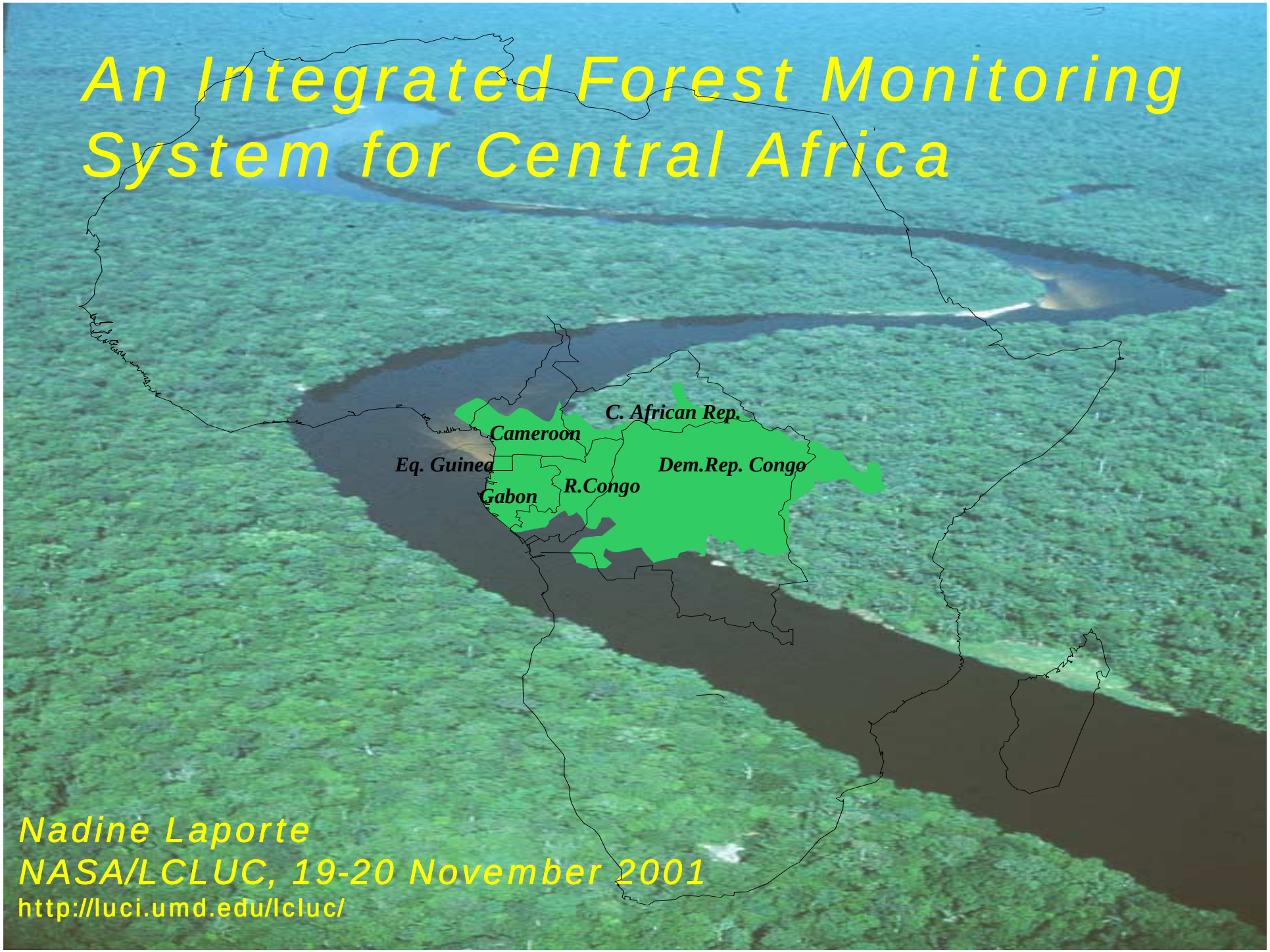
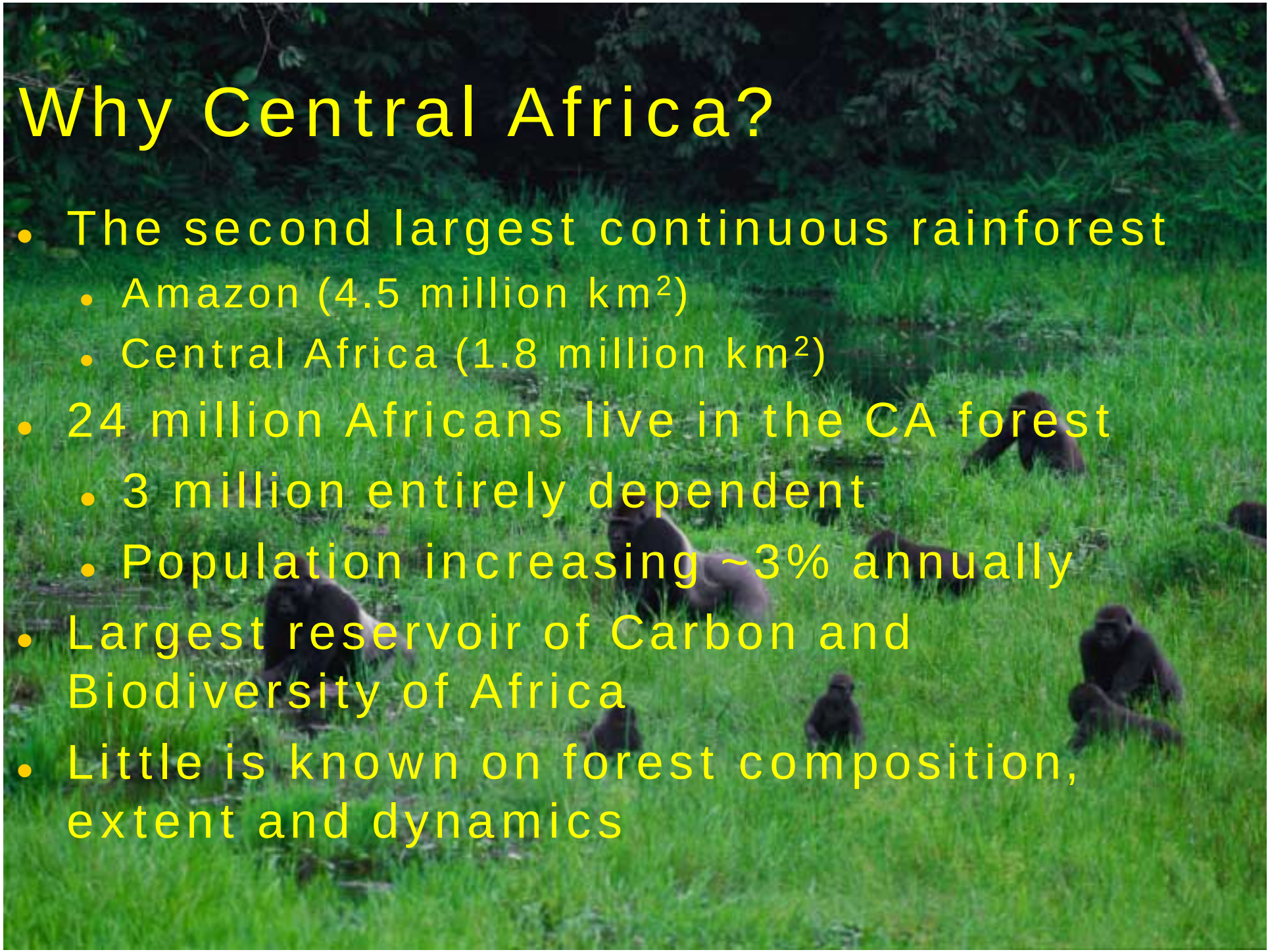
An Integrated Forest Monitoring System for Central Africa



Nadine Laporte
NASA/LCLUC, 19-20 November 2001
http://luci.umd.edu/lcluc/



Why Central Africa?

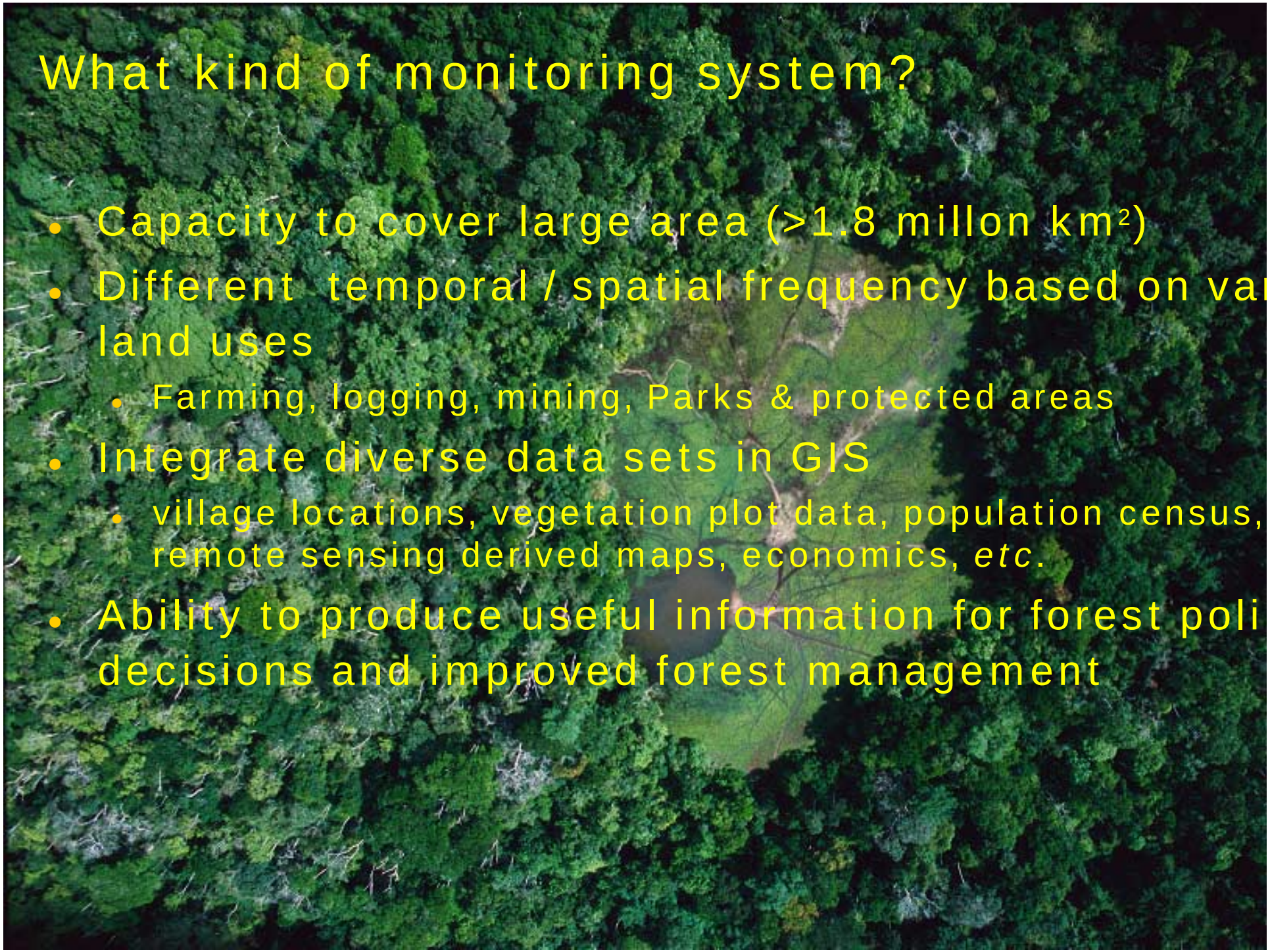
- The second largest continuous rainforest
  - Amazon (4.5 million km^2)
  - Central Africa (1.8 million km^2)
- 24 million Africans live in the CA forest
  - 3 million entirely dependent
  - Population increasing ~3% annually
- Largest reservoir of Carbon and Biodiversity of Africa
- Little is known on forest composition, extent and dynamics

Main Objectives

- Better characterisation of tropical forest land surfaces and processes (Carbon, human population, biodiversity)
- Promote interdisciplinary research (between biologists, foresters, geographers) to monitor tropical forests
- Integration of Central African research scentists in regional science activities
  - IGBP and GOFC workshops, CARPE-USAID SOS grants

Specific Goals

- Develop a forest monitoring system …
- Methods to map Central Africa forest dynamics using a multi-sensor multi-scale approach (AVHRR, MODIS, JERS, ERS, etc.)
  - Regional / local scale
  - Focus on high biodiversity sites
  - Map extent of logging and other land use change
- Develop validation protocols for regional land cover products (Field, Video, Ikonos, Landsat)
- Ensure that research findings reach policy makers (CARPE collaboration)



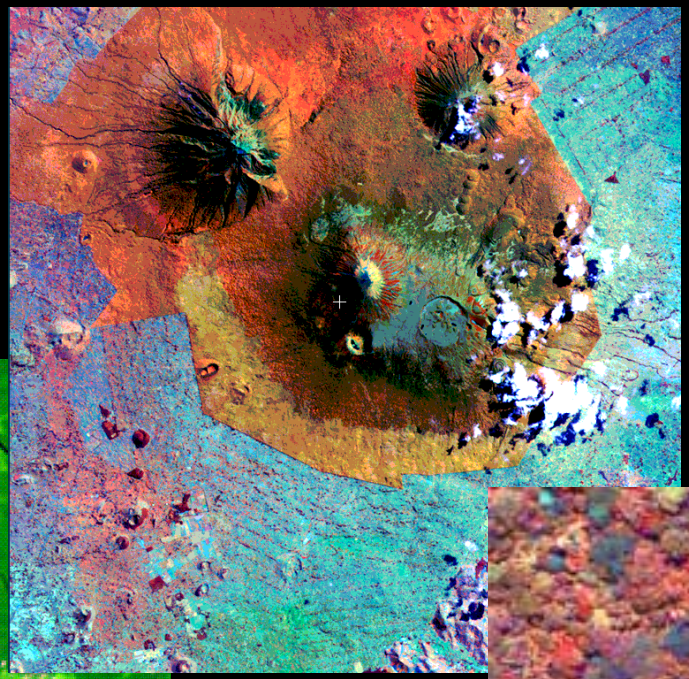
What kind of monitoring system?

- Capacity to cover large area (>1.8 millon km^2)
- Different temporal / spatial frequency based on va land uses
  - Farming, logging, mining, Parks & protected areas
- Integrate diverse data sets in GIS
  - village locations, vegetation plot data, population census, remote sensing derived maps, economics, *etc*.
- Ability to produce useful information for forest poli decisions and improved forest management

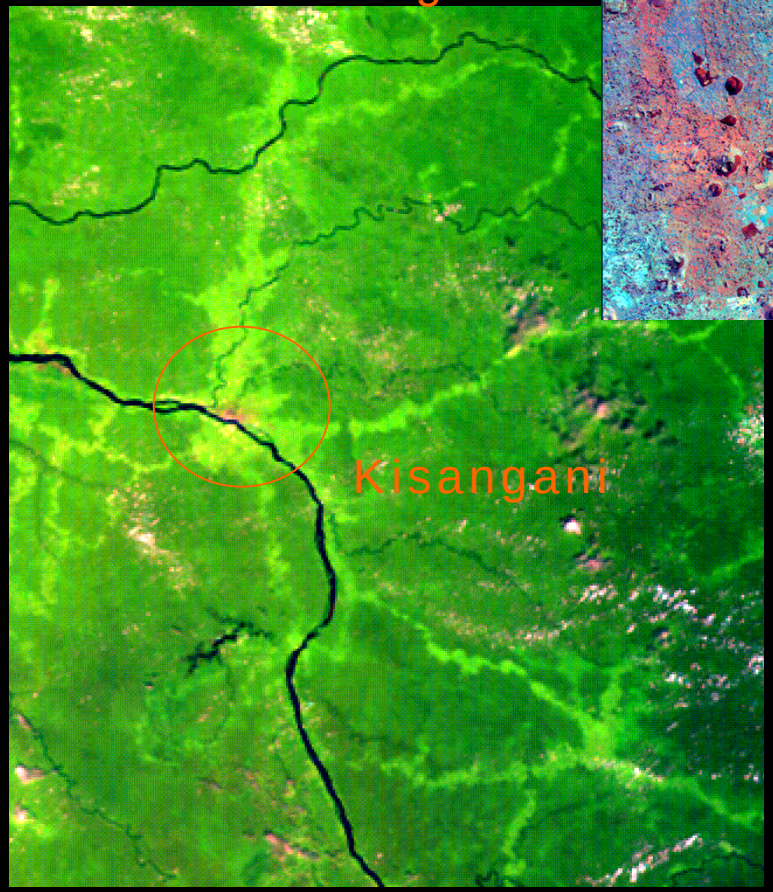
A Multi- Scale Approach

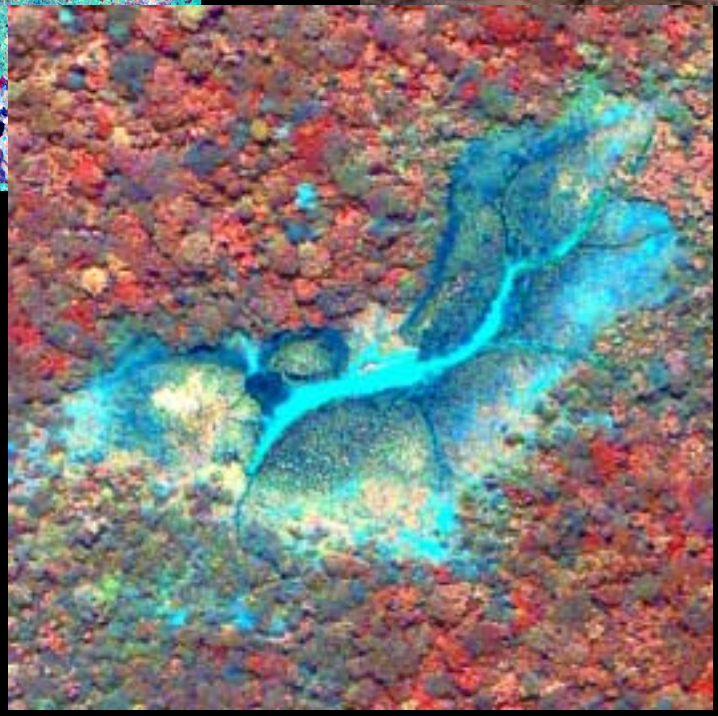
Field data sets

Landsat 30 m



AVHRR/ SPOT Veg. 1km





Ikonos 1 - 4 m

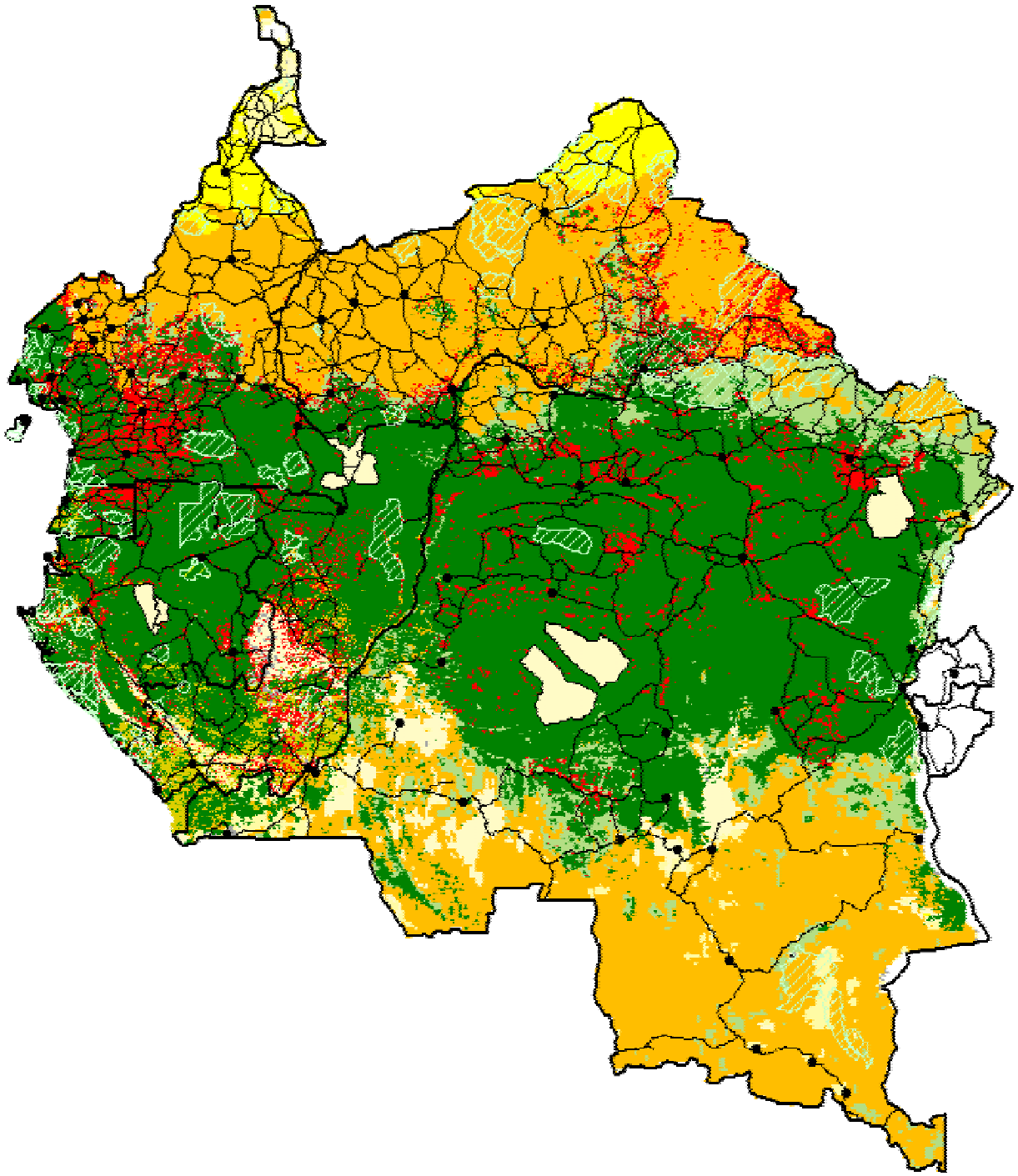
Study Sites

Primary:
- Lope Reserve
- Tri-National Park area
  - Ndoki Nat. Park
  - CIB (North Congo)
- Okapi Reserve
- South Cameroon
- Salonga Nat. Park

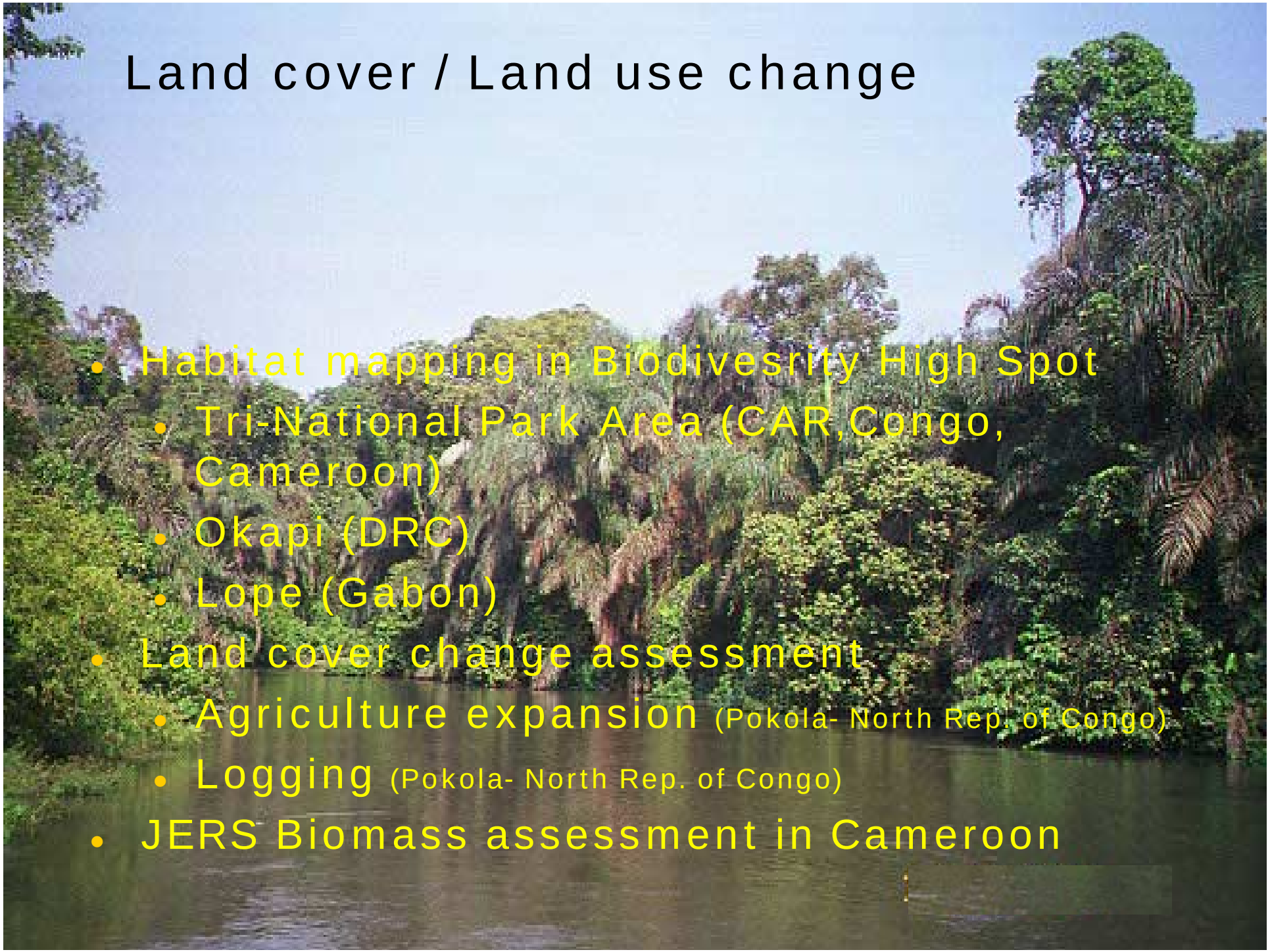
Secondary:
- Ngotto Reserve
- Mbaiki

Proportion of Forest Protected

Central Africa Republic	25
Eq. Guinea	24
Gabon	18
Cameroon	13
Rep. of Congo	10
DRC	7

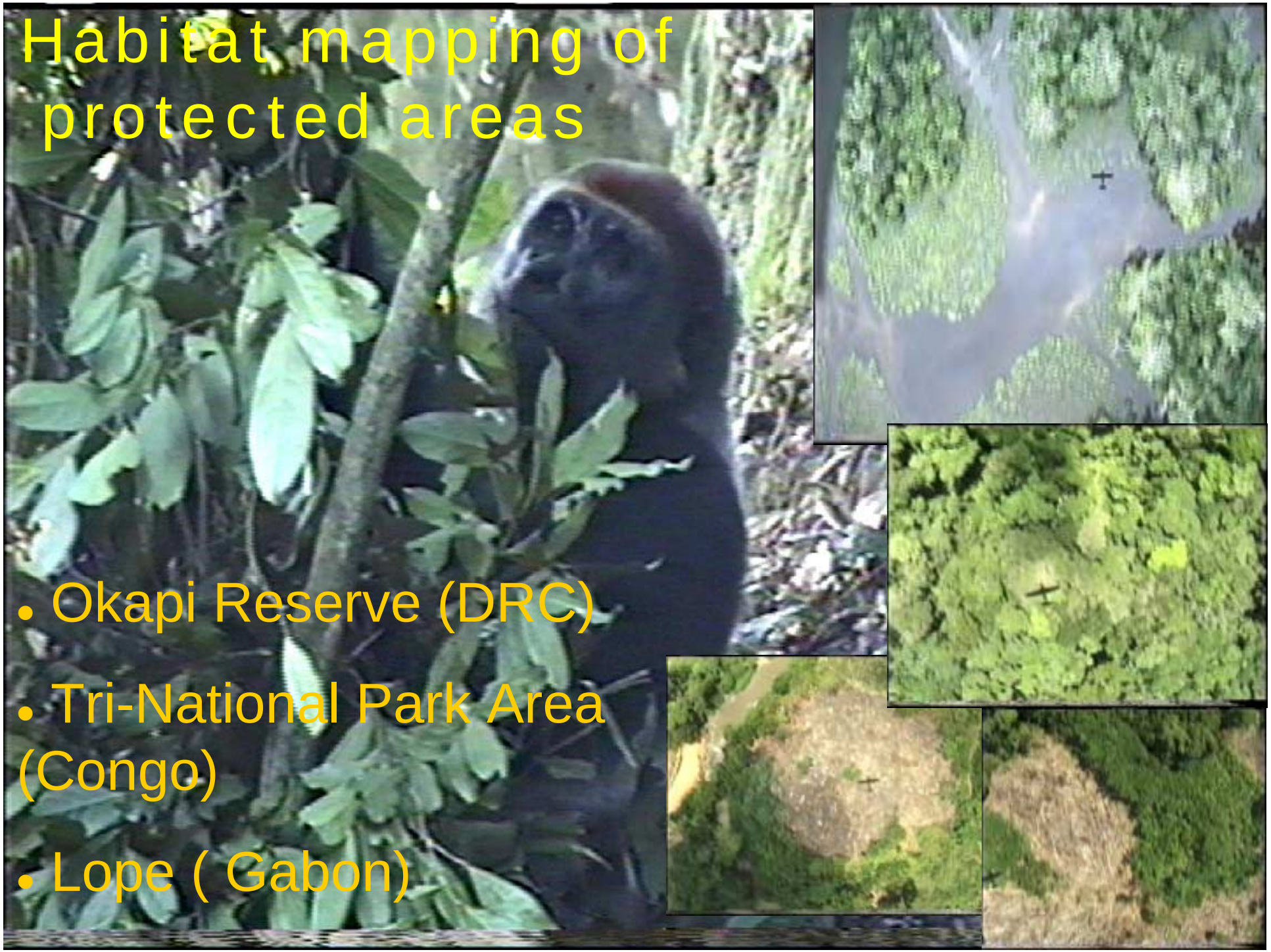


Land cover / Land use change



- Habitat mapping in Biodivesrity High Spot
  - Tri-National Park Area (CAR,Congo, Cameroon)
  - Okapi (DRC)
  - Lope (Gabon)
- Land cover change assessment
  - Agriculture expansion (Pokola- North Rep. of Congo)
  - Logging (Pokola- North Rep. of Congo)
- JERS Biomass assessment in Cameroon

Habitat mapping of protected areas

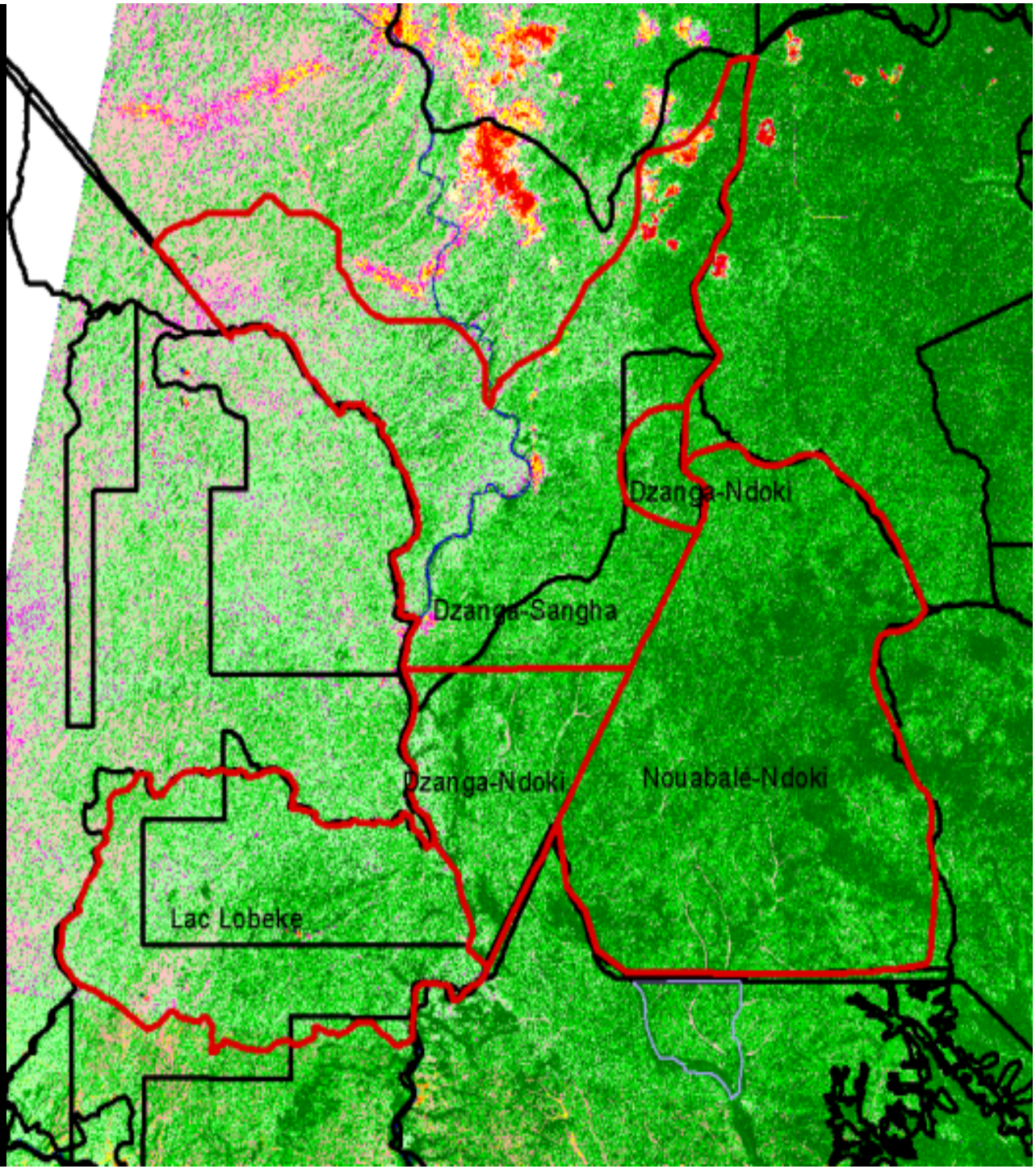


- Okapi Reserve (DRC)
- Tri-National Park Area (Congo)
- Lope (Gabon)

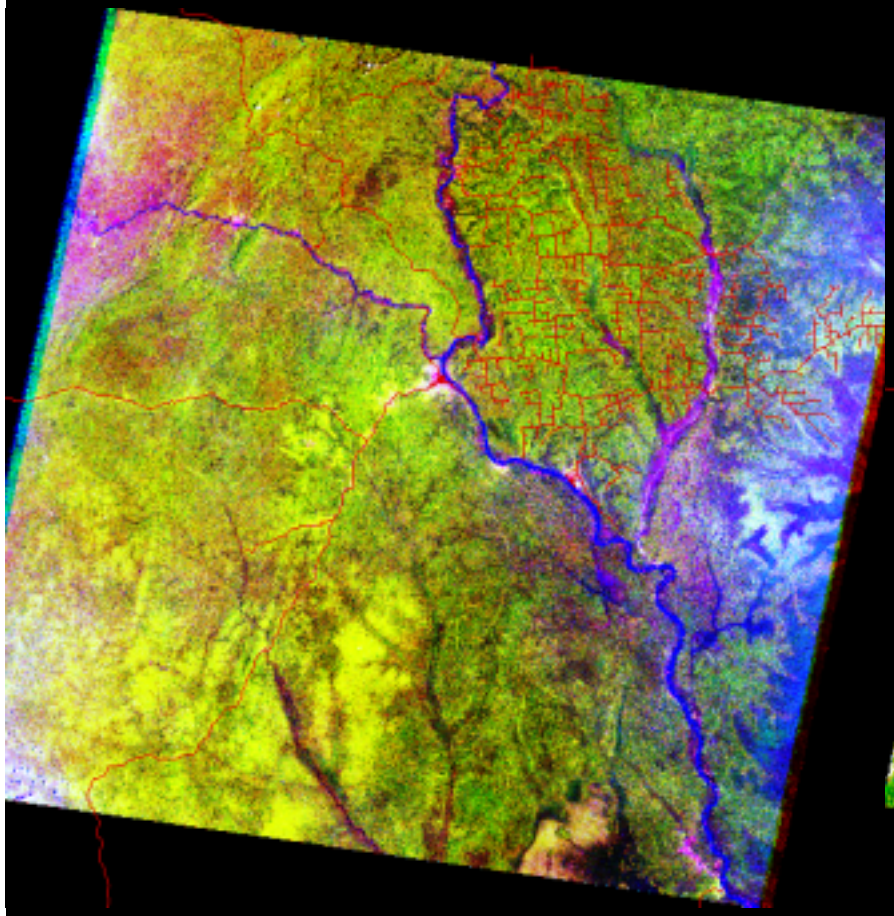
Tri-National Park Area

An island of conservation in a sea of forest exploitation

- Forest monodominant closed canopy
- Forest mixed closed canopy
- Forest mixed open canopy
- Forest mixed open canopy riparian
- Agriculture
- Savanna
- Bare soils

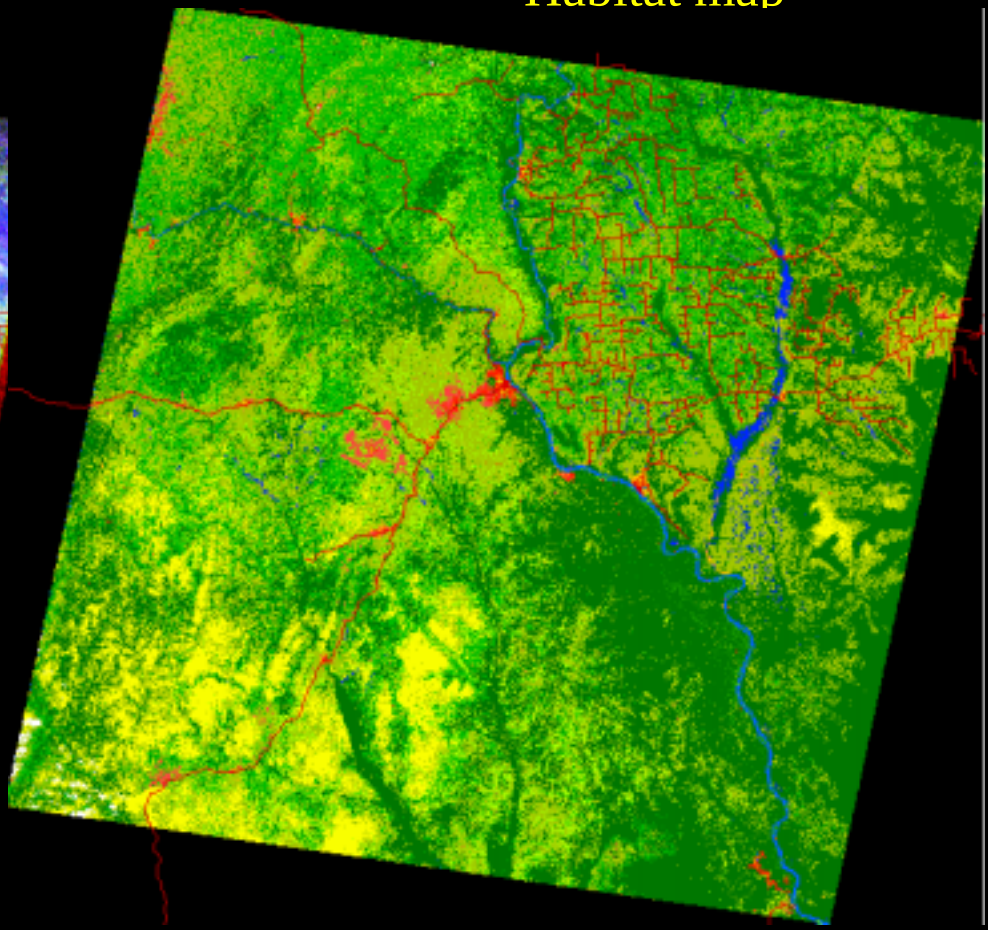


Tri-National Park Area

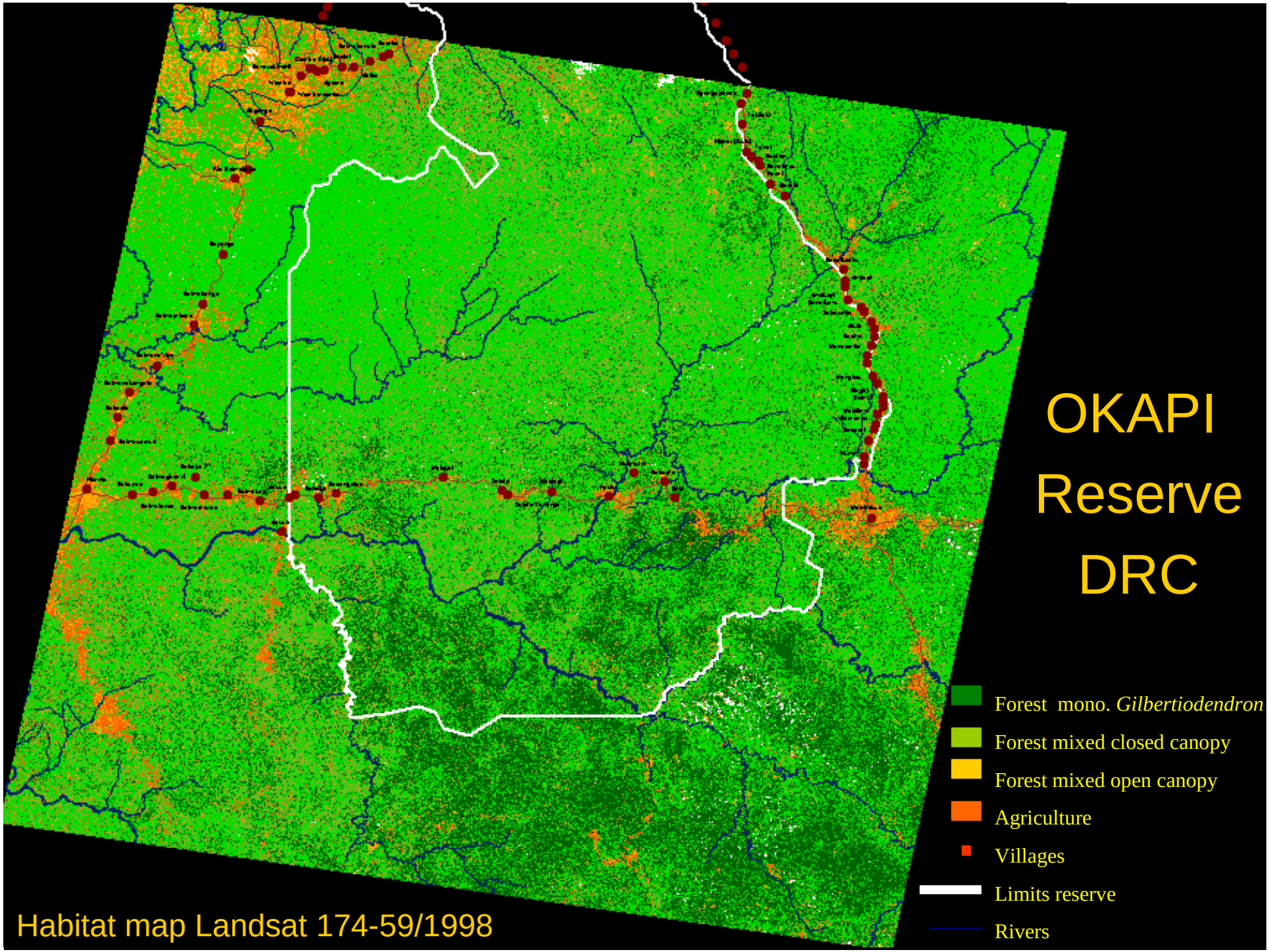


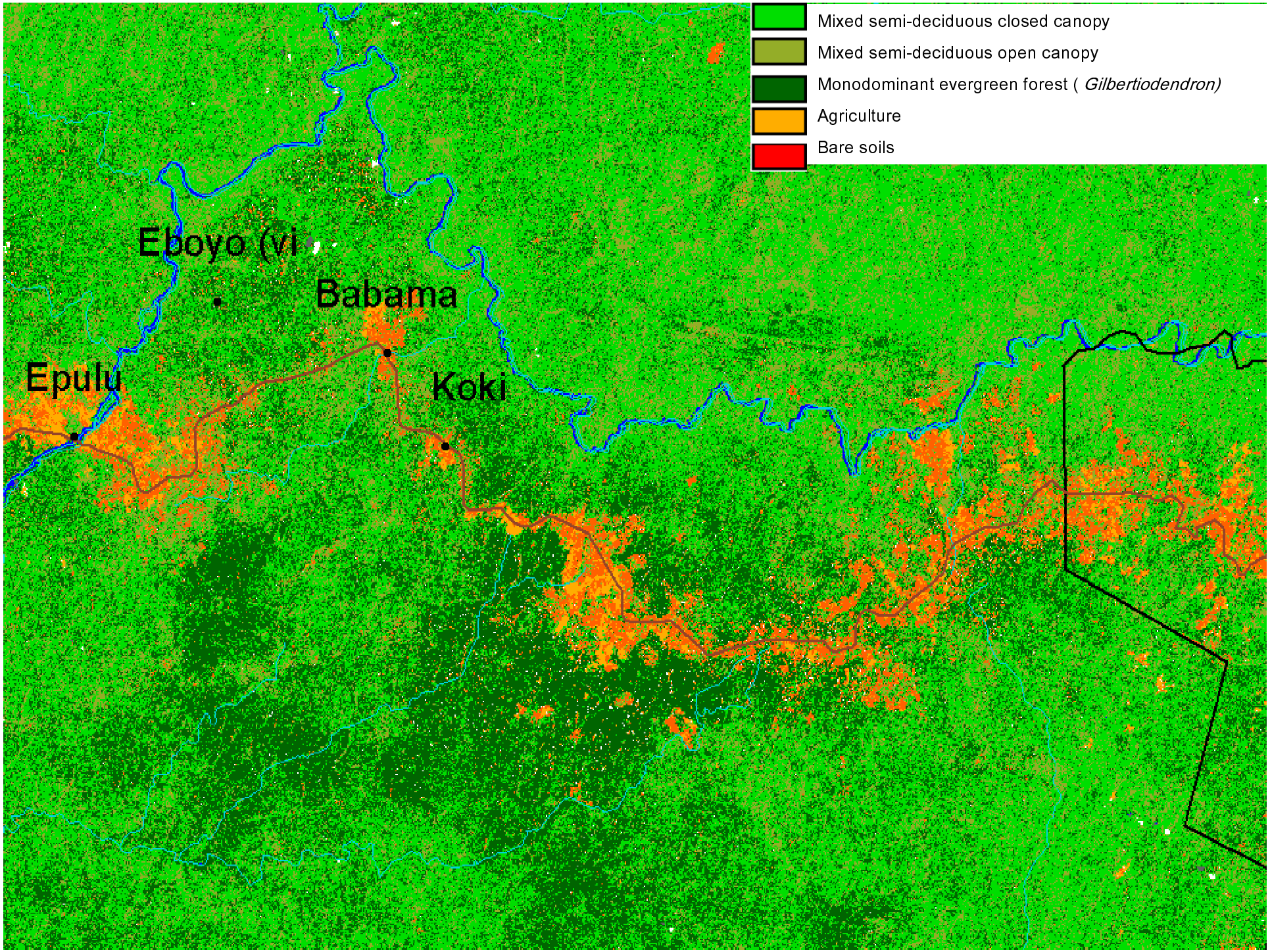
Landsat 182-59 – 9 Feb 2001 (5,4,3)

Habitat map

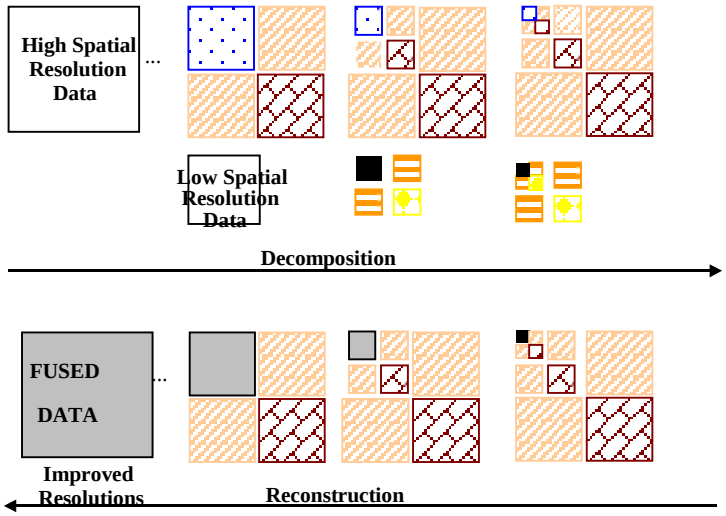


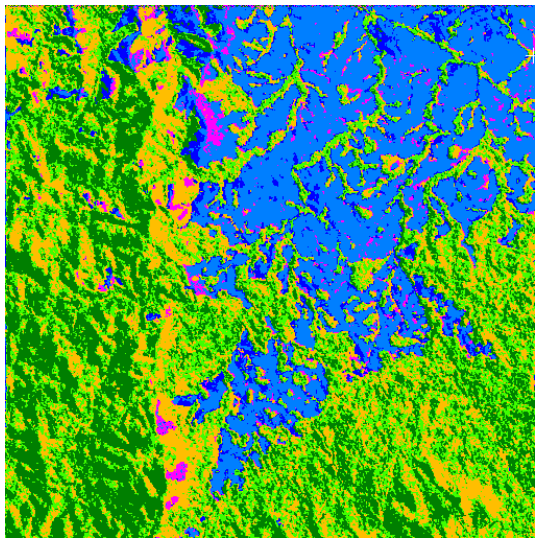
- Forest monodominant closed canopy (*Gilbertiodendron*)
- Forest mixed closed canopy
- Forest mixed open canopy (*Marantace*)
- Forest mixed open canopy riparian
- Agriculture


OKAPI
Reserve
DRC
Forest mono. *Gilbertiodendron*
Forest mixed closed canopy
Forest mixed open canopy
Agriculture
Villages
Limits reserve
Rivers
Habitat map Landsat 174-59/1998

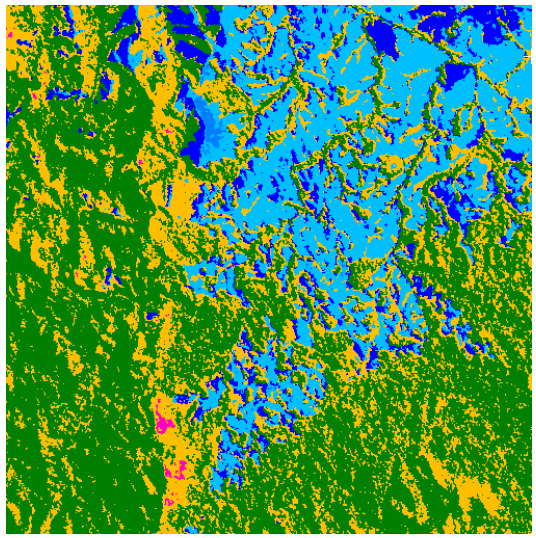

Mixed semi-deciduous closed canopy
Mixed semi-deciduous open canopy
Monodominant evergreen forest (*Gilbertiodendron)*
Agriculture
Bare soils
Eboyo (vi
Babama
Epulu
Koki

Wavelet base fusion SAR/TM





Classification results of fused image (More detailed discrimination of veg types)



Classification results of Landsat

Enhancement of Tropical Land Cover Mapping with Wavelet-Based Fusion and Unsupervised Clustering of SAR and Landsat Image Data
International Society for Optical Engineering (SPIE), Toulouse, 17-21 September 2001, Toulouse, France
J. Le Moigne, N. Laporte and N.S. Netanyahu

Resolution Merge

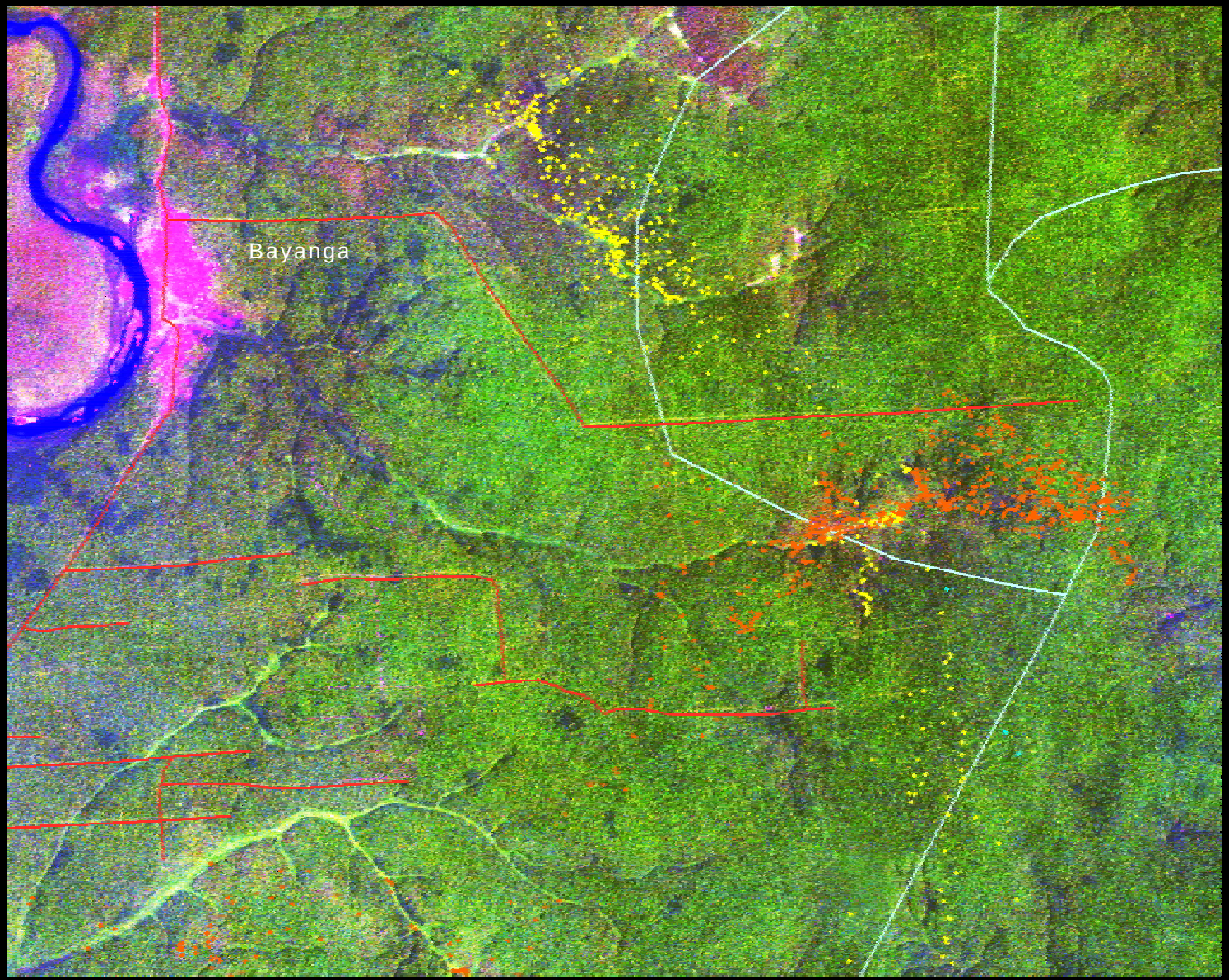
HIS transform

PC transform

Multiplicative

Brovey transform

Biodiversity Monitoring / Modeling



Logging Roads

Park Limits

Elephant 1

Elephant 2

Elephant movement data sets WCS

Summary: Habitat Mapping & Monitoring

- TM images are providing habitat maps for biodiversity & wildlife population monitoring
- Identify incursions - illegal farming, mining, or logging activities in and around Parks
- Assist in monitoring Park limits with local assistance

What are the drivers of Deforestation?

Proximate factors

Agricultural expansion

Wood extraction

Infrastructure

Underlying factors

Macro economic forces

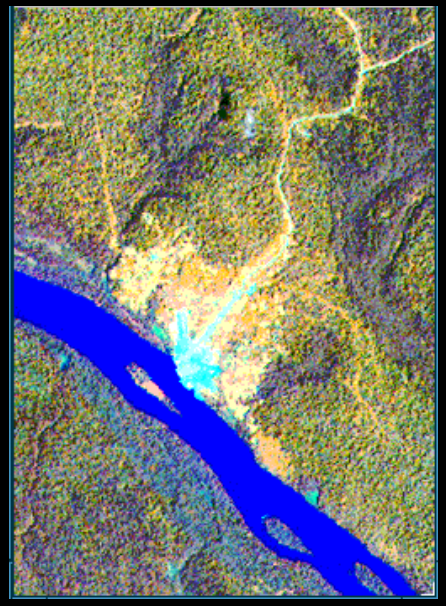
Population dynamics

Land Use Land Cover Change around Logging Towns

Pokola (1990-2001)

TM 1990/12/28

Bands: 4,5,3 (RGB)

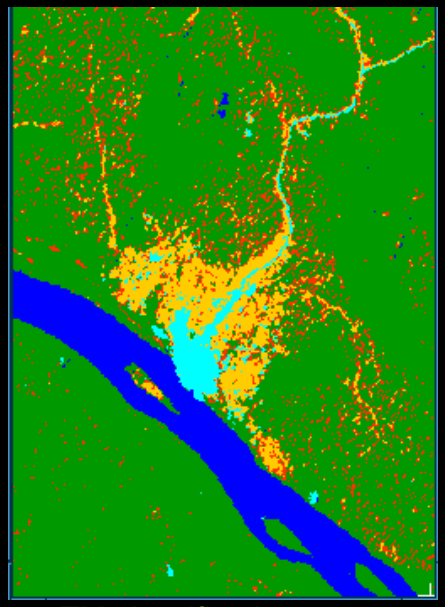


7 km by 10 km

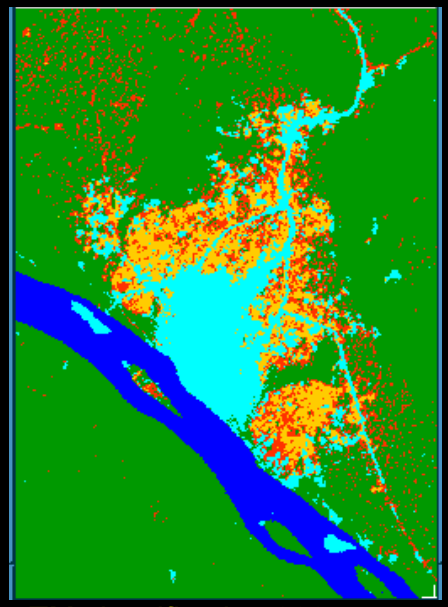
Pokola increased in area 38% while agricultural land increased only 5%

The total forest area decreased 12%

Annual deforestation rate 1.1%



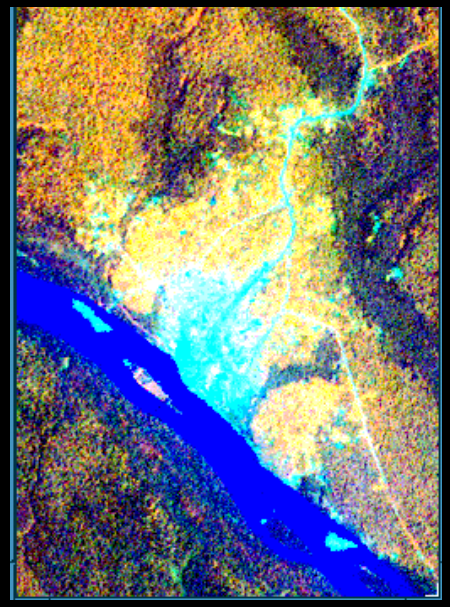
TM classification 1990



TM classification 2001

TM 2001/02/09

Bands: 4,5,3 (RGB)



7 km by 10 km

Green = Forest

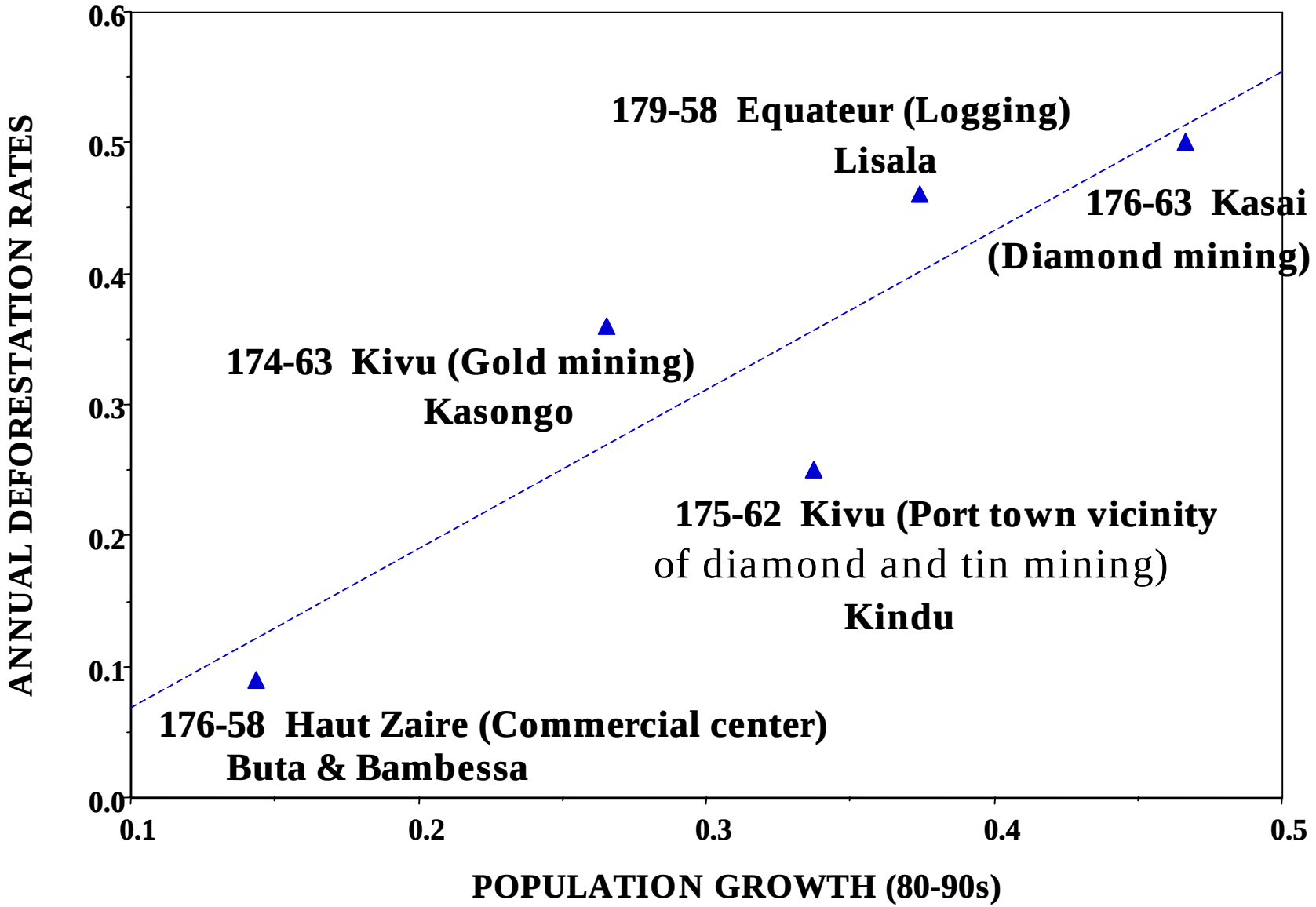
Red = Degraded Forest

Orange = Agriculture

Cyan = Bare Soil

Blue = Water

Population Growth and Deforestation

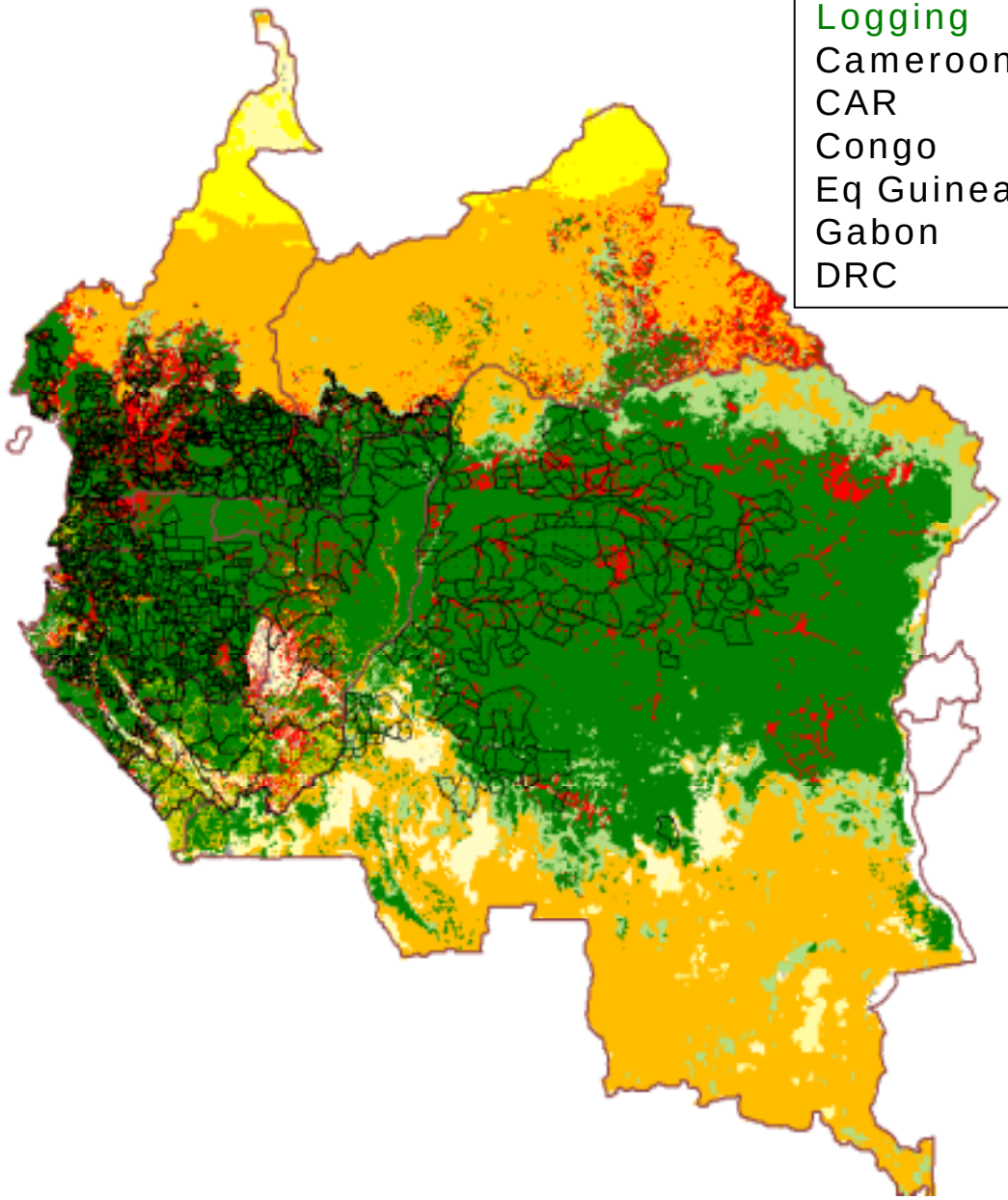


Human population growth ~3% per year

Summary: Deforestation rates

- Annual rates of deforestation in the Congo Basin are variable
  - 0.02% to 1% (DRC) 1984-1998
  - 1% Pokola (Congo) 1990-2001
  - 0.5 - 0.8% (Gabon)Franceville 1953-94 & Oyem
  - 0.6 - 0.7% (CAR) Bayanga 1979-90
- Need to better understand how different factors interact (Migration, logging, urbanisation, macroeconomics, etc.)
  - Cameroon deforestation rates increased during the economic crisis
  - DRC rates decreased during the war
  - Population alone is not a good predictor of deforestation rates

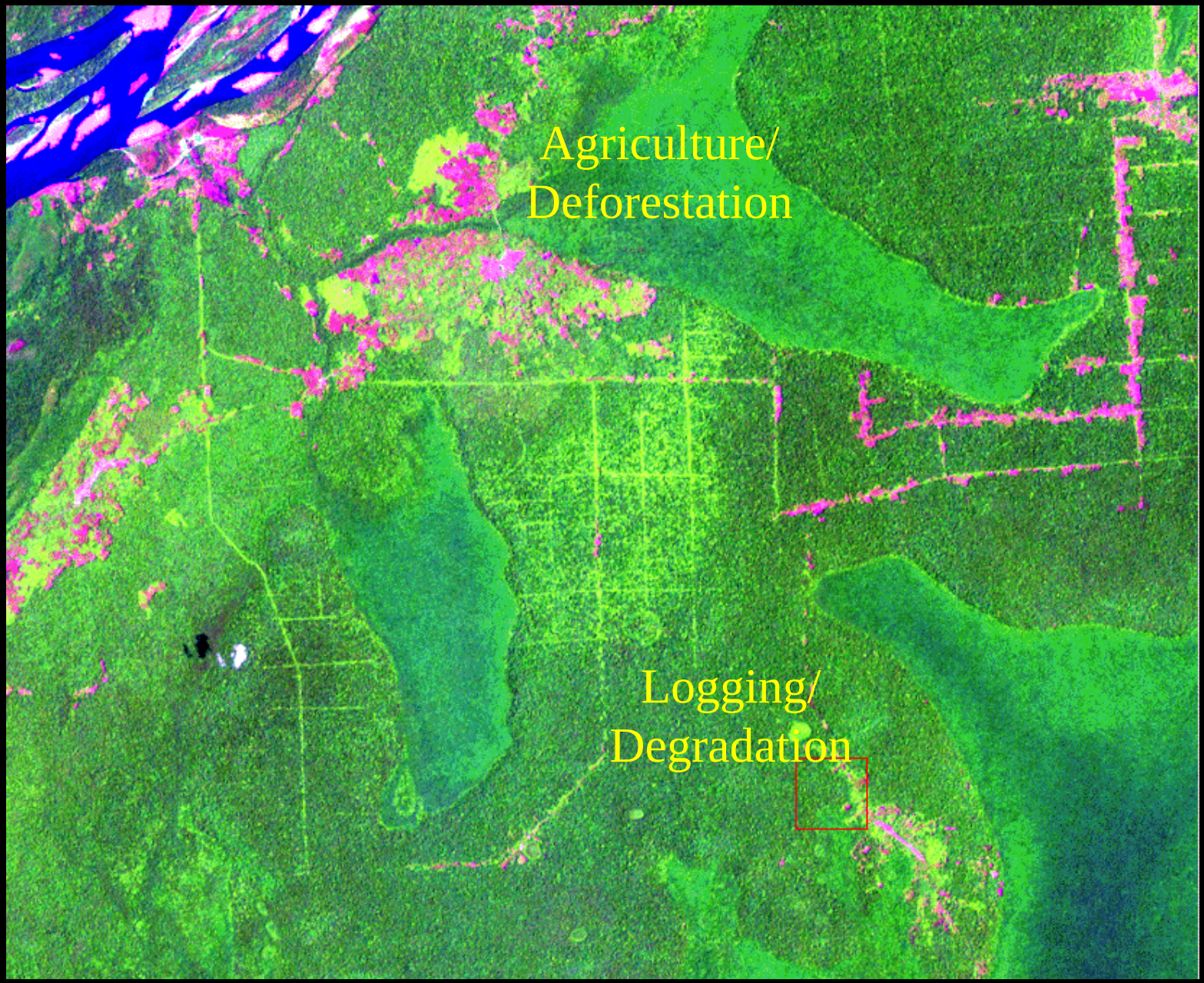

Mapping Forest DEGRADATION
Logging Intensity Mapping
using TM imagery

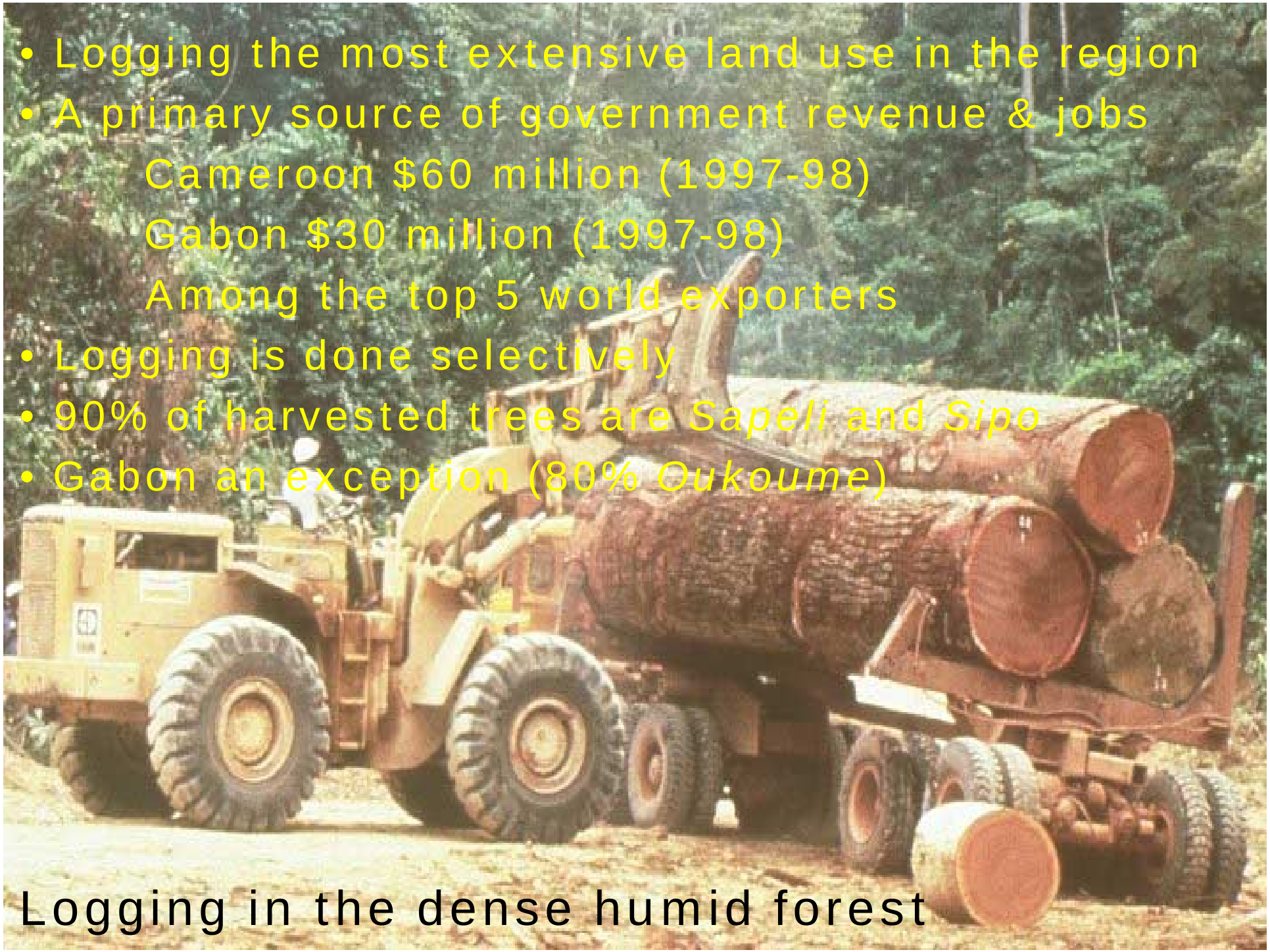


Logging	%Country	%DHF	%DF
Cameroon	31	62	47
CAR	6	43	9
Congo	61	59	60
Eq Guinea	61	64	59
Gabon	48	55	24
DRC	18	31	39

Over half of the region is under Logging concessions

From Degradation to Deforestation..



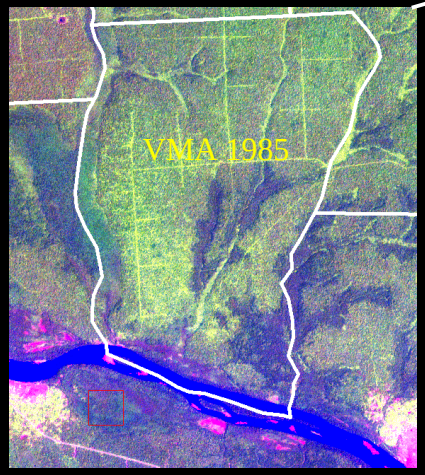


Logging in the dense humid forest

Mapping Forest Degradation: Northern Congo Site

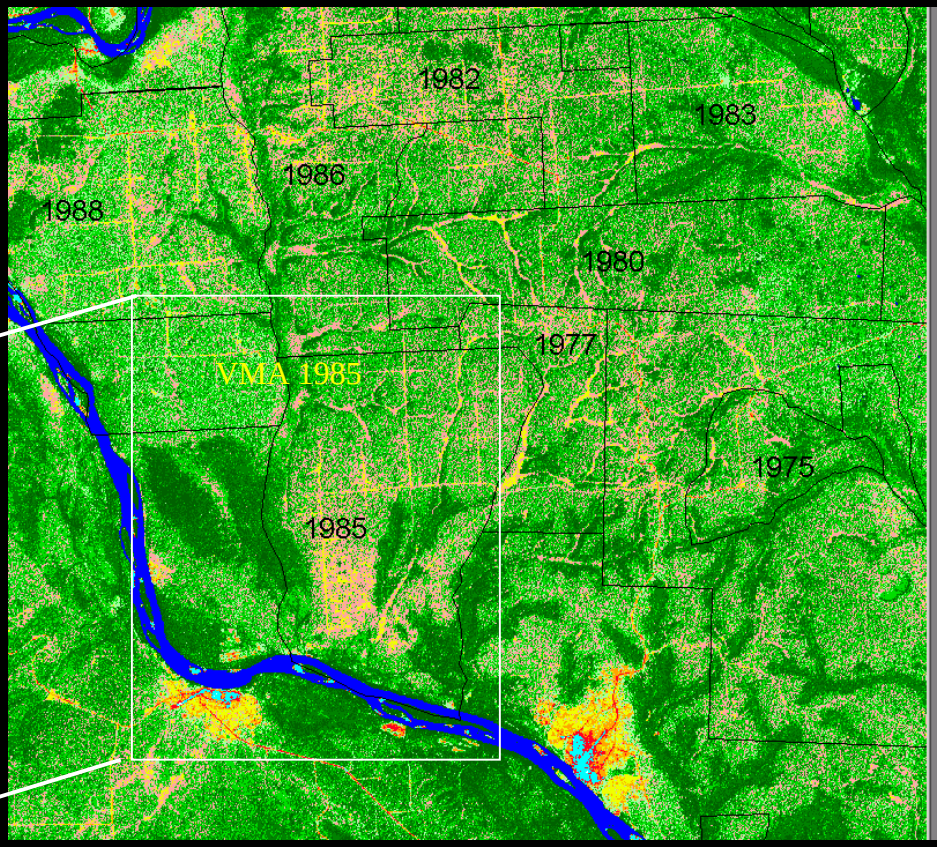
1year old *Musanga* regrowth

- Landsat ETM allows us to estimate the extent of forest impacted by logging, as well as logging intensity.
- More than 1,000 km^2 of forest is dominated by regrowth in the CIB company concessions.
- Early stages of regeneration (0-12 year) are dominated by pioneer species (e.g. *Musanga cecropioides)*



Red= Band5, Green=Band4, Blue=Band3
ETM (9 Feb 2000)

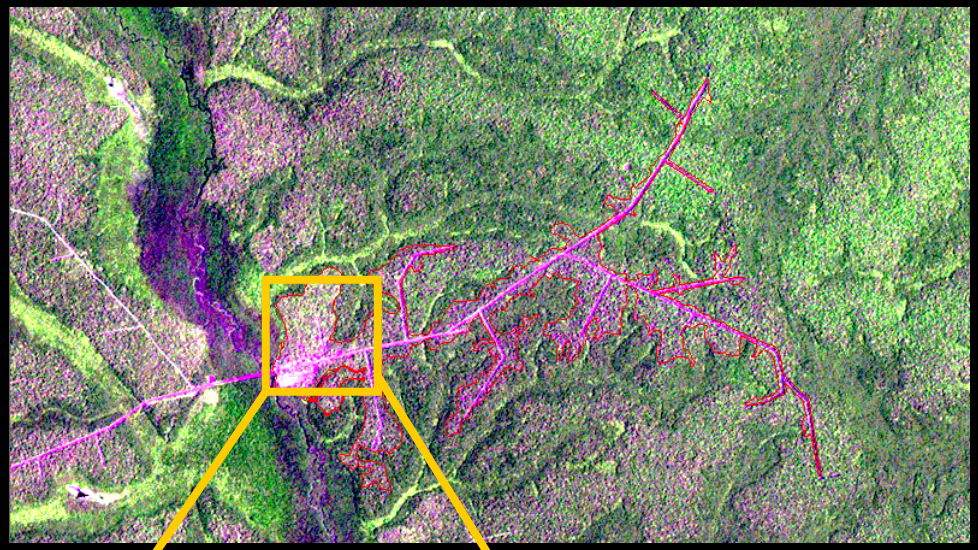
Landsat ETM classification 9 Feb 2001 40 by 40 km



Dark green=*Gilbertiodendron* forest. Light green= Mixed forest.
Pink=Logged forest, Cyan= Bare soils. Dark blue= rivers.
Red and Yellow = Agriculture.

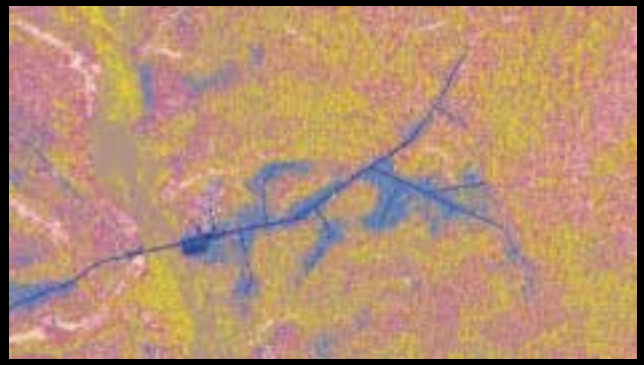
Logging Intensity Mapping using TM imagery

Landsat TM 12 Feb 1999



Gilbertiodendron forest (unlogged)

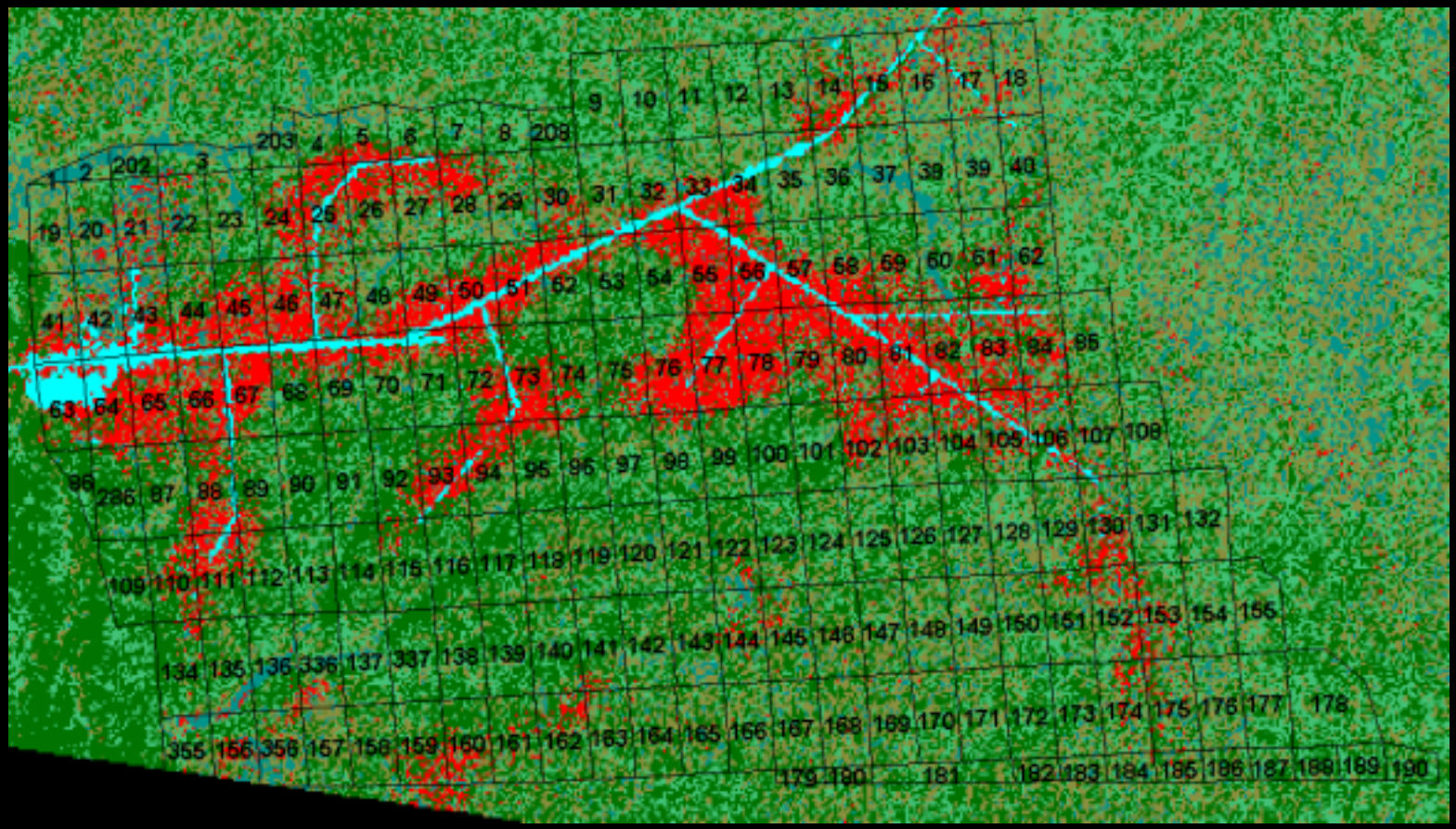
Supervised classification using textural information

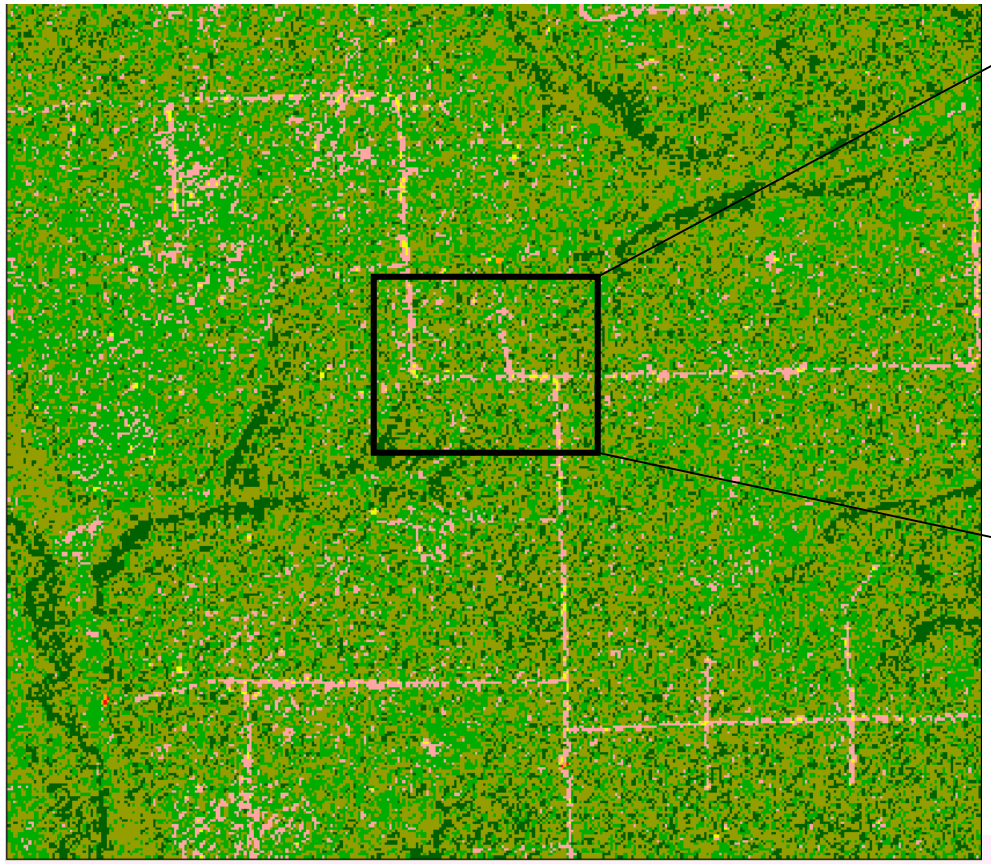


Digital Video NDOKI II- Logged Forest

Blue= Area logged (large gaps in the canopy)
Yellow=*Gilbertiodendron* and swamp forests
Pink=Mixed forest (not logged)

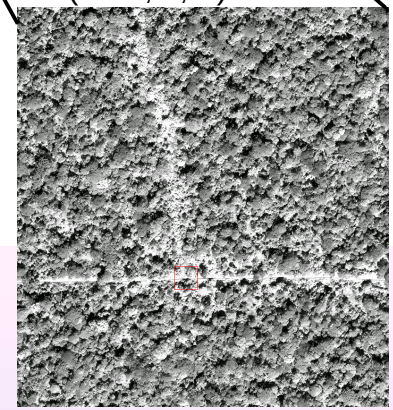
Logging Intensity Assessment





Landsat ETM 9 Feb 2001

IKONOS 23 Oct 2000 (NIR,R,G)



IKONOS 23 OCT 2000 (P)

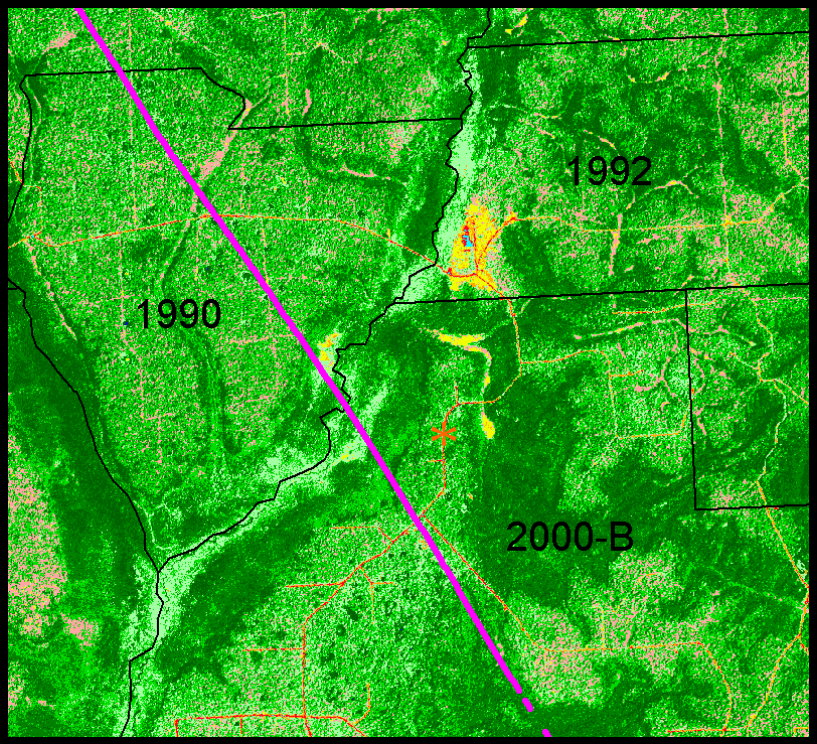
WRI-GFW collaboration – Illegal Logging

Summary: Logging / Forest Degradation

- Logging is not the main cause of deforestation but it…
  - causes forest degradation (biomass and diversity loss)
  - impacts wildlife populations (increased hunting)
- Reduced impact logging should be promoted
- Local populations will benefit from well managed forests
- Certification of tropical woods and carbon credits is an incentive for better forest management by the logging sector
  - These are being promoted through active collaborations
  - CIB logging company in Northern Congo

FIELD VALIDATION

Landsat ETM Classification 9 Feb 2001

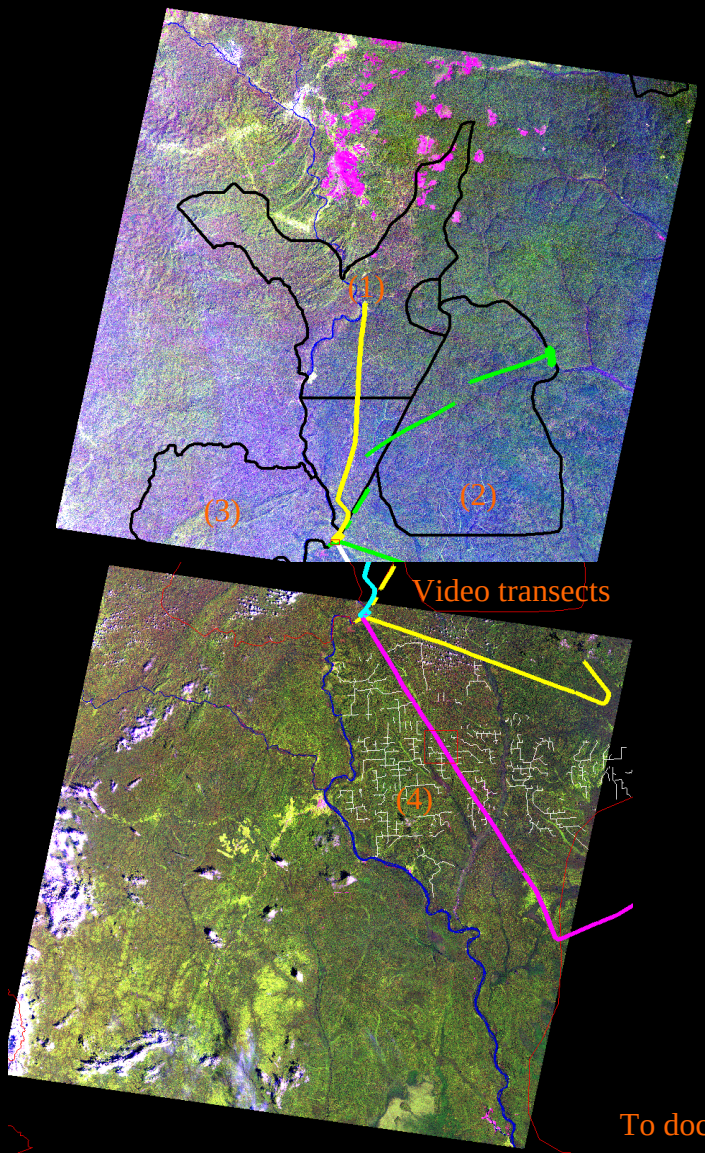


Digital video-transect 16 March 2001

* Field visit with CIB Forest Management Unit

Ndoki Airborne Digital Videography - March 2001

Trinational Park Area:
Nouabale-Ndoki (1), Dzanga Sangha (2),
Lac Lobeke (3) and CIB logging area (4)




Gilbertiodendron Forest


Raphia Swamp Forest


Marantace Forest


Open forest with old logging road

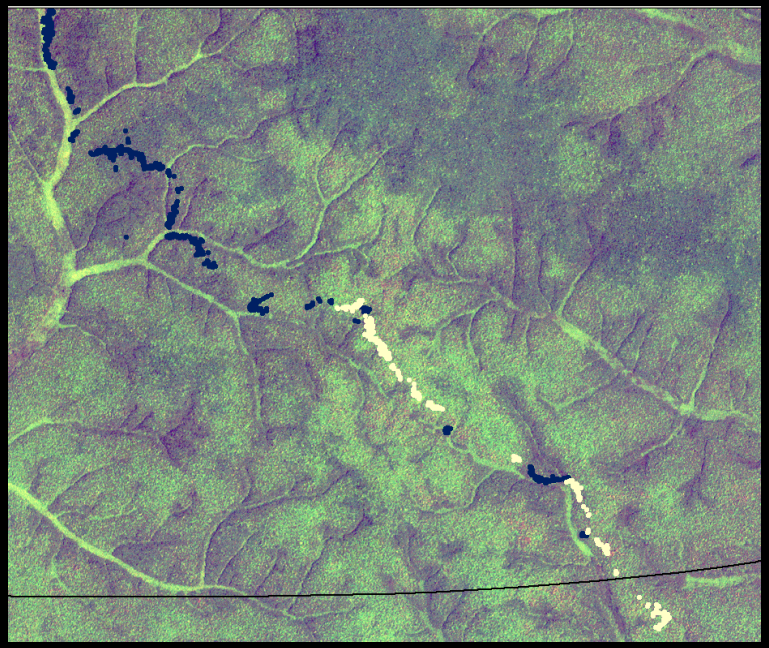

Mixed Closed forest


Mixed Forest with Yanga

To document and validate vegetation types, frames were extracted from recent digital videos

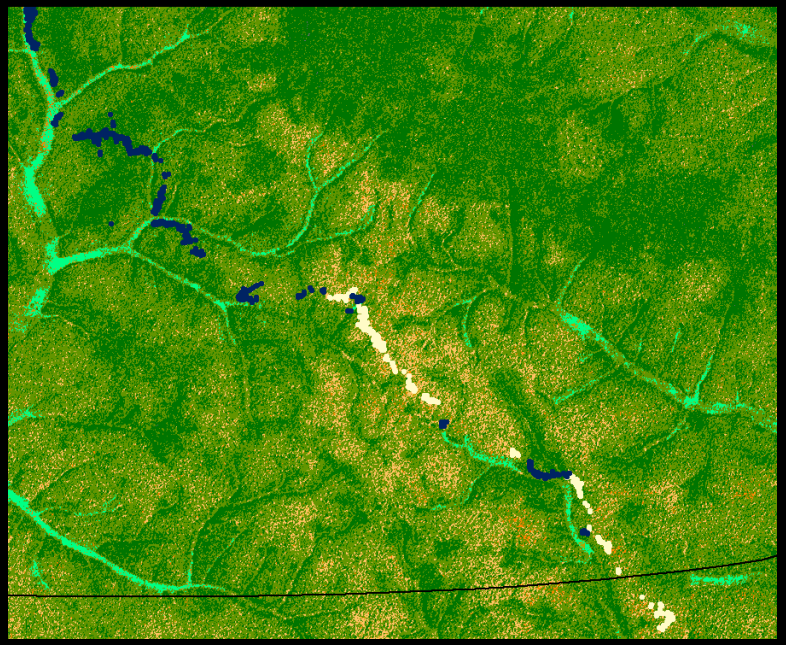
Habitat Map Validation using Biodiversity surveys

26 km by 21 km Landsat 7 Band 5,4,3 RGB



Landsat composite color image

Nouabale Ndoki Park

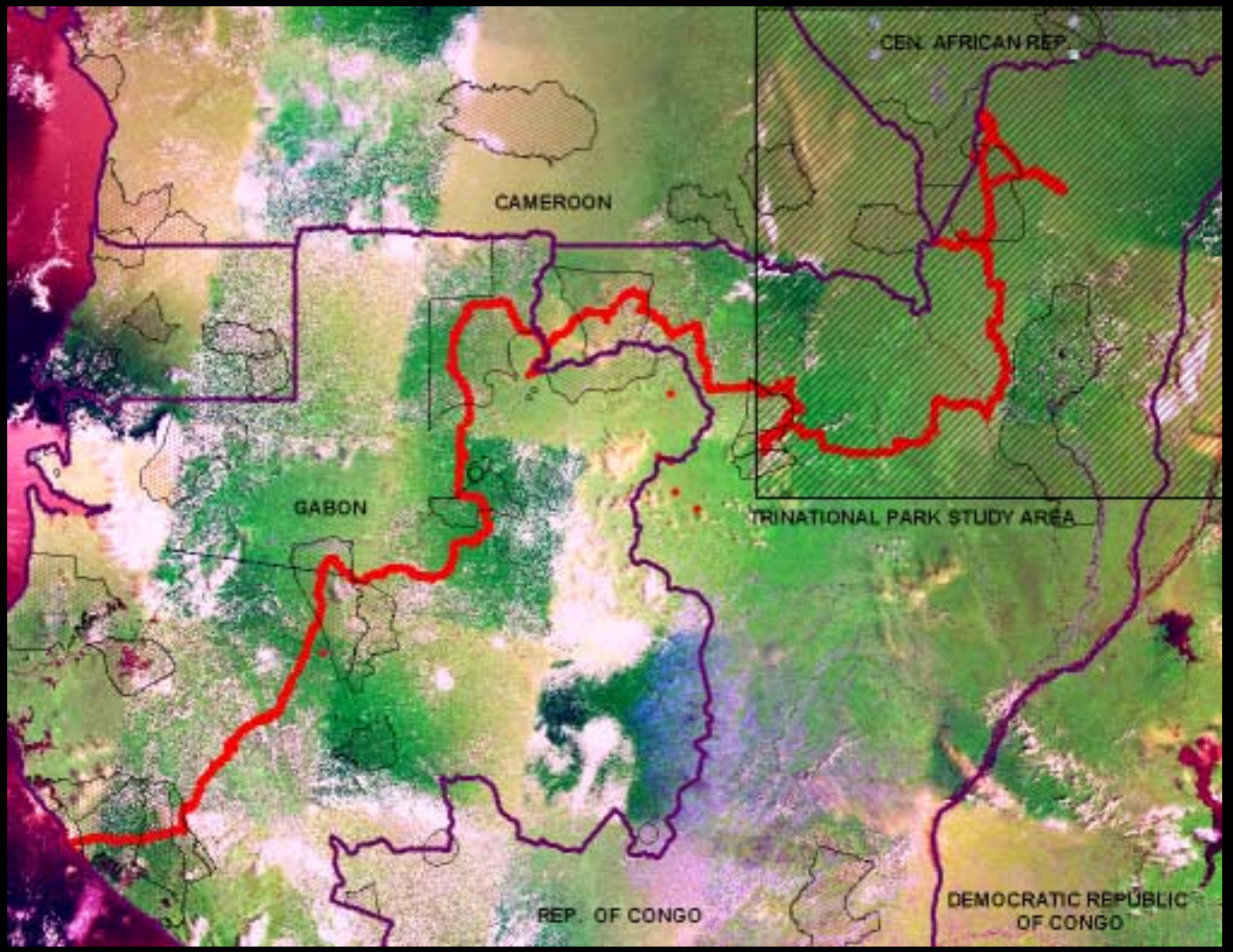


Habitat map derived from Landsat

- Forest (Fo)- Monodominant (Mo)- Close canopy (C)
- Forest (Fo)- Mixed (Mi)- Close canopy (C)
- Forest (Fo)- Mixed (Mi)- Open canopy (O)
- Forest (Fo)- Mixed (Mi)- Open canopy (O)-Riparian (Ri)
- *Gilbertiodendron* Forests (Fo-Mo-C) from survey
- *Triplochiton* Forests (Fo-Mi-O- deciduous) from survey
- Nouabale Ndoki Park Limit

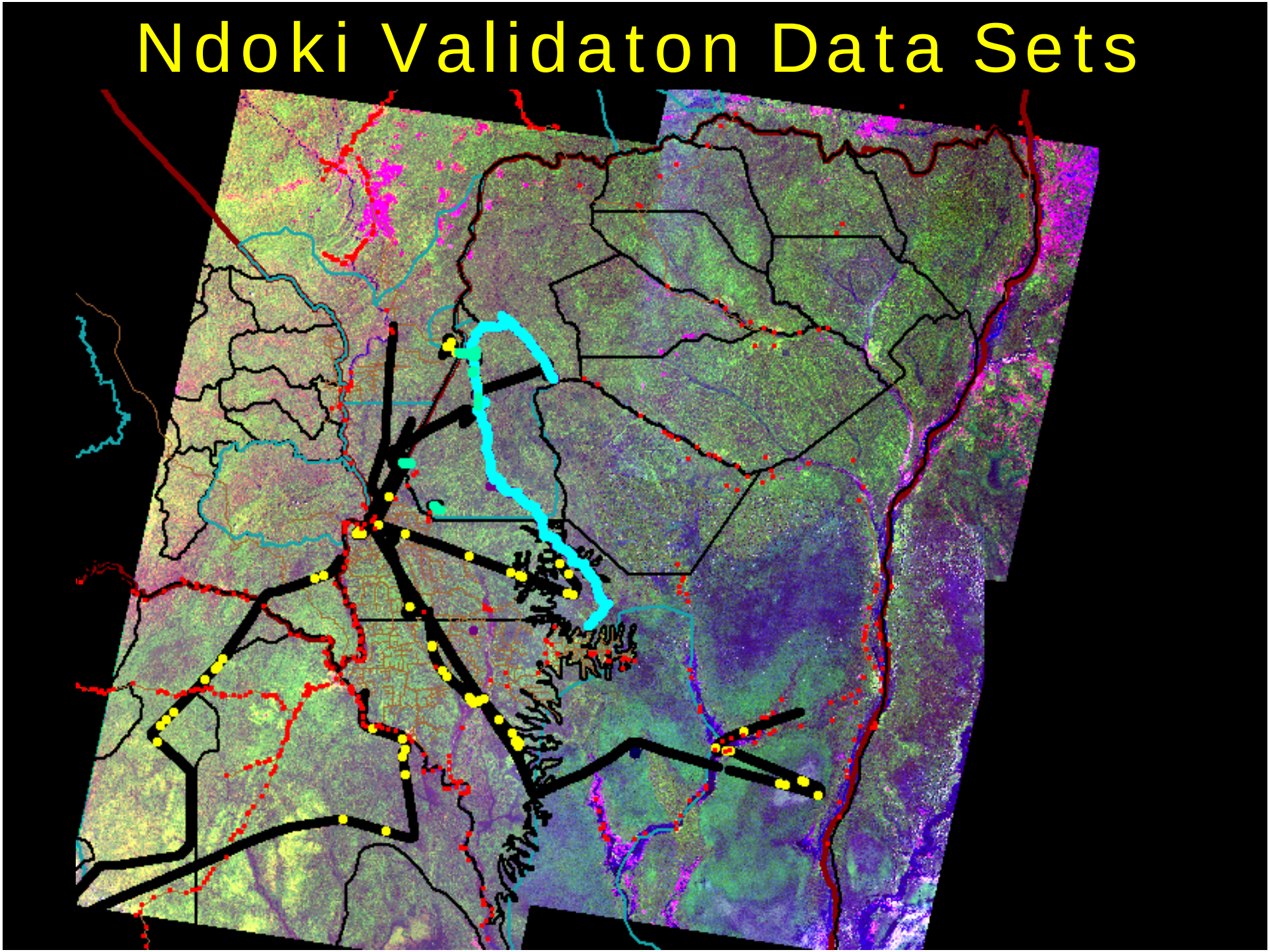
Land cover map - Laporte N, Devers D.(Dept Geography- UMD)
Field data for land cover validation- Steve Blake (WCS)

MegaTransect - a 1500 mile walk led by Mike Fay

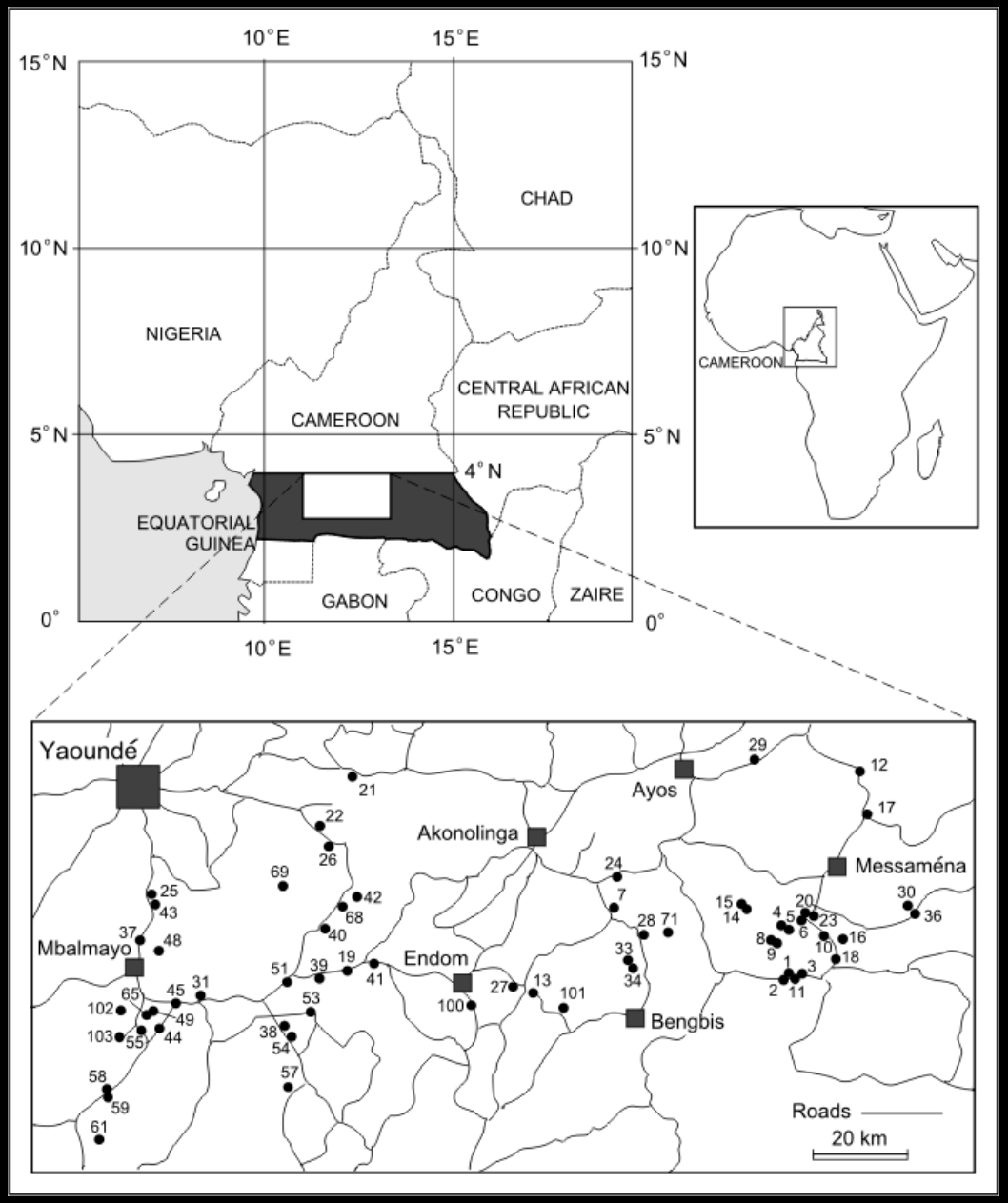


MegaTransect
Trinational Park Study Area
Country border
Protected area

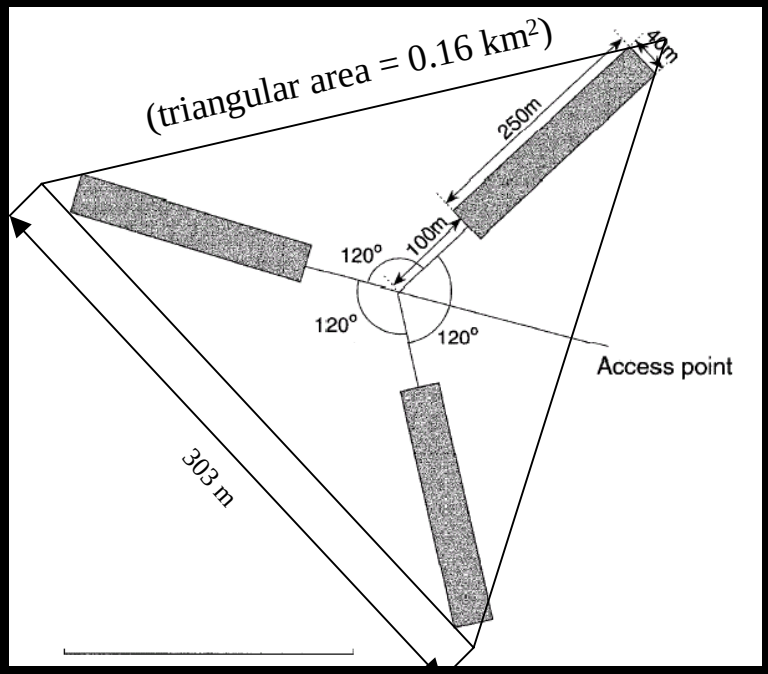
Ndoki Validaton Data Sets



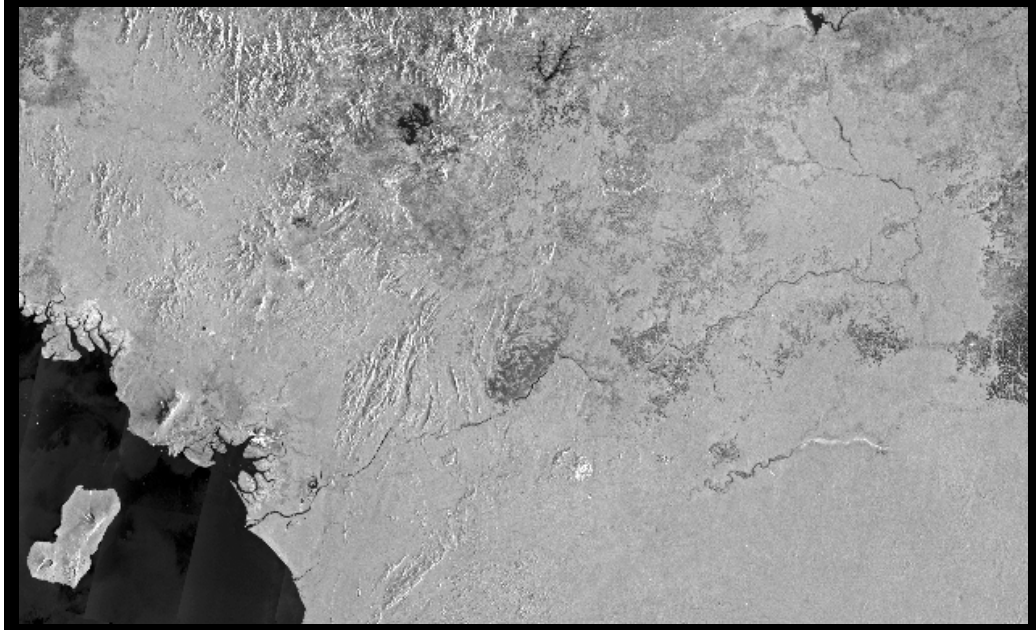
Biomass Estimation in Southern Cameroon

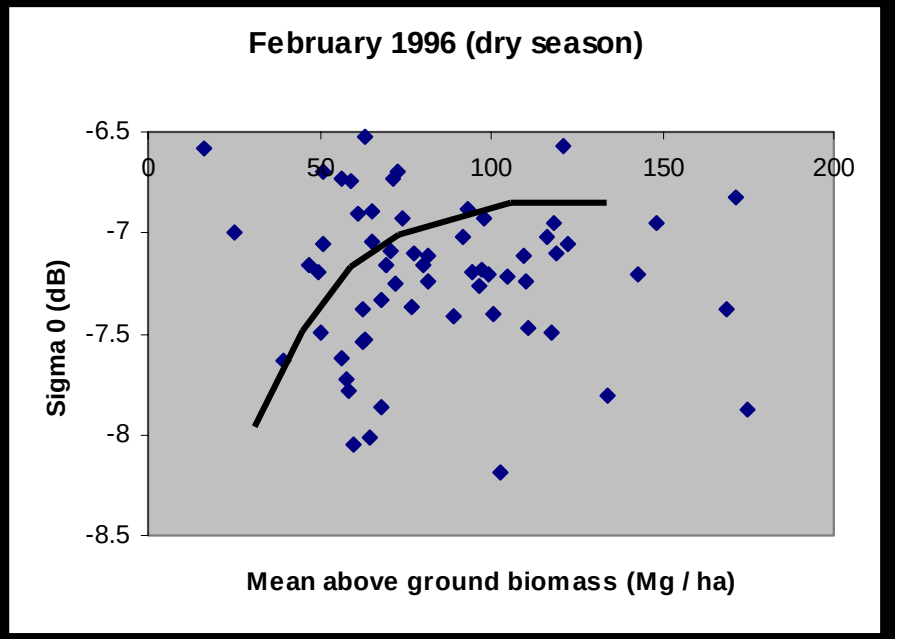


Mean Above-Ground Biomass
Estimated at 61 sites from measurements within three 1 ha sub-plots.



Mean Above-Ground Biomass -vs- JERS-1 Normalized Backscatter (Sigma 0) February 1996 (dry season)





Correlation poor (0.10) and insignificant ($p > 0.05$)

Next Steps - Biomass Estimation..

- **RADAR SYSTEMS**
  - **JERS (not operational)**
  - **Radarsat/ ERS commercial system (expensive for large areas)**
  - **SIR-C (need to be tested)**

- **LASER SYSTEM**
  - **SLA (Shuttle laser altimeter)**
  - **GLASS (April 2002)**
  - **VCL (2004)**
  - **LVIS (VCL team)**
  - **Single return portable LIDAR (Nelson /GSFC)**

- **LANDSAT /AVHRR**
  - **Good results with AVHRR in Cameroon**
  - **Fusion method of Radar and Landsat data**

- **MAJOR LIMITATIONS**
  - **Operational Radar system expensive**
  - **Field data sets for validation are expensive and time consuming (Ndoki collaboration with CIB)**

Future plans

- **Validation of Land cover / Habitat maps in high biodiversity areas *(UMD/WCS)***
- **Monitor logging & impacts on forest (biomass, forest diversity, etc.) *(UMD/CIB)***
- **Apply fusion methods to land cover and biomass mapping *(UMD/NASA-GSFC)***
- **Test the use of IKONOS for biodiversity and forestry applications *(UMD/WCS/ Yale University/ CIRAD-foret)***
- ***Develop GOFC workshop 2002***

http://luci.umd.edu/lcluc

Interdisciplinary Research - Collaborators

Remote Sensing :

- Guoquing Sun (UMD/NASA-GSFC)- Radar biomass assessment
- Ross Nelson (NASA/GSFC) - Lidar biomass estimation
- Jacqueline Le Moigne (NASA-GSFC) / Miro Honzack (UMD)- Data fusion methods
- Philippe Mayaux (TREES/JRC, Italy) - Regional radar land cover mapping
- Bwangoy Bakanza (Univ. of Kinshasa DRC)- Habitat mapping in RDC
- Marcellin Nziengui & Michelle Pain Orcet (CIRAD Foret-France)-IKONOS/forestry

Biodiversity / Forestry field work

- Lee White (WCS) - Lopé Reserve (Gabon)
- Mike Fay (WCS) - Megatransect (covers 3 countries)
- John Hart and René Beyers (WCS) – Okapi Reserve (DRC)
- Steve Blake & Fiona Maisels (WCS) –Nouabale- Ndoki Park (Rep of Congo)
- Inogwabini Bila-Isia & Gay Reinartz (Zool. Soc. Milwaukee) - Salonga Park (DRC)
- Frederic Glannaz (CIB) , Paul & Sarah Elkan (WCS) - Buffer zone Ndoki, Logging
- Jeff Hall (Yale, School of Forestry and Environmental Studies)

Policies

- Jean Gael Collomb & Ralph Ridder (WRI) - Global Forest Watch
- CARPE National Focal Points
- National Forest Ministeries of Environment