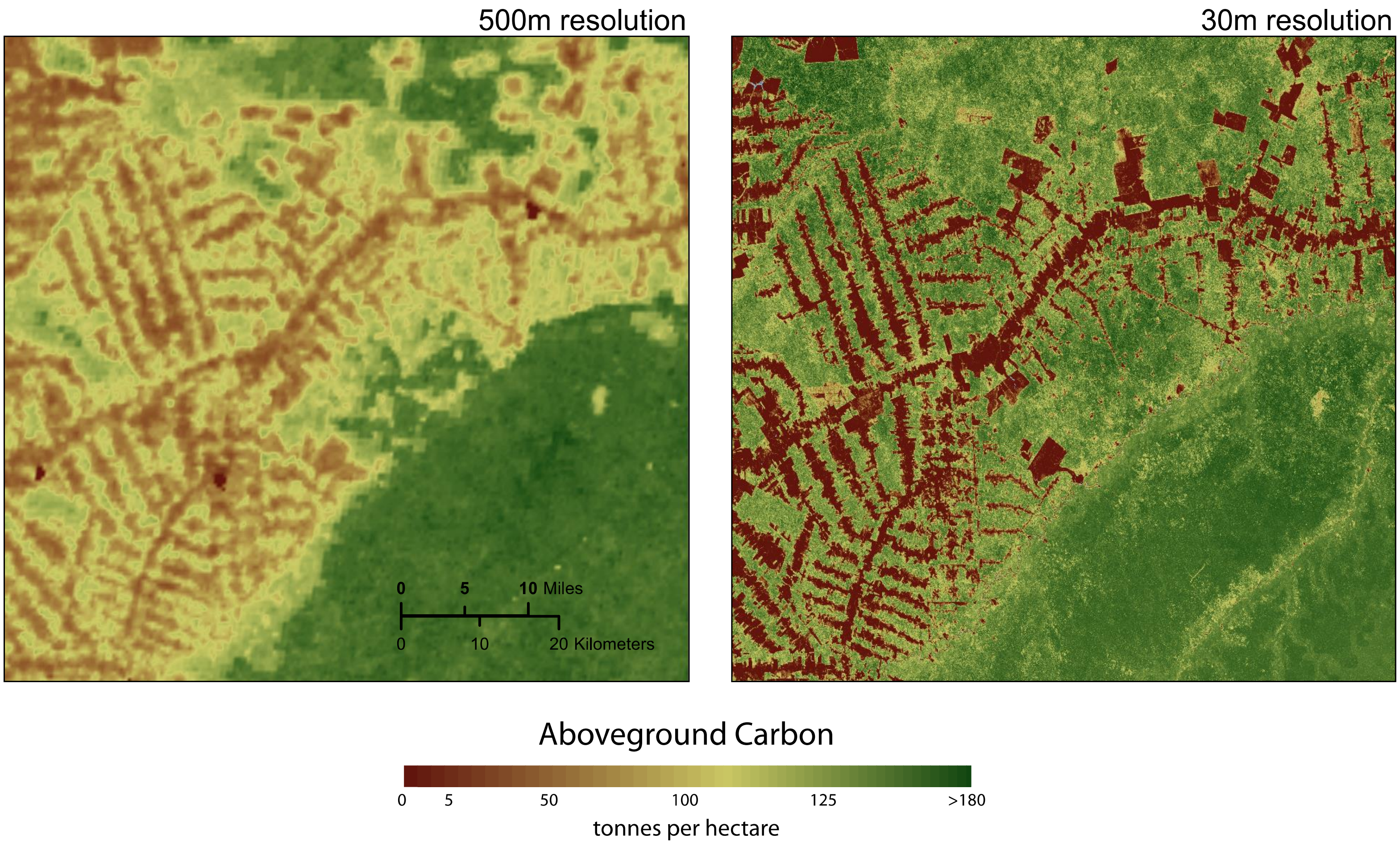


GLAS based biomass density estimates (Baccini et al. 2012)

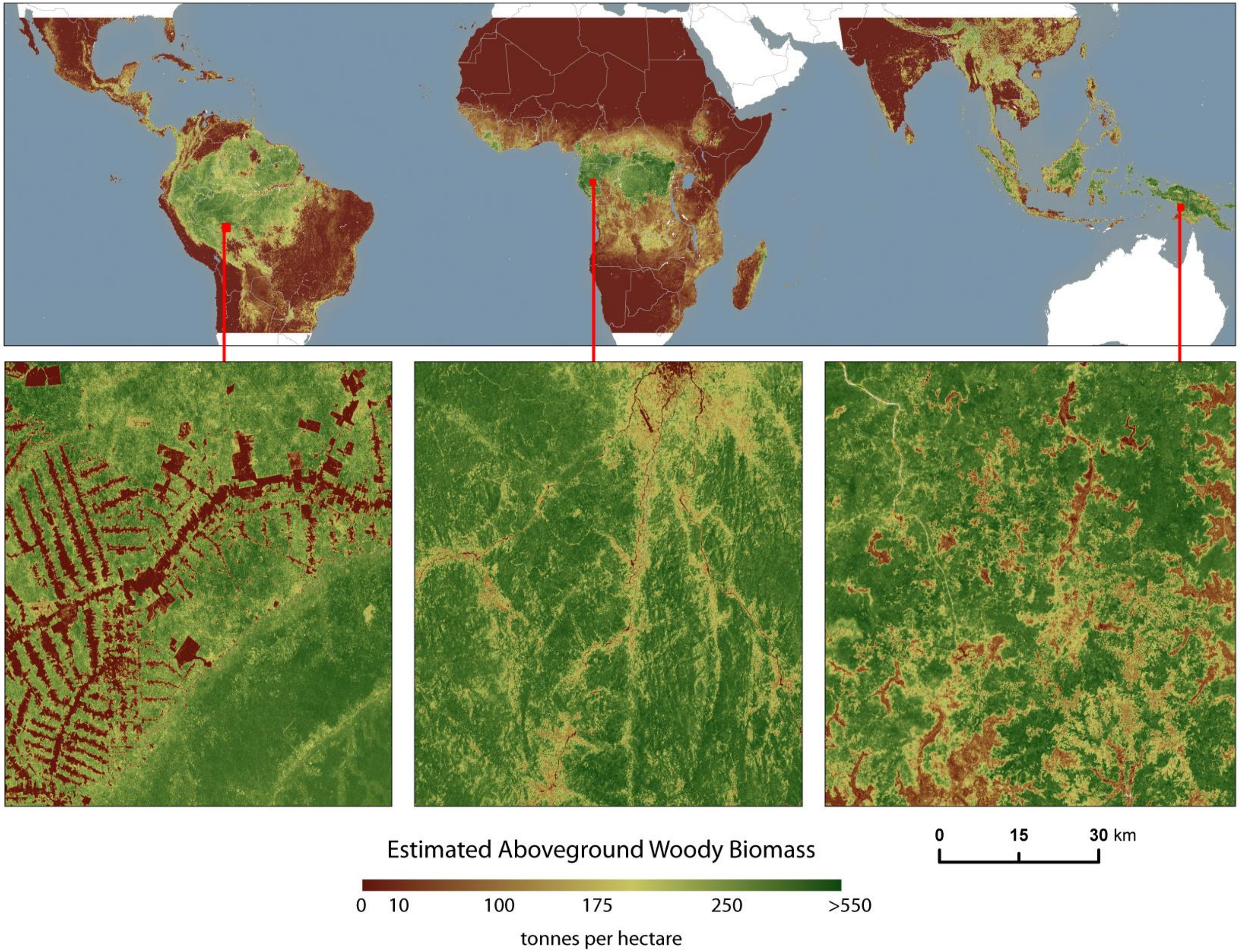


Based on similar approach of Baccini et al. 2012

Improvement in Spatial Resolution



Landsat Based Biomass Density (Yr. 2000)

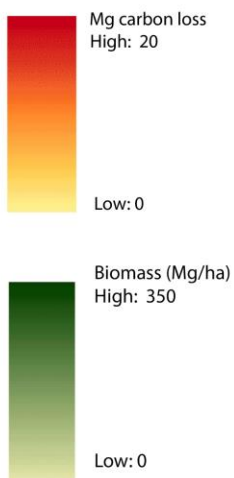


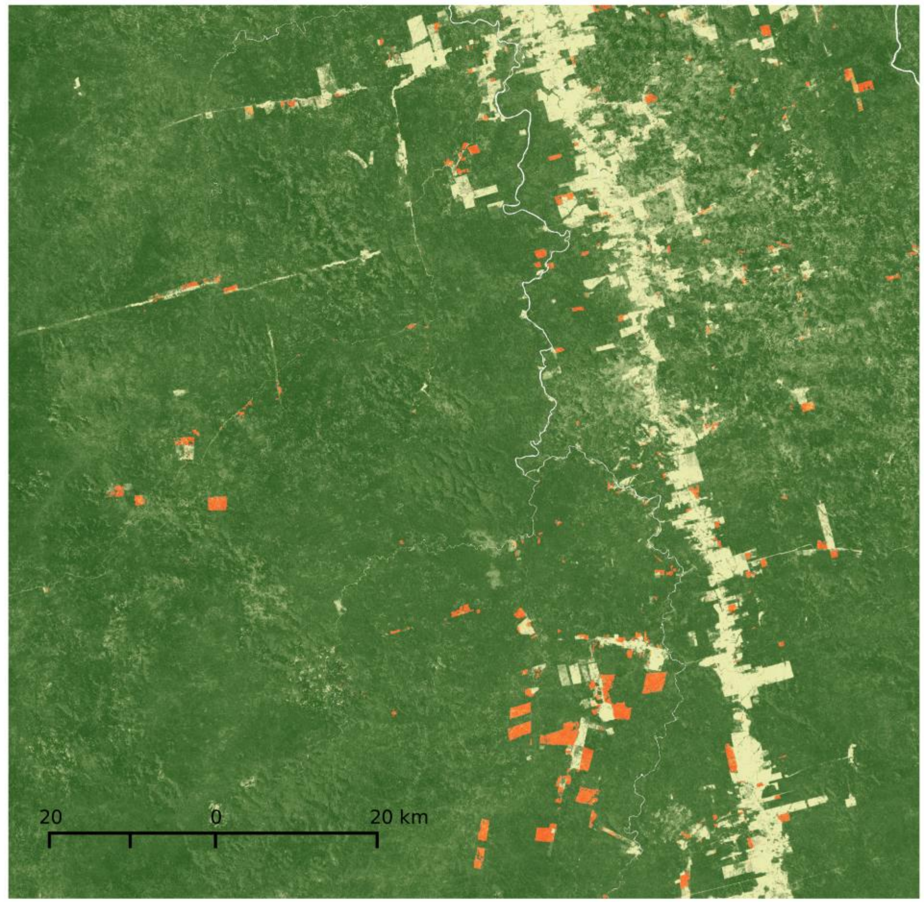
Landsat Annual Biomass Loss from Deforestation

Biomass reference year 2000

Year: 2001

Tg carbon lost since year 2000: 1.77

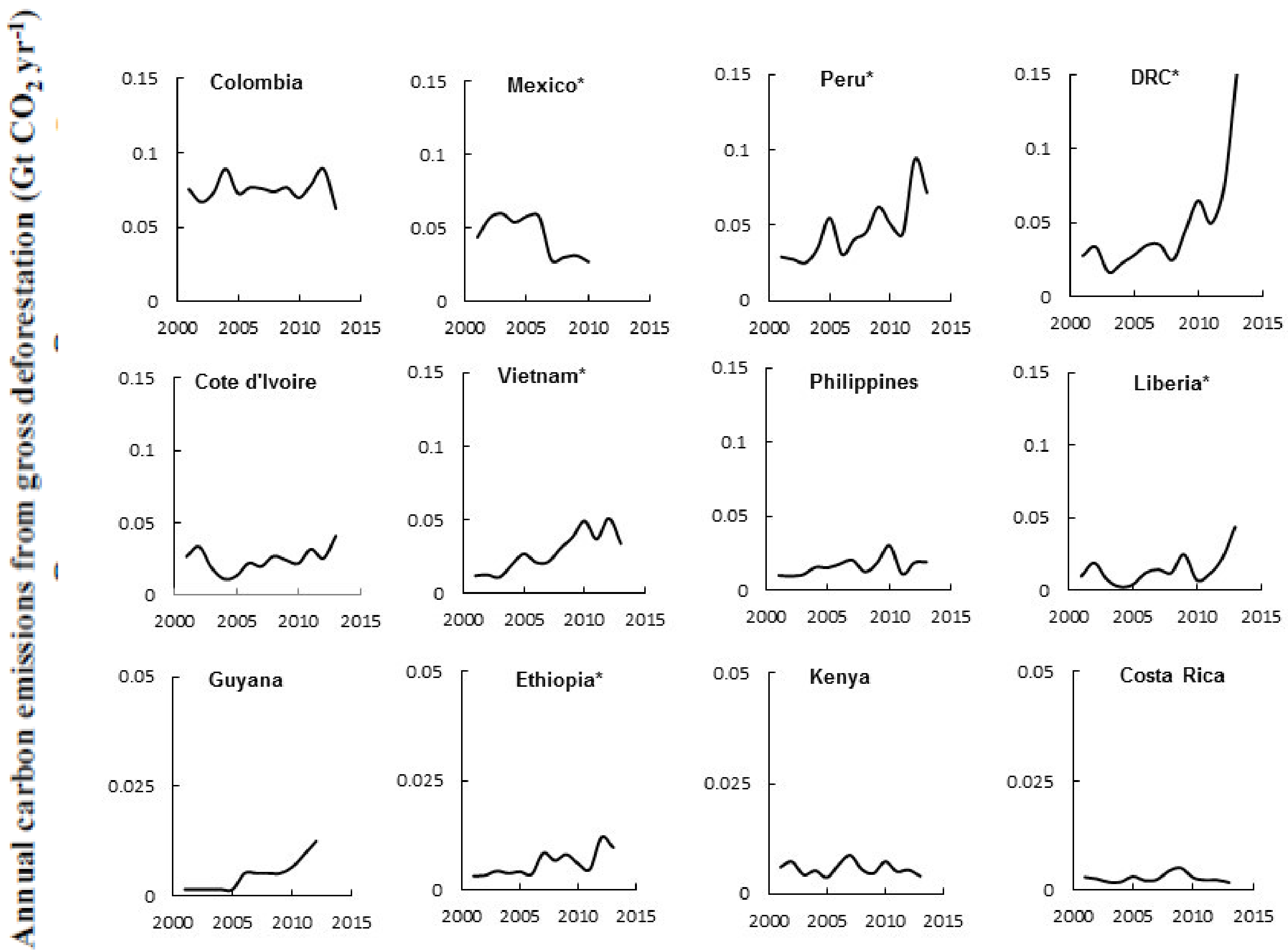




Landsat biomass density circa 2000 combined with Hansen et al. 2013 deforestation

Annual Gross Emissions from Deforestation

Zarin et al. 2015

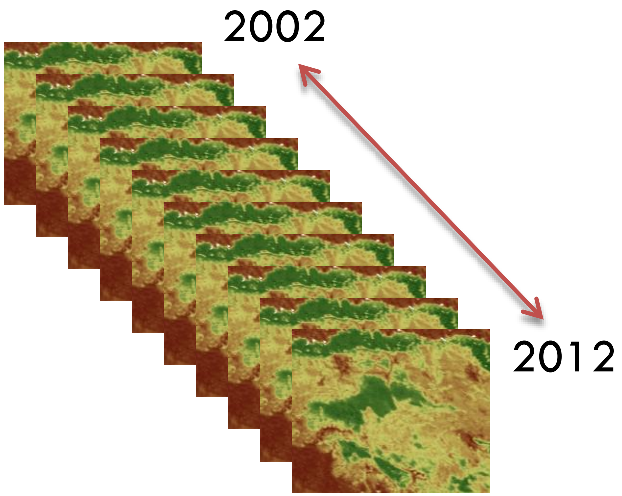


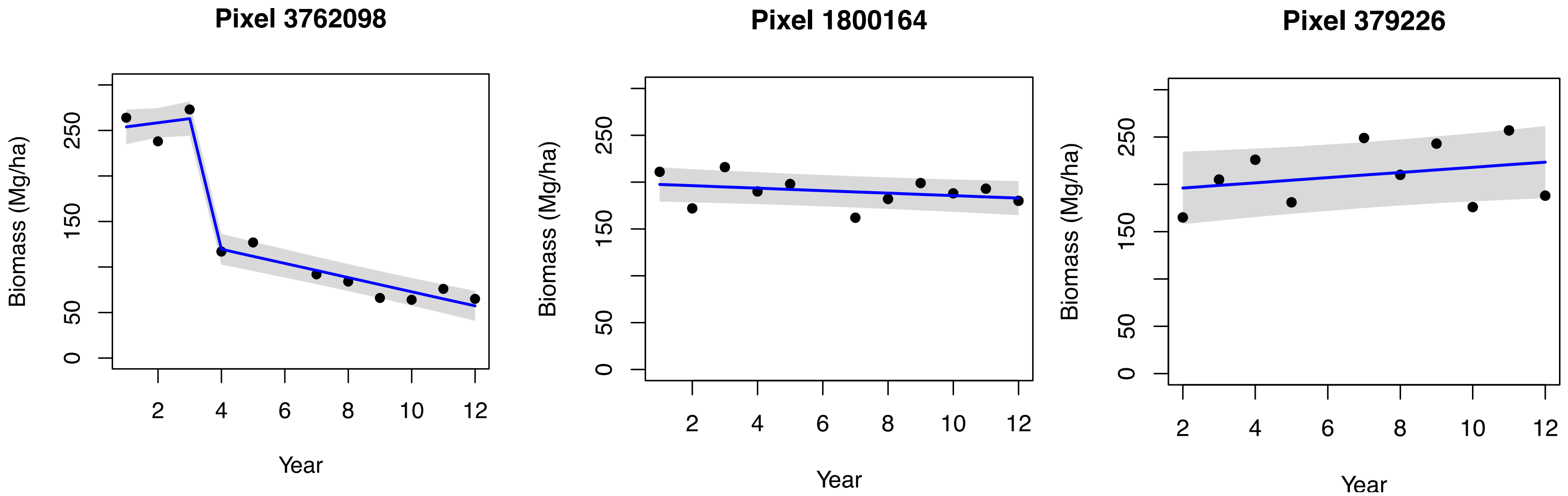
$$AGCloss = \sum \cancel{AD_i} * \Delta EF$$

No need to define Deforestation and Degradation

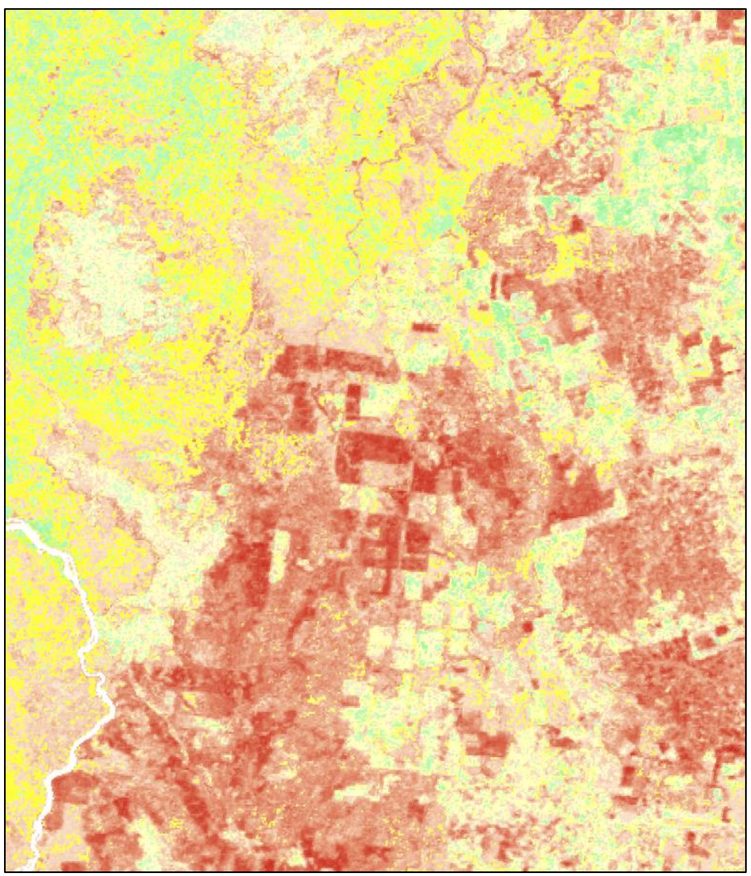
Carbon density trajectories over time and space

- Time series approach based on "change point" analysis
- For each 500 m x 500 m pixel we identify the trajectory of carbon density

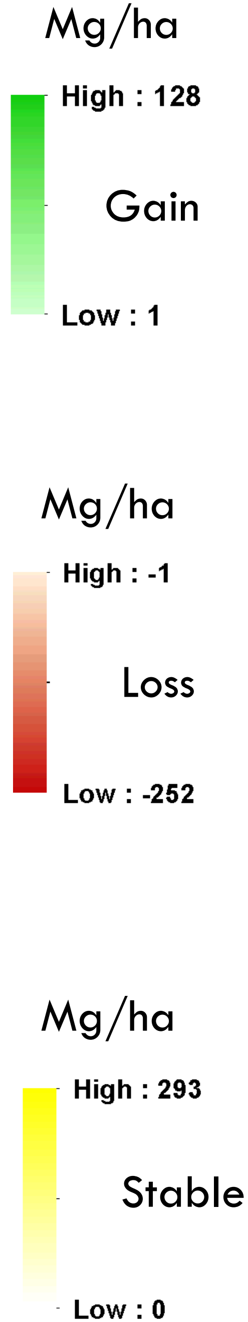


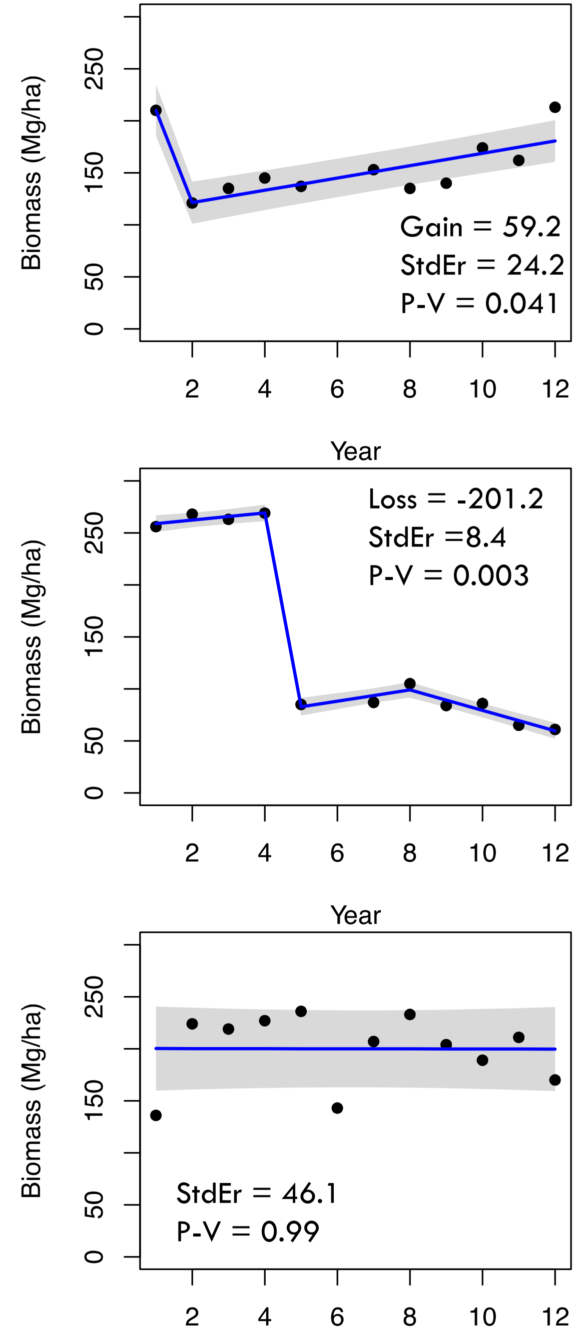


Continuous spatially explicit carbon density change with measurable uncertainty



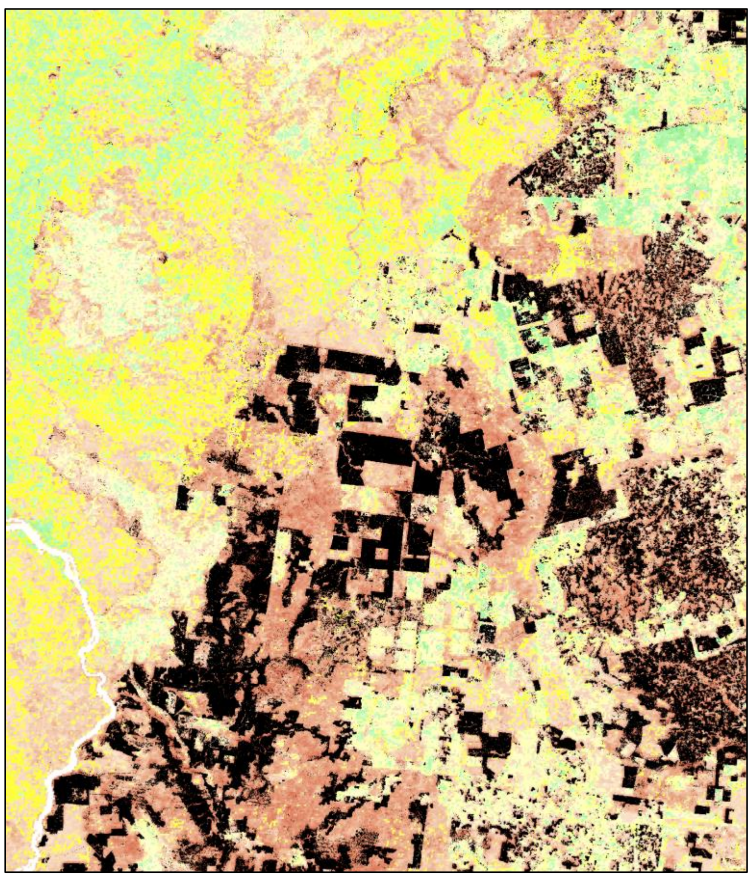
190 km x 215 km





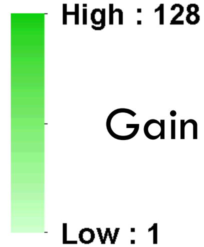
Consistent with deforestation and sensitive to “degradation” ?

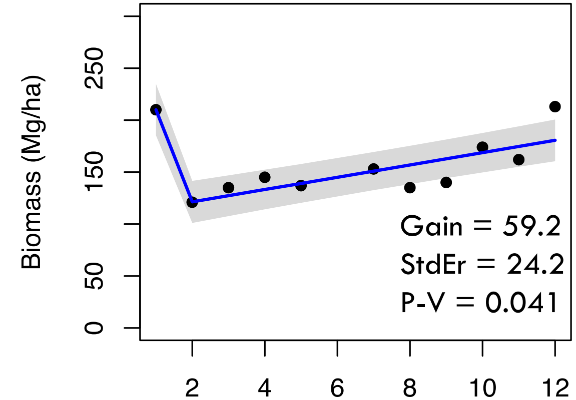
Deforestation Landsat based (30 m resolution) Hansen et al. 2014



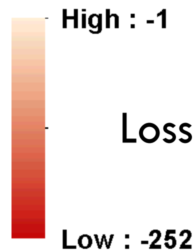
190 km x 215 km

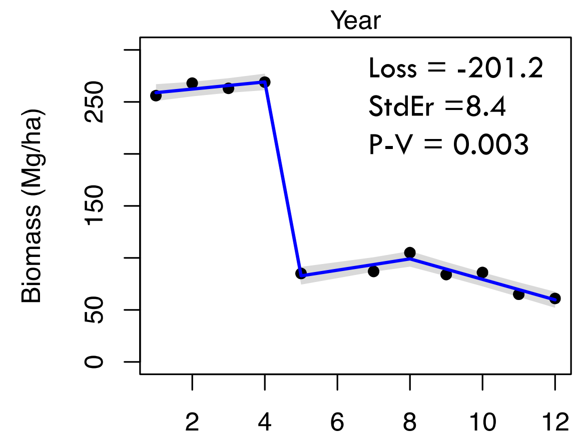
Mg/ha



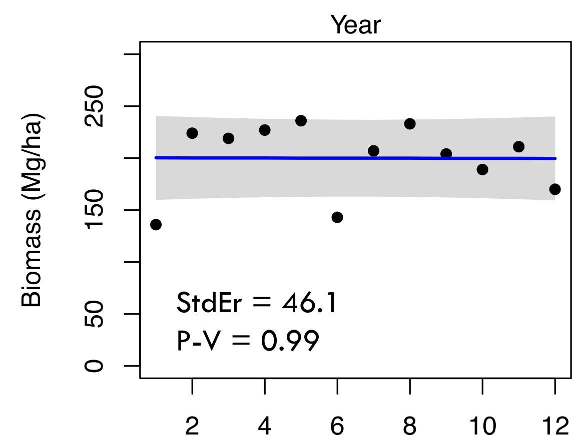


Mg/ha

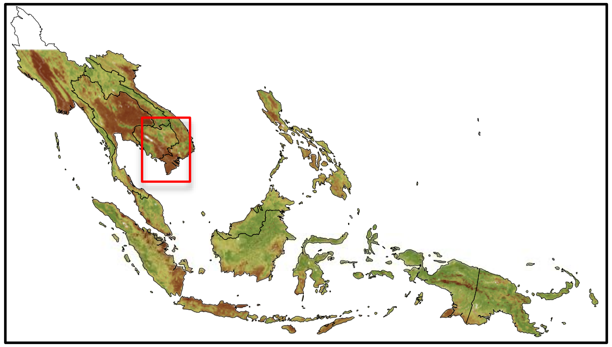


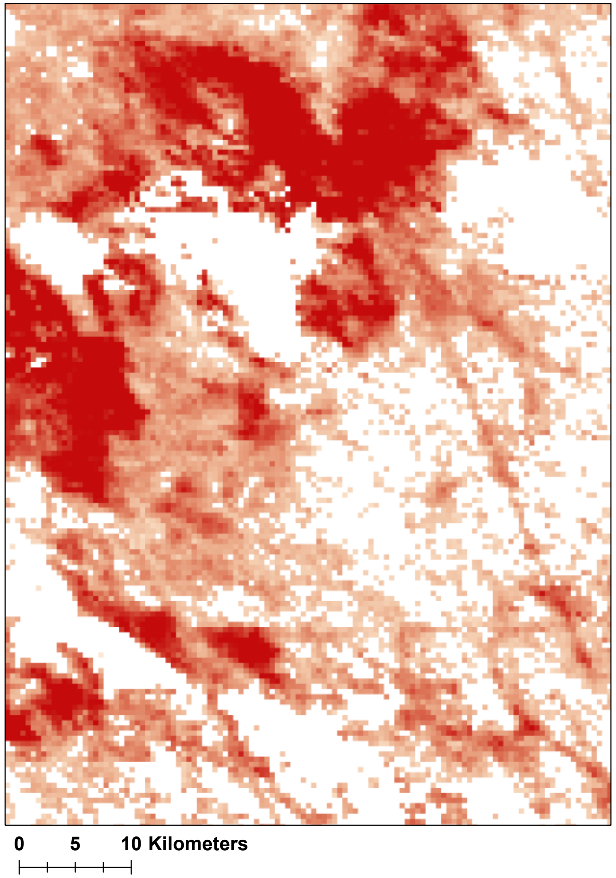


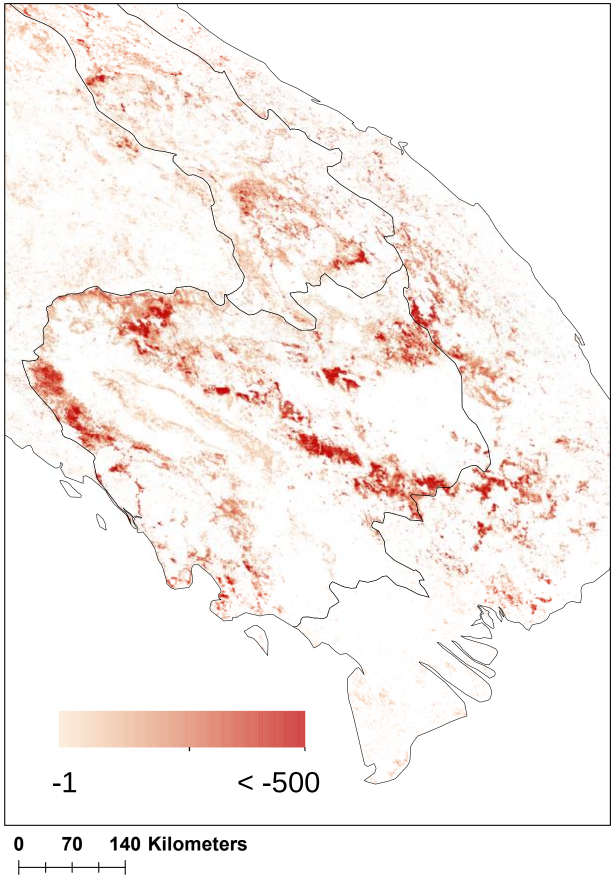
Mg/ha



South East Asia Biomass change 2002 - 2012







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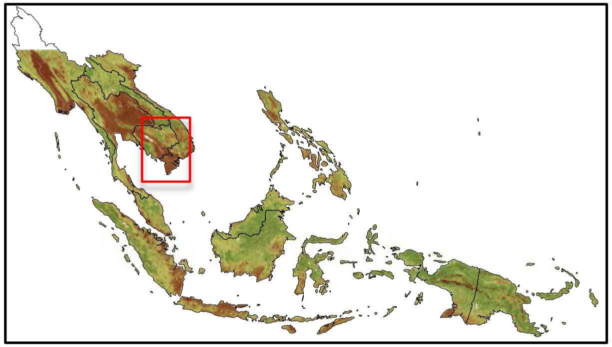
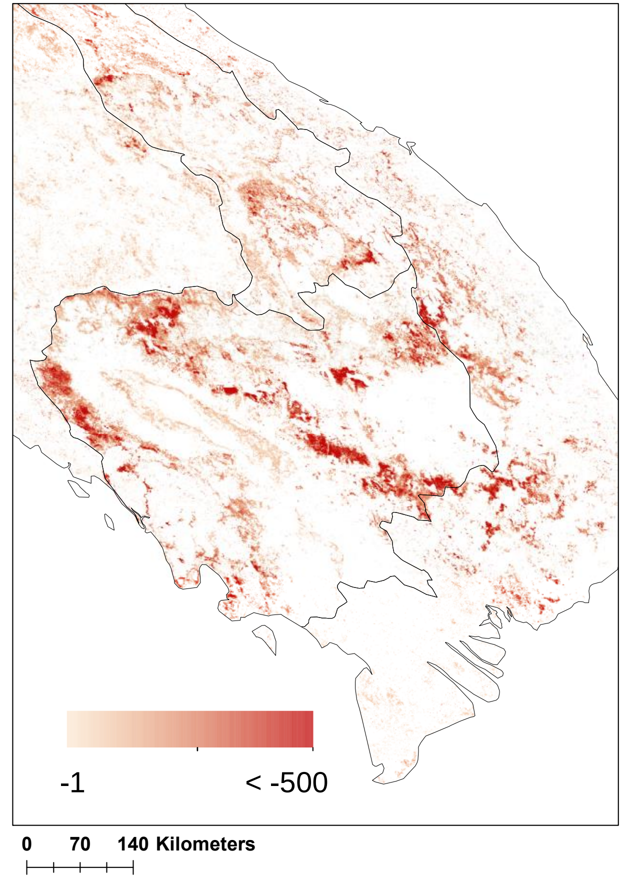
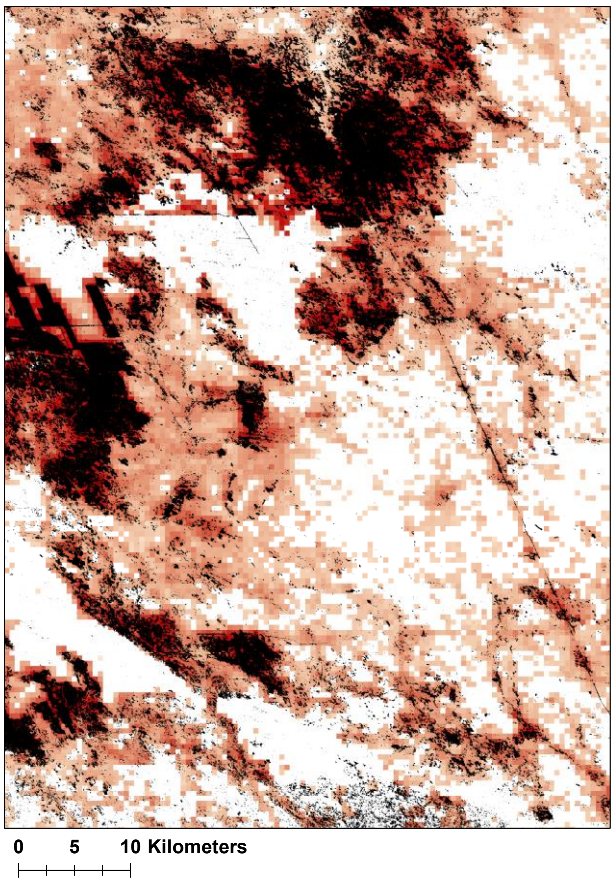
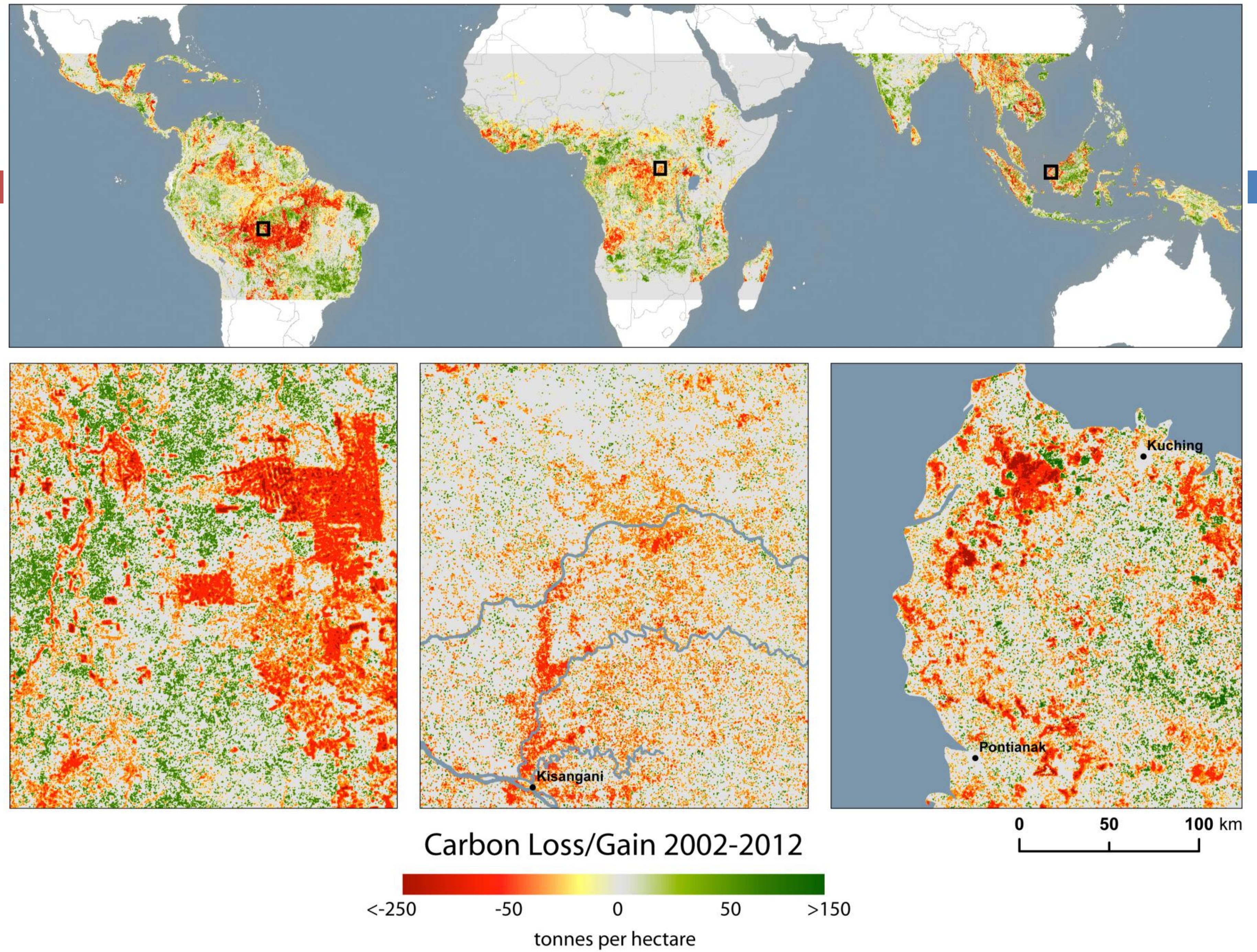




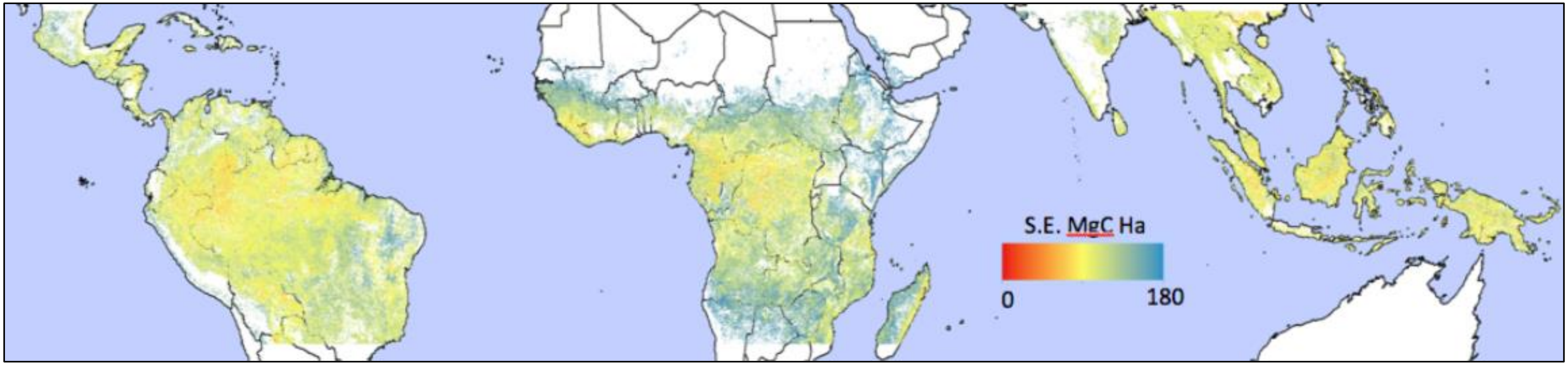


Deforestation Landsat based (30 m resolution) Hansen et al. 2014



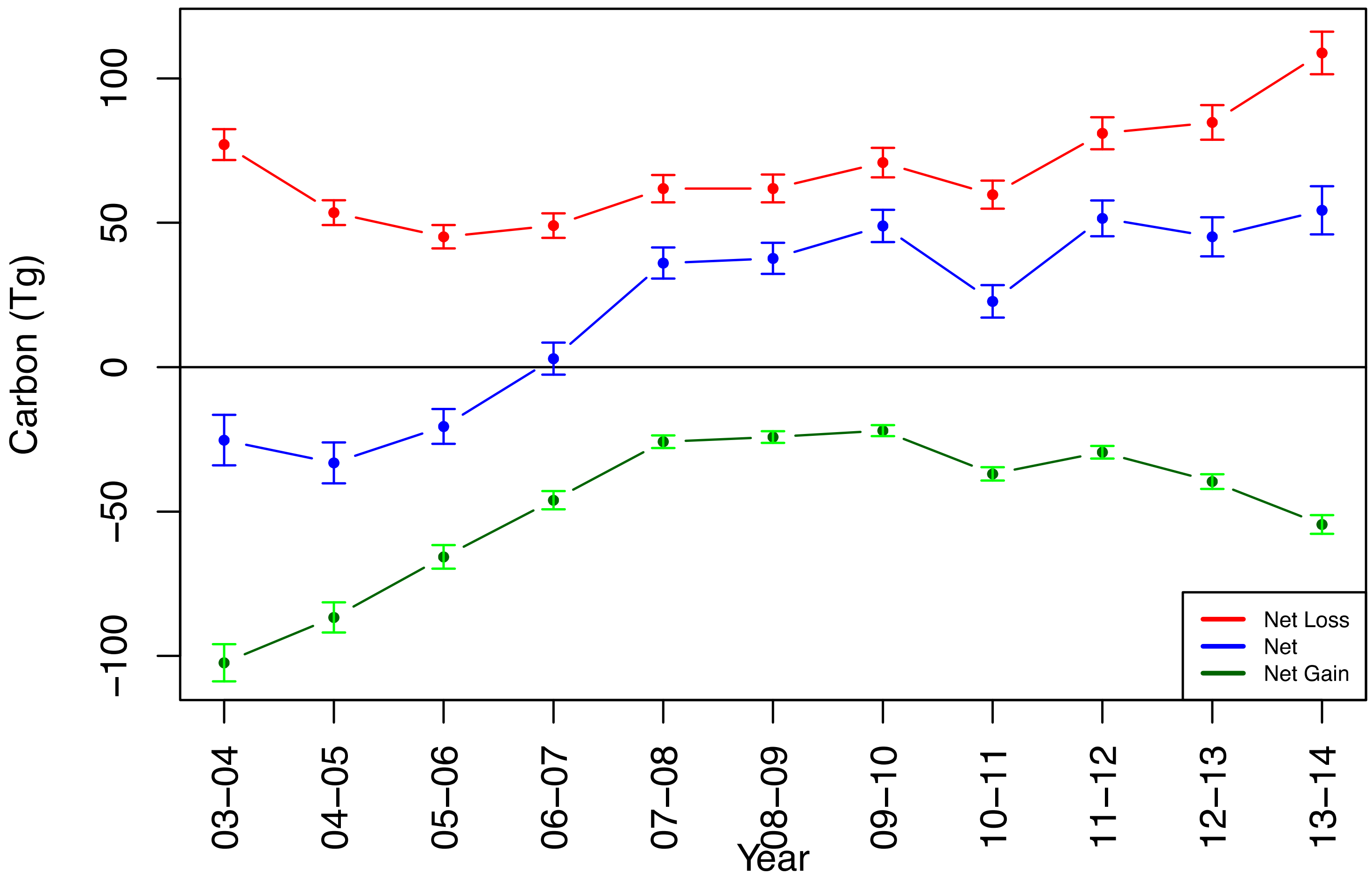
Kuching
Pontianak
Kisangani
0
50
100 km
Carbon Loss/Gain 2002-2012
<-250
-50
0
50
>150
tonnes per hectare

Uncertainty Associated to Change



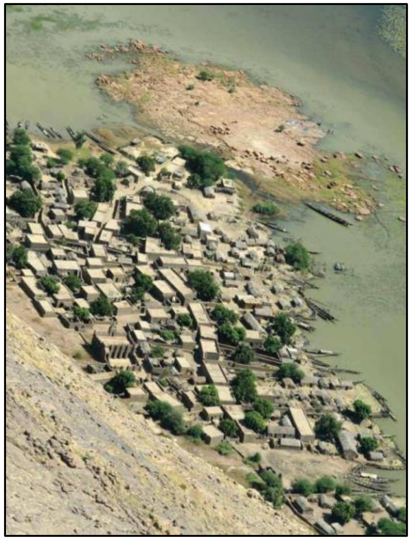
Democ. Rep. Congo Annual Carbon Net Loss and Gain

Baccini et al. 2016. *In review Nature*



Trees Outside Forest

- Trees that do not meet the criteria of "Forest"
  - It depends on Forest definition/country/agency
- Monitoring requires high resolution RS



Planet Lab data 3-5 m resolution

SUMMARY

- “Direct” approach to quantify changes in carbon density over time and space
- Based on multiple annual observations, improvement over the T1 – T2 approach
- Globally consistent, continuous, no need to classify forest and land cover change
- Fewer inputs resulting in smaller uncertainty
- Preliminary results are encouraging, what about attribution?

Summary

- Errors from allometry are relatively small
- Spatial aggregation reduce uncertainty in the estimates
- Different vegetation types tent do show different errors
- Biomass density maps can help in region with few field data
- There is the need for better remote sensing data
  - Airborne LiDAR significantly improve the estimates (Baccini & Asner, 2014)