SURVEY OF BIOMASS, CARBON STOCKS, BIODIVERSITY, AND ASSESSMENT OF THE HISTORIC FIRE REGIME FOR INTEGRATION INTO A FOREST MONITORING SYSTEM IN SOUTH SUMATRA, INDONESIA

Assessment of historic fire regime

Work Package 4

BIOCLIME Workshop
Palembang 13 October 2016

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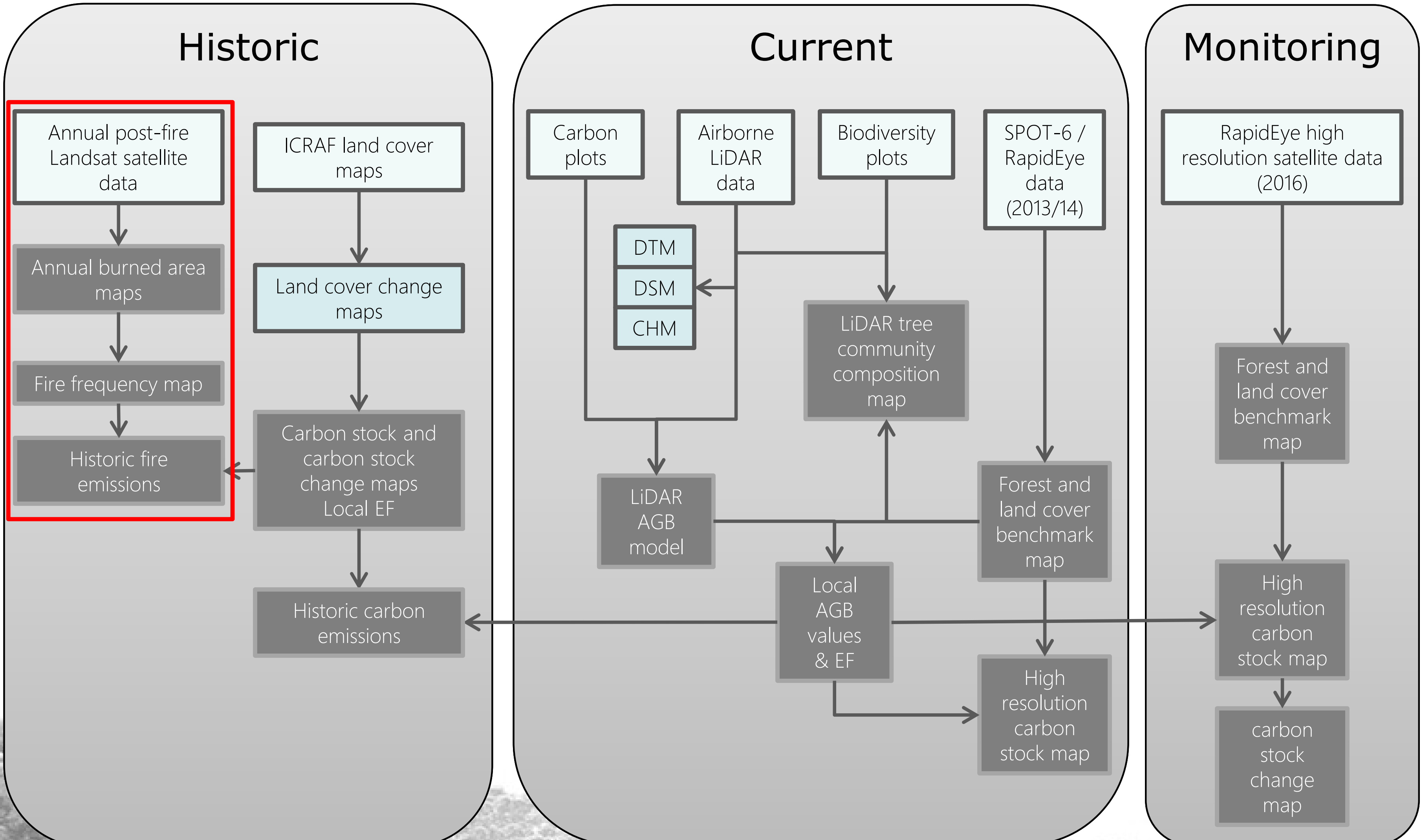
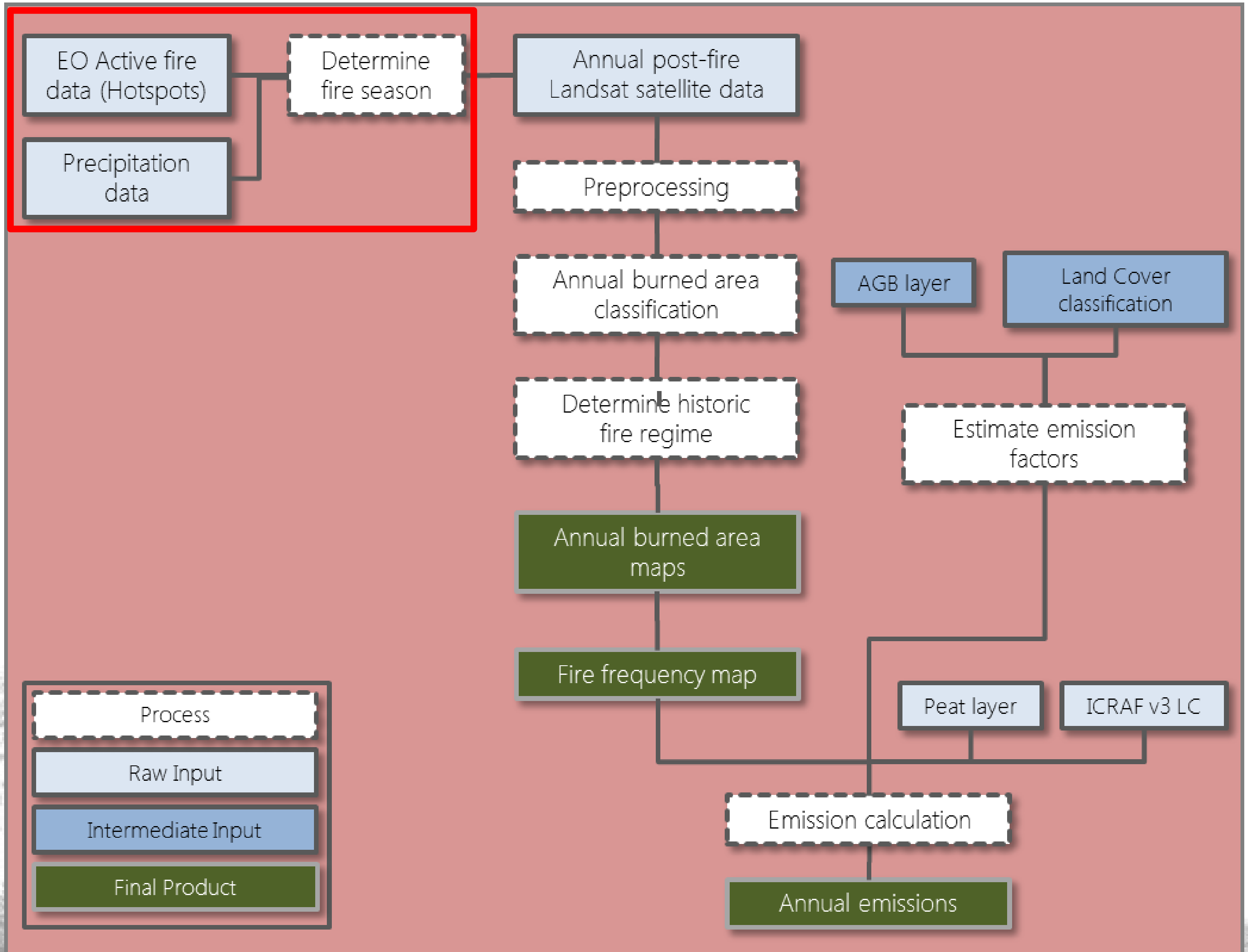
Concept of the monitoring system



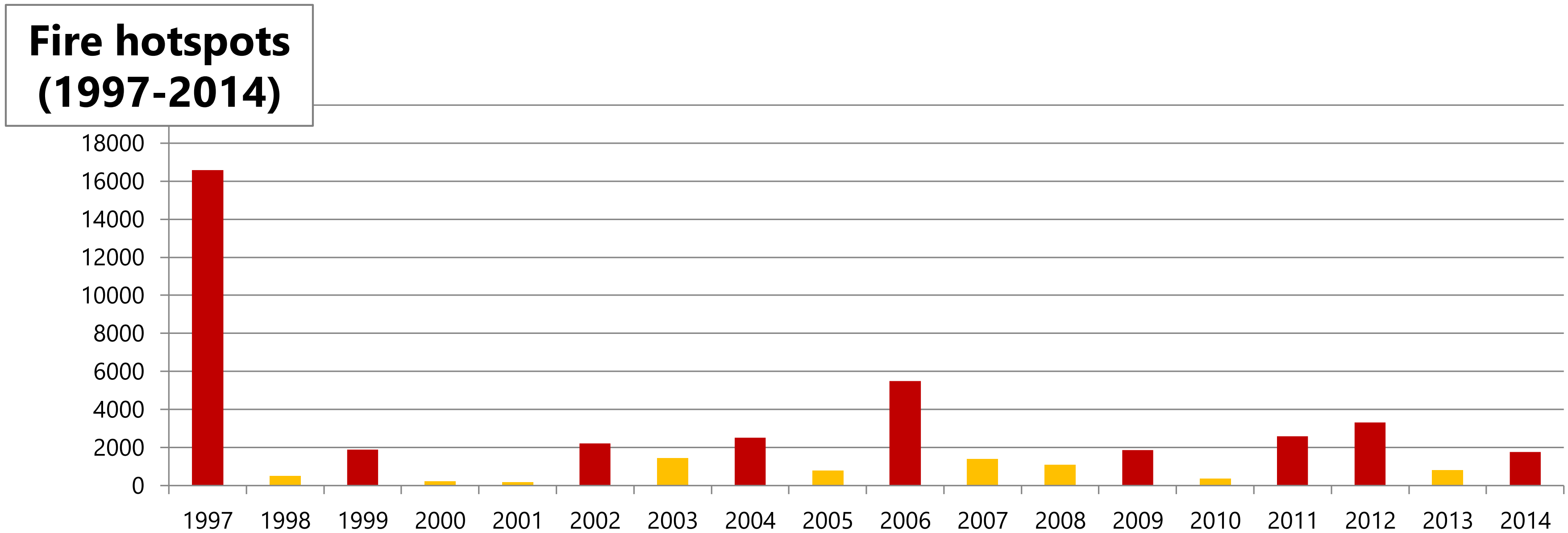
Objectives

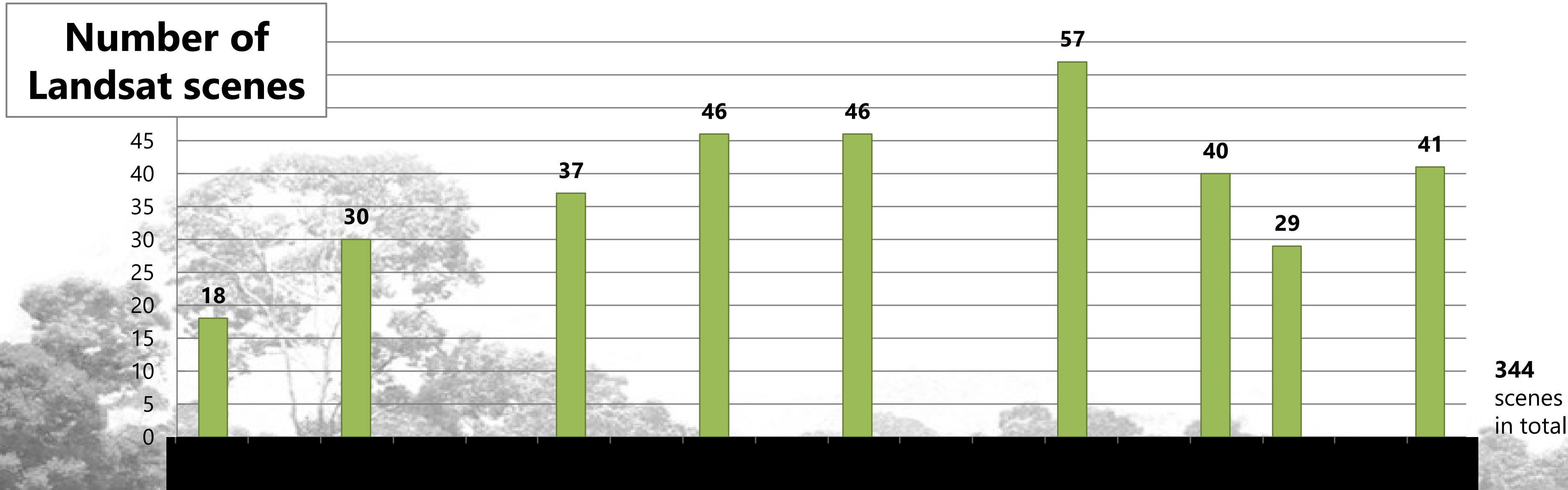
- Generation of burned area maps for different years based on optical satellite data (1997 onwards)
- Selection of years for classification based on number of hotspots (MODIS) per year and precipitation distributions (only classification of severe years)
- Classification of burned areas based on the combination of two methodologies
- Derivation of a fire frequency map in order to locate areas of higher and lower fire frequency
- Calculation of annual and total emission from aboveground biomass and peat burning

Workflow

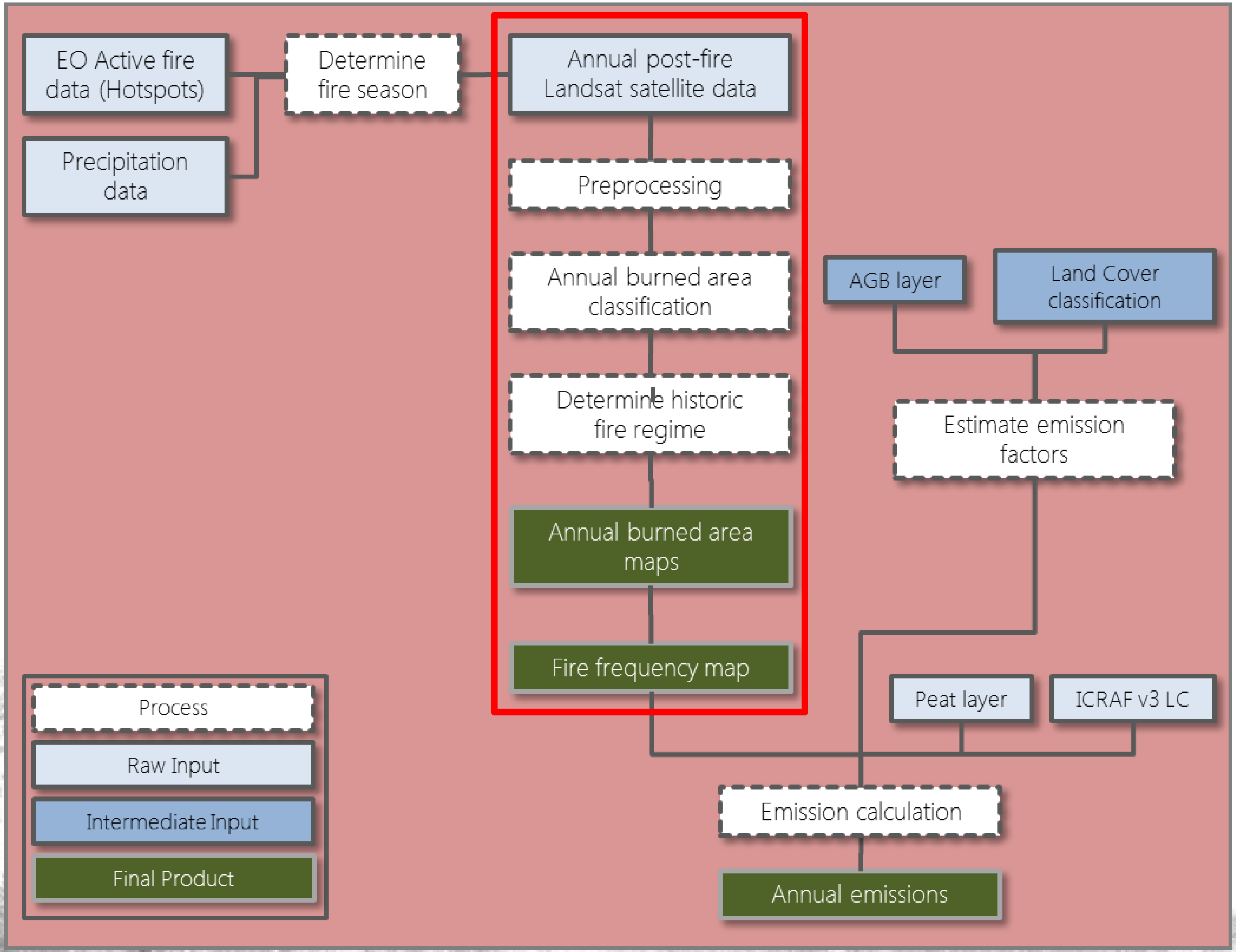

EO Active fire data (Hotspots)
Precipitation data
Determine fire season
Annual post-fire Landsat satellite data
Preprocessing
Annual burned area classification
Determine historic fire regime
Annual burned area maps
Fire frequency map
AGB layer
Land Cover classification
Estimate emission factors
Peat layer
ICRAF v3 LC
Emission calculation
Annual emissions
Process
Raw Input
Intermediate Input
Final Product

Determination of fire-intensive years





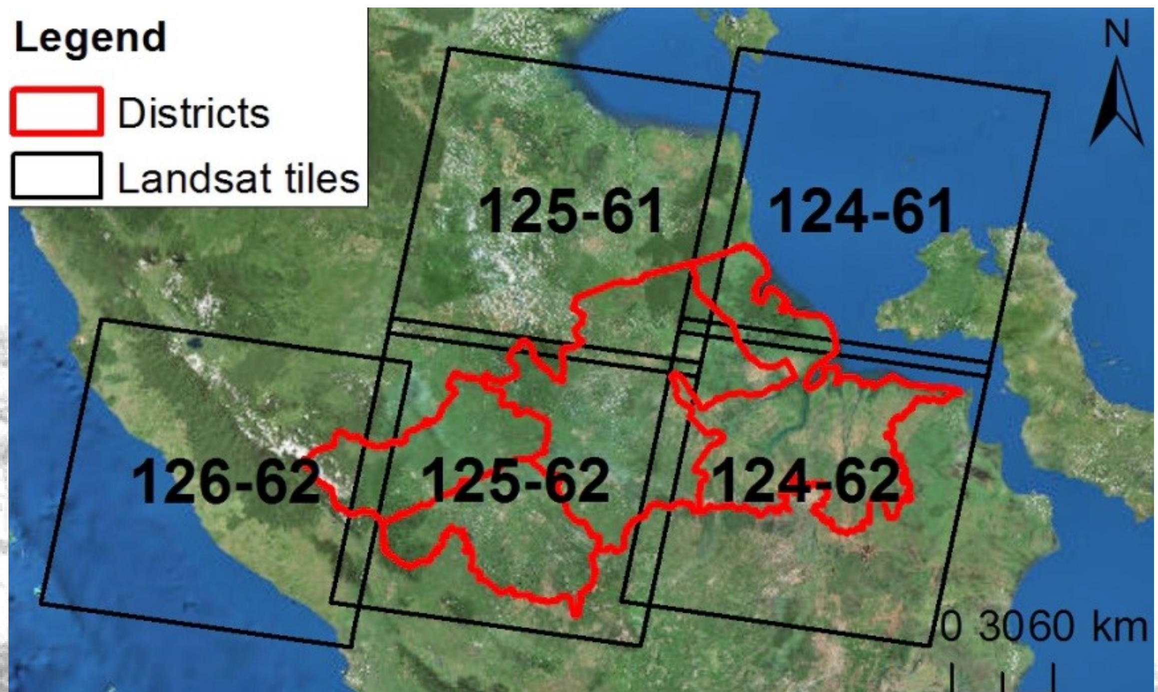
Derivation annual burned area maps



Landsat data

Selection of Landsat data:

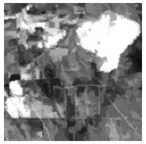
- 5 Landsat tiles
- For period of fire season until 2 months after
- Landsat-5, Landsat-7 and Landsat-8
- If not enough images: images before next fire season from following year will be considered



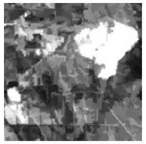
Burn ratios

Burn ratios

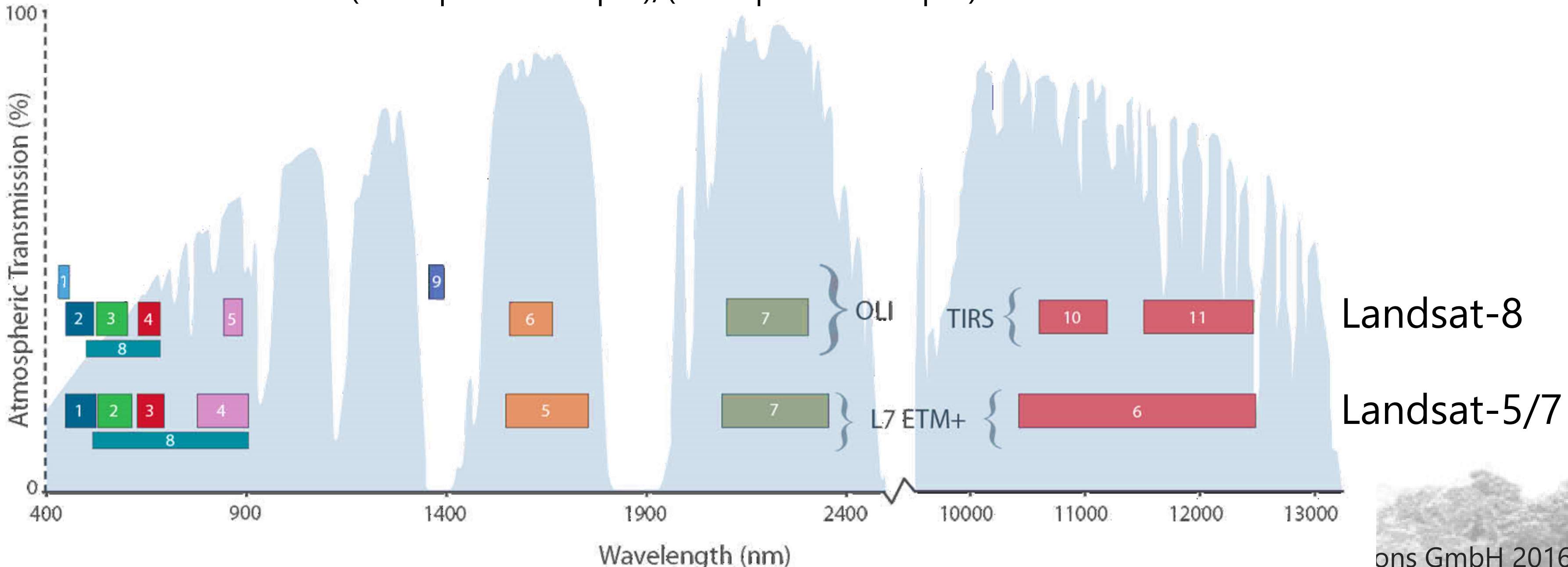
- BR1
  - (NIR– TIR) \ (NIR + TIR)
  - (b0.84µm - b11.45µm) / (b0.84µm + b11.45µm)



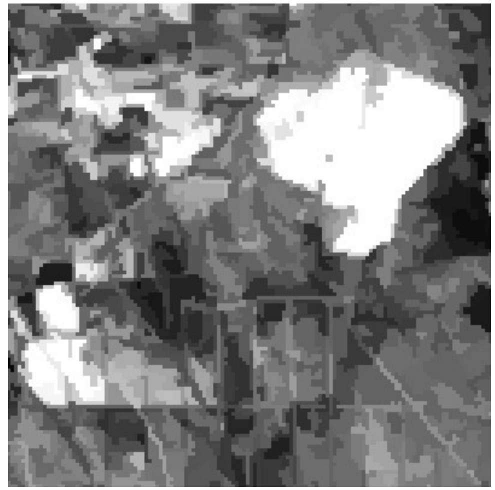
- BR2
  - (NIR - SWIR) \ (NIR + TIR)
  - (b0.84µm - b2.22µm) / (b0.84µm + b11.45µm)



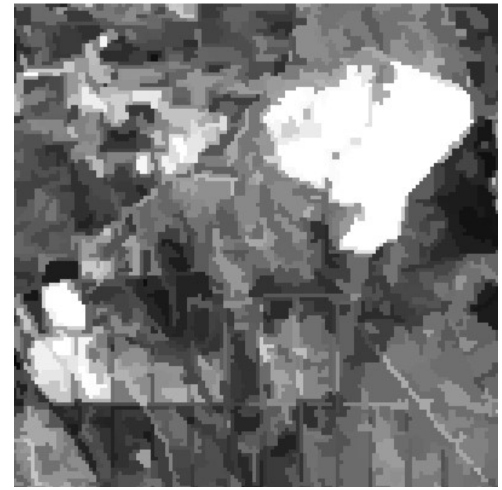
- NBR
  - (NIR - SWIR) \ (NIR + SWIR)
  - (b0.84µm - b2.22µm)/(b0.84µm + b2.22µm)



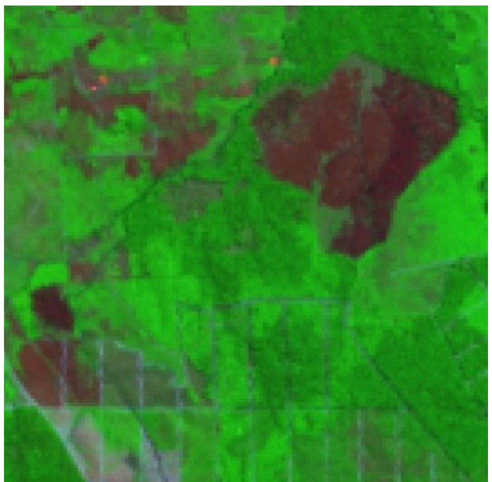
Burn ratios



BR1

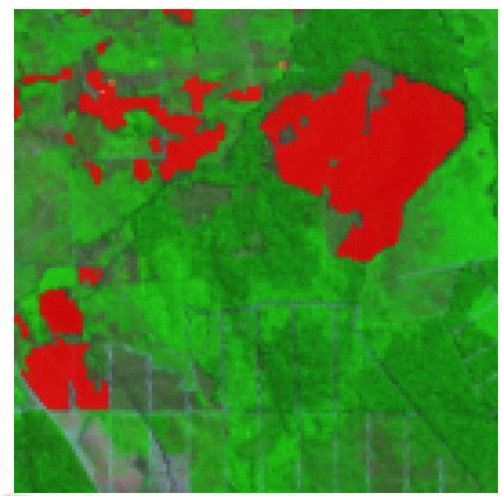


BR2



Landsat

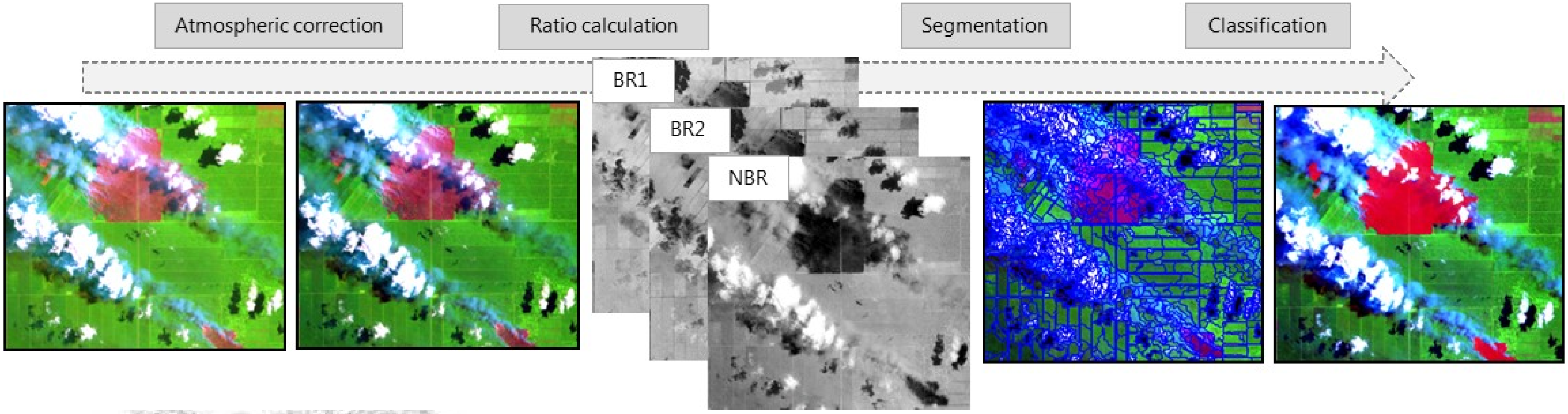
NBR



Burned area classification

Image processing

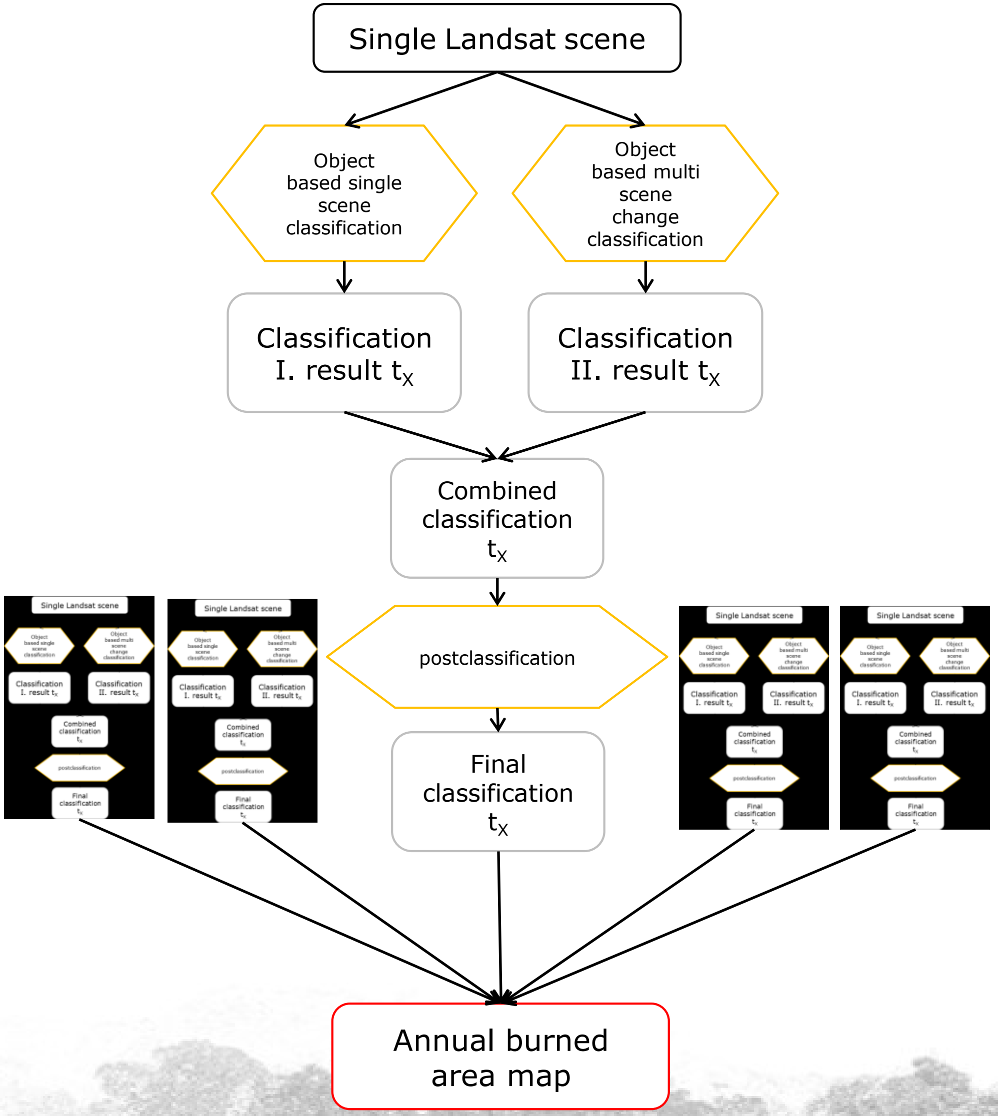
- Atmospheric correction
- Cloud masking
- Object-based classification with hierarchical rule-set based on burn ratios



Classification approaches

- Object based classification based on **single scene** using burn indices (BR1, BR2, NBR)
- Object based **multi scene** change detection ($t_1 - t_2$) (based on NDVI and NBR) and classification
  - Based on paper by MELCHIORI et al. (2014): A Landsat-TM/OLI algorithm for burned areas in the Brazilian Cerrado: preliminary results
  - Every scene compared to each other within one year

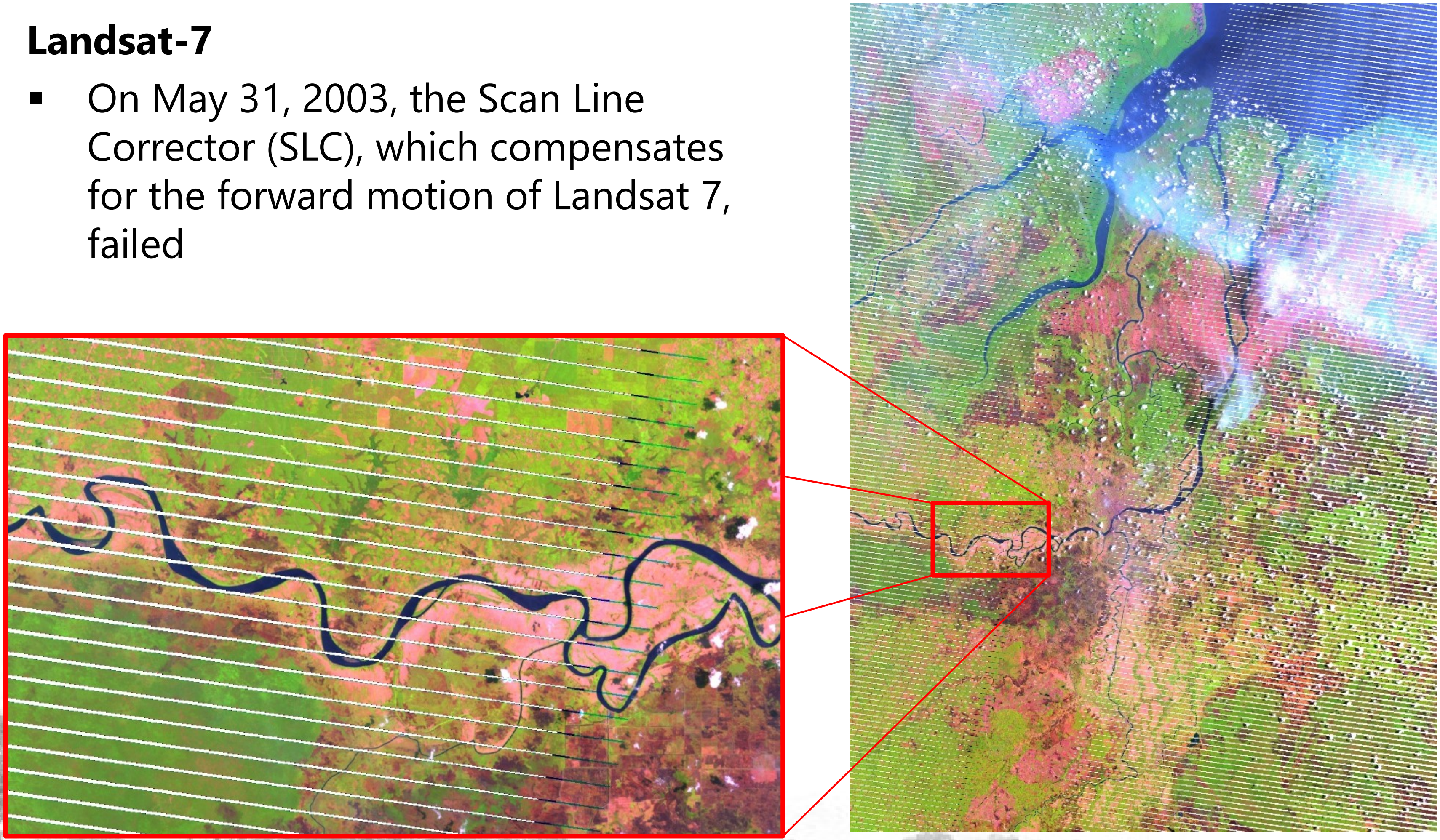
➢ **The final Classification is a combination of these two approaches to grant high accuracy and diminish false positives**



Limitations

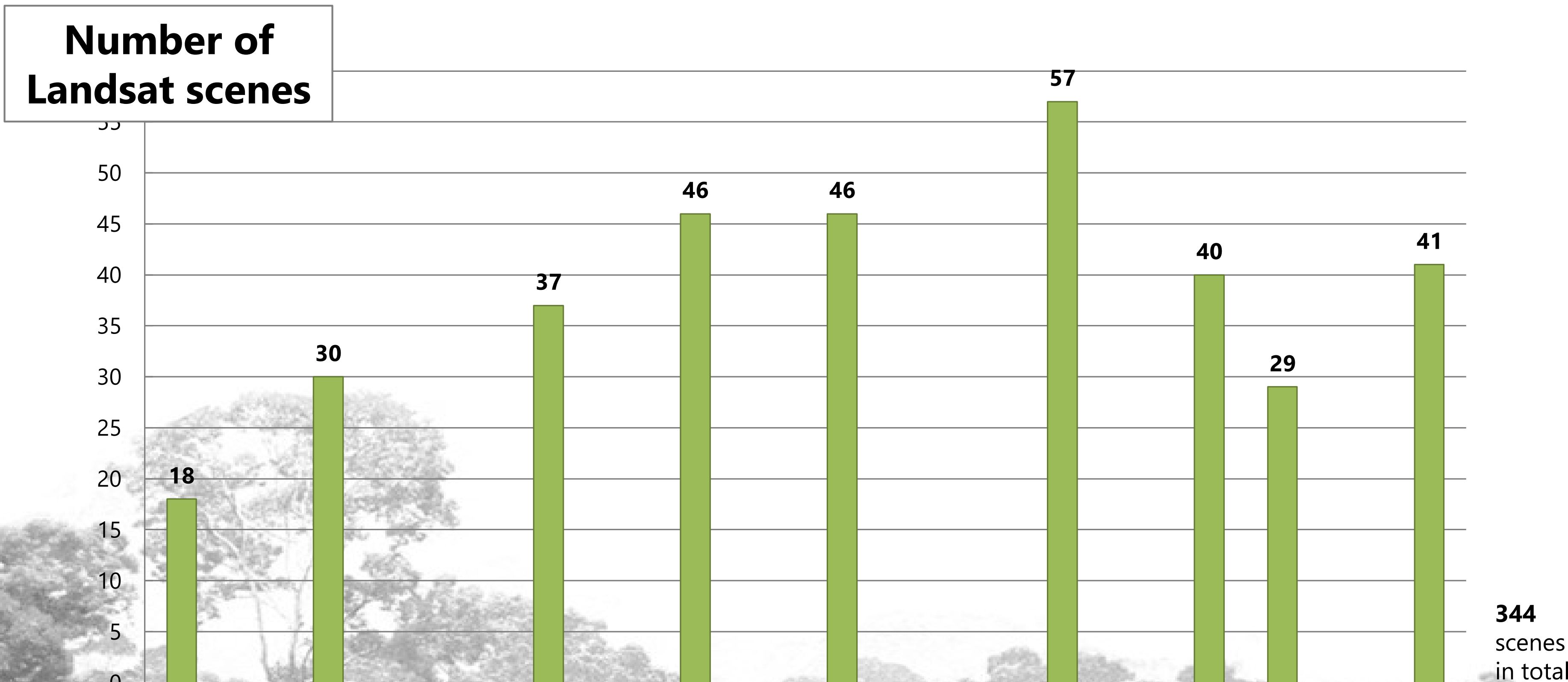
Landsat-7

- On May 31, 2003, the Scan Line Corrector (SLC), which compensates for the forward motion of Landsat 7, failed



Limitations

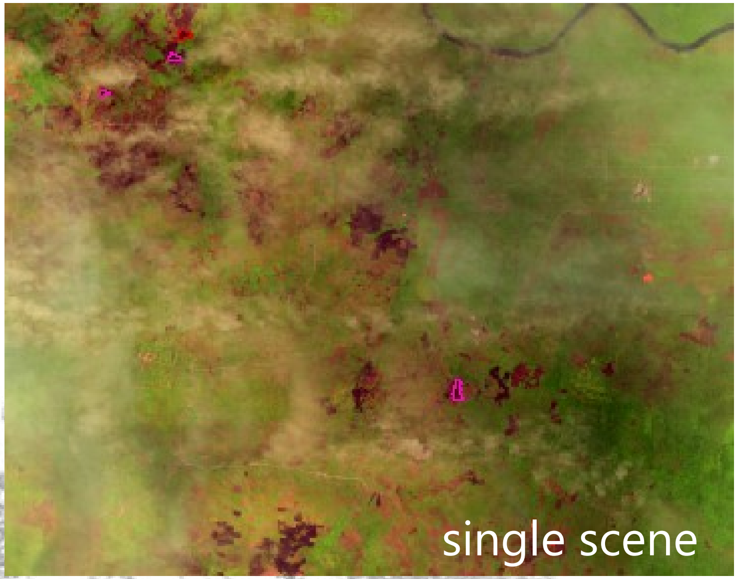
- Total number of scenes
  - Fewer scenes mean smaller area to classify and lower probability having a cloud-free scene

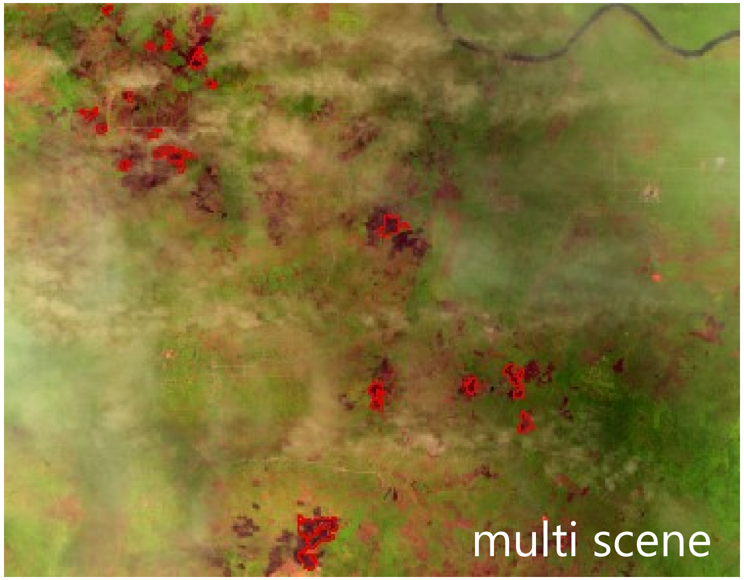


Limitations

Single scene approach

- In unique situations **cloud shadow** is falsely classified as burned area
- Limitation by **haze**
  - Haze leads to low detection of burned areas
  - Not a problem for the multi scene approach

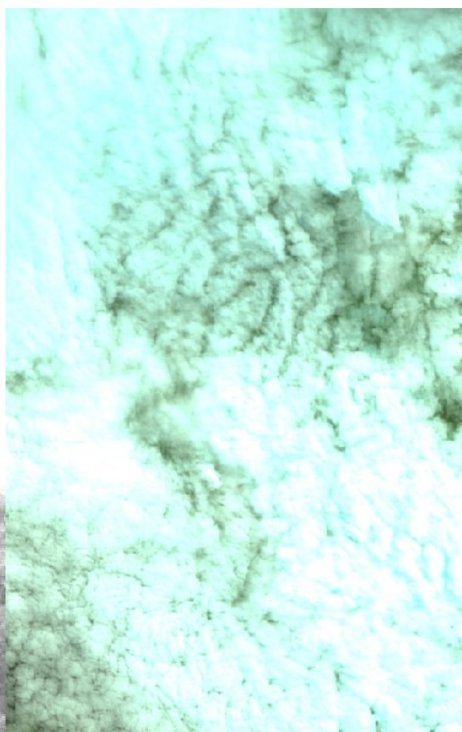




Limitations

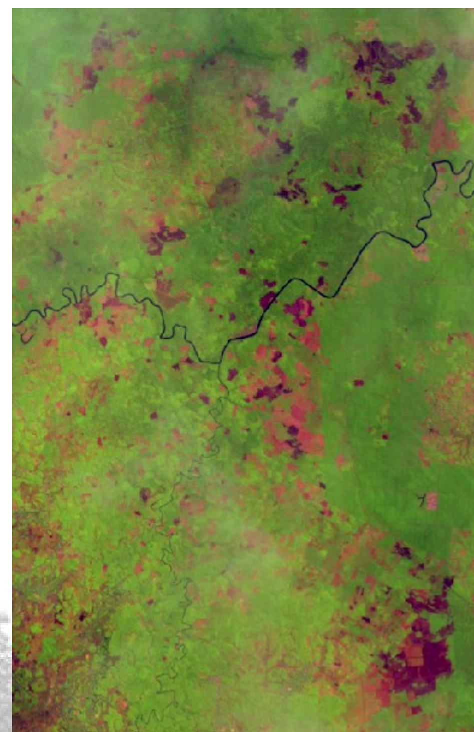
Multi scene approach

- Bare areas in oil palms plantations can be classified as burned
- Both scenes have to be cloud free for classification
- Usually high cloud cover percentage in tropics
- This "problem" is tackled via change calculation of all possible combinations
  - t_1-t_4 | t_2-t_4 | t_3-t_4



t_1

−



t_4

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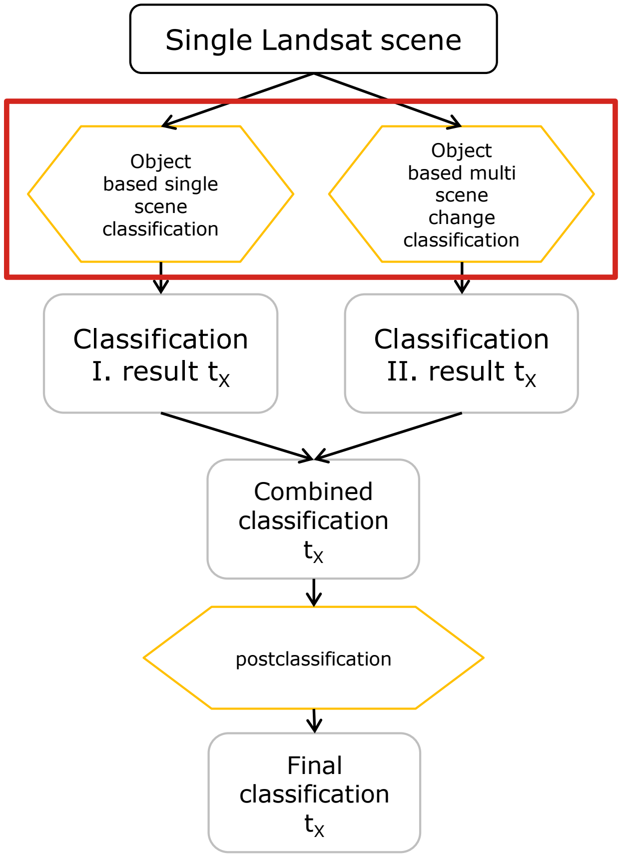
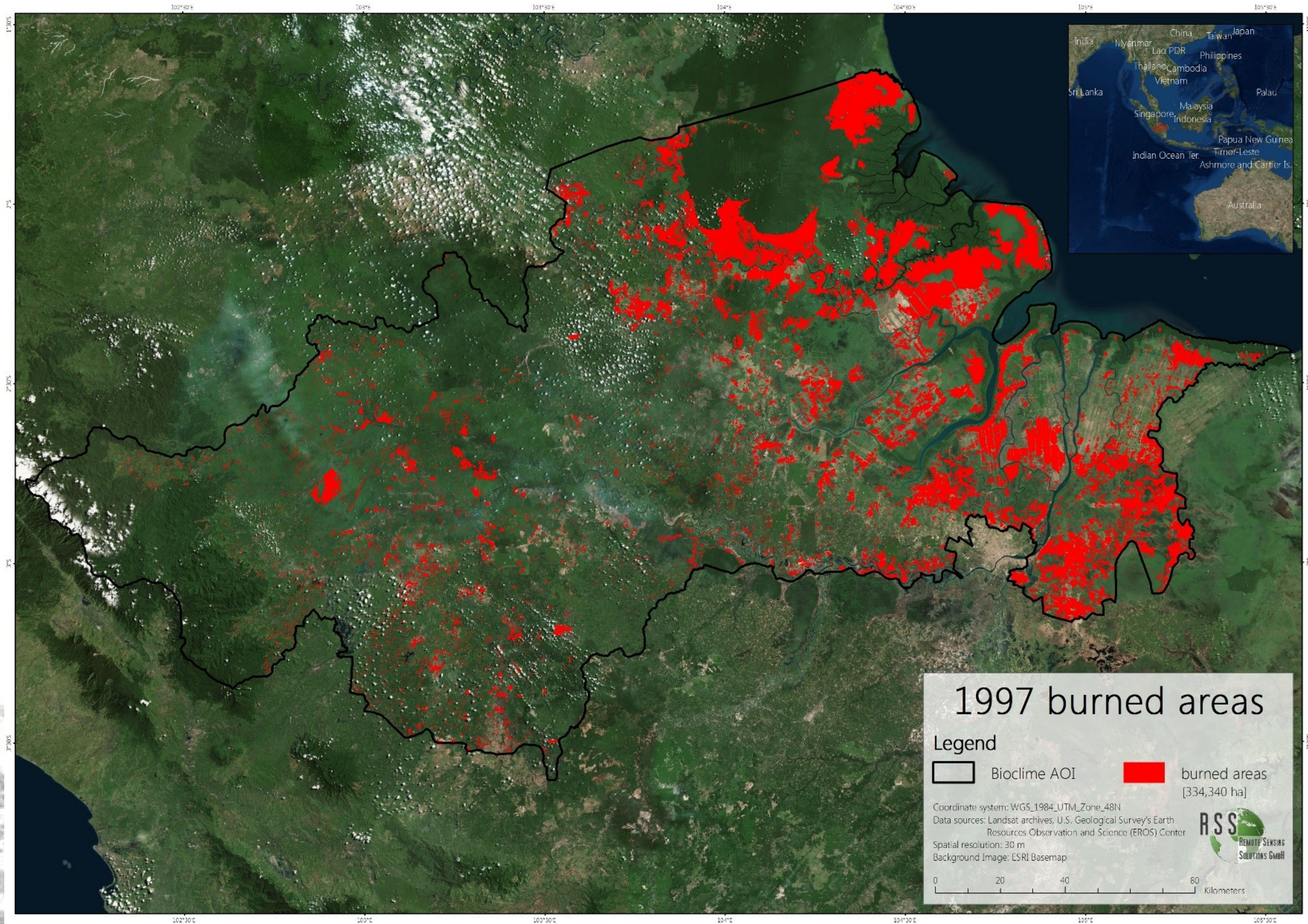
No classification possible

Classification approach

- The combination of both approaches represents a robust approach which overcomes the respective limitations of the single- and the multi-scene approach
- The results are merged for **each month** and **each year**
- **Manual editing** needs to be conducted to grant high accuracies and to overcome the limitations



1997



1997 burned areas
Legend
Bioclime AOI
burned areas
[334,340 ha]
Coordinate system: WGS_1984_UTM_Zone_48N
Data sources: Landsat archives, U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center
Spatial resolution: 30 m
Background Image: ESRI Basemap
0 20 40 80 Kilometers
China
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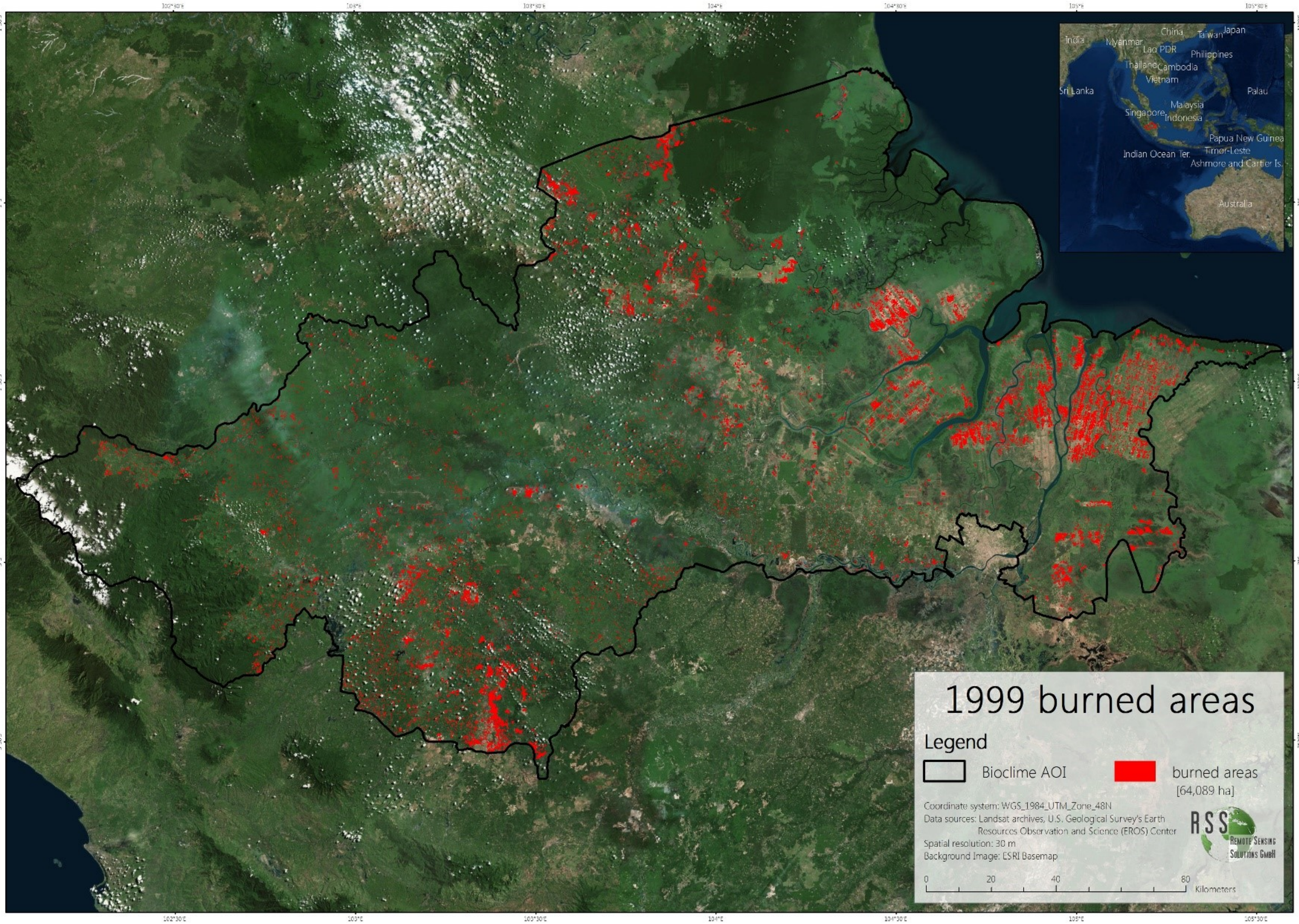
Indonesia
Papua New Guinea
Indian Ocean Ter.
Timor-Leste
Ashmore and Cartier Is.
Australia

1999



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Papua New Guinea
Indian Ocean Ter.
Timor-Leste
Ashmore and Cartier Is.
Australia
1999 burned areas
Legend
Bioclime AOI
burned areas
[64,089 ha]
Coordinate system: WGS_1984_UTM_Zone_48N
Data sources: Landsat archives, U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center
Spatial resolution: 30 m
Background Image: ESRI Basemap
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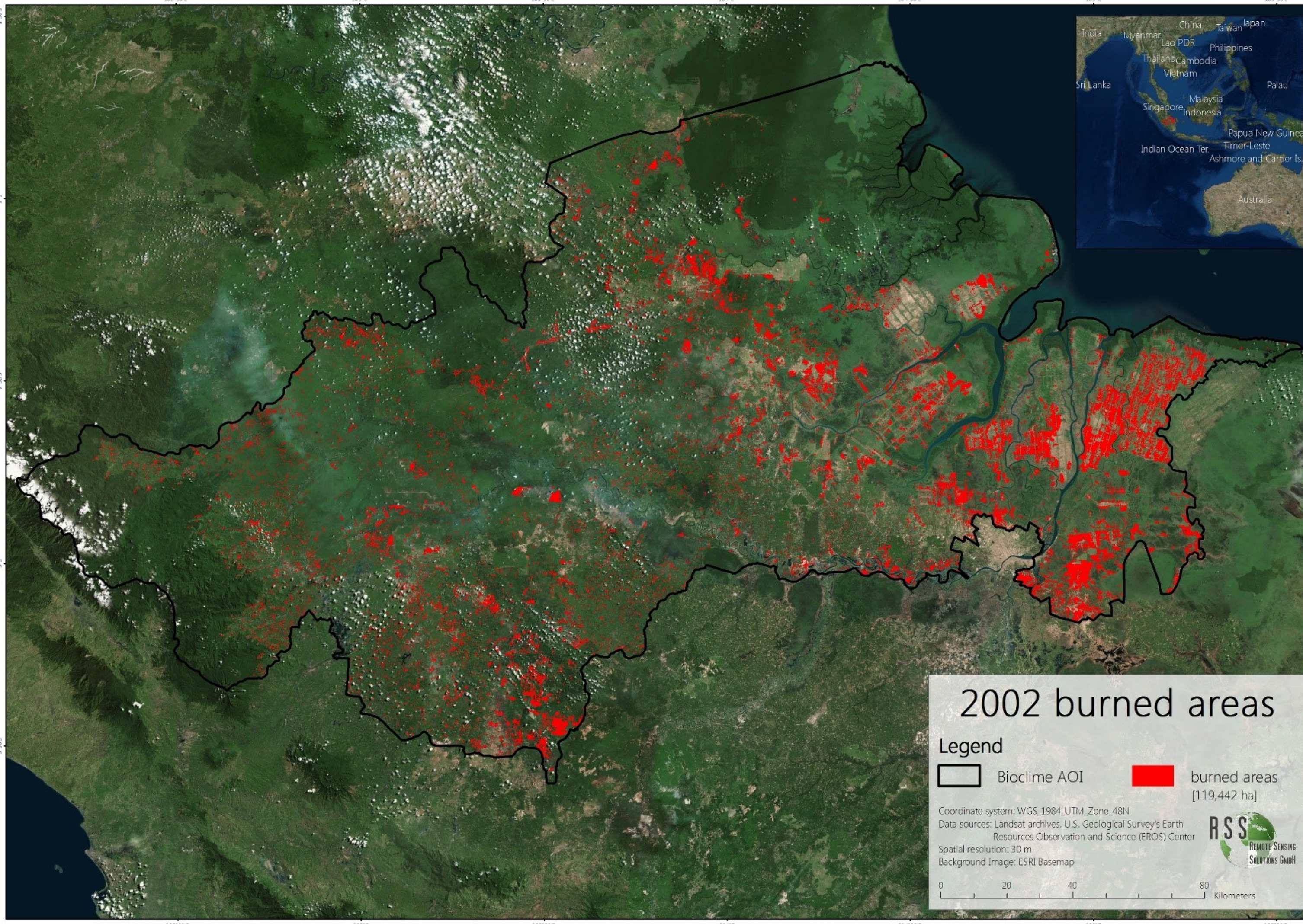
Kilometers
104°30'E
105°E
105°30'E

2002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Timor-Leste
Ashmore and Cartier Is.
Australia
2002 burned areas
Legend
Bioclime AOI
burned areas
[119,442 ha]
Coordinate system: WGS_1984_UTM_Zone_48N
Data sources: Landsat archives, U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center
Spatial resolution: 30 m
Background Image: ESRI Basemap
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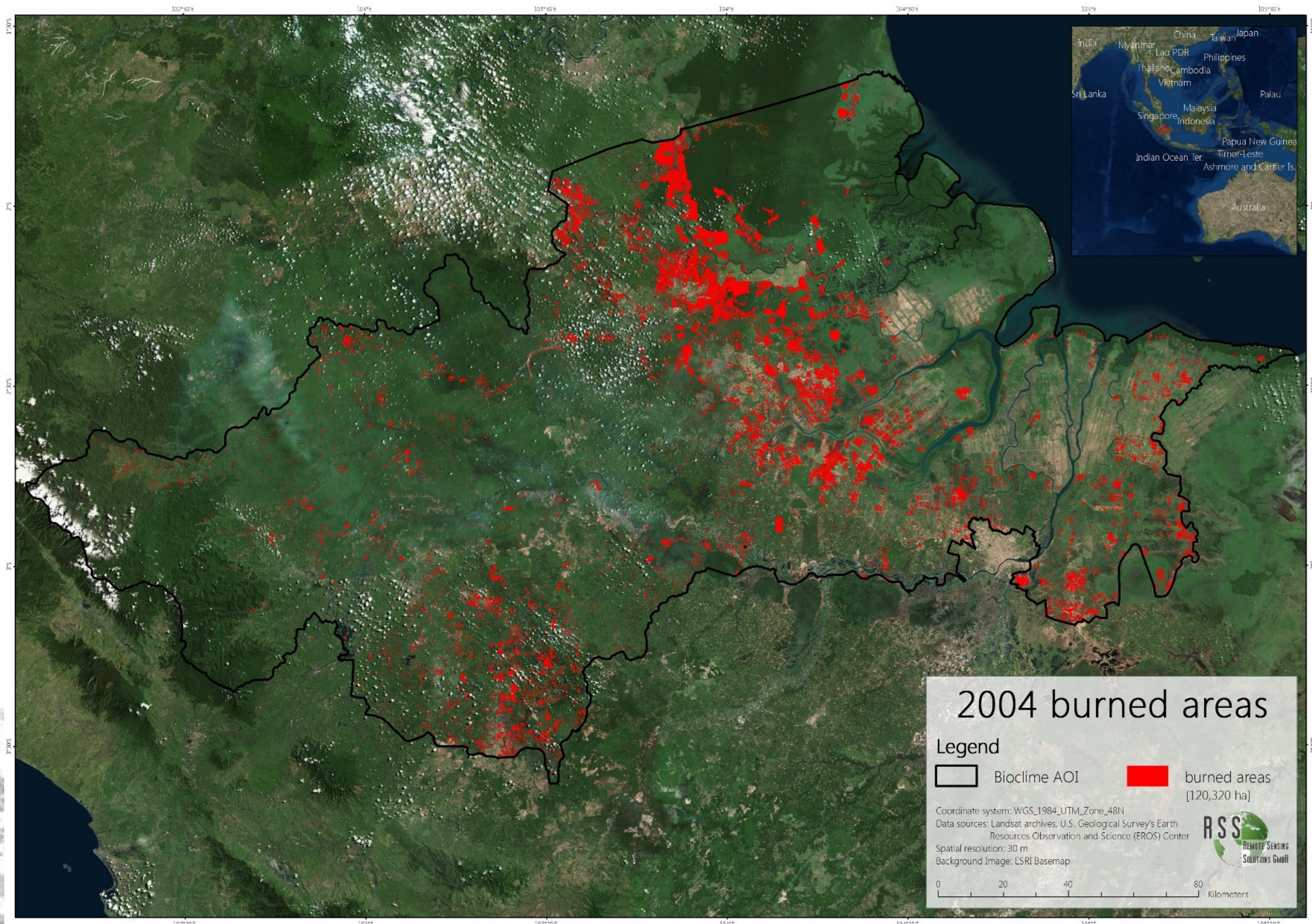
2004



2004 burned areas
Legend
Bioclime AOI
burned areas
[120,320 ha]
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Data sources: Landsat archives, U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center
Spatial resolution: 30 m
Background Image: ESRI Basemap
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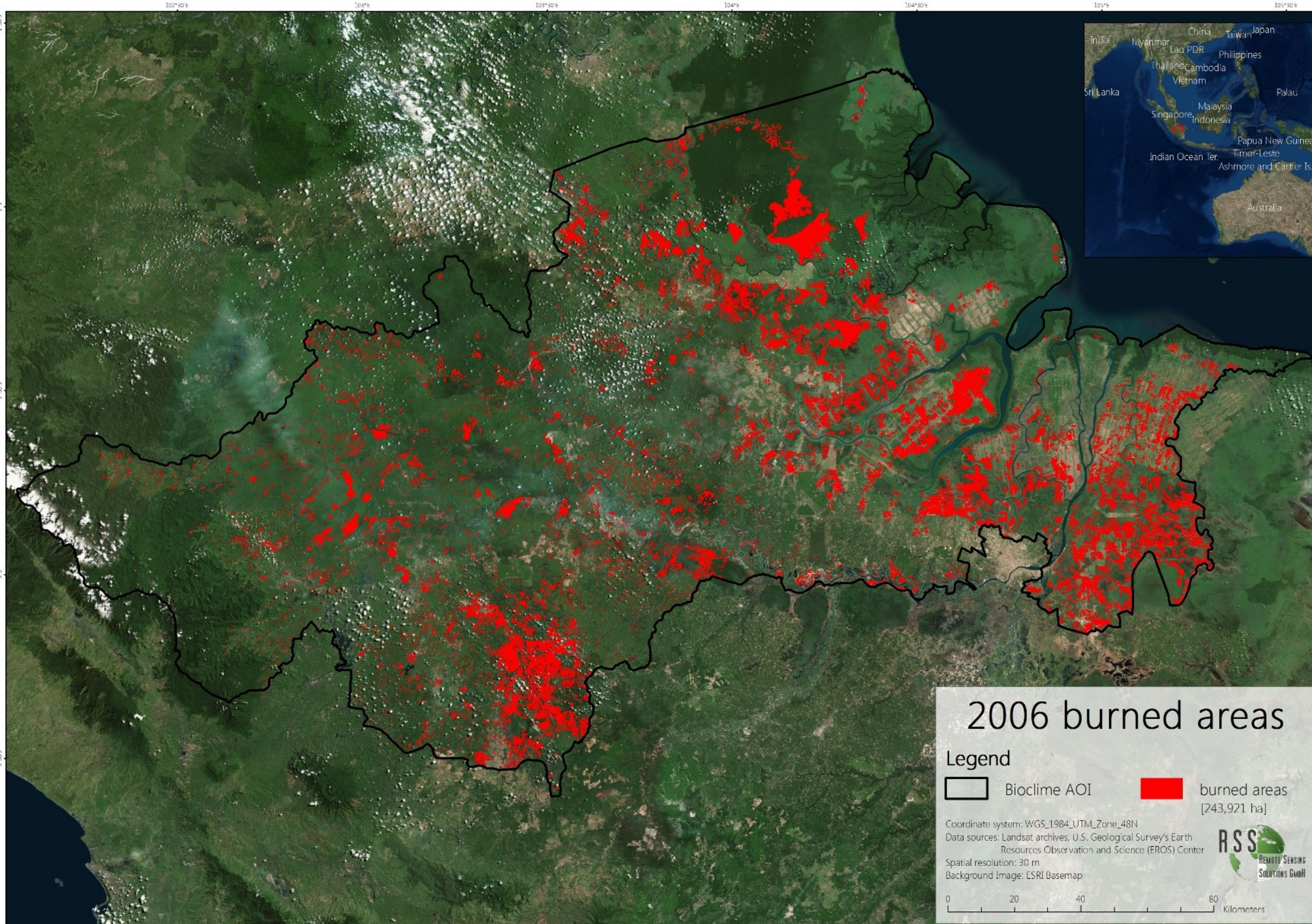
2006



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2006 burned areas
Legend
Bioclime AOI
burned areas
[243,921 ha]
Coordinate system: WGS_1984_UTM_Zone_48N
Data sources: Landsat archives, U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center
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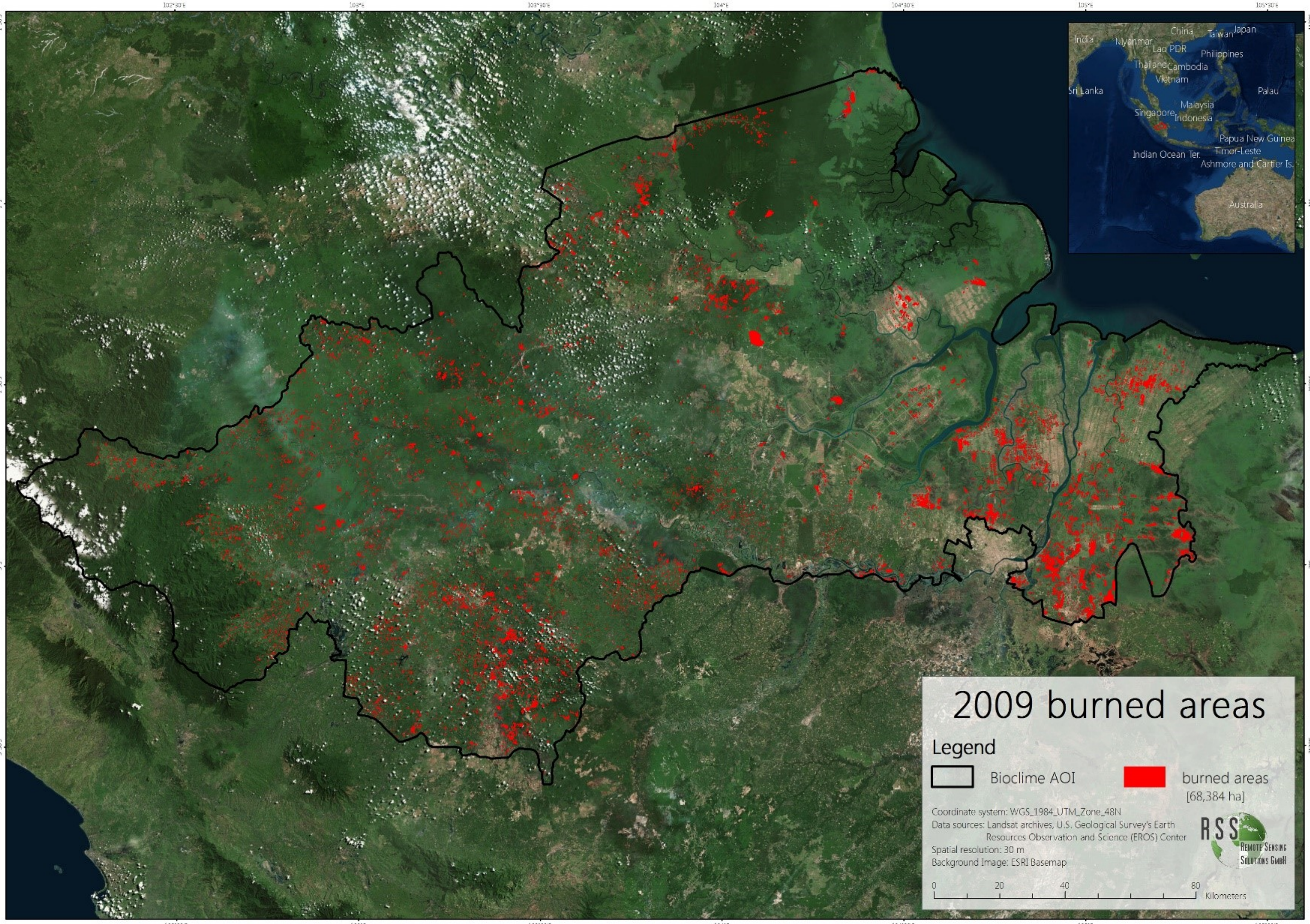
Background Image: ESRI Basemap
RSS Remote Sensing Solutions GmbH
0 20 40 80
Kilometers

2009


2009 burned areas
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Bioclime AOI
burned areas
[68,384 ha]
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Spatial resolution: 30 m
Background Image: ESRI Basemap
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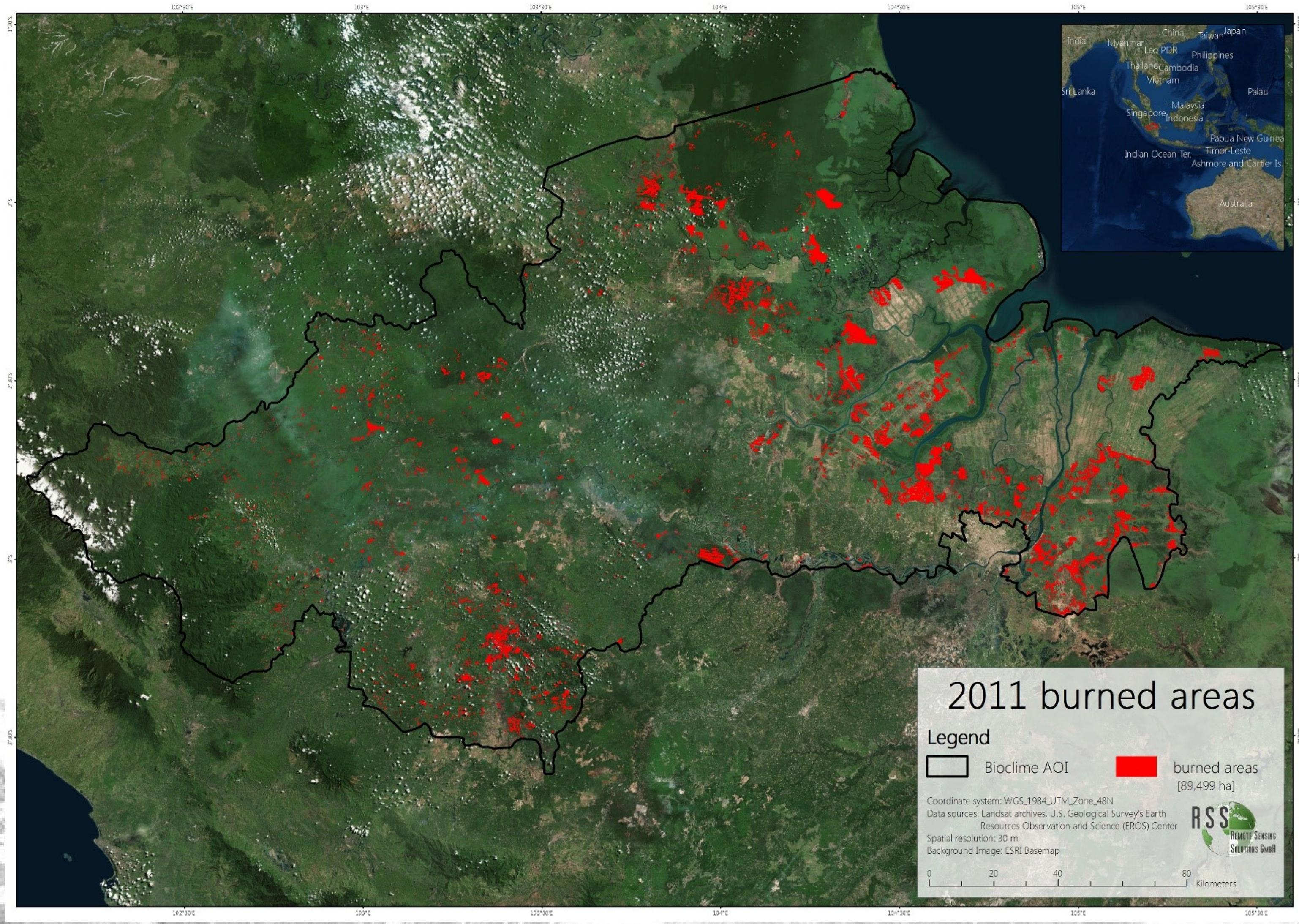
Kilometers

2011



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2011 burned areas
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burned areas
[89,499 ha]
Coordinate system: WGS_1984_UTM_Zone_48N
Data sources: Landsat archives, U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center
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Background Image: ESRI Basemap
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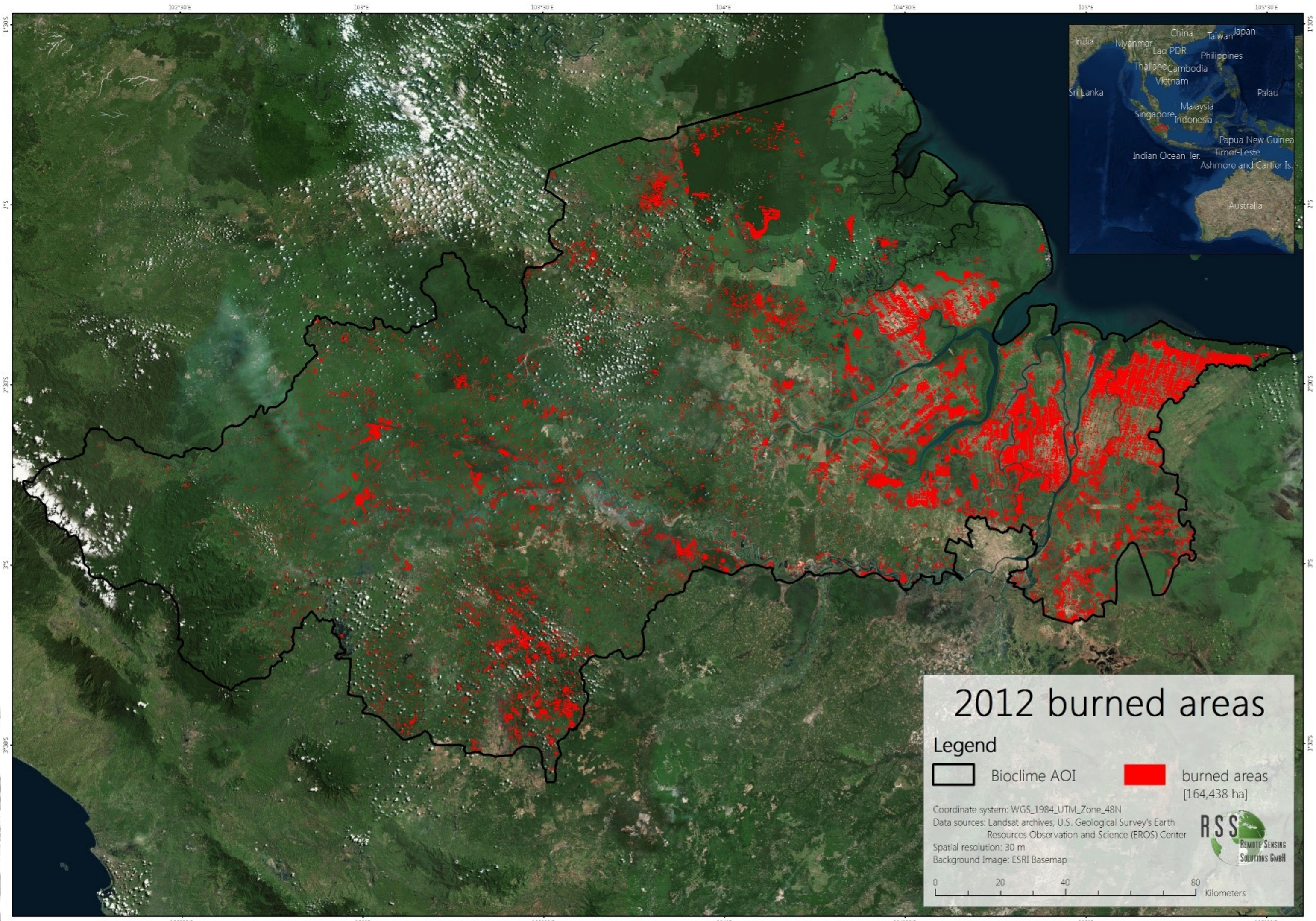
2012



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2012 burned areas
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burned areas
[164,438 ha]
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Data sources: Landsat archives, U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center
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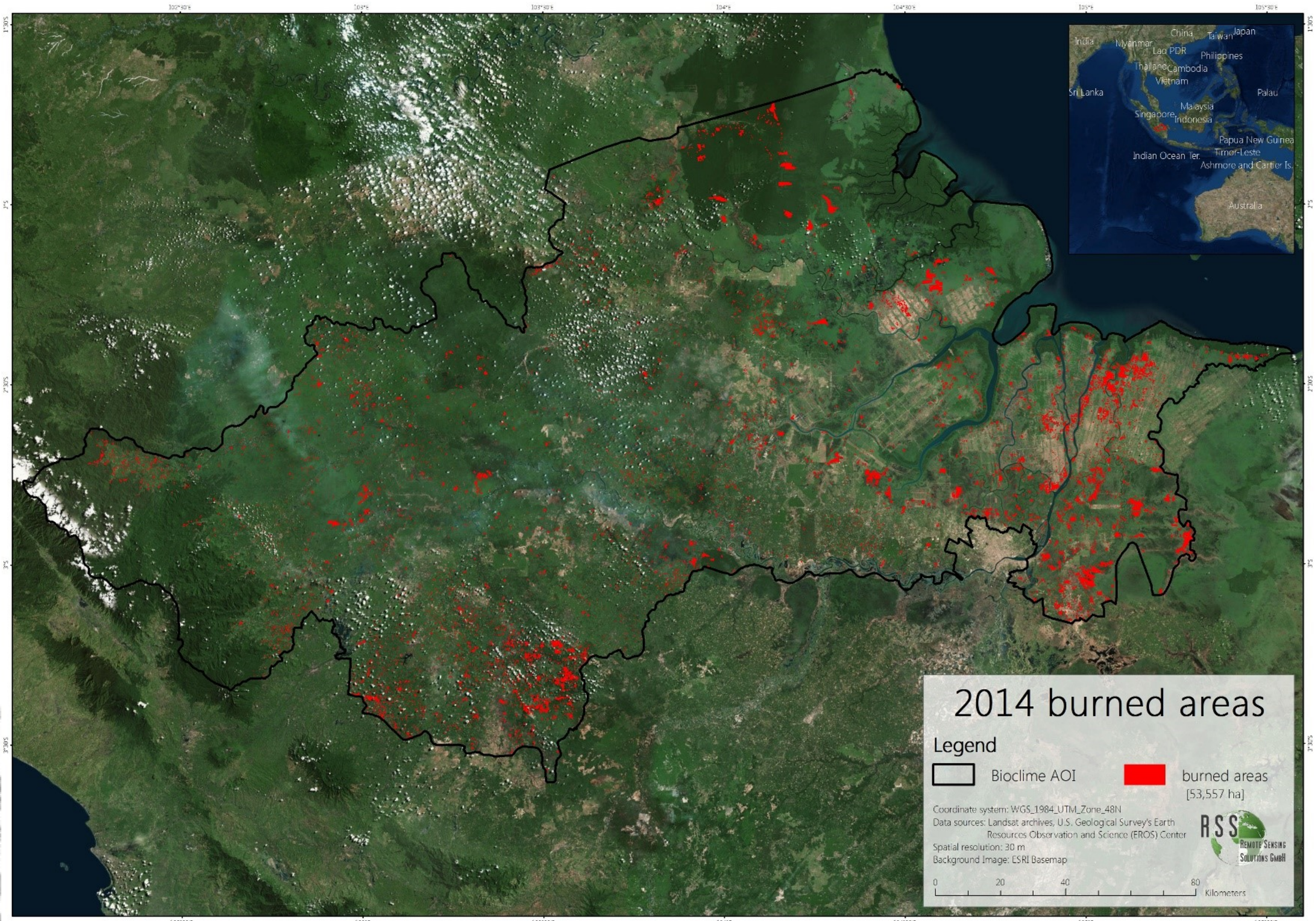
2014



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Papua New Guinea
Indian Ocean Ter.
Timor-Leste
Ashmore and Cartier Is.
Australia
2014 burned areas
Legend
Bioclime AOI
burned areas
[53,557 ha]
Coordinate system: WGS_1984_UTM_Zone_48N
Data sources: Landsat archives, U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center
Spatial resolution: 30 m
Background Image: ESRI Basemap
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Kilometers
104°30'E
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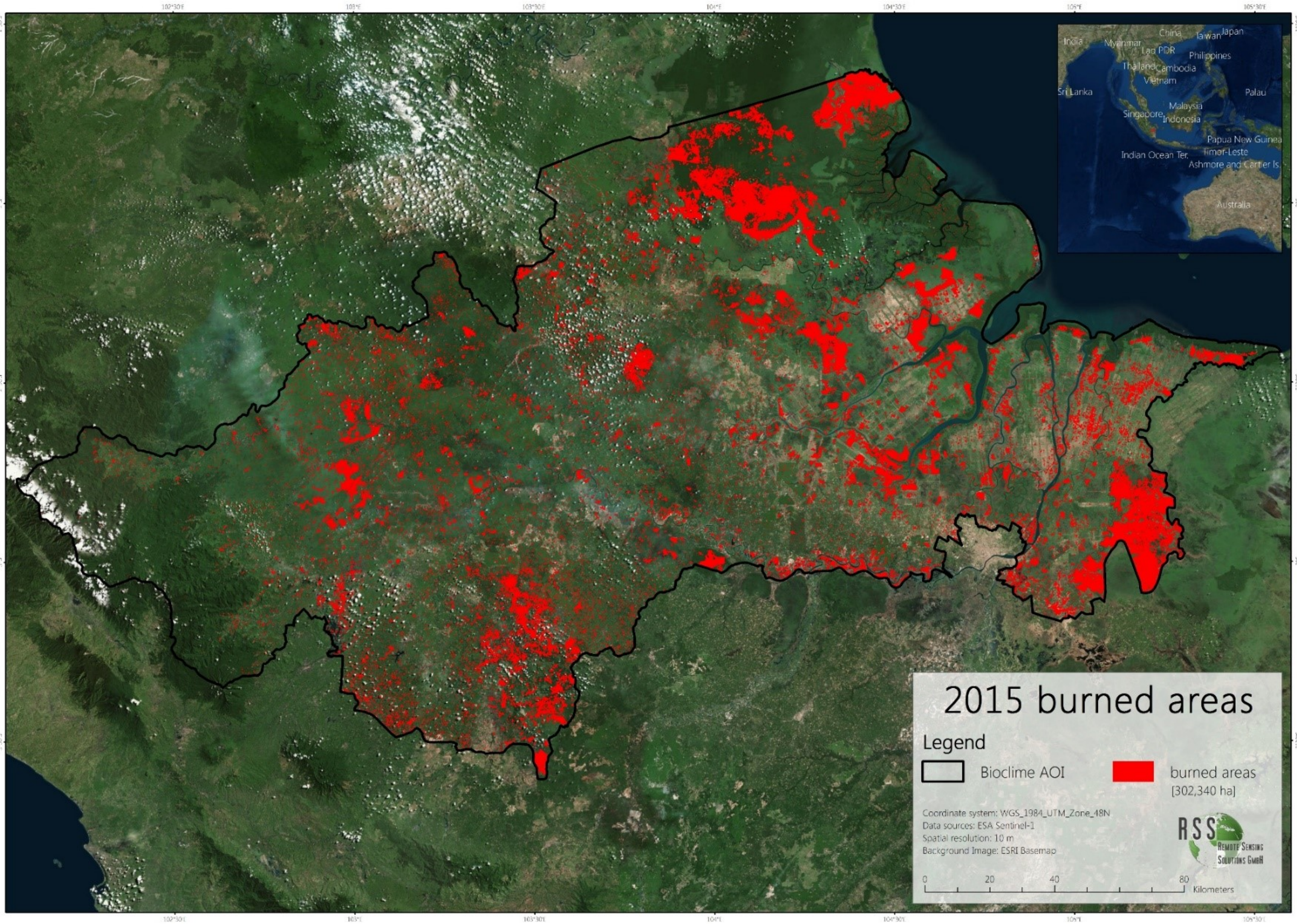
105°30'E

2015



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Indian Ocean Ter.
Timor-Leste
Ashmore and Cartier Is.
Australia
2015 burned areas
Legend
Bioclime AOI
burned areas
[302,340 ha]
Coordinate system: WGS_1984_UTM_Zone_48N
Data sources: ESA Sentinel-1
Spatial resolution: 10 m
Background Image: ESRI Basemap
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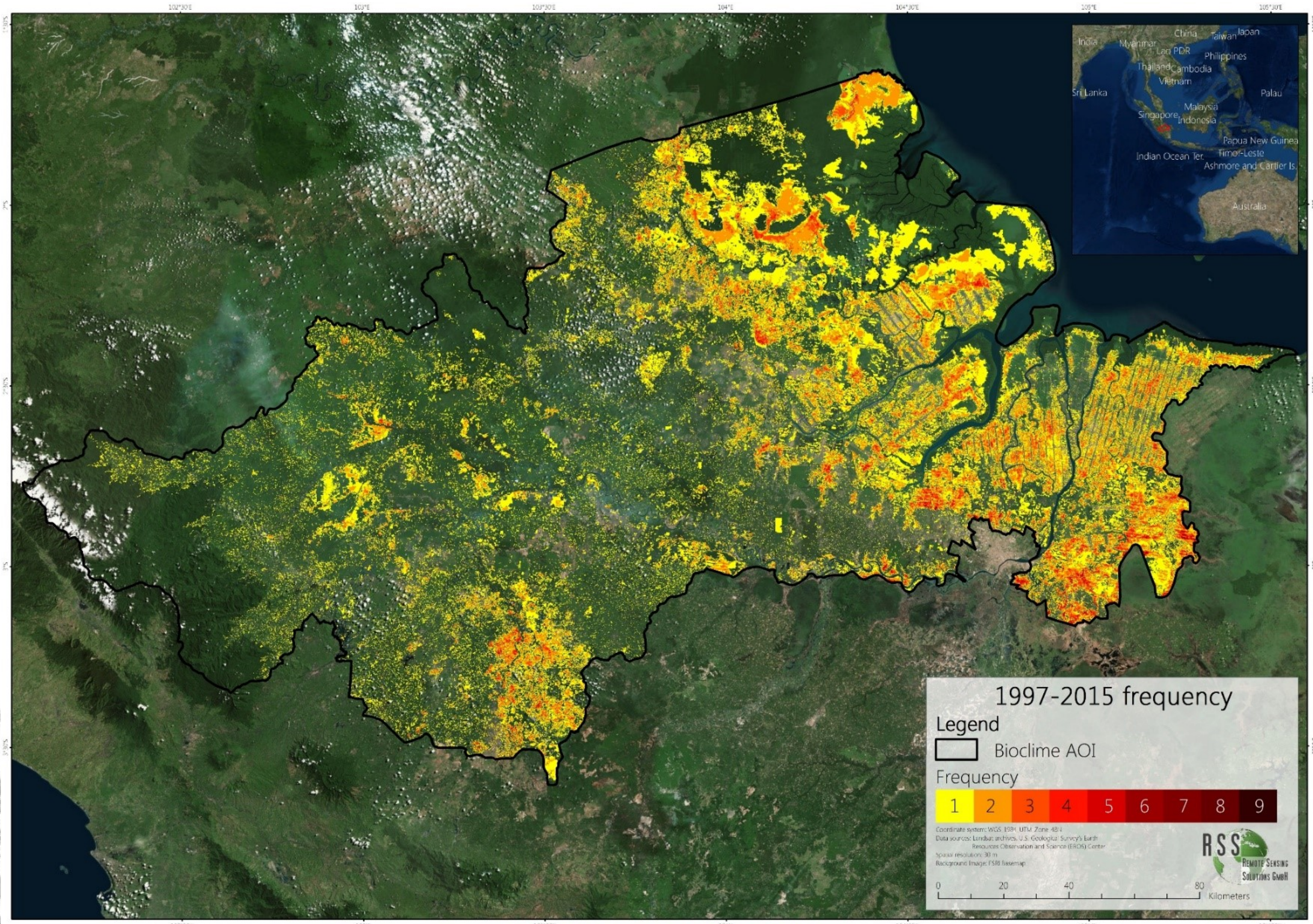
Kilometers

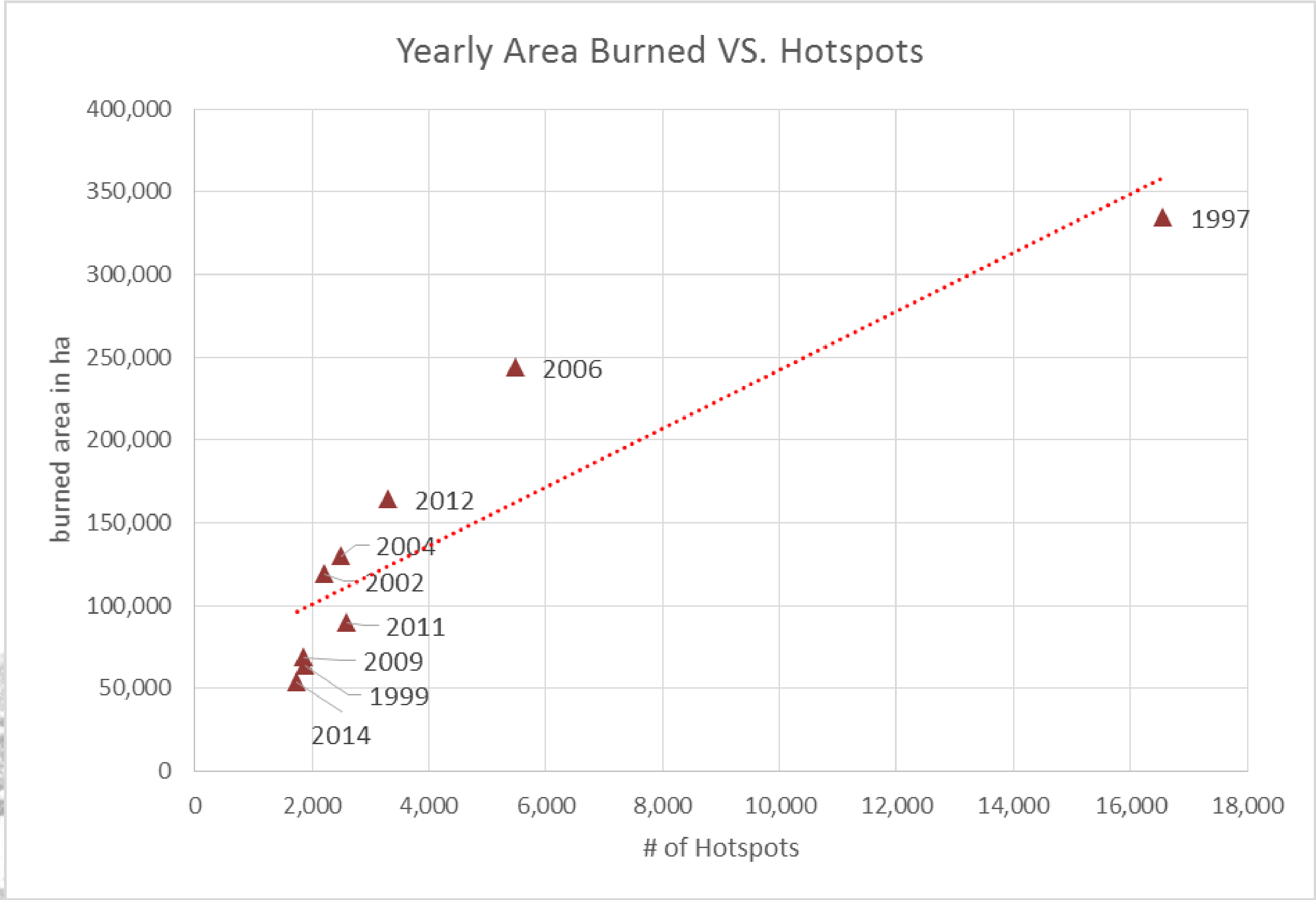
1997-2015 fire frequency



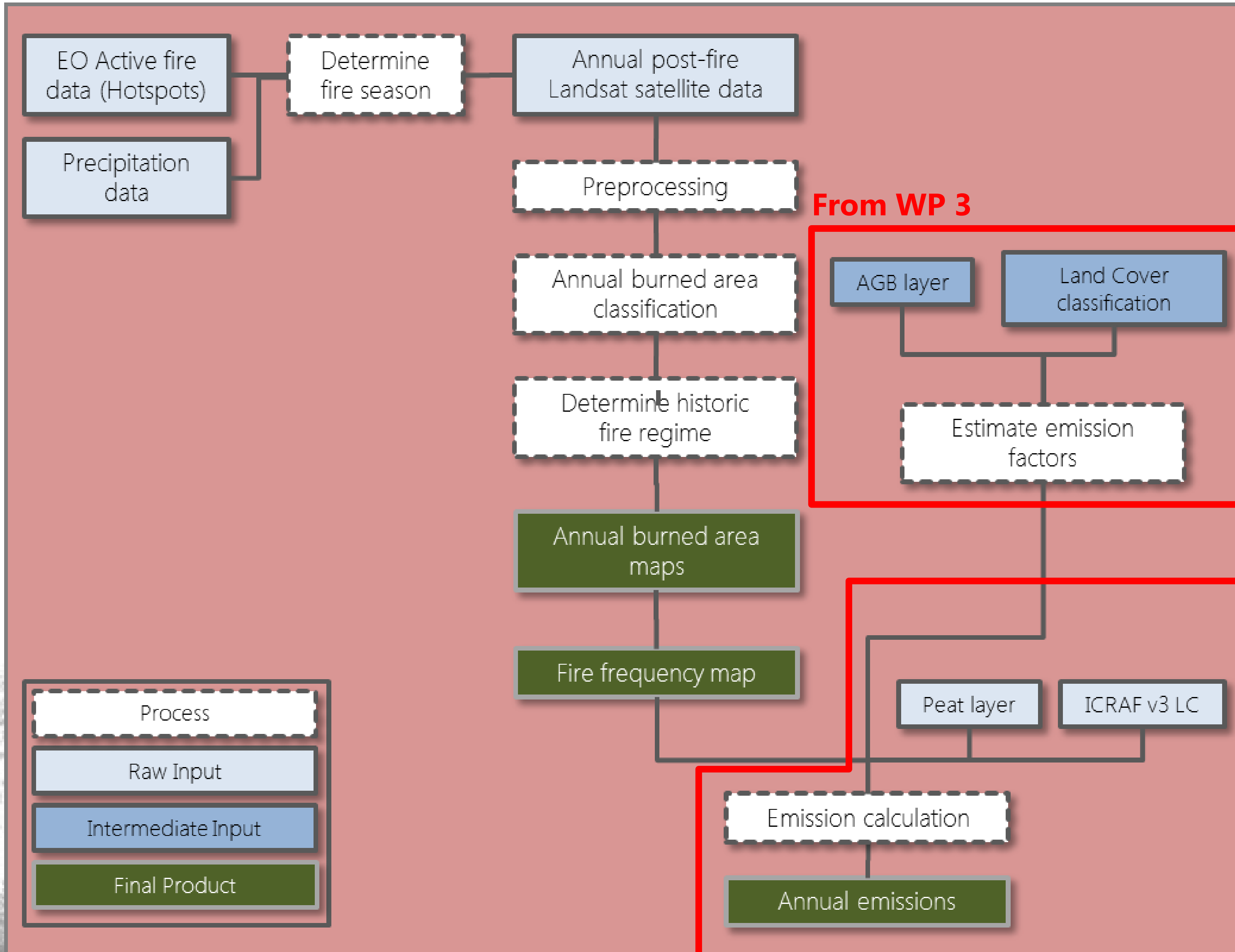
Summary of burned area

Year	No. Scenes	Hotspots	Total Area Burned [ha]
1997	18	16,573	334,340
1999	30	1,888	64,089
2002	37	2,216	119,442
2004	46	2,515	130,320
2006	46	5,494	243,922
2009	57	1,875	68,384
2011	40	2,592	89,499
2012	29	3,319	164,439
2014	41	1,755	53,557
2015	Sentinel-1	8,582	323,397

Mapped area burned vs. hotspots



Annual emission from fires



Aboveground carbon emissions

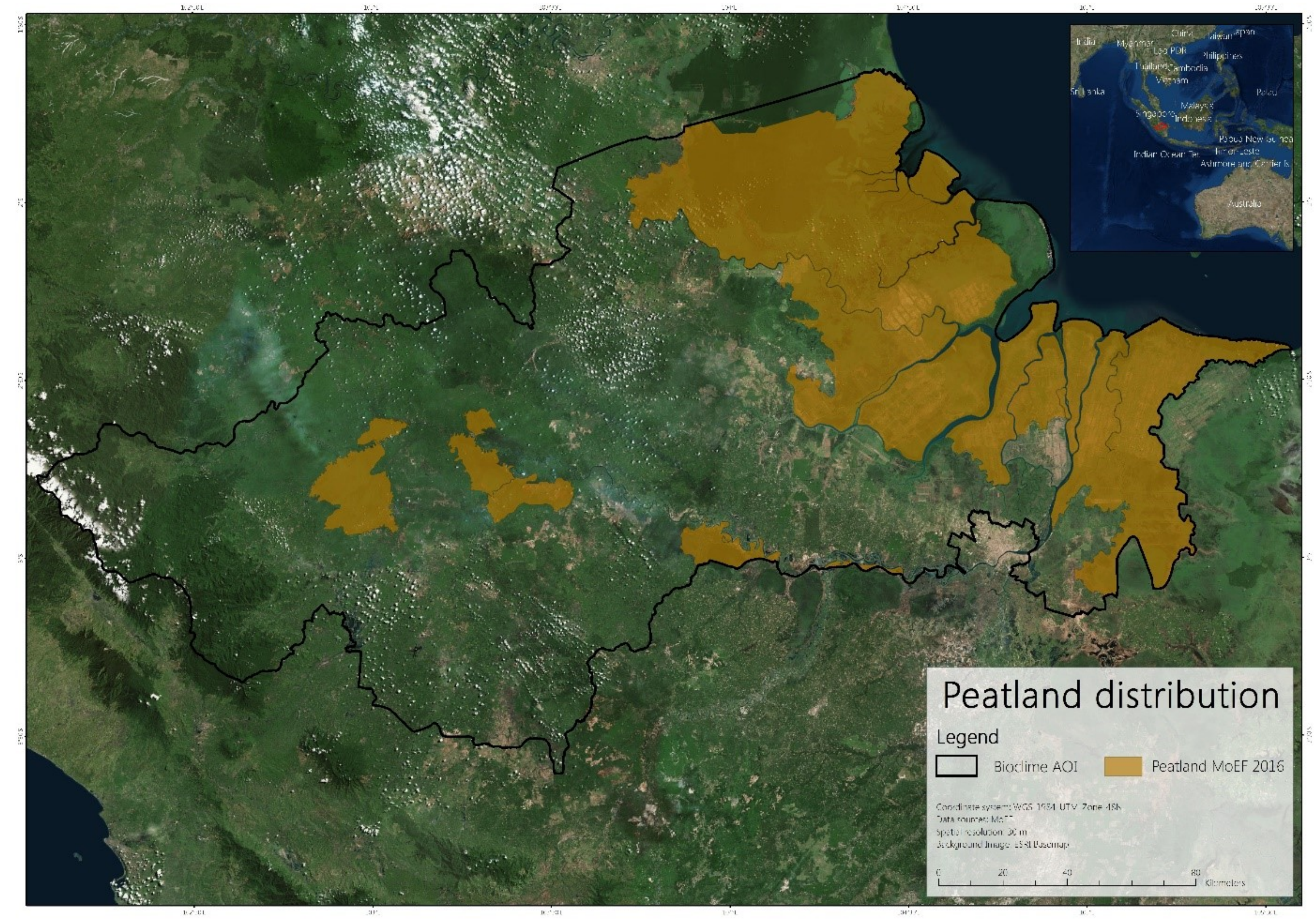
- Stratify & multiply approach
- ICRAF Land cover classification v3 products were used
- To each strata (land cover class) a local aboveground biomass value was attributed
- Local aboveground biomass values derived from LiDAR based aboveground biomass model (WP 3)
- Carbon content of 0.5 assumed
- Aboveground carbon emission were calculated by multiplying burned area with the carbon content per stratum per hectare

Peat carbon emissions

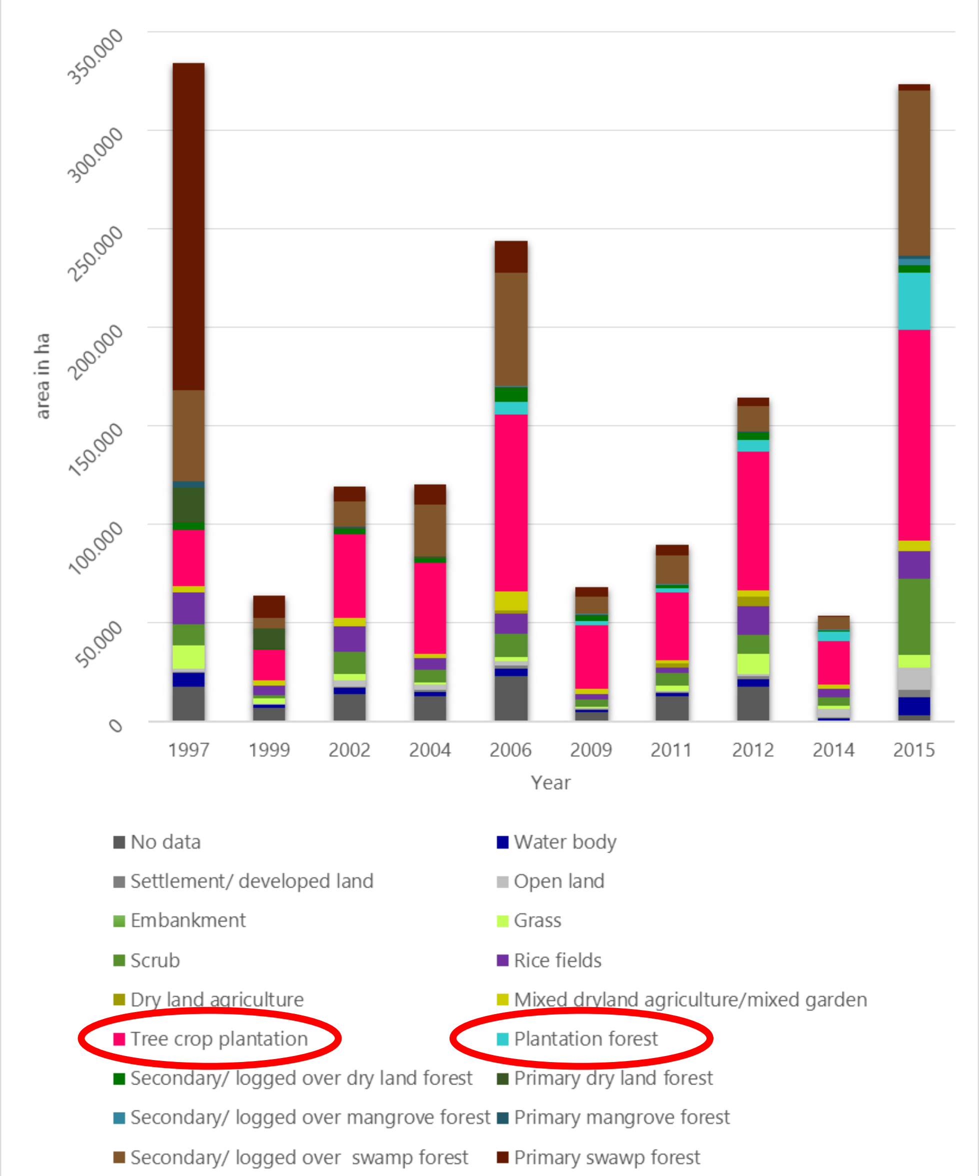
- Approach by Konecny *et al.* (2016)
- Discriminates between first, second and more fires in regard to burn depth
- Pre fire land cover is taken into account
- Burned areas on formerly forested peatlands are considered to be first-fires and therefore a burn depth of 17 cm (114 tC/ha) is applied
- All other land cover classes are then assigned to second or more fires with a reduced burn depth of 8 cm (51 t C/ha).

Konecny, K., Ballhorn, U., Navratil, P., Jubanski, J., Page, S. E., Tansey, K., Hooijer, A., Vernimmen, R. and Siegert, F. (2016), Variable carbon losses from recurrent fires in drained tropical peatlands. Glob Change Biol, 22: 1469–1480.

Peatland distribution MoEF 2016



Pre-fire vegetation



- In 1997 the share of burned Primary Forest is by far the biggest
  - 165,865ha of Primary Swamp Forest
  - 17,710ha of Primary Dry Land Forest
  - 3,282ha of Primary Mangrove Forest
  - sums up to 186,857ha
- The second largest Primary Forest burning took place in 2006 (17,133ha)
- The burning of the land cover class Tree Crop Plantation is increasing over the years and in 2015 more than 106,773 ha of it burned.
- The same increase over time is visible for the class Plantation Forest where more than 29,275 ha burned in 2015.

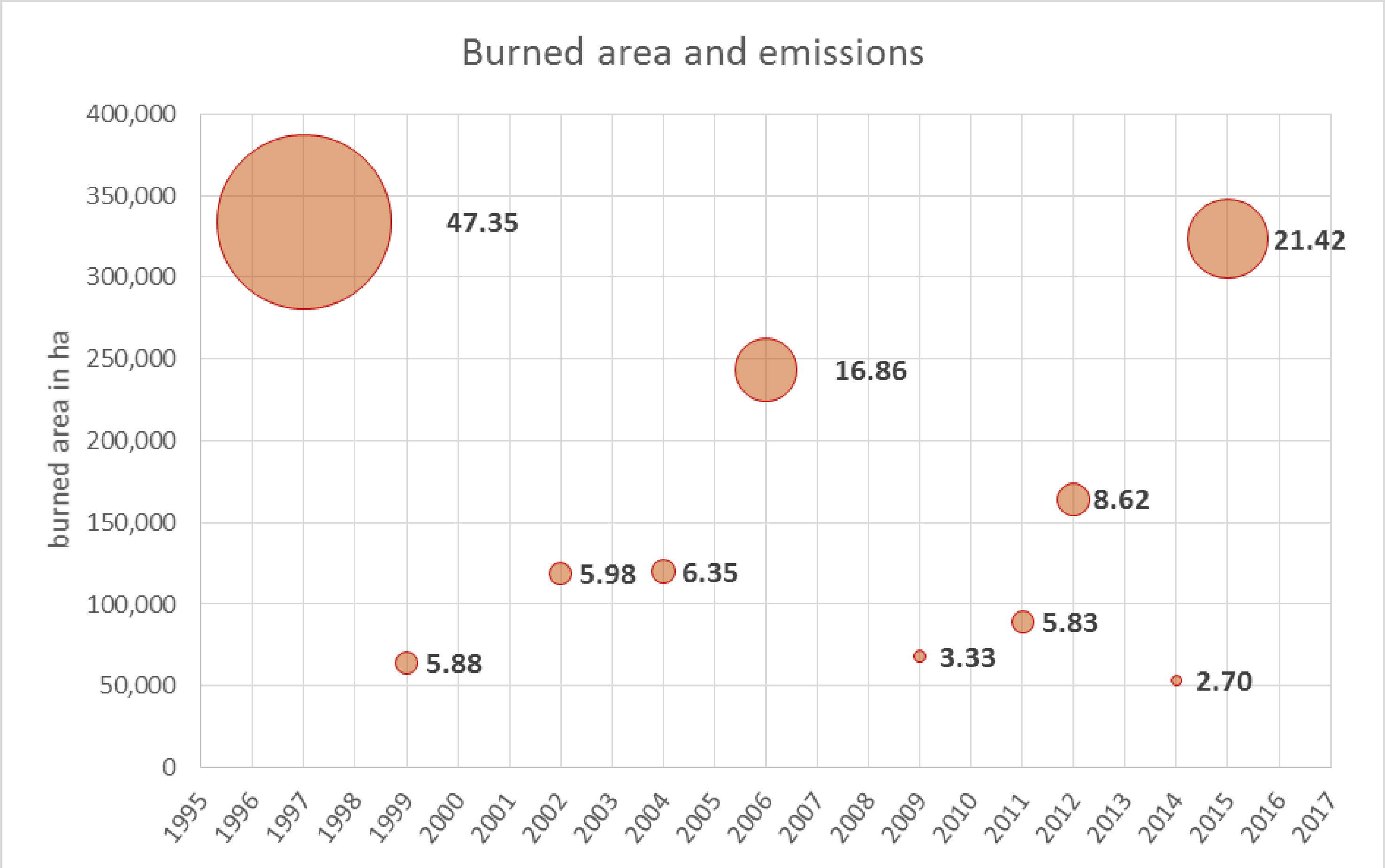
➢ **There is a clear change in ration of land cover classes burned over the last two decades**

Annual emission from fires

EMISSIONS				
	ha	Carbon in Mt		
YEAR	area burned	ABOVE	PEAT	Total
1997	333,931	26.99	20.36	47.35
1999	64,009	3.87	2.01	5.88
2002	119,204	3.02	2.96	5.98
2004	120,029	3.18	3.17	6.35
2006	243,561	7.41	9.45	16.86
2009	68,172	1.84	1.49	3.33
2011	89,310	2.19	3.64	5.83
2012	164,246	2.92	5.70	8.62
2014	53,440	1.03	1.67	2.70
2015	323,397	7.15	14.26	21.42
Total	1,579,297	59.60	64.71	124.31

- Emissions are not directly connected to the total burned area.
- Different land cover lead to different emissions as well as the distribution of the peat layer plays an important role in estimating the emissions.
- The years with highest emissions were:
  - 1997 with 46.71 Mt C
  - 2015 with 21.42 Mt C
  - 2006 with 16.07 Mt C
  - 2012 with 8.05 Mt C
- For areas within the land cover class No Data aboveground biomass emissions were set to zero and peat emissions to the value for second or more fires

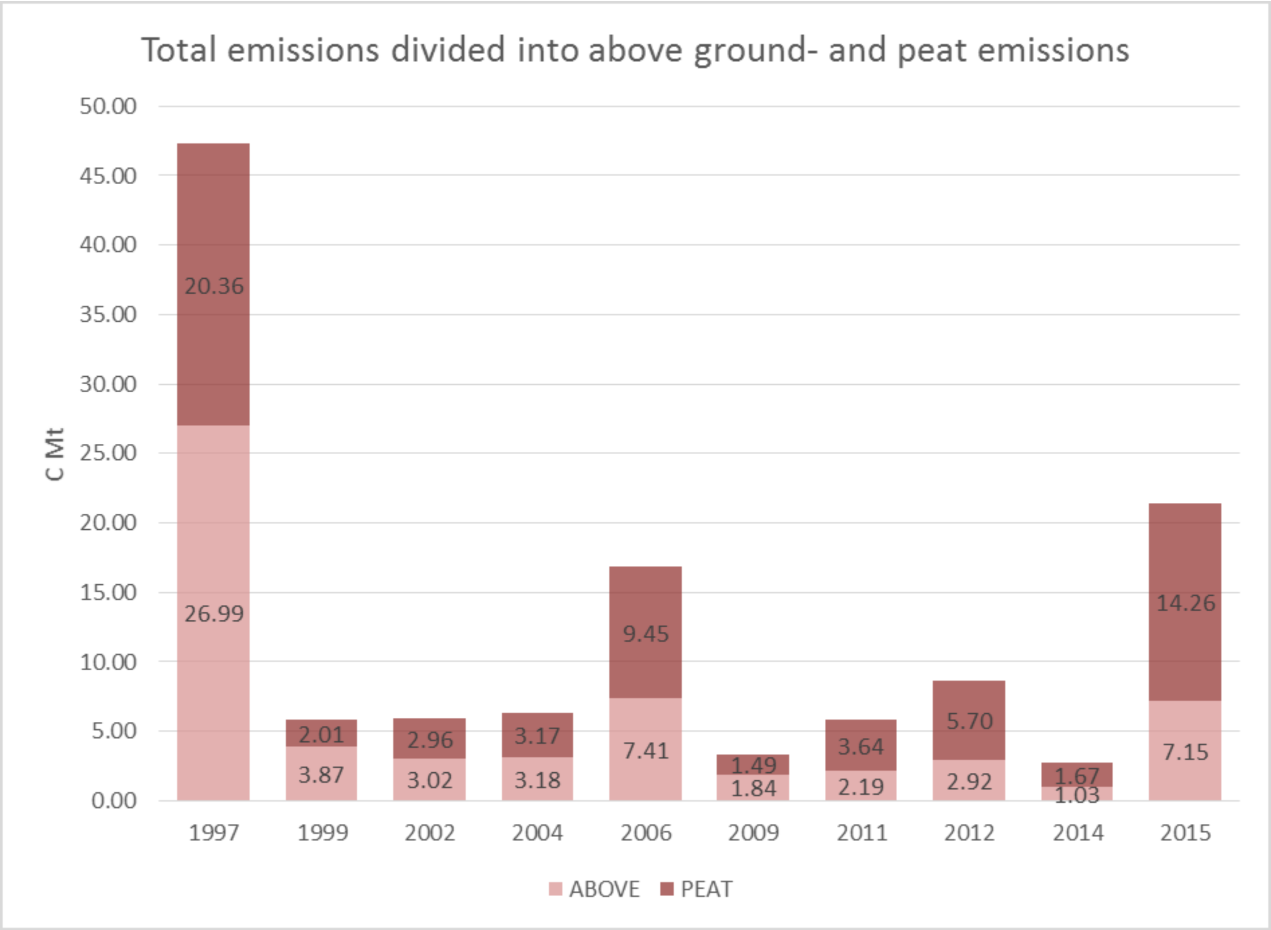
Annual emission from fires



The diameter of each circle depicts the emissions in Carbon Mt

- **Emissions are not directly connected to the total burned area.**
- **Different land cover lead to different emissions as well as the distribution of the peat layer plays an important role in estimating the emissions.**

Annual emission from fires



- The ratio of emissions from aboveground biomass to peat changes over time
- In the past proportionally more emissions from aboveground biomass burning
- In recent years proportionally more emissions from peat burning

Conclusions

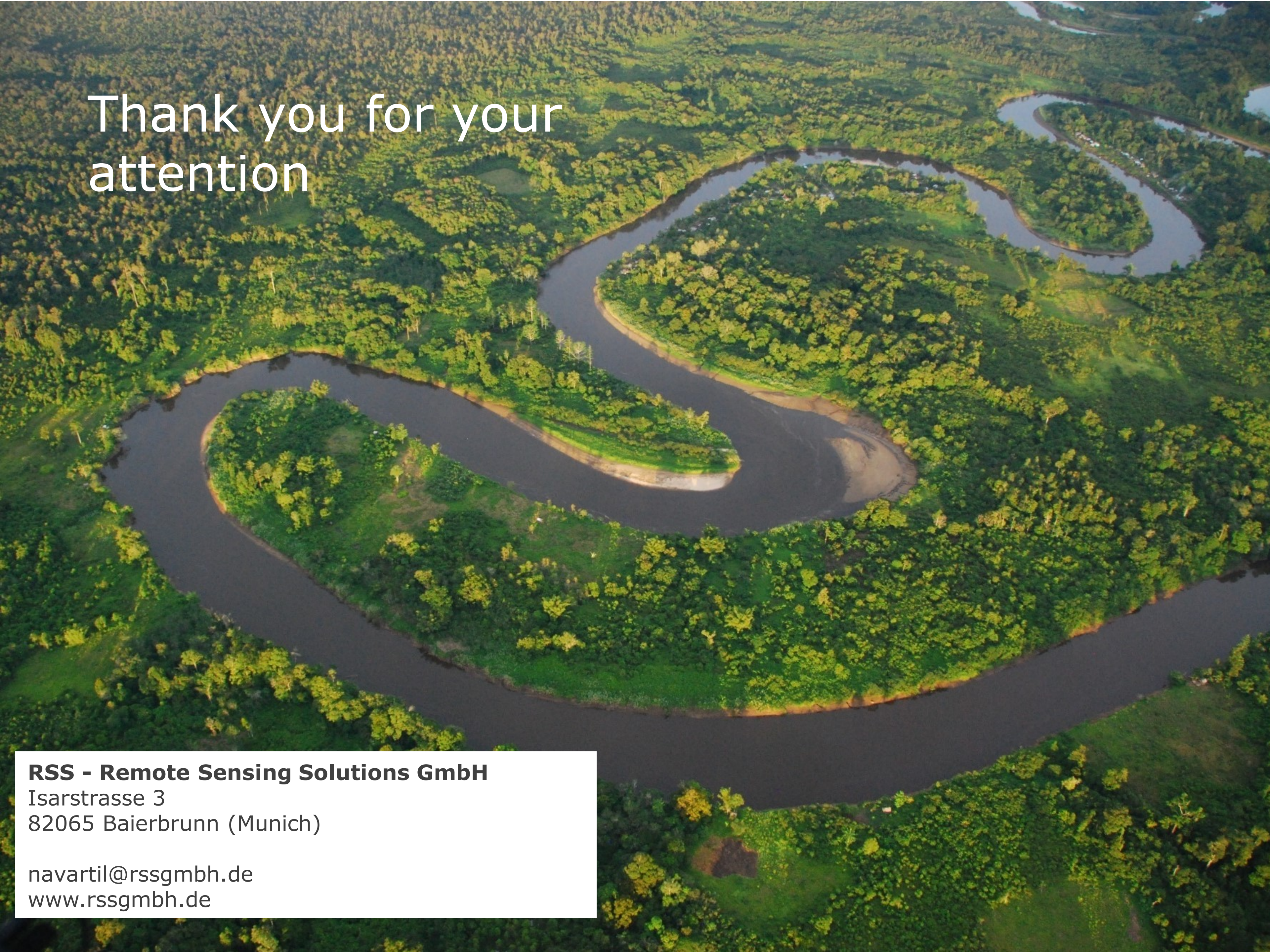
- In 1997 the share of burned Primary Forest is by far the biggest
- The second largest Primary Forest burning took place in 2006
- The burning of the land cover classes Tree Crop Plantation and Plantation Forest is increasing over the years
- There is a clear change in ration of land cover classes burned over the last two decades

Conclusions

- The years with highest emissions were:
  - 1997 with 46.71 Mt C
  - 2015 with 21.42 Mt C
  - 2006 with 16.07 Mt C
  - 2012 with 8.05 Mt C
- Emissions are not directly connected to the total burned area
- Different land cover lead to different emissions as well as the distribution of the peat layer plays an important role in estimating the emissions

Conclusions

- The ratio of emissions from aboveground biomass to peat changes over time
- In the past proportionally more emissions from aboveground biomass burning
- In recent years proportionally more emissions from peat burning



Thank you for your attention

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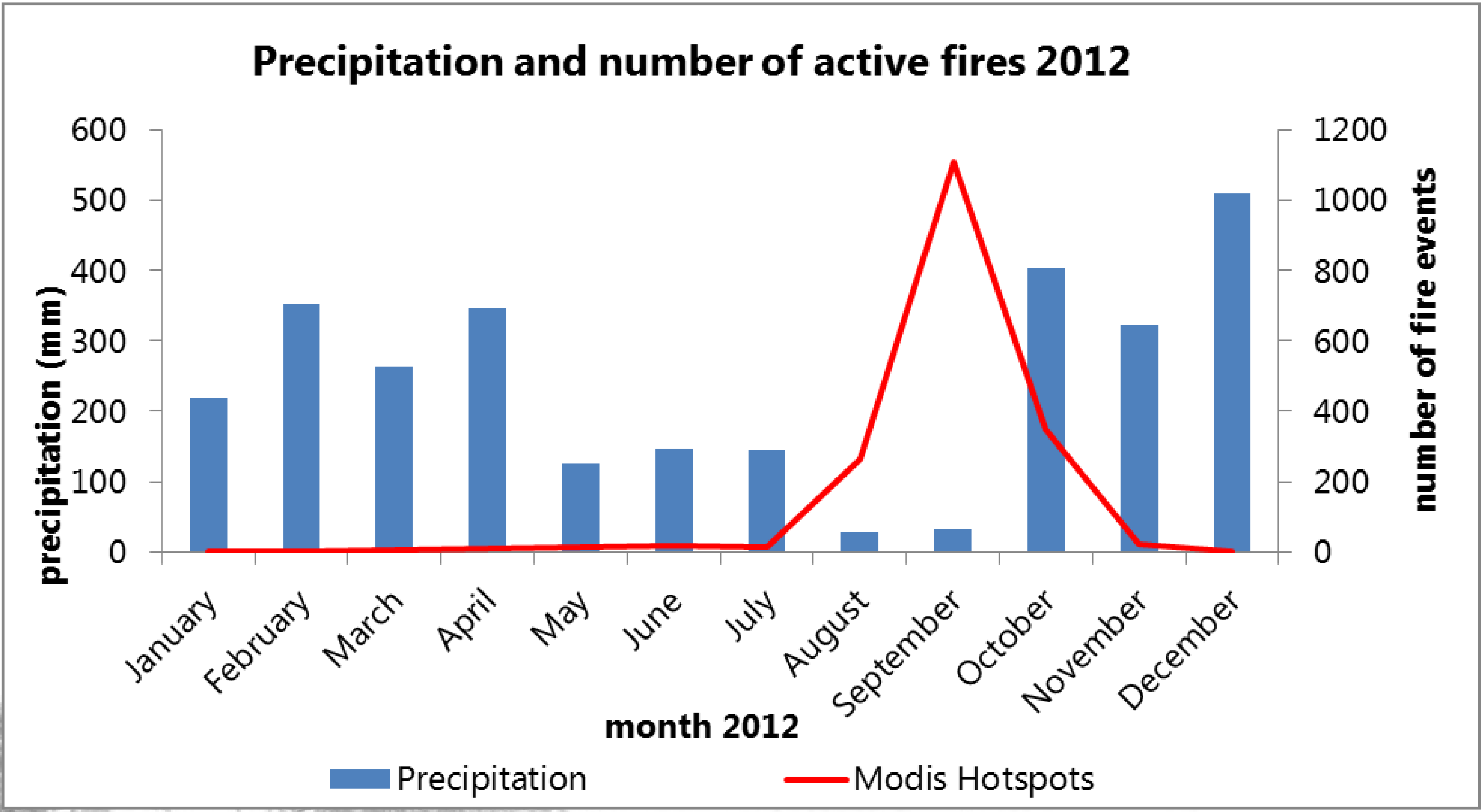
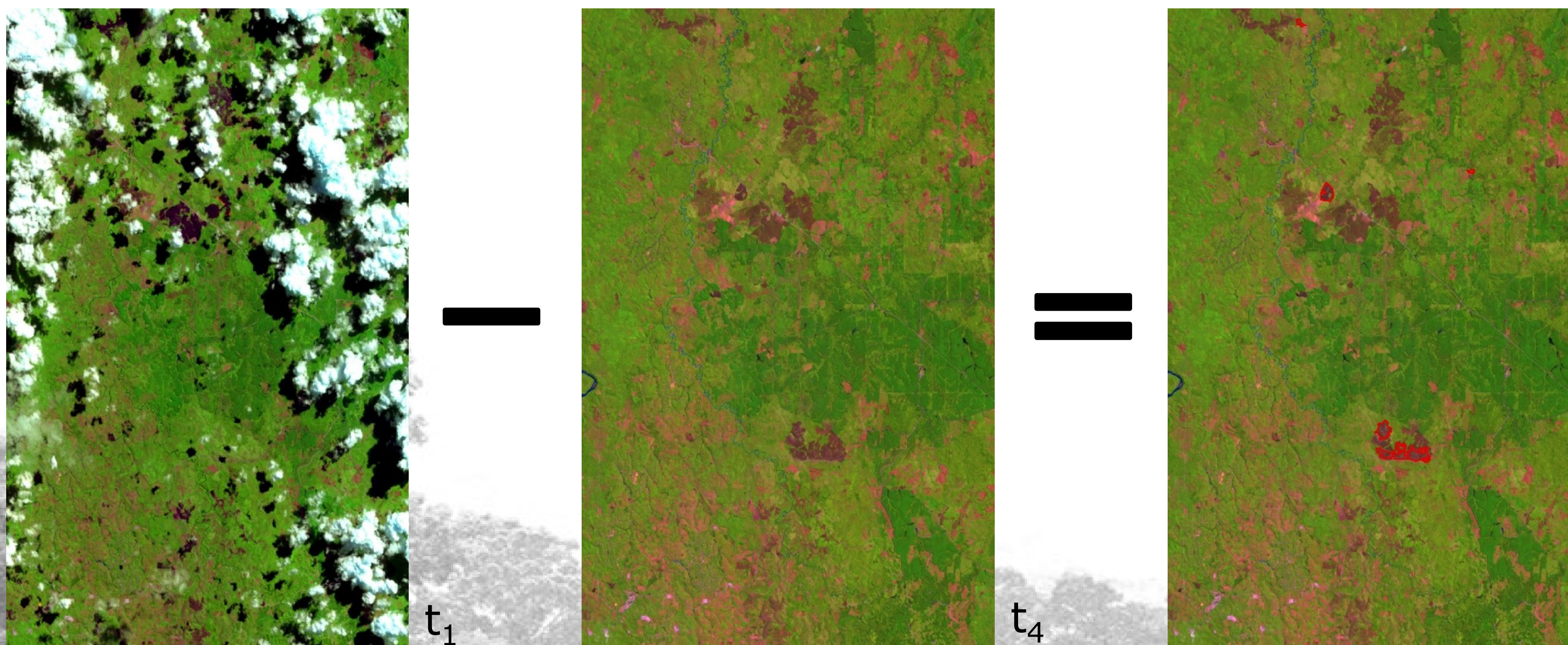
Analysis of fire season of each year



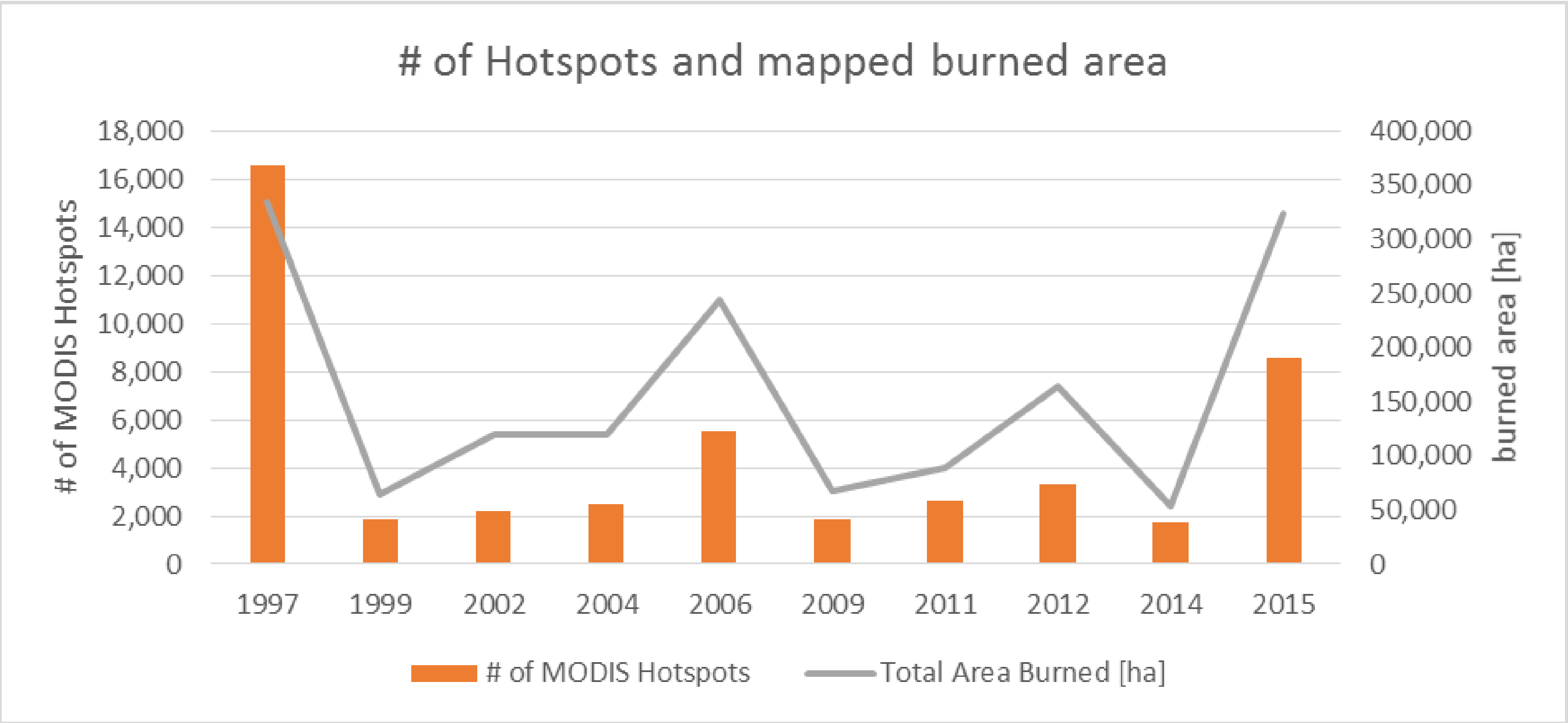
Limitations

Multi scene approach

- Bare areas in oil palms plantations can be classified as burned
- Both scenes have to be cloud free for classification
- Usually high cloud cover percentage in tropics
- This “problem” is tackled via change calculation of all possible combinations
    - t_1-t_4 | t_2-t_4 | t_3-t_4



Mapped area burned vs. hotspots



Annual emission from fires

Burned area per year within the land cover class No Data

Burned in LC "No Data"			
	ha		
YEAR	area burned	burned area and no data	percentage
1997	333,931	17,646	5.28%
1999	64,009	7,090	11.08%
2002	119,204	13,591	11.40%
2004	120,029	12,538	10.45%
2006	243,560	22,904	9.40%
2009	68,172	4,782	7.02%
2011	89,310	12,778	14.31%
2012	164,245	17,402	10.59%
2014	53,440	514	0.96%
2015	323,397	3,244	1.00%
Total	1,579,297	112,489	7.12%

- Should be taken into consideration when assessing emissions
- No aboveground biomass could be calculated for these areas
- For peat emissions simply the amount of carbon emitted was set to second and more fires