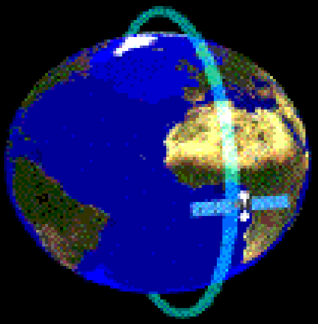
ICWEES 2018, Edan Star Hotel, Djerba-Zarsis, Tunisia, May 8-11, 2018



Carbon emissions caused by woodland fires in the African tropical savannas

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EAST CHINA UNIVERSITY OF TECHNOLOGY

Outlines

I. Global Carbon Cycle & Emission Partition
II. Impacts of Land Management on Carbon Emissions: an Example in African Tropical Savannas
   1. Problems & Objective
   2. Data and Processing Approaches
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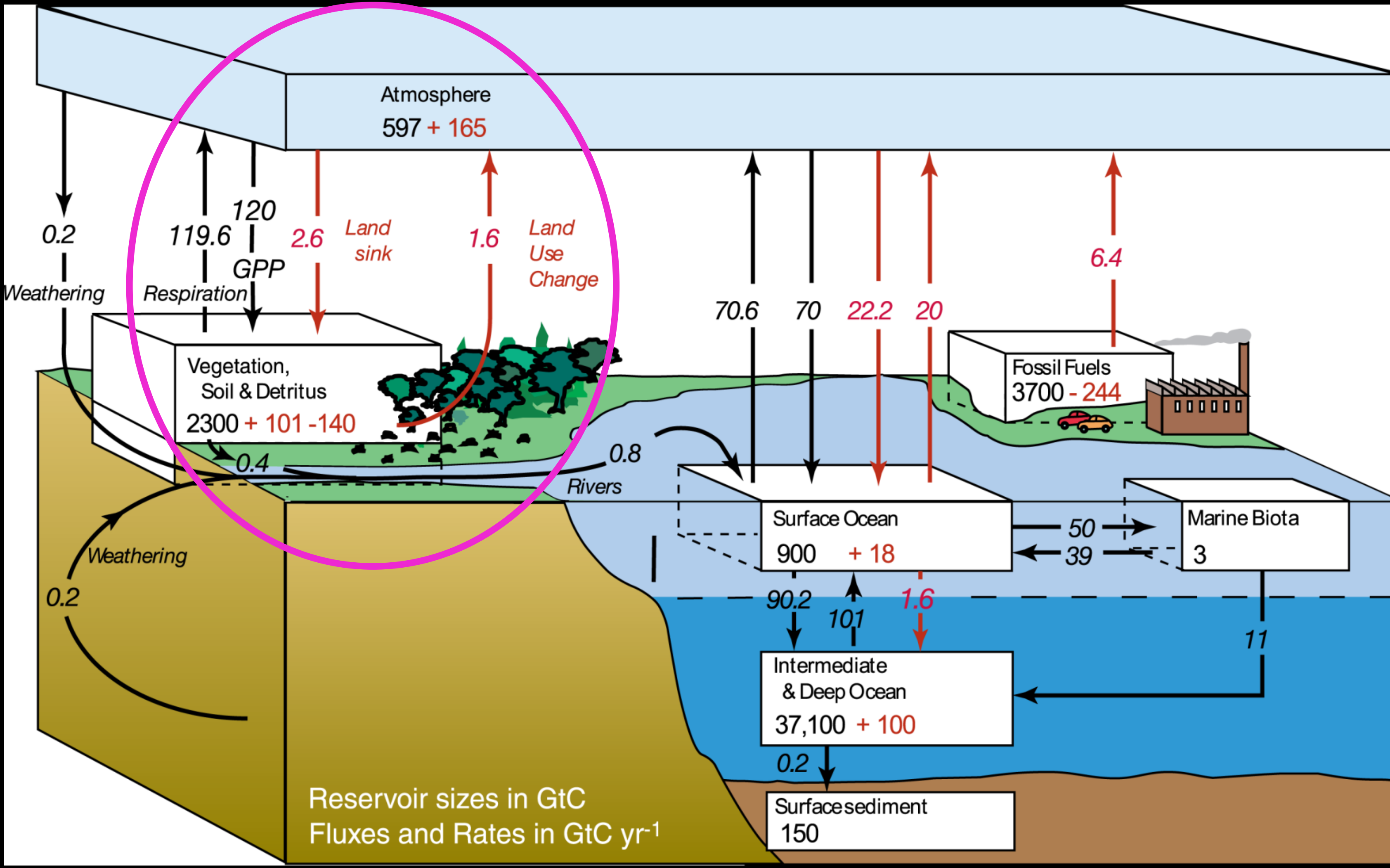
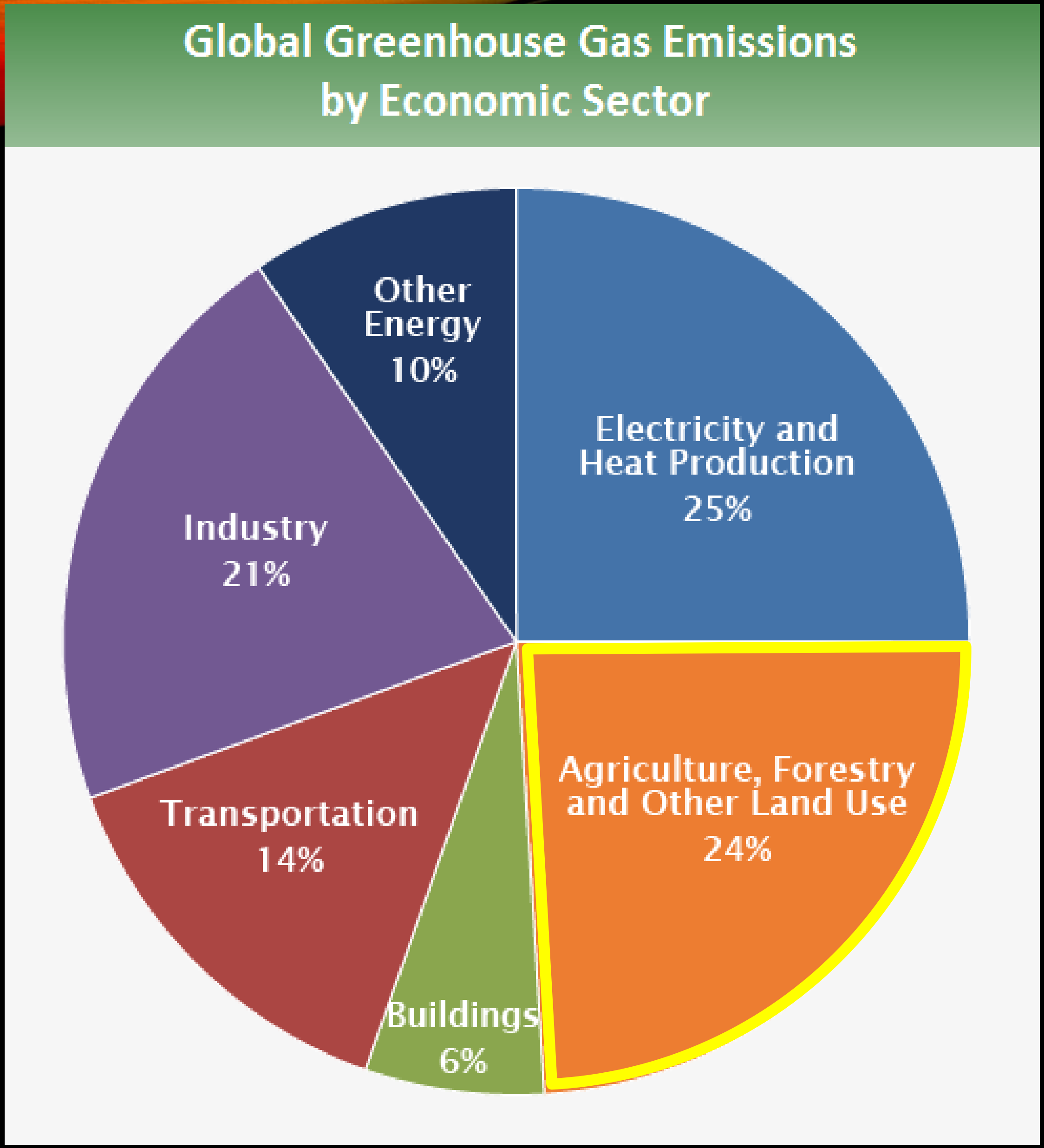
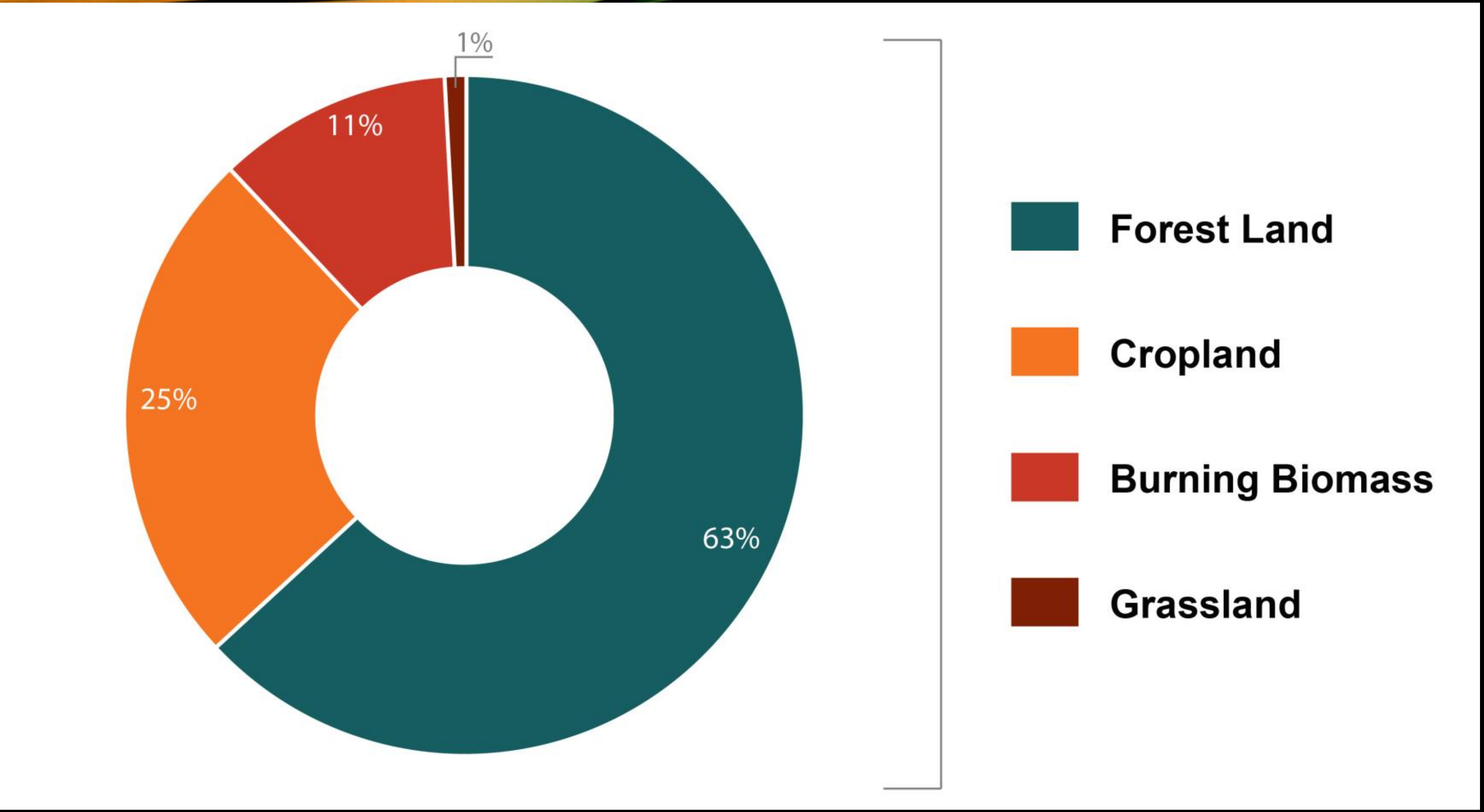
I. Global Carbon Cycle & Emission Partition



Source: IPCC 2007, 4th Assessment Report, WG1

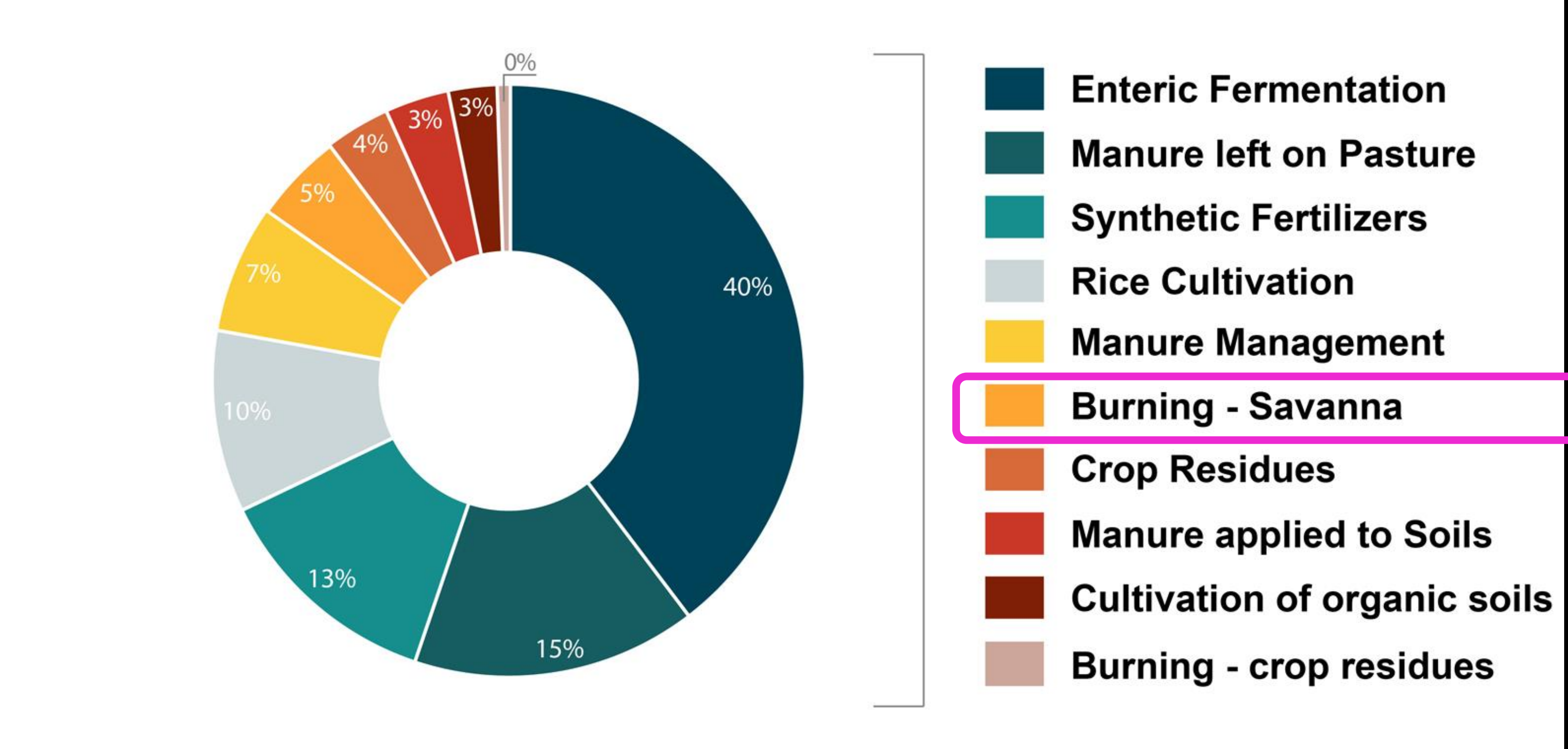


IPCC 2014, 5th Assessment Report, WGIII



All land use categories were globally net emission sources:
The largest was forest land (63%), followed by cropland (25%) and grassland (11%)

(Source: FAO 2014)



(Source: FAO 2014)

2001-2011 Trends: Sub-sectors

Emissions from *enteric fermentation* were the greatest contributor to agricultural emissions (40%), followed by manure left on pasture (16%), synthetic fertilizers (13%), rice cultivation (10%), manure management (7%) and burning of savanna (5%) .

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II. Impacts of Land Management on Carbon Emissions -- An Example in African Tropical Savannas

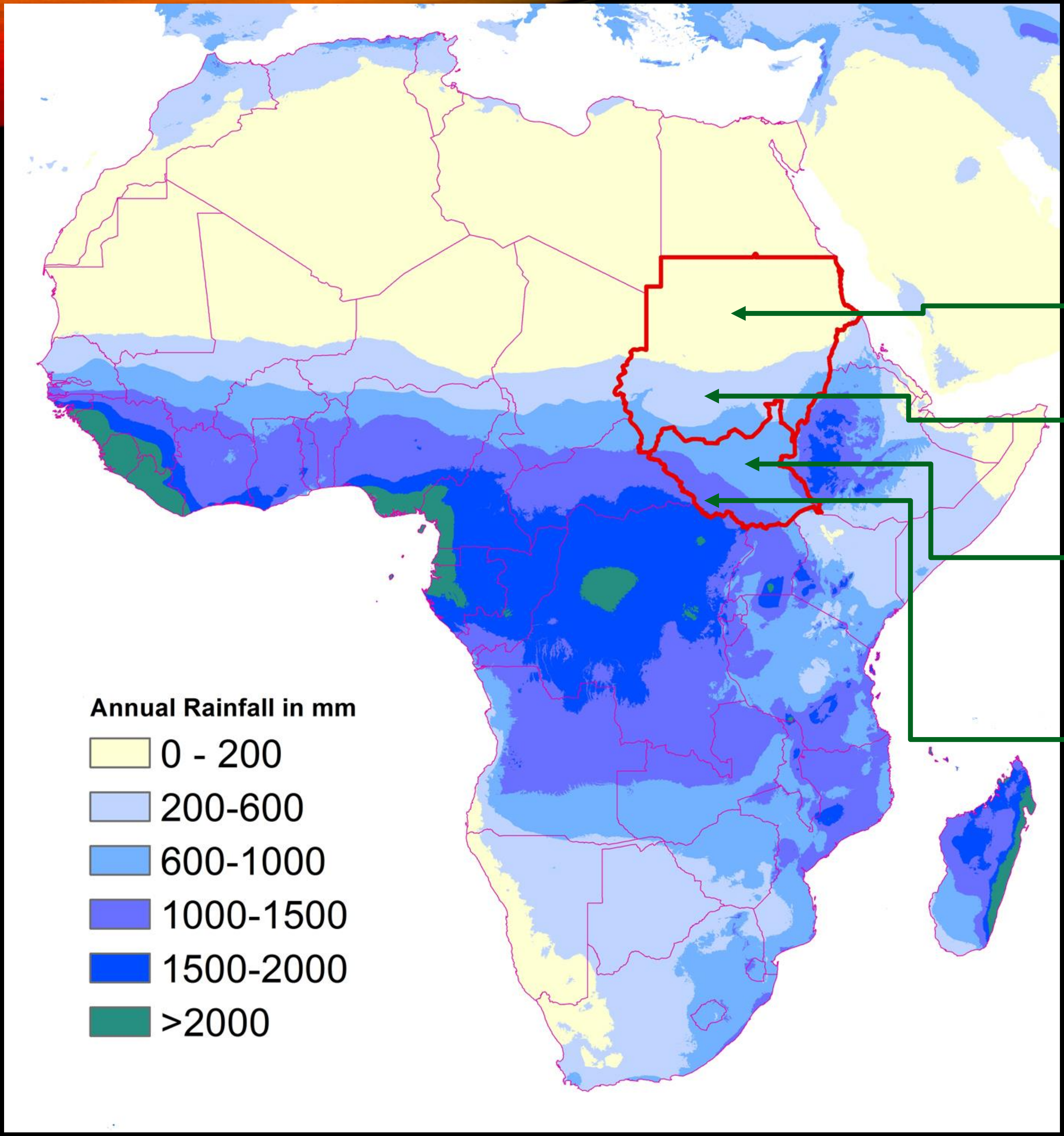
Tropical Area

S – Sudan

SS – South Sudan

Two Sudan

A Typical Savanna Country Crossing Ecoregions:



Saharan Desert

Sahelian Savanna

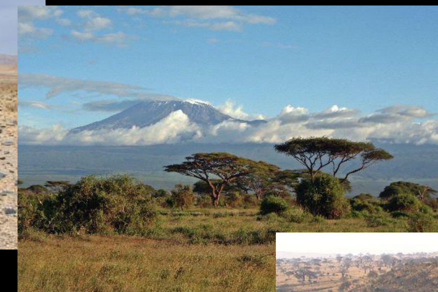
Sudanian Savanna

Congolian Forest-Savanna

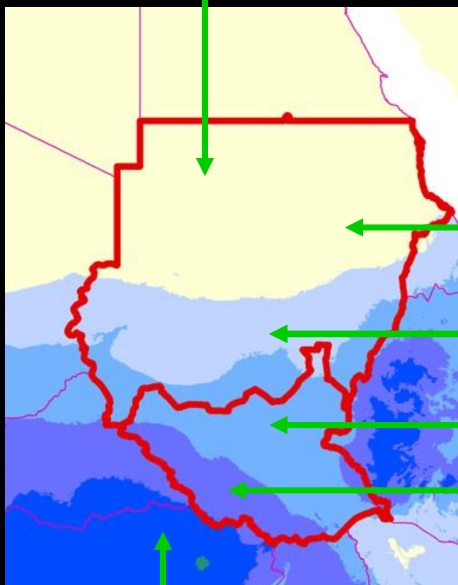
(After WWF 2010)

(Classified from the annual rainfall data of 1970-2000, source: http://worldclim.org)

(Source: http://www.awf.org/land-protection/ecosystems)

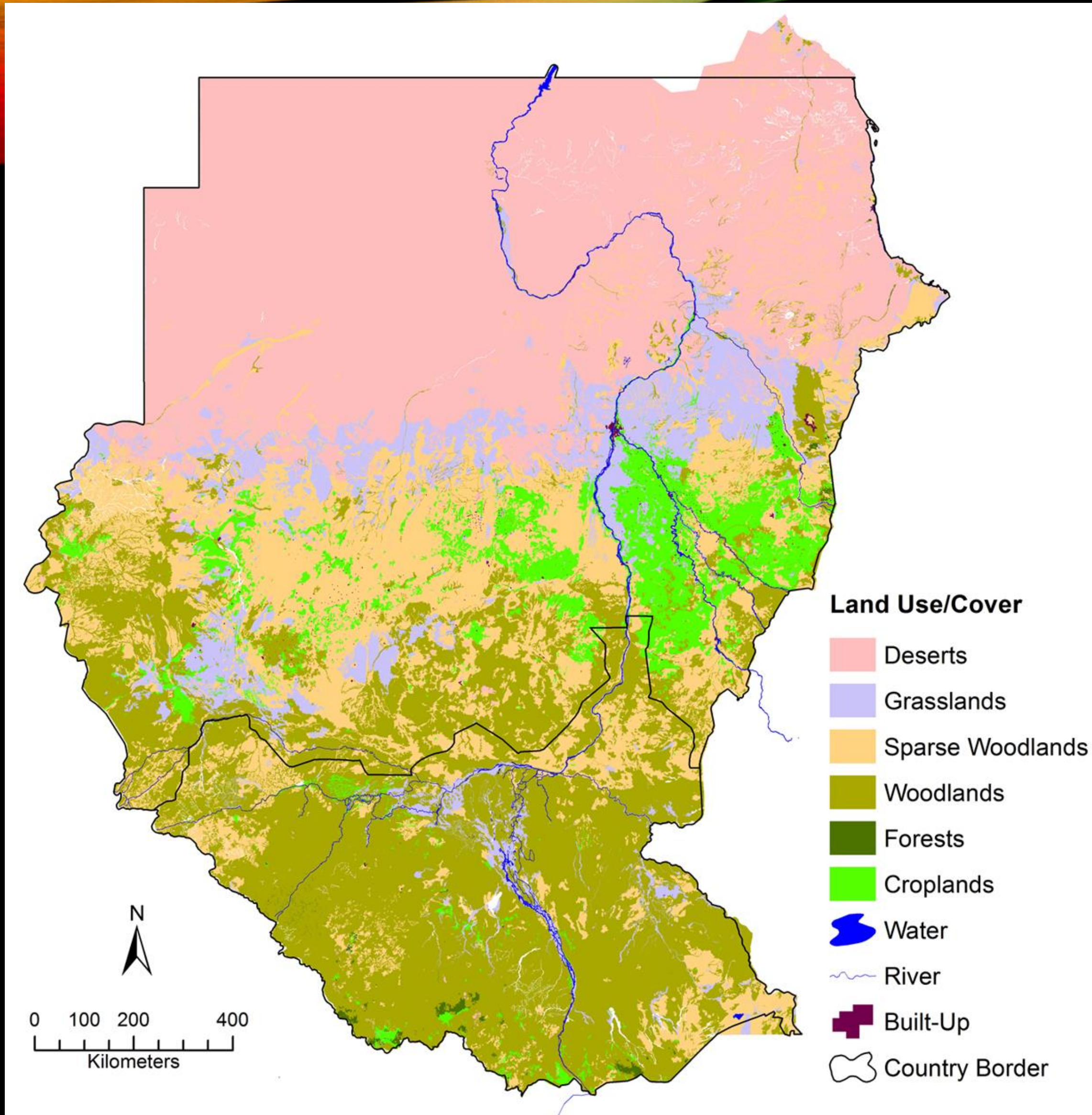


(Source: http://www.bioexpedition.com/savanna-biome/)



(Source: http://www.nationalgeographic.com/environment/)

(Source: http://www.awf.org/land-protection/ecosystems)

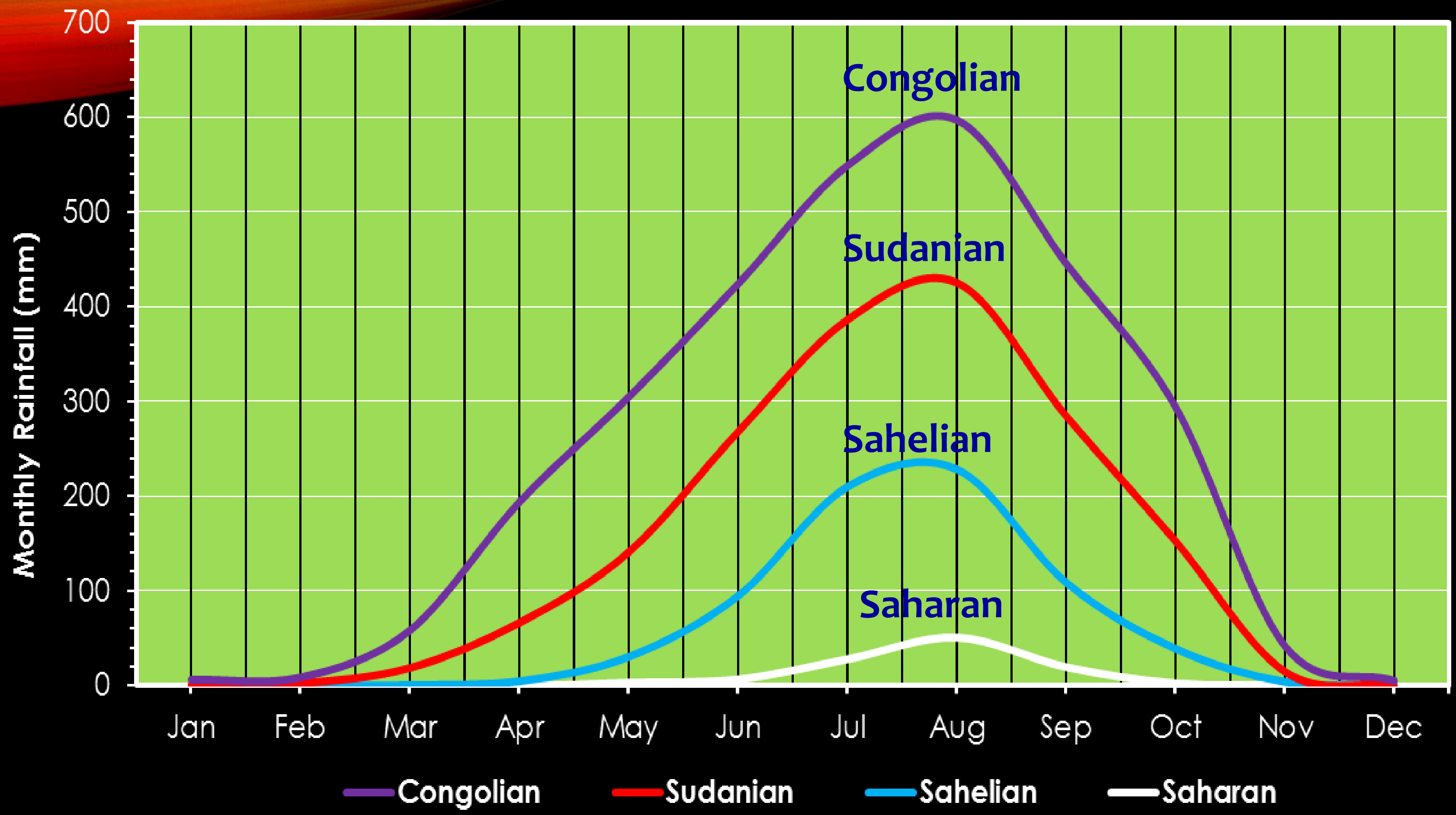


(Simplified from FAO 2003, Africover Project)

Major Land Cover	%
Saharan Deserts,	36.33%
Grasslands	8.19%
Sparse woodlands	16.88%
Woodlands	31.59%
Forests	0.29%
Croplands	5.83%
Water Bodies	0.78%
Artificial	0.11%
Total LC	**100%**

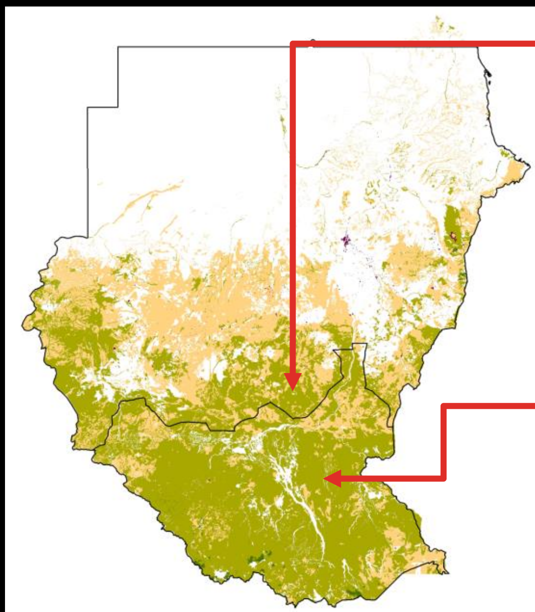
All Woodlands: 48.47%!!!

(Wu et al. 2013a)



Dry Season: Oct – Apr in Sahelian & Saharan;
Nov - Mar in Sudanian & Congolian
Rainy Season: May-Sep in Saharan (96.4%) & Sahelian (92.8%)
Apr-Oct in Sudanian (96.8%) & Congolian (92.8%)

(Wu and De Pauw 2010)



(https://blog.plantwise.org/2013/02/)

Agroforestry

https://www.nasa.gov/sites/default/files/thumbnails/image/15-144a.jpg

http://africa-regreening.blogspot.fr/2012/11/

Traditional land management: Burn agroforestry croplands & forageland in DRY SEASON to get a better regrowth next year!!!!

1. Problems & Objectives

- Fires extended or even set in National Reserves
- Animals killed & habitats changed
- Savanna woodlands burnt, biomass loss, carbon emitted into atmosphere!!!
- Carbon emissions INFLUENCE C-Cycle & Climate System!!! How to quantify?

The objectives were to find a way /approach to detect accurately the burnt areas and to evaluate and quantify such carbon emissions.

Detect fires & burnt scars/areas ⇒ Burnt woody biomass ⇒ Estimate emitted carbon

2. Data & Processing Approaches

(1) Data

- 996 MODIS data (MOD13A1/MYD13A1): 500 m, 2000-2010:

  Oct (Start of the Dry Season): **Pre-Burning**

  Dec-Mar (Dry Season) : **Burning & Post-Burning**
- >90 Landsat: Jan-Feb (Dry Season), 30 m (verification)
- Google Earth: GeoEye and QuickBird (verification)
- SRTM: DEM (90 m)
- Climate data: Monthly and Annual Rainfall, Annual Mean T, Dry-season Mean T, Dry-season Wind Speed (1970-2000)
- FAO land use and land cover map (2003)

(2) Rationale

Spectral and biophysical features of Burning & After burning:
T ↑, NDVI ↓, NIR ↓, MIR ↑
Visually: After burning, Scars left (called Burnt Scars)

⇒ **T – Based index** (NASA) → **Active Fire Products (1 km)**

⇒ **Spectral change → NIR → EU Copernicus BA Product**

⇒ **Normalized Burn Ratio (NBR) = (NIR-MIR)/(NIR+MIR)**
(Lopez-Garcia and Caselles 1991; Pereira and Setzer 1993; White et al 1996; Key and Benson 1999)

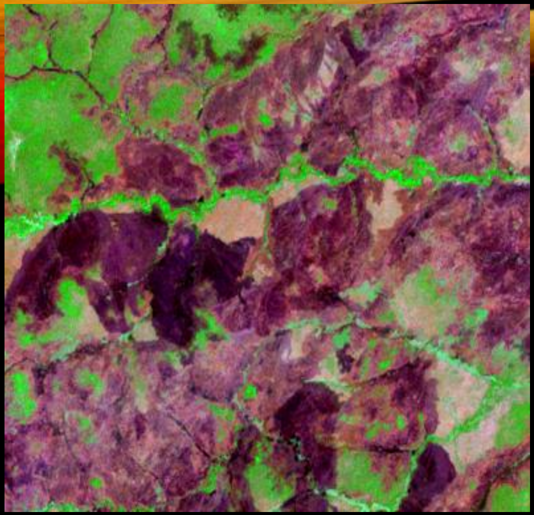
⇒ **Reversed NBR (RevNBR) = (MIR-NIR)/(MIR+NIR)**

Signature: the more severe the burning , the higher **RevNBR !!**

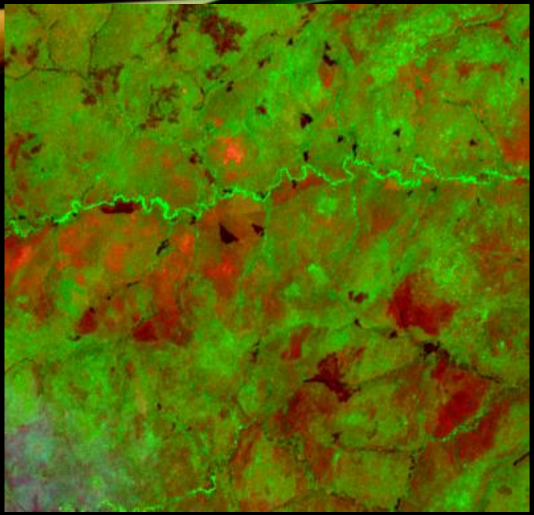
(3) Main Algorithms & Procedure for Burnt Area Identification

- **(3.1) Preparation of Datasets**
  - Derivation of the RevNBR
  - Stacking all RevNBR of the same dry-season
  - Apply a **Maximization** algorithm to get the cloud-free RevNBR, **why?**
  - Mosaicking the max RevNBR: PreBurn and PostBurn

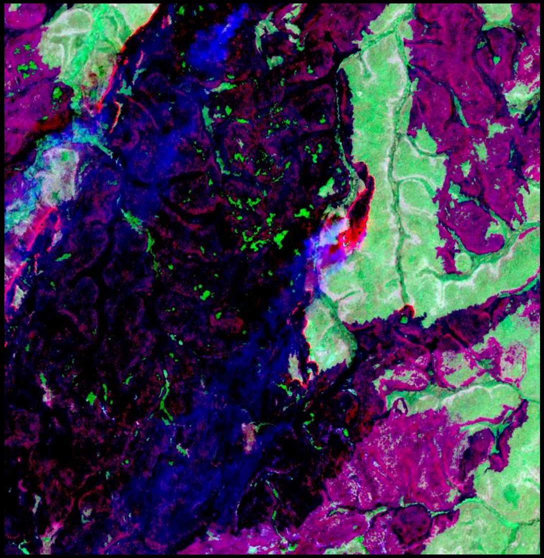
Strong recovery of the herbaceous vegetation after burning: Congolian Forest-Savannas



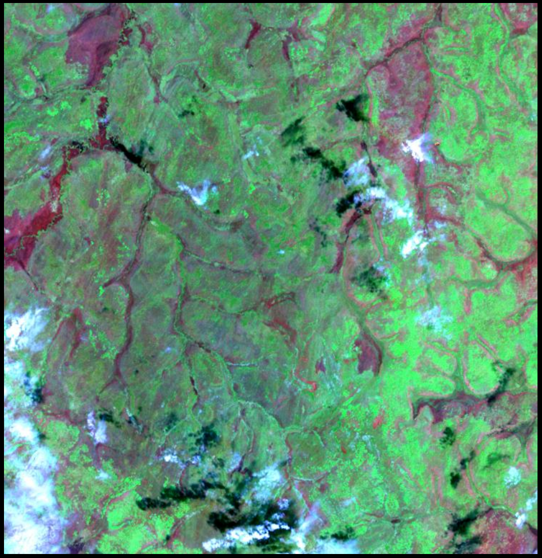
Zoom 1: Scene 173/57
Burnt on Jan 15, 2003



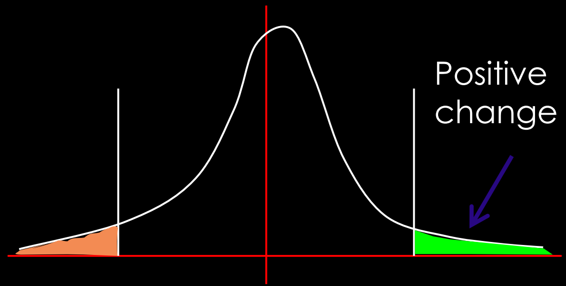
Zoom 1: Scene 173/57
Recovered on Feb 16, 2003



Zoom 2: Scene 174/56
Burning on Dec 15, 2000



Zoom 2: Scene 174/56
Recovered on Feb 17, 2001



➢ **(3.2) Differencing & Thresholding**

ΔRevNBR = PostBurn Max RevNBR – PreBurn Max RevNBR

Difficulty:

Spatial variability → Underestimation or overestimation if single thresholding applied!!

Ecoregion-level thresholding, better but still not ideal

Landscape unit-level, should be more promising!!

How to derive landscape units?

Landscape: Shaped by landform + climate

Annual RF, Dry-season RF, Annual MT, Dry-season MT, Dry-season mean windspeed or sum;

Elevation+Aspect+Slope (%)

Random Forest Regression:

To determine the importance of the landscape and climate parameters:

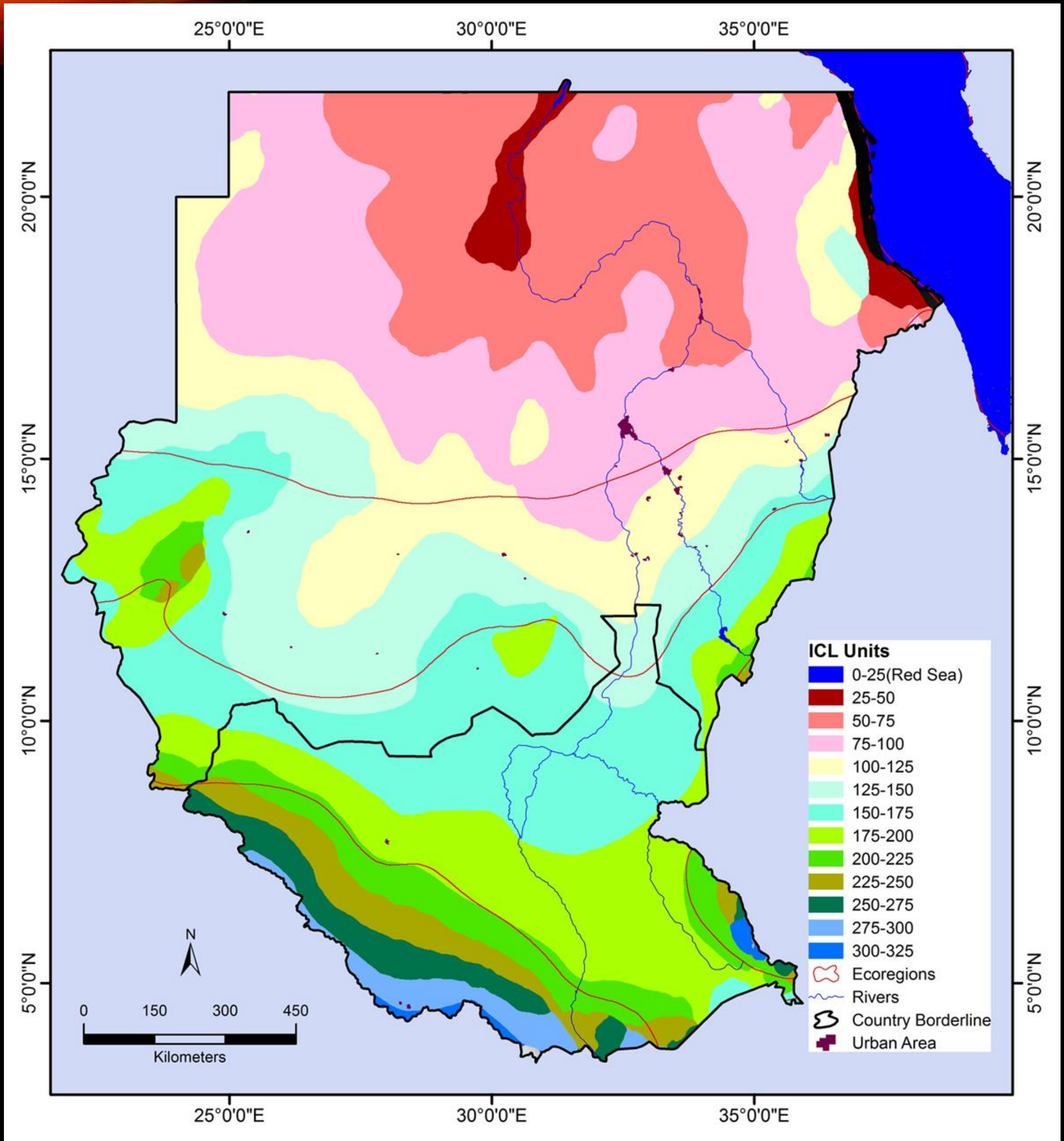
Integrated Climate-Landscape Indicator (ICLI)=

14.35%*AMT+13.75%*DMT+12.65%*DRF+12.61%*ARF+ 12.36%*E+ 12.21%*DWSS +10.51%*DWSM+7.57%*S+3.99%*A

ICLI classified into **22 ICL Units**

- **(3.3) Conditional Thresholding at ICLU level**

  To Identify the burnt areas in each dry-season



Ecoregions and Integrated Climate-Landscape Units (ICLU)

(4) Biomass loss and carbon emisson calculation

- Maximum NDVI of PreBurn state (Oct) → Decomposition → Woody Component (Woody NDVI).
- Mean NDVI of the PostBurn state (Dec-Mar) to avoid MODIS mask problem
- $\Delta NDVI = PreBurn\ NDVI_W - PostBurn\ Mean\ NDVI$
- Using woody biomass models of Wu et al (2013):

  Model 1: $\Delta B = B_{BURNT} = 71.095\Delta NDVI - 5.3283$ (tons/ha) for *Acacia*-dominated Sparse Woodlands (Saharan & Sahelian)

  Model 2: $\Delta B = B_{BURNT} = 0.8868(153.09\Delta NDVI - 10.12)^{1.1069}$ (tons/ha) for *Anogeissus–Isoberlinia–Uapaca–Terminalia*-dominated Woodlands/Forests (Sudanian & Congolian Forest-Savannas)

  To calculate woody biomass loss

- From the loss, estimate carbon emission (how much left as ash and charcol, and how much emitted into atmos as CO2)

  $0.45\times(1-10.8\%)\times\Delta B$ (tons/ha)

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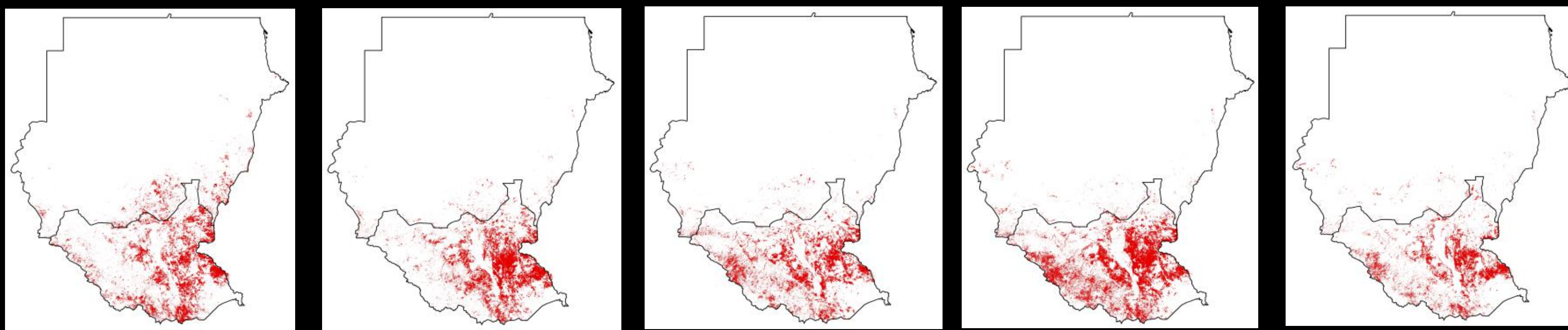
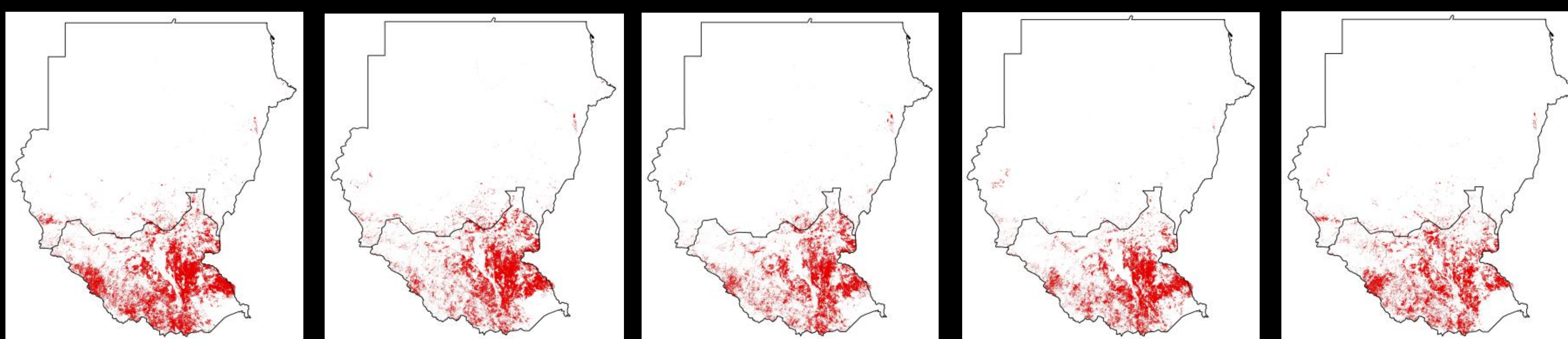
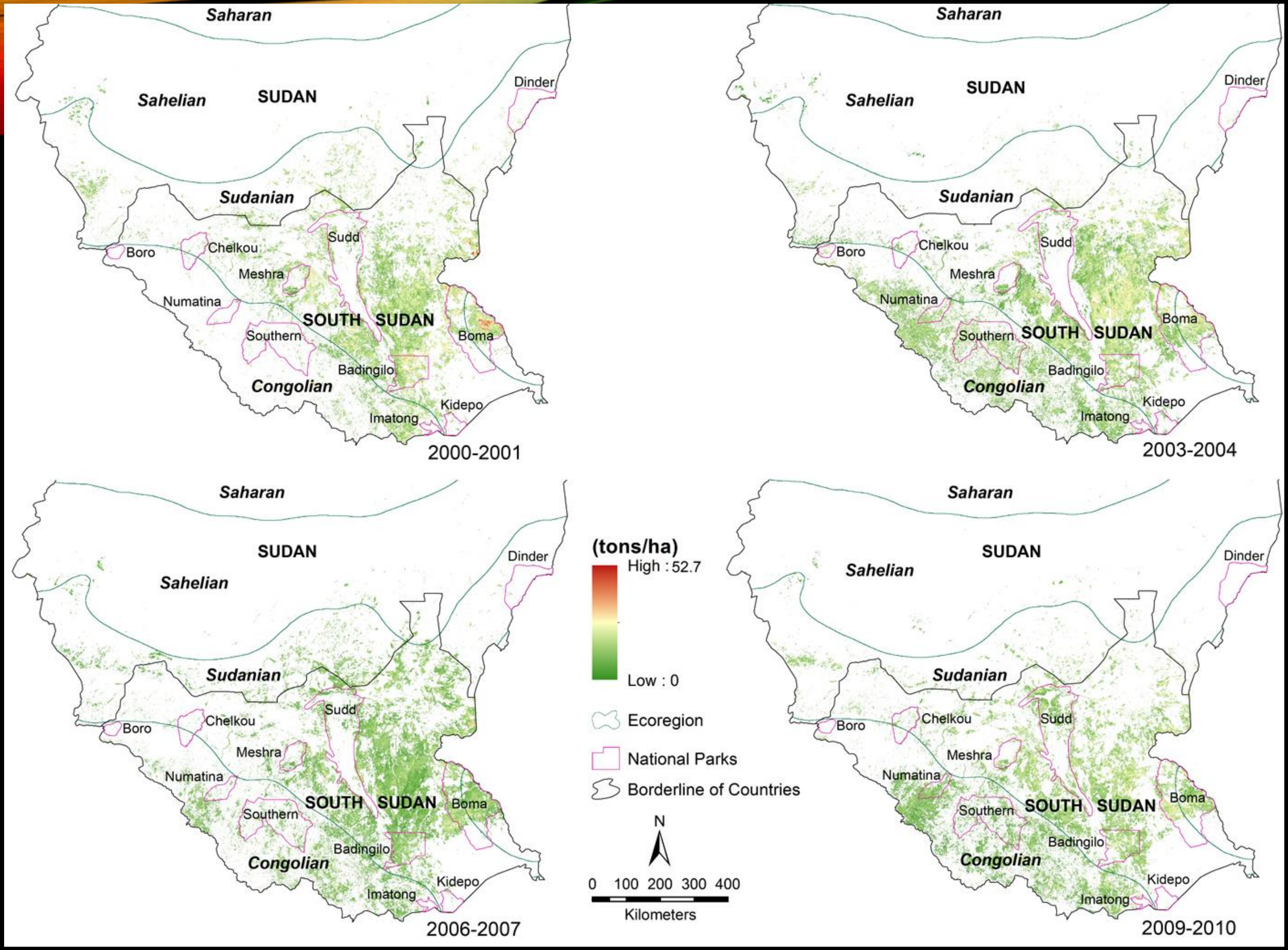


2000-2001 2001-2002 2002-2003 2003-2004 2004-2005



2005-2006 2006-2007 2007-2008 2008-2009 2009-2010

Burnt area detected in the dry-seasons of the period 2000-2010



Burnt woody biomass

Note: Burning extended to or set in National Reserves & Parks!!!

Table showing the burnt woodland areas, woody biomass loss and carbon emission in Sudan & South Sudan

Observed Winters		2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
Burnt Woodlands	Pixels	1017057	1320131	1034954	1388844	1228382	1278500	1290199	1388233	1333865	1172132
	Area (km^2)	211066	273962	214781	288222	254922	265323	267751	288095	276813	243249
% of the Total Woodlands		17.38 %	22.560 %	17.69 %	23.70 %	20.99 %	21.85 %	22.05 %	23.72 %	22.80 %	20.03 %
Verification Accuracy		90.49 %	91.21 %	92.50 %	92.75 %	93.78 %	95.12 %	98.53 %	94.48 %	96.30 %	92.57 %
Woody Biomass Loss (million tons)		11.76	3.41	10.76	10.46	20.15	13.86	11.43	10.25	13.98	9.07
Carbon Emission (million tons)		4.72	1.375	4.32	4.2	8.09	7.85	4.59	4.11	5.61	3.64

NASA: 95.12% 88.5%

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III. Summary

1. Uncontrolled fires resulted from irrational land management caused 17-24% of woodlands burnt, 3.4-20.5 million tons of biomass loss, and emitted 1.4-8.1 million tons of C into atmosphere every winter (or dry season).

   The huge amount of carbon, that could have been avoided, due to the irrational land management and practice, was emitted.

2. Differencing and conditional thresholding at ICL unit (ICLU) level (the approach developed in this study), may provide rather accurate burnt scars detection, 90.5-98.5% in accuracy. Better than the burnt area product NASA which was 1.5-4.5% lower in accuracy than our results.

3. The findings and results of the study could serve as references to decision makers in tropical Africa to improve land management and control carbon emission to mitigating climate change.

Thank you for your attention!

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