Introduction to Remote Sensing in relation to Forest Ecology

1. What is Remote Sensing
2. Tools & Sensors used in Forest Ecology
3. Examples of Applications

Cyrille Cornu

1

1 What is remote sensing?

Definition

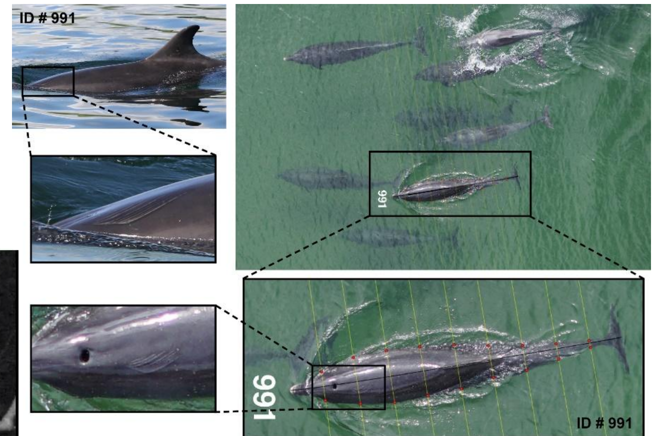
Remote sensing: observing an object/scene/phenomenon using instrument-based techniques.

2

1 What is remote sensing?

Definition

Widely used in numerous fields of biological and environmental sciences.
→ **not only satellite or aerial imagery!**



Principles of Remote Sensing (Tempfli et al., 2009); Bowler et al., 2016; Cheney et al., 2022; Mann et al., 2022

3

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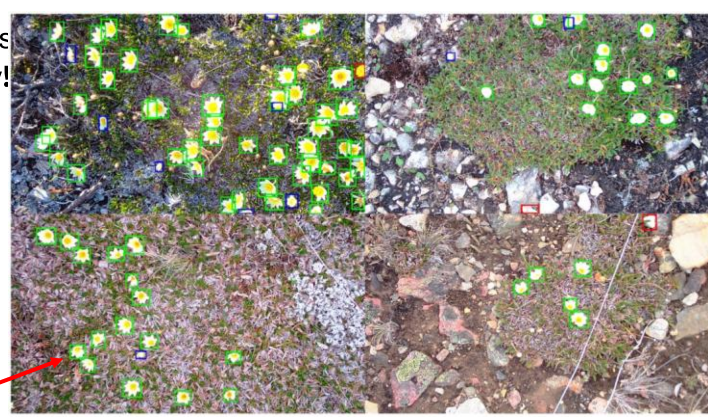


Automated detection using AI

Principles of Remote Sensing (Tempfli et al., 2009); Bowler et al., 2016; Cheney et al., 2022; Mann et al., 2022

4

1 What is remote sensing?

Past & current

Means and purposes of RS have changed since the first uses of RS.

無人航空載具

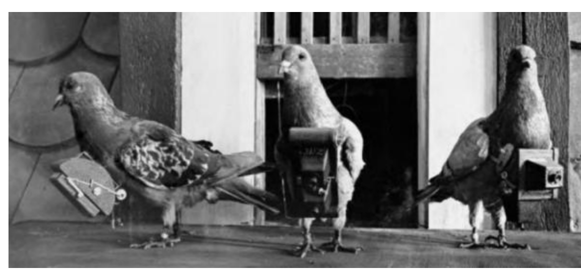
5

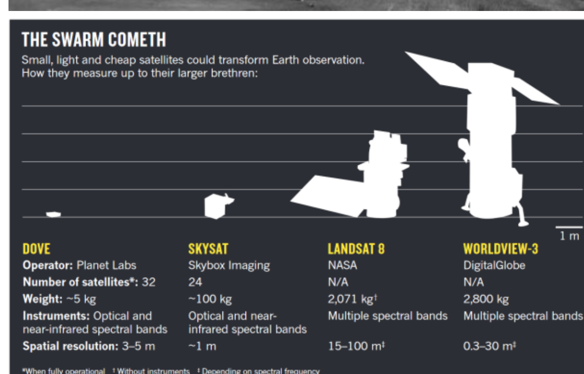
1 What is remote sensing?

Past & current

Improvements in at least 3 aspects:

- Sensor
- The device carrying the sensor (*platform*)
- Data recording capacity





Butler, 2014

6

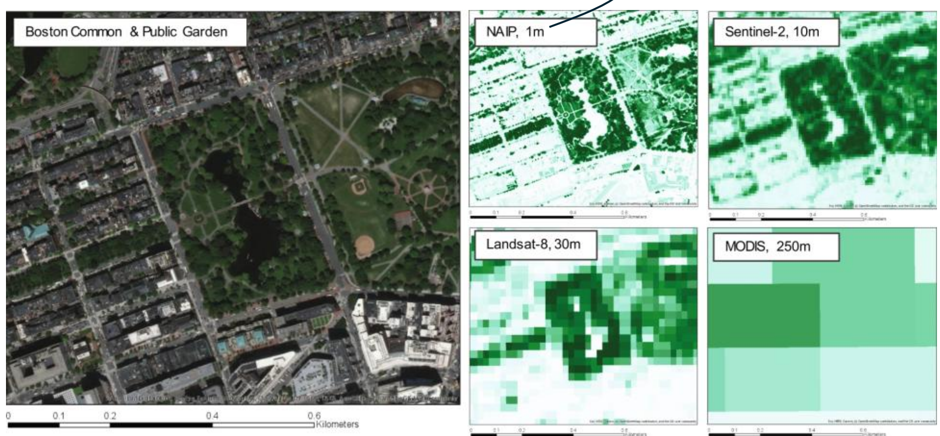
1 What is remote sensing?

Past & current

Improvements in at least 3 aspects:

- **Sensors**

Spatial resolution



Jimenez et al., 2022

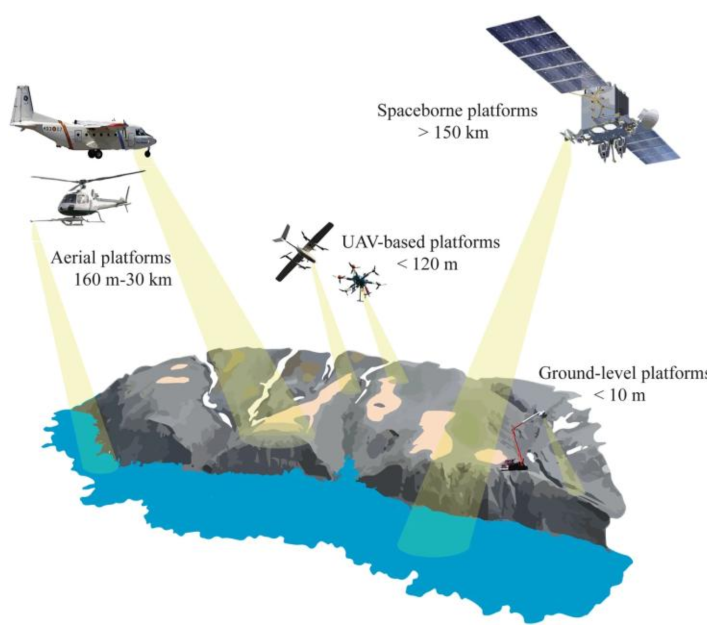
7

1 What is remote sensing?

Past & current

Improvements in at least 3 aspects:

- **Platforms**



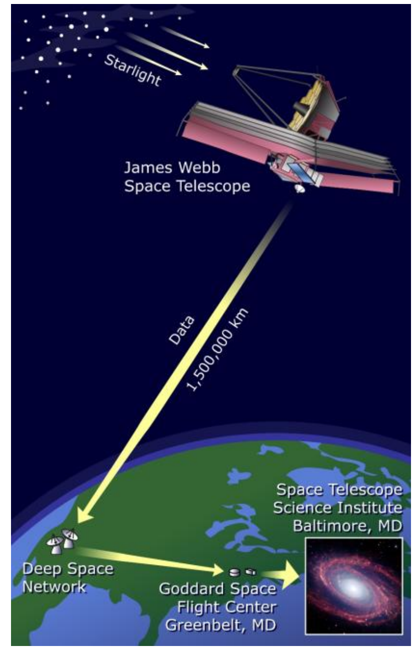
Bonnet Dunbar et al., 2022

8

1 What is remote sensing?

Past & current

Data transmission



9

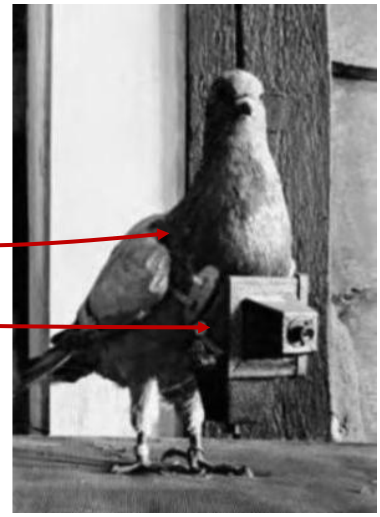
Remote Sensing tools in Forest Ecology

10

2 Tools & Sensors used in Forest Ecology

Tools of remote sensing: platforms

Data is sensed and recorded by a **sensor** which is carried by a **platform**



Akins *et al.*, 2020

11

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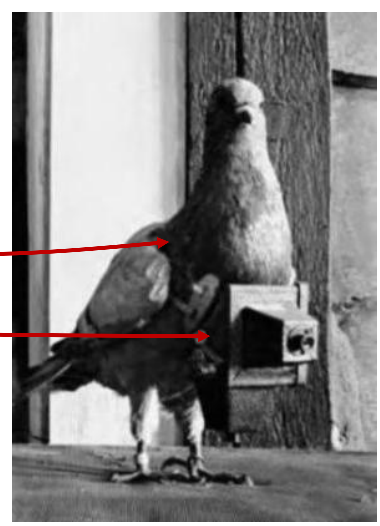

Akins *et al.*, 2020

12

2 Tools & Sensors used in Forest Ecology

Tools of remote sensing: platforms

Mobility?
camera traps,
geostationnary satellites,
drones, planes, handheld

Manned?
Satellite,
drone // planes,
handheld cameras

Akins *et al.*, 2020

13

2 Tools & Sensors used in Forest Ecology

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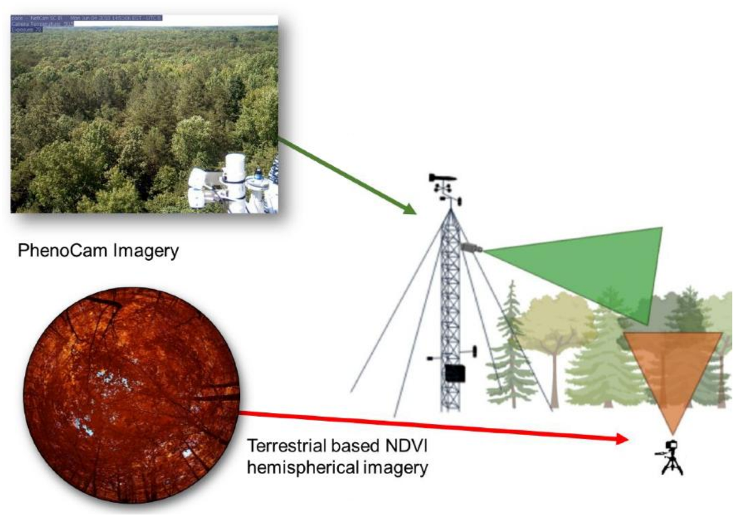

Akins *et al.*, 2020

14

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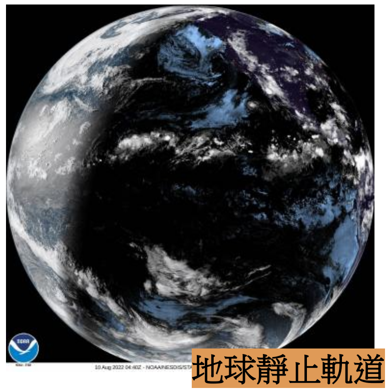

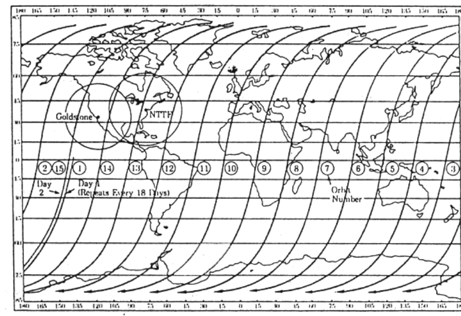

15

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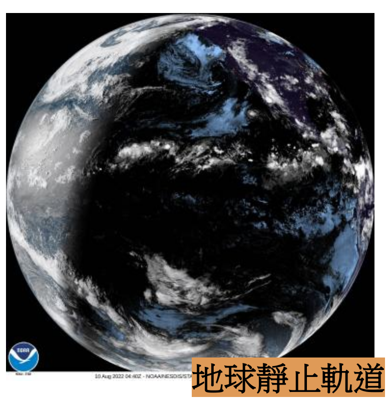
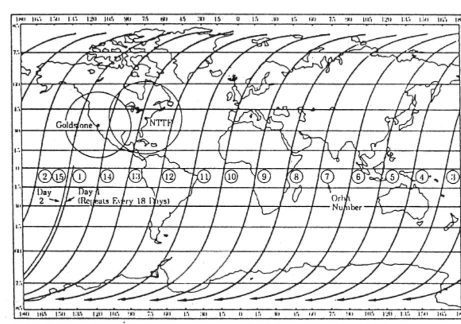




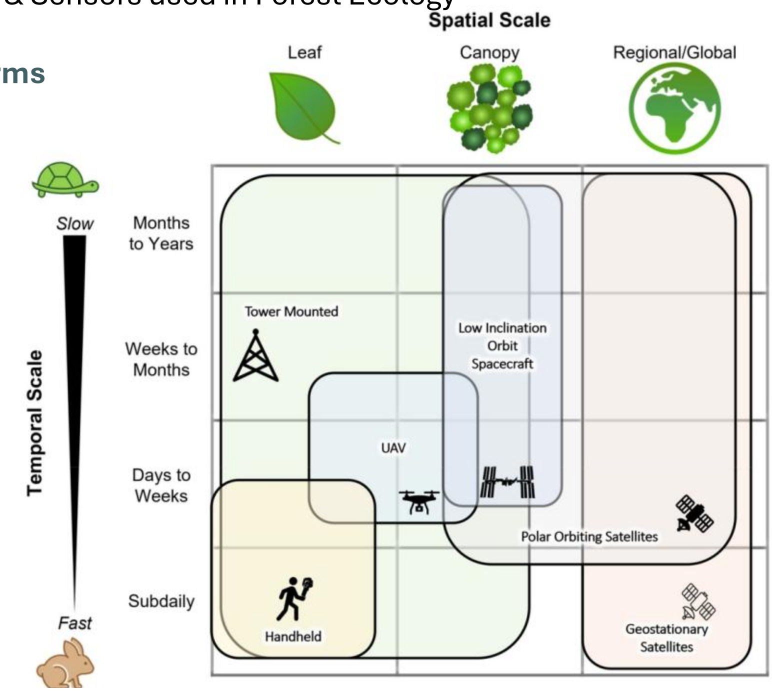
Repeated observations?
Elevation?

16

2 Tools & Sensors used in Forest Ecology

Tools of remote sensing: platforms

The selected platform will depend on the study's aims.



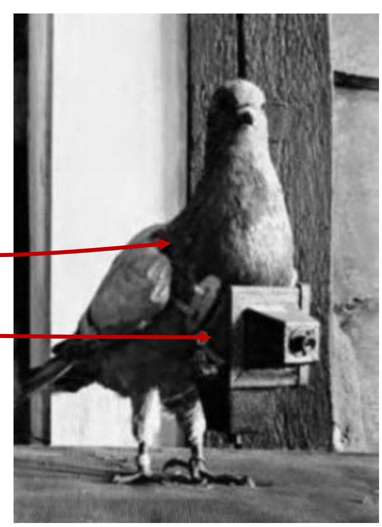
Farella et al., 2022

17

2 Tools & Sensors used in Forest Ecology

Tools of remote sensing: Sensors

Data is sensed and recorded by a **sensor** which is carried by a **platform**



Akins *et al.*, 2020

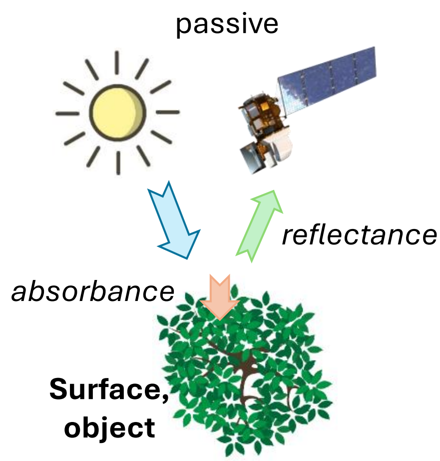
18

2 Tools & Sensors used in Forest Ecology

Tools of remote sensing: Sensors

A sensor will recorded whatever it is sensitive to: light, radiowave, etc

- **Passive**:
  → optical, spectral



19

2 Tools & Sensors used in Forest Ecology

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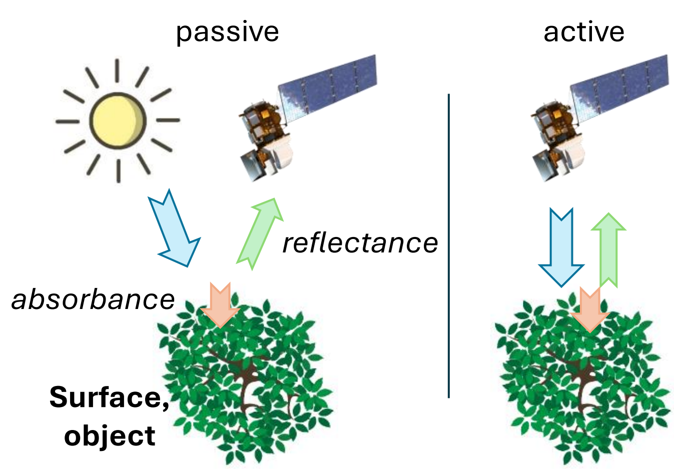

20

2 Tools & Sensors used in Forest Ecology

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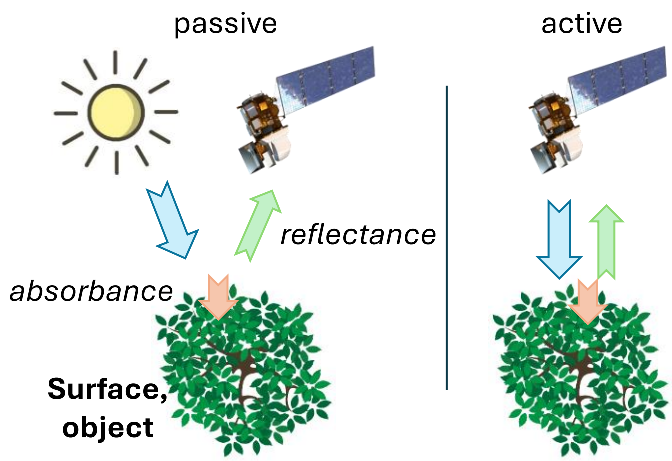


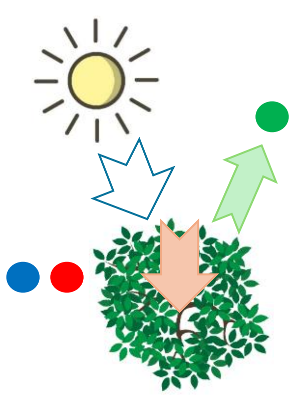
21

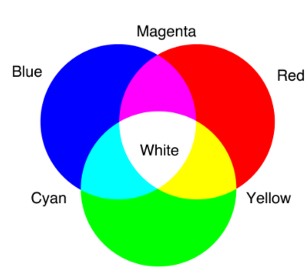
2 Tools & Sensors used in Forest Ecology

Spectral remote sensing

Based on the properties of light:

What is not **absorbed** by a surface, is **reflected**





22

2 Tools & Sensors used in Forest Ecology

Spectral remote sensing

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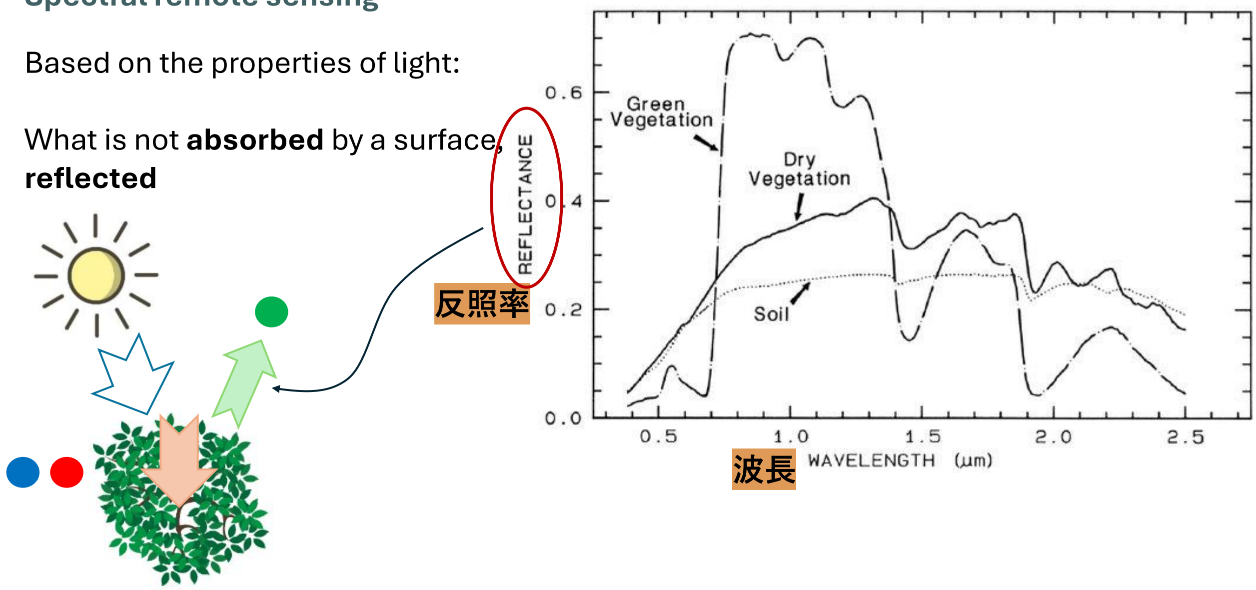

23

2 Tools & Sensors used in Forest Ecology

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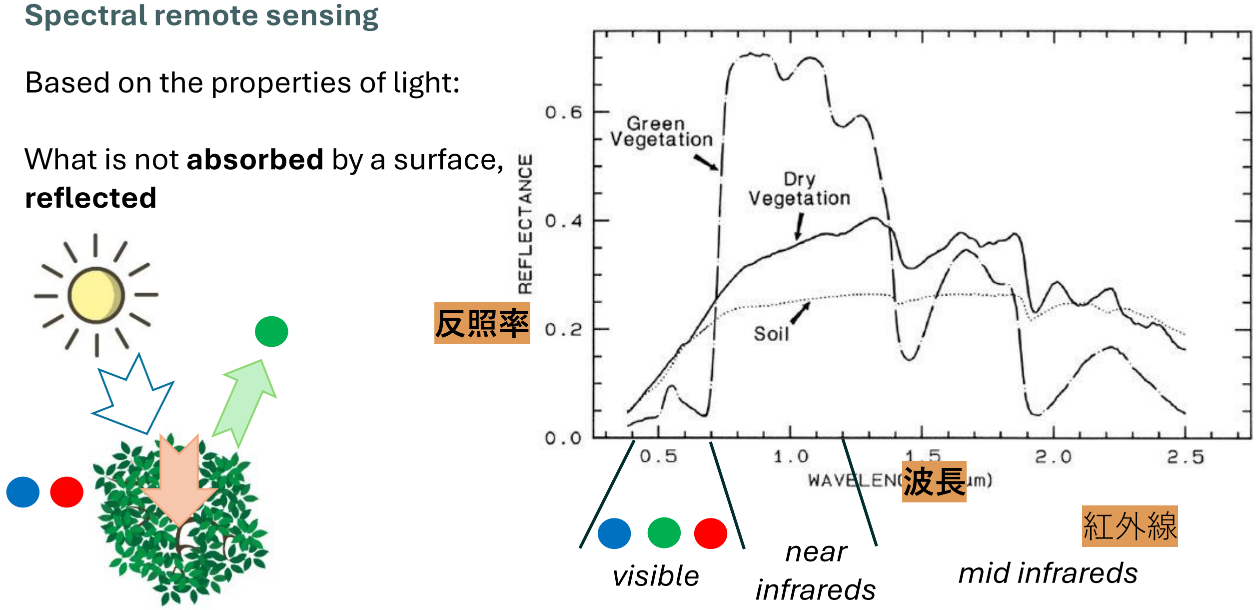

24

2 Tools & Sensors used in Forest Ecology

Spectral remote sensing

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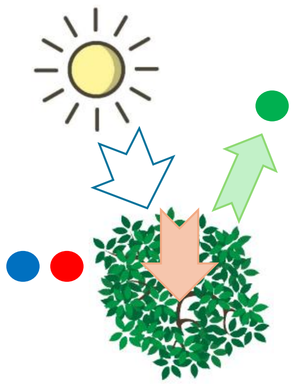
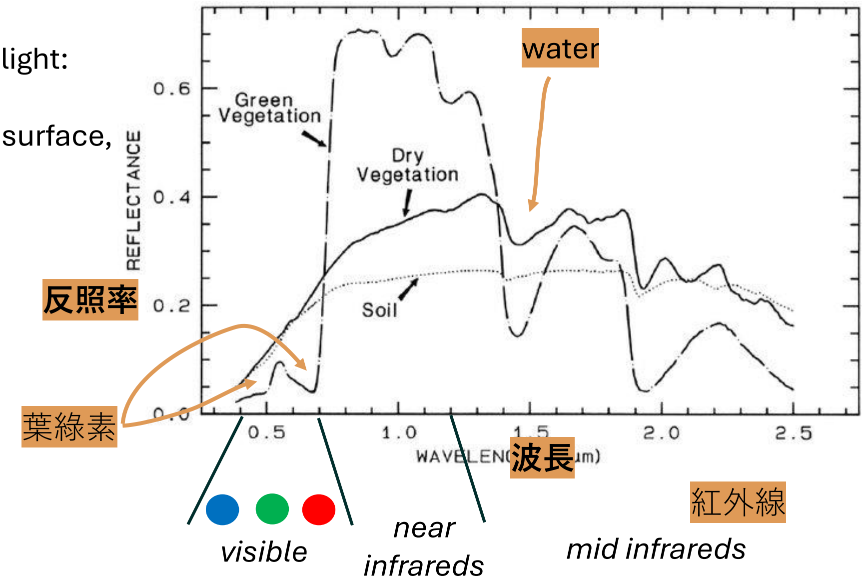




25

2 Tools & Sensors used in Forest Ecology

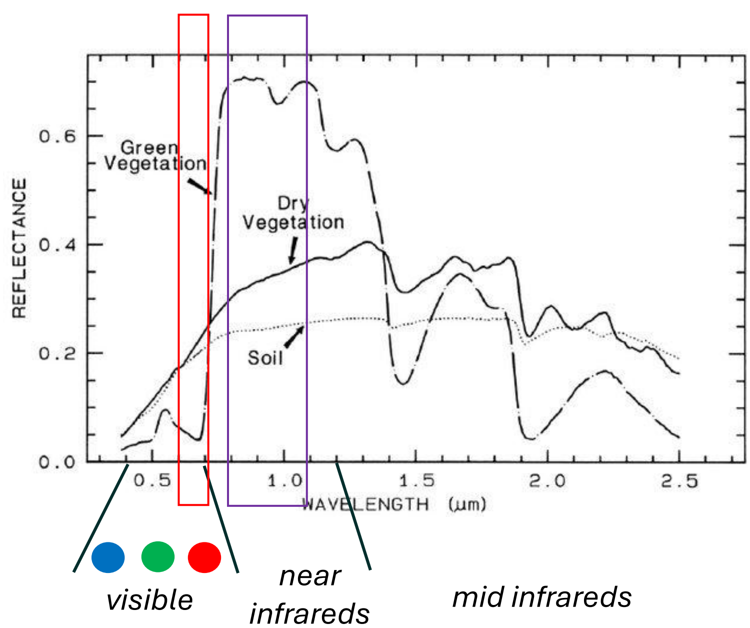
Spectral remote sensing

Using reflectance change at different wavelengths to monitor vegetation health:

near infrared

$$NDVI = \frac{NIR - R}{NIR + R}$$

red

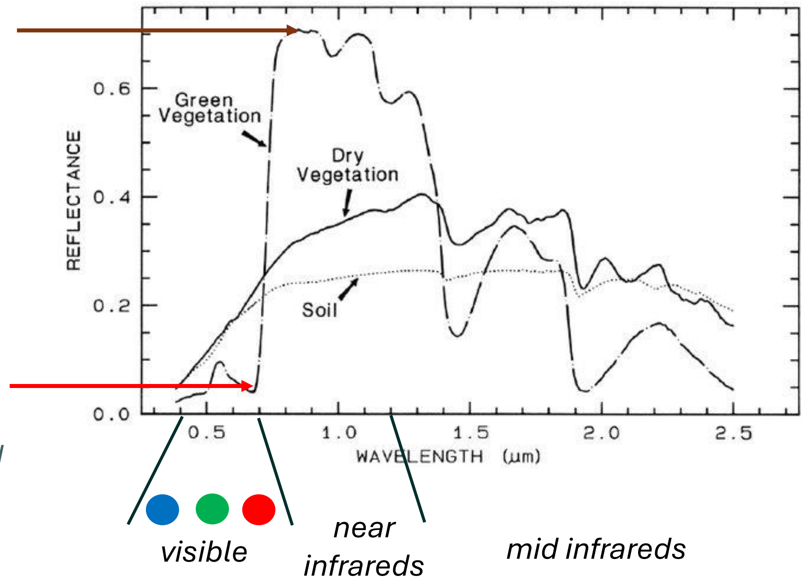


26

2 Tools & Sensors used in Forest Ecology

Spectral remote sensing

Healthy vegetation:
Red = 0.05, NIR = 0.65
→ NDVI = 0.85



near infrared

$$NDVI = \frac{NIR - R}{NIR + R}$$

red

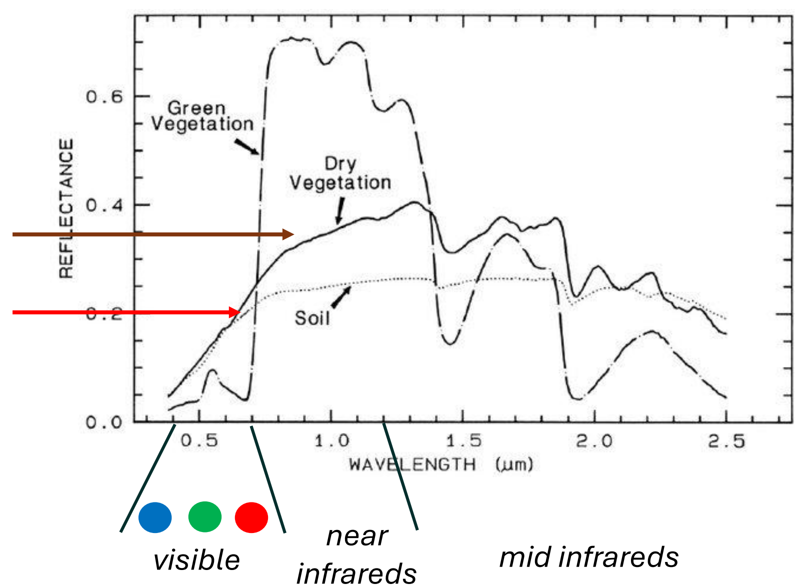
27

2 Tools & Sensors used in Forest Ecology

Spectral remote sensing

Healthy vegetation:
Red = 0.05, NIR = 0.65
→ NDVI = 0.85

Dry vegetation:
Red = 0.2, NIR = 0.35
→ NDVI = 0.27



near infrared

$$NDVI = \frac{NIR - R}{NIR + R}$$

red

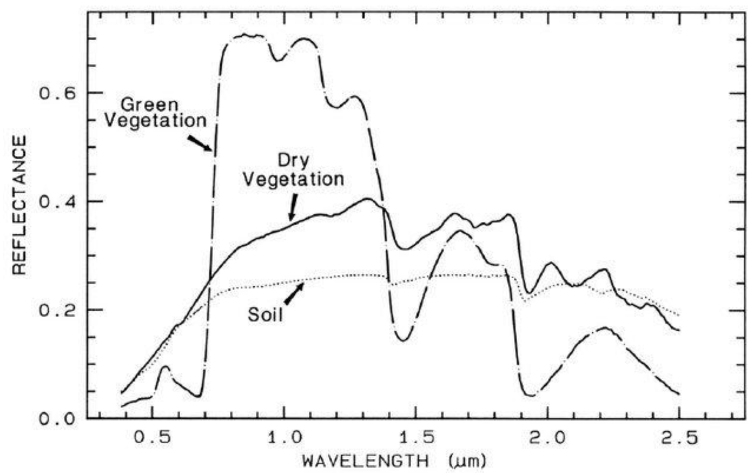
28

2 Tools & Sensors used in Forest Ecology

Spectral remote sensing

To track what?

Chemical composition:
- Water content
- Chlorophyll concentration
- Soil type
- …



29

2 Tools & Sensors used in Forest Ecology

Spectral remote sensing

To track what?

Chemical composition:
- Water content
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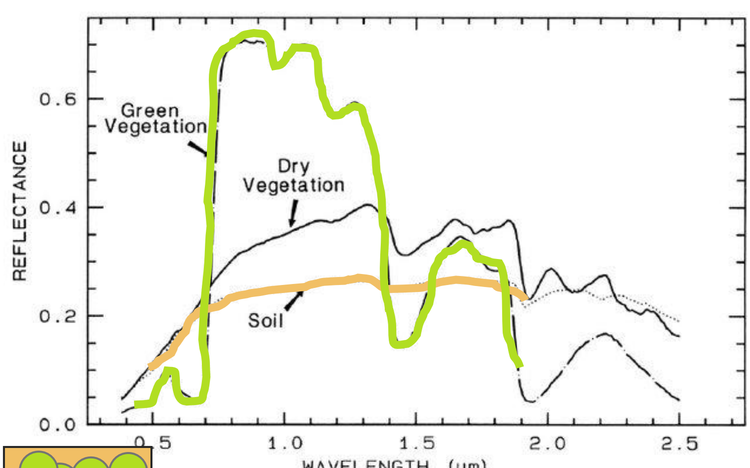
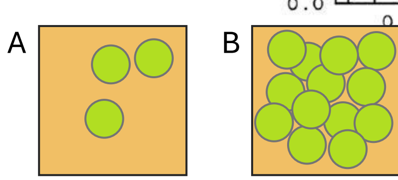
- Soil type
- …

Physical characteristics:
- Plant density
- …





30

2 Tools & Sensors used in Forest Ecology

Tools of remote sensing: Sensors

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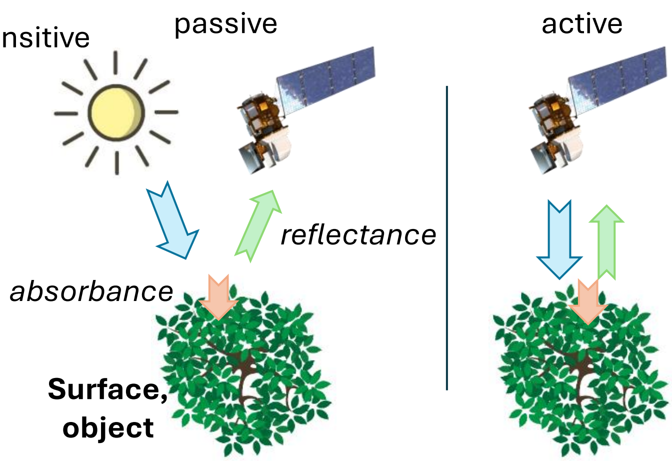


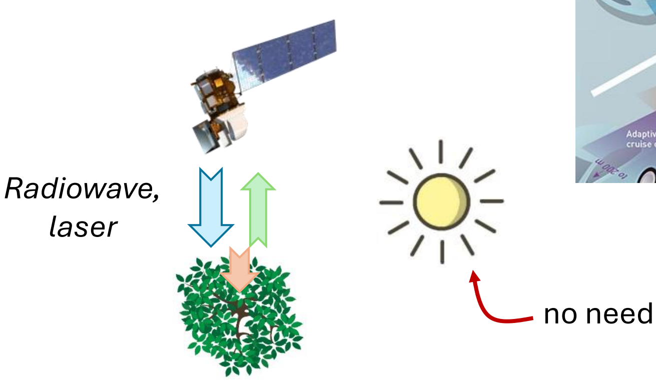
31

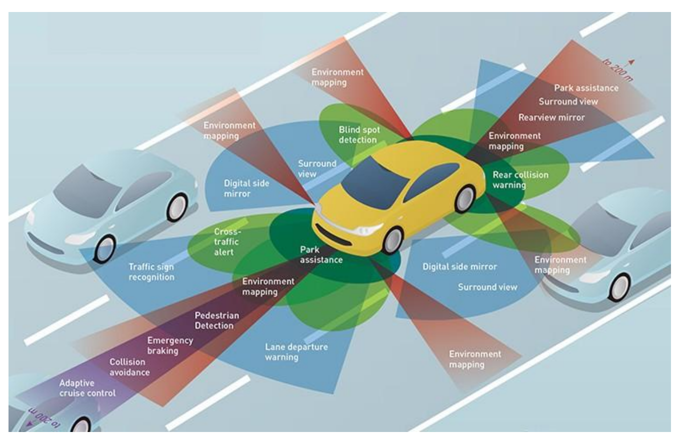
2 Tools & Sensors used in Forest Ecology

Active RS: RADAR / LiDAR

Radio/Light Detection And Ranging

Distance ↔ the time for the radio wave/laser to return to sensor.



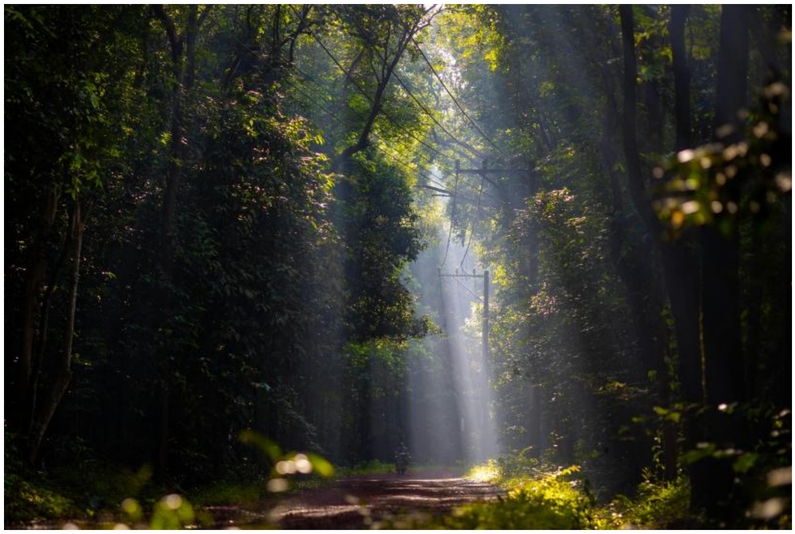


https://www.optica-opn.org

32

2 Tools & Sensors used in Forest Ecology

Active RS: LiDAR



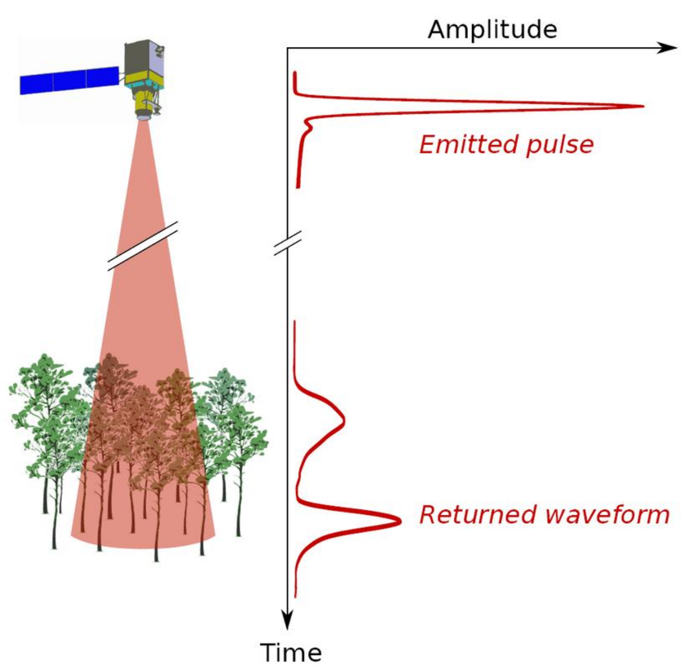
Trường Nguyễn Thanh

33

2 Tools & Sensors used in Forest Ecology

Active RS: LiDAR

In forests, the LiDAR beams can penetrate through the canopy and be reflected at different elevations.



34

2 Tools & Sensors used in Forest Ecology

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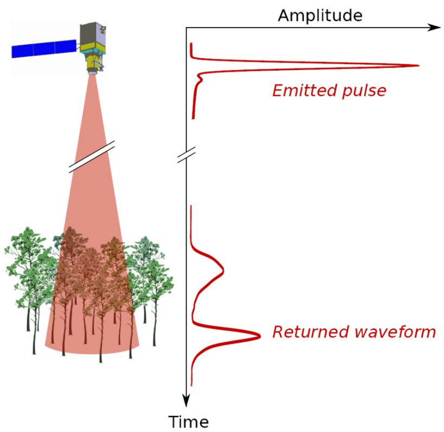

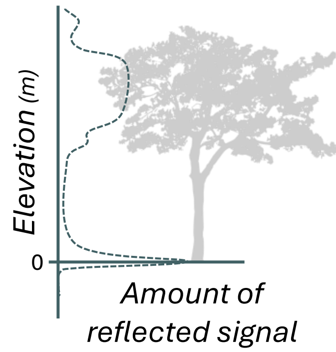

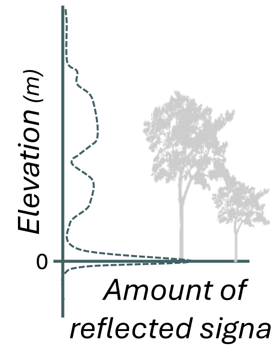

35

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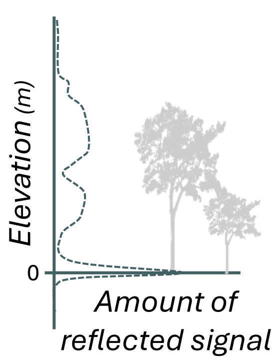

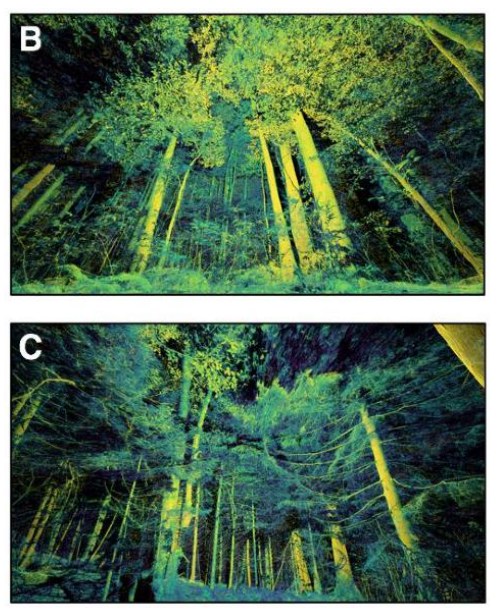

36

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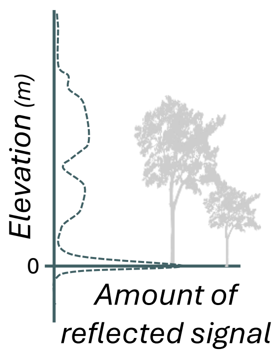


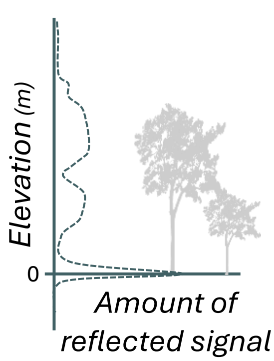
archeology

37

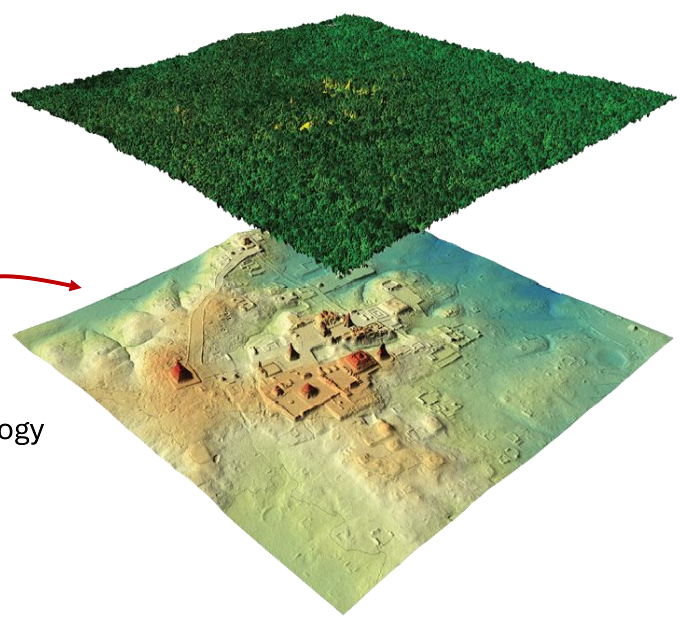
2 Tools & Sensors used in Forest Ecology

Active RS: LiDAR

In forests, the LiDAR beams can penetrate through the canopy and be reflected at different elevations.



archeology



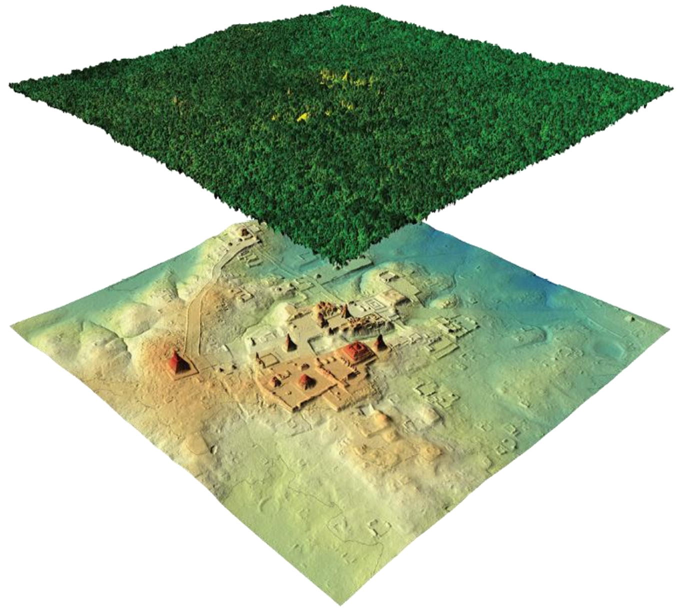
38

2 Tools & Sensors used in Forest Ecology

Active RS: LiDAR

To track what?

Physical characteristics:
- Height
- Density
- Number of trees
- Topography
- ...



39

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Active RS: LiDAR

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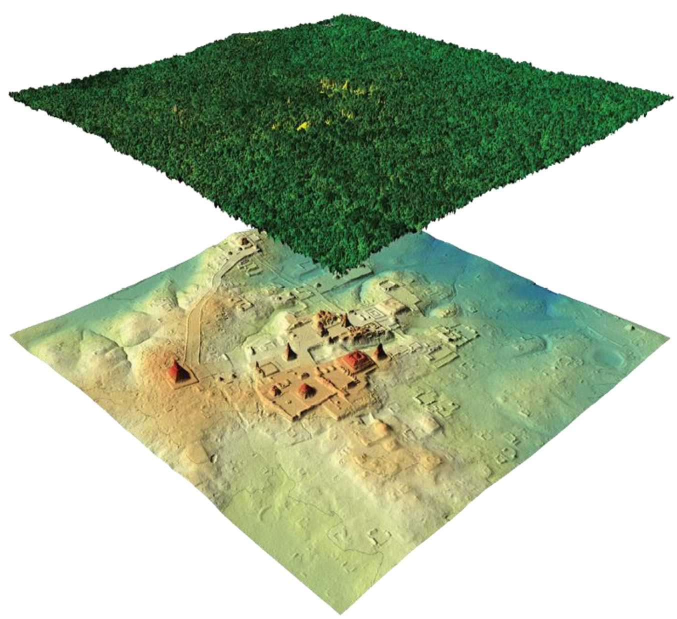


! Passive remote sensing can provide some information on forest structure

40

2 Tools & Sensors used in Forest Ecology

Photogrammetry and SfM

Repeated photography under different angles
→ *structure from motion* → 3D

KU Leuven

41

2 Tools & Sensors used in Forest Ecology

Photogrammetry and SfM

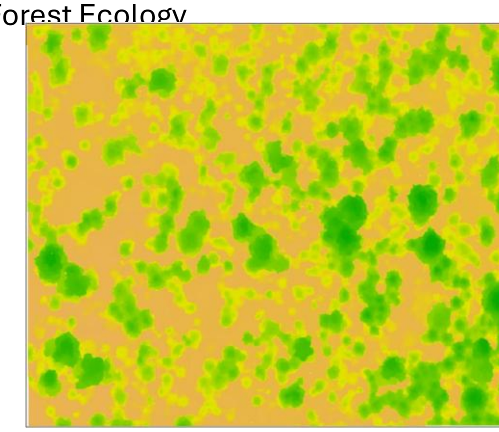
Repeated photography under different angles
→ *structure from motion* → 3D

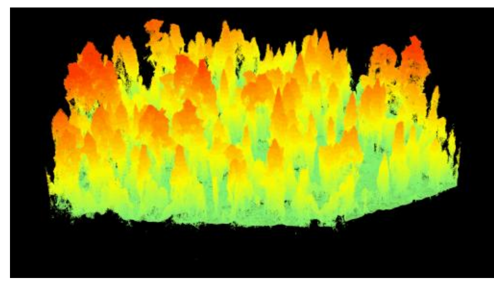
42

2 Tools & Sensors used in Forest Ecology

Photogrammetry and SfM

Repeated photography under different angles
→ *structure from motion* → 3D





43

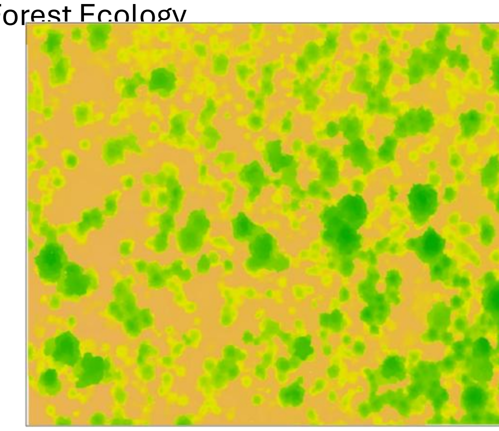
2 Tools & Sensors used in Forest Ecology

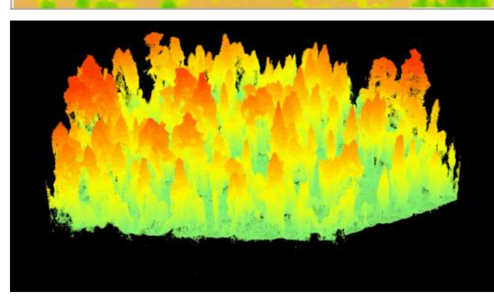
Photogrammetry and SfM

To track what?

Physical characteristics:
- Height
- Density
- Number of trees (sometimes)

! Less information than LiDAR





44

Four remote sensing applications in forest ecology

45

Four remote sensing applications in forest ecology

46

1 Hyperspectral imagery and spatial patterns of foliar characteristics

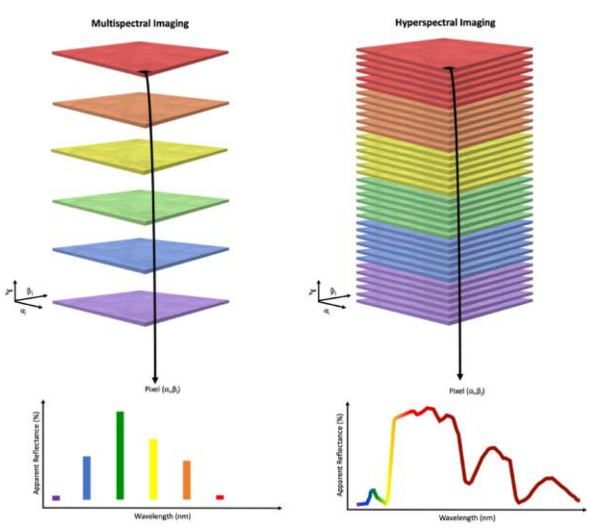
“Hyperspectral”?

“Foliar characteristics”?

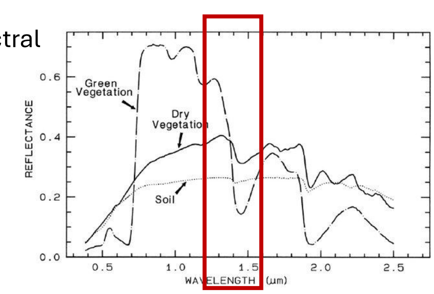
47

1 Hyperspectral imagery and spatial patterns of foliar characteristics

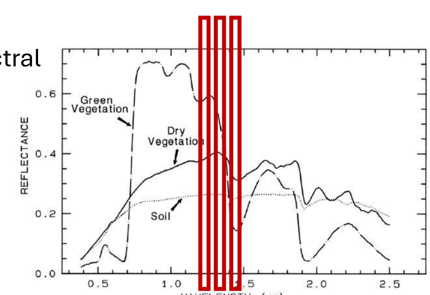
“Hyperspectral”?



multispectral



hyperspectral



48

1 Hyperspectral imagery and spatial patterns of foliar characteristics

"Foliar characteristics"?

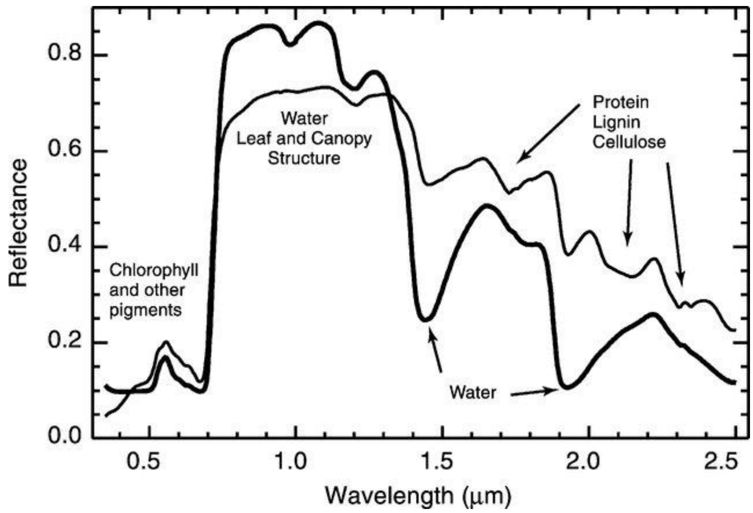
木質素

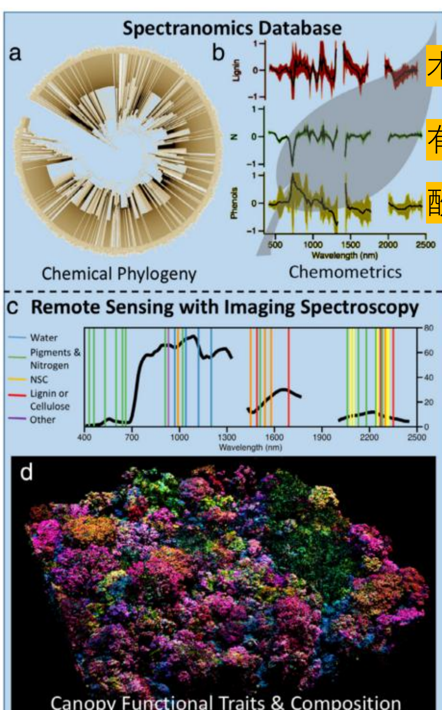
有機氮

酚

…

反照率





木質素

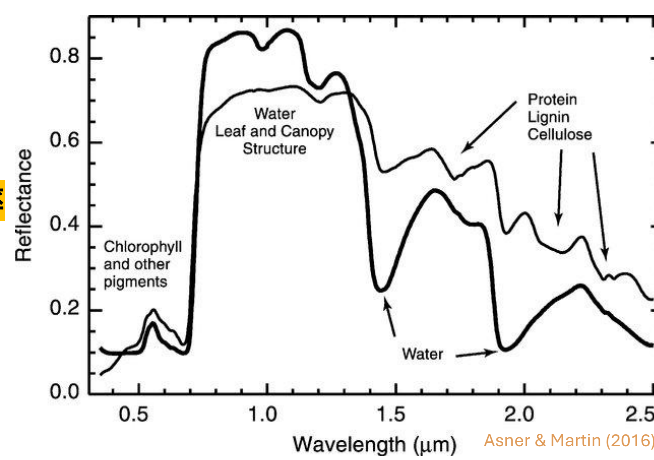
有機氮

酚

Hyperspectral data and plant functional types

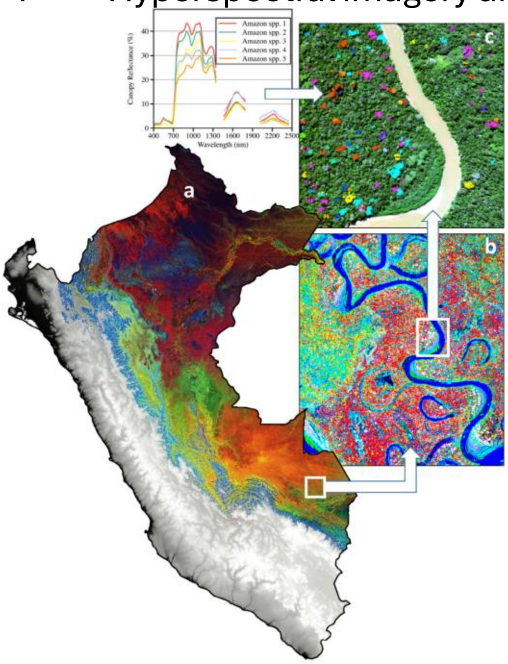
Fine spectral resolution ↔ chemical properties

反照率



Asner & Martin (2016)

1 Hyperspectral imagery and spatial patterns of foliar characteristics



Hyperspectral data and plant functional types

Fine spectral resolution ↔ chemical properties

Identifying species based on their specific reflectance pattern: *spectranomics*

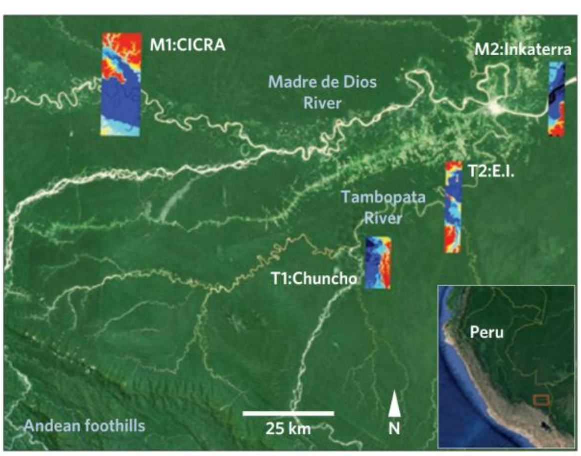
Asner et al. (2015)

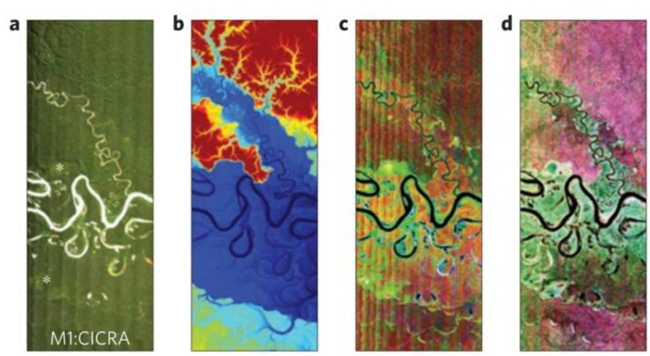
51

1 Hyperspectral imagery and spatial patterns of foliar characteristics

Landscape biogeochemistry reflected in shifting distributions of chemical traits in the Amazon forest canopy

Gregory P. Asner*, Christopher B. Anderson, Roberta E. Martin, Raul Tupayachi, David E. Knapp and Felipe Sinca





true colour | elevation | Ca, P, Mg | lignin, Soluble C, cellulose

- Ca
- P
- Mg

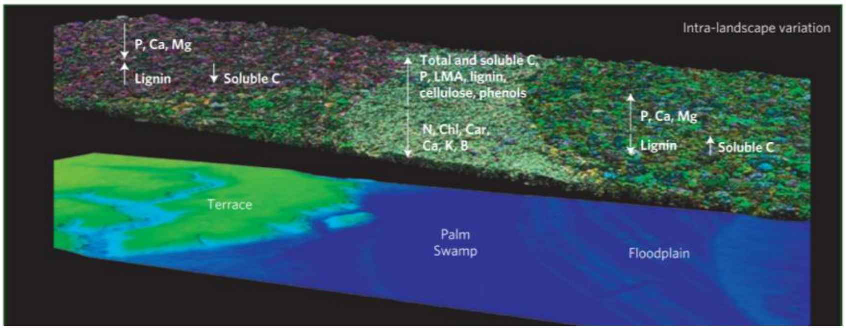
- lignin
- Soluble C
- cellulose

木質素
有機氮

Asner et al. (2015)

52

1 Hyperspectral imagery and spatial patterns of foliar characteristics



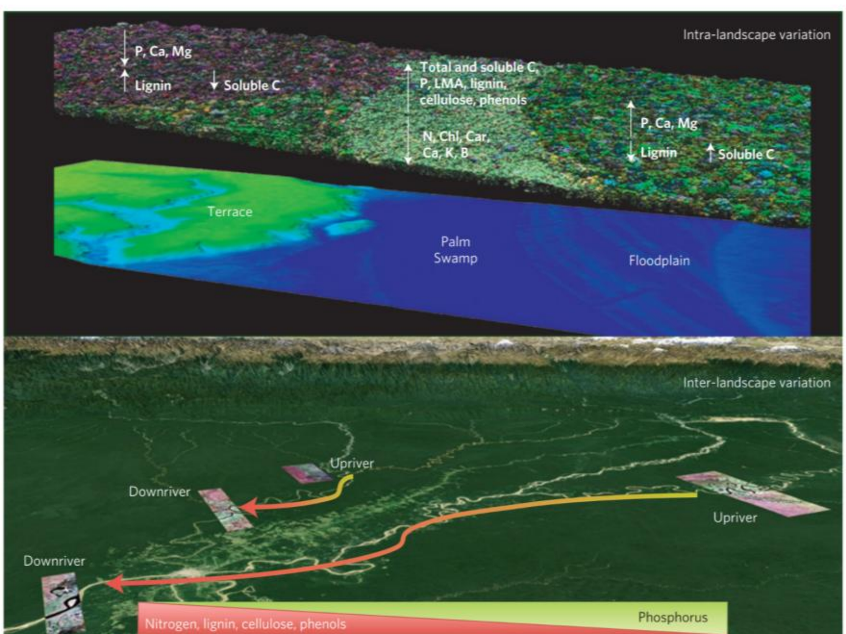
Microtopography
→ functional trait distribution across landscape.

Floodplains: High P, Ca, Mg, low lignin
Swamp forests: high investment in defense

Asner et al. (2015)

53

1 Hyperspectral imagery and spatial patterns of foliar characteristics



Microtopography
→ functional trait distribution across landscape.

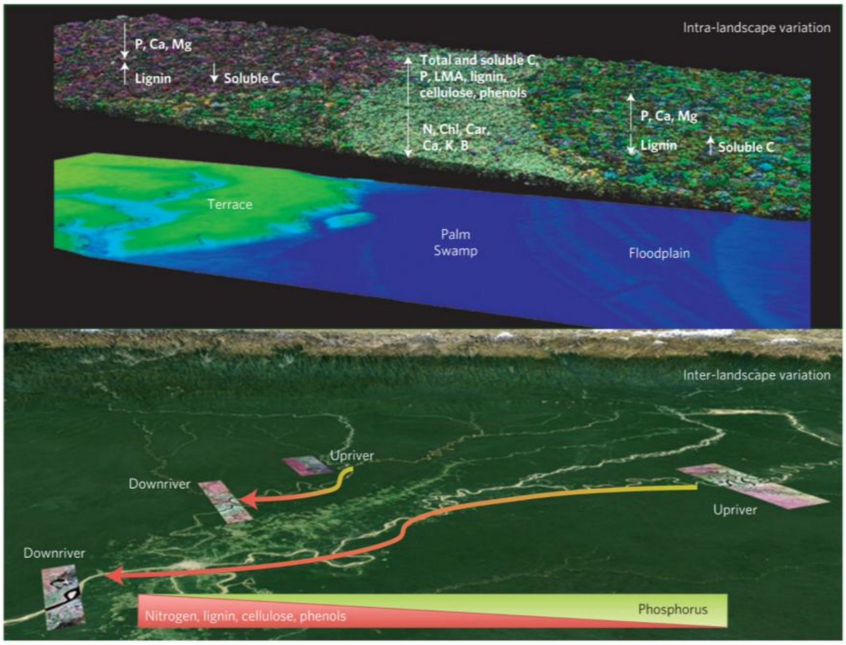
Floodplains: High P, Ca, Mg, low lignin
Swamp forests: high investment in defense

Landscape position is more important to explain trait variation than forest type
Forest type important for leaf [P] [N]

Asner et al. (2015)

54

1 Hyperspectral imagery and spatial patterns of foliar characteristics



Strong link with forest canopy characteristics

Landscape-to-regional insights

Asner et al. (2015)

55

Four remote sensing applications in forest ecology

56

2 Sacred forests as another tool for forest conservation

All inhabited continents,
small size,
very variable age and condition but often > 100 years

57

2 Sacred forests as another tool for forest conservation

Some known benefits :

- Local biodiversity hotspots
- Pollination of nearby crops
- Urban green spaces

58

2 Sacred forests as another tool for forest conservation

In comparison to most
legally protected areas

- small but numerous,
- close to inhabited areas,
- managed by local communities

But

- unclear conservation potential
- most studies are based on few sites

Church forest (Ethiopia); Emergence Magazine

Shrine forest (Japan); wiki

59

2 Sacred forests as another tool for forest conservation

Questions

1. Do sacred forests experience less forest area loss than other forests at large scale (country)?

60

2 Sacred forests as another tool for forest conservation

Questions

1. Do sacred forests experience less forest area loss than other forests at large scale (country)?

2. How do sacred forests compare with protected areas (legal protection)?

61

2 Sacred forests as another tool for forest conservation

Questions

1. Do sacred forests experience less forest area loss than other forests at large scale (country)?

2. How do sacred forests compare with protected areas (legal protection)?

3. Effect of religion and location?

62

2 Sacred forests as another tool for forest conservation

Methods - Datasets

GIS

Location of sacred places
+ their characteristics

Map of protected areas of Japan

Population density maps

Based on Remote Sensing

Forest types

Forest dynamics:
- structure (height)
- area

63

2 Sacred forests as another tool for forest conservation

Methods - Datasets

Location: Japan → OpenStreetMap Foundation → Many information: filter shrines and temples

64

2 Sacred forests as another tool for forest conservation

Methods - Datasets

Location: Japan → OpenStreetMap Foundation → Many information: filter shrines and temples

Variables:

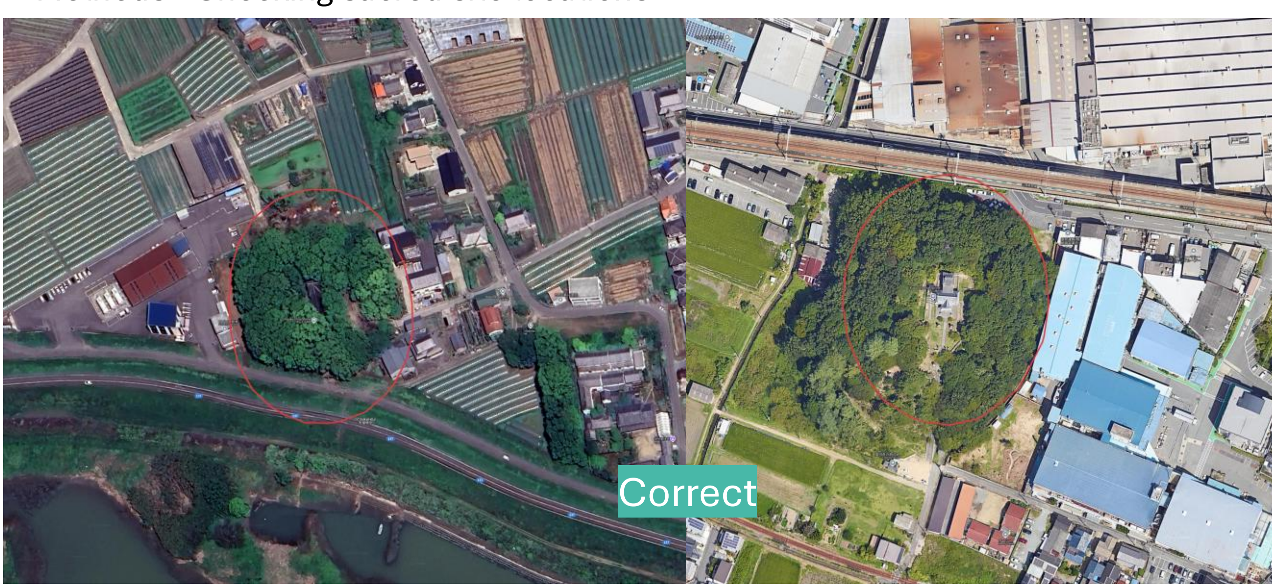
Forest structure (1 year)
Forest area (2000 and 2020)
Urban and rural areas

→ Available, derived from remote sensing

Protected areas → Global dataset from UNEP

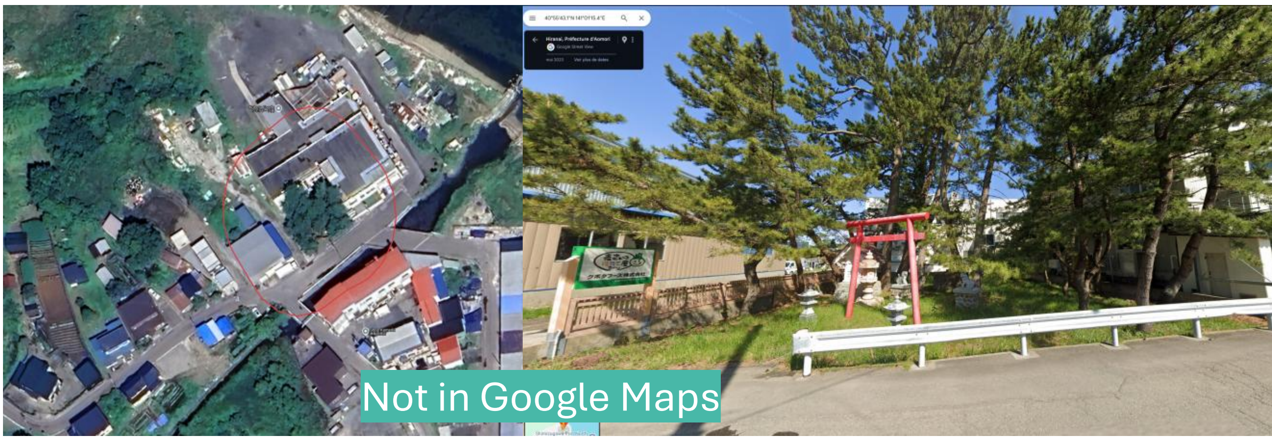
2 Sacred forests as another tool for forest conservation

Methods - Checking sacred site locations



2 Sacred forests as another tool for forest conservation

Methods - Checking sacred site locations



67

2 Sacred forests as another tool for forest conservation

Methods - Checking sacred site locations

68

2 Sacred forests as another tool for forest conservation

Methods - Checking sacred site locations

69

2 Sacred forests as another tool for forest conservation

Methods - Analysis

Comparison

sacred forests ⟷ nearby non-sacred forests

for

Forest characteristics

- Forest Loss Rate (2000-now)
- Forest Height (2020)

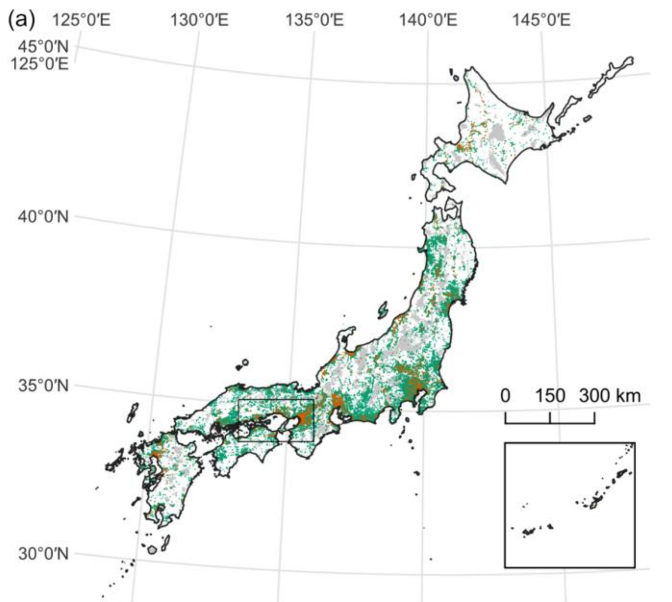
with

Factors

- Religious Identity (Buddhist or Shinto)
- Location (Urban or Rural)
- Protected Area (Inside or Outside)
- Forest Composition (types, ...) — 照葉林

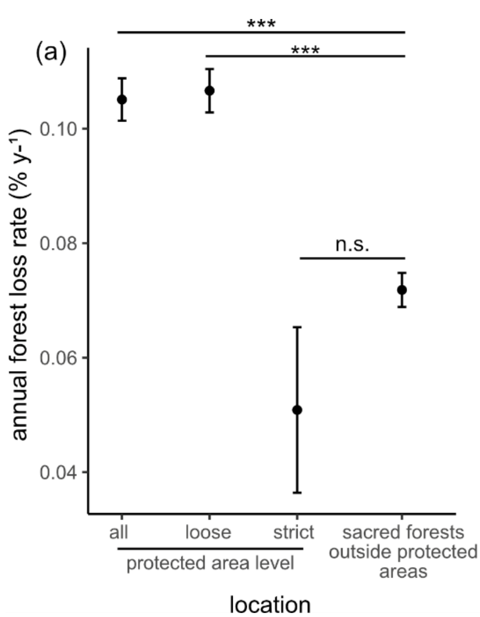
70

2 Sacred forests as another tool for forest conservation



71

2 Sacred forests as another tool for forest conservation

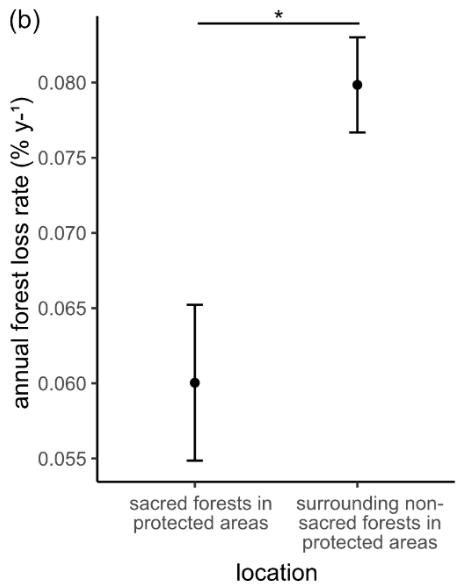


Findings

Less forest loss in sacred forests vs. their landscape, even in protected areas

72

2 Sacred forests as another tool for forest conservation



Findings

Less forest loss in sacred forests vs. their landscape, even in protected areas

73

2 Sacred forests as another tool for forest conservation

Findings

Less forest loss in sacred forests vs. their landscape, even in protected areas

Taller trees in sacred forests

Sacred forest's effect is more important in cities than in rural areas

74

2 Sacred forests as another tool for forest conservation

Findings

VGI is valuable when there are no other sources of information

OpenStreetMap Foundation

75

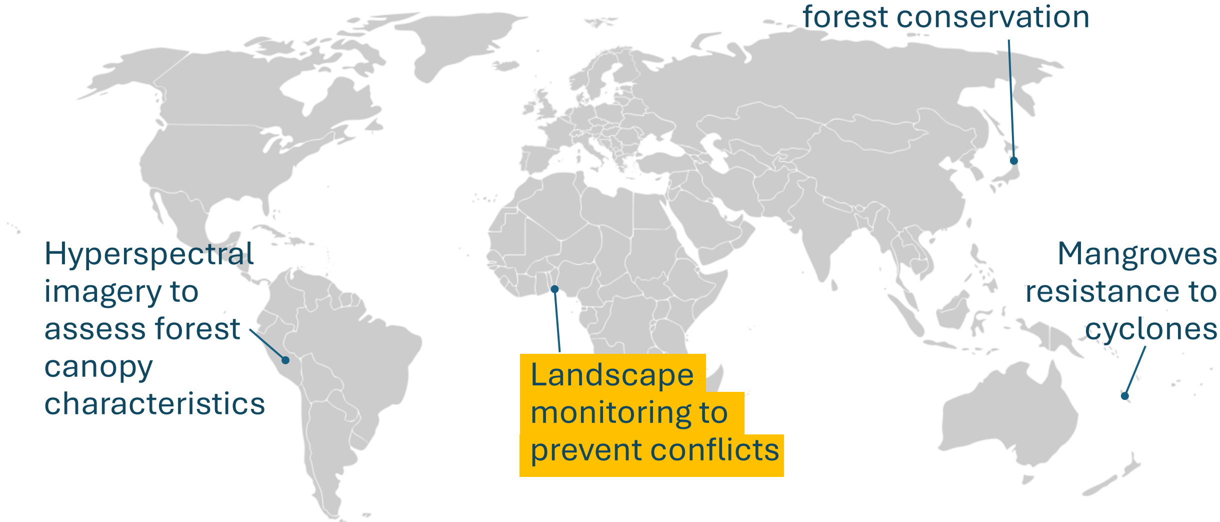
2 Sacred forests as another tool for forest conservation

Lot of existing data derived from RS

Spatio-temporal patterns can be investigated

76

Four remote sensing applications in forest ecology



77

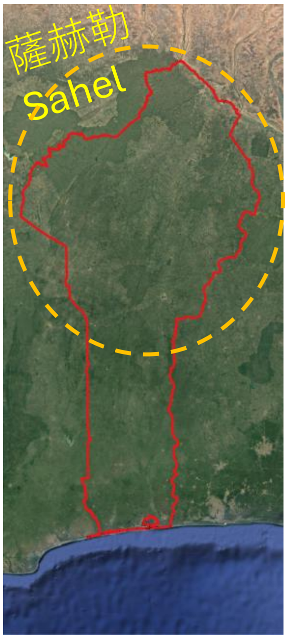
3 Landscape remote sensing: conflict mitigation, management

South-North rainfall gradient

Rain and dry seasons

78

3 Landscape remote sensing: conflict mitigation, management



Benin

貝南共和國

South-North rainfall gradient

Rain and dry seasons

79

3 Landscape remote sensing: conflict mitigation, management

Benin

貝南共和國

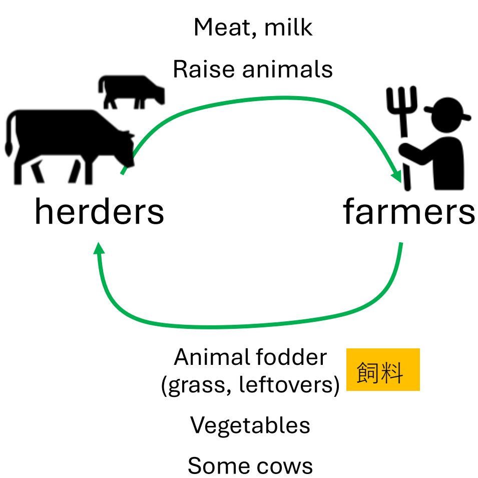
Traditional occupations related to ethnic groups

80

3 Landscape remote sensing: conflict mitigation, management

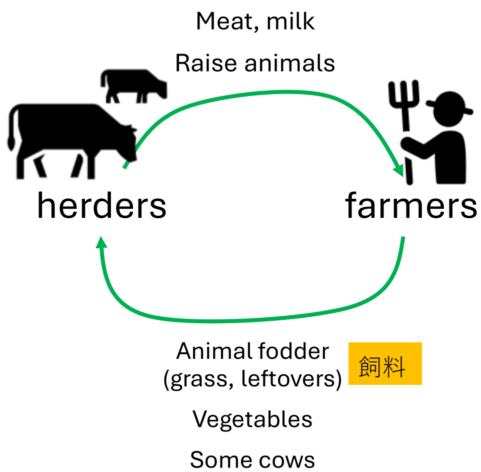
81

3 Landscape remote sensing: conflict mitigation, management

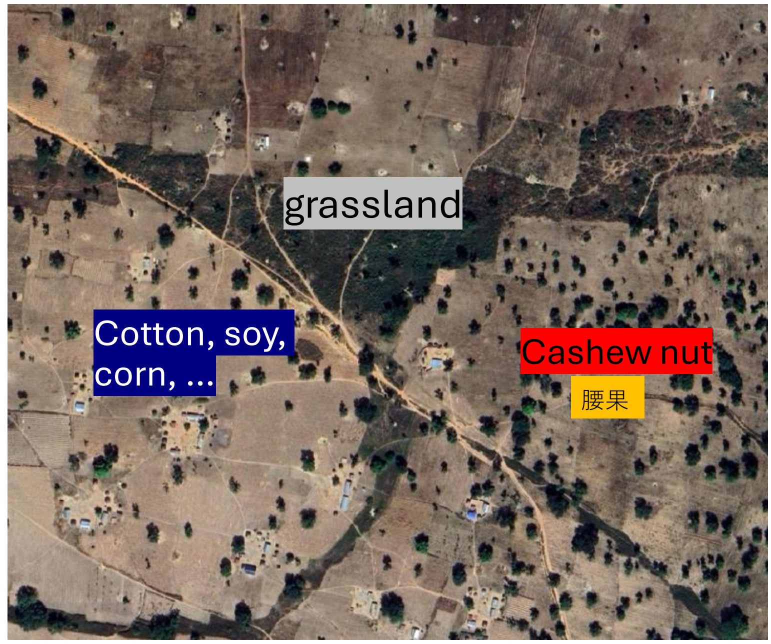


82

3 Landscape remote sensing: conflict mitigation, management

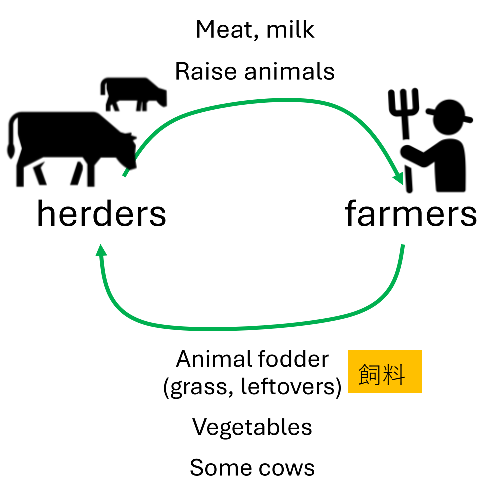


Farmers and herders occupy the same space but not at the same time → Shared landscape



83

3 Landscape remote sensing: conflict mitigation, management



Farmers and herders occupy the same space but not at the same time → Shared landscape

84

3 Landscape remote sensing: conflict mitigation, management

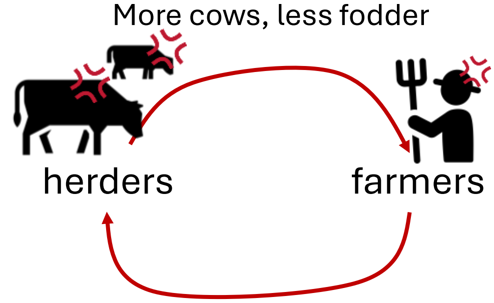
Conflicts?

Subsistence to cash crops

自給式農業→經濟作物

More animals

Protected areas



85

3 Landscape remote sensing: conflict mitigation, management

Conflicts?

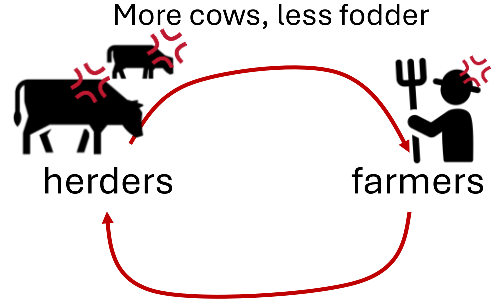
Subsistence to cash crops

自給式農業→經濟作物

More animals

Protected areas

→ Remote sensing to understand landscape dynamics



86

3 Landscape remote sensing: conflict mitigation, management

Use of remote sensing techniques

1. Create a Land Cover map 遙測影像土地利用
2. Identify water holes
3. Accessible areas OK /
4. Count single trees in farms
5. Assess available biomass

87

3 Landscape remote sensing: conflict mitigation, management

1. Create a Land Cover map 遙測影像土地利用

Ground data + fine resolution multispectral images

type of land cover → spectral signature 光譜信號

Use ground data to train computer to identify other areas

88

3 Landscape remote sensing: conflict mitigation, management

1. Create a Land Cover map 遙測影像

Ground data + fine resolution multispectral images

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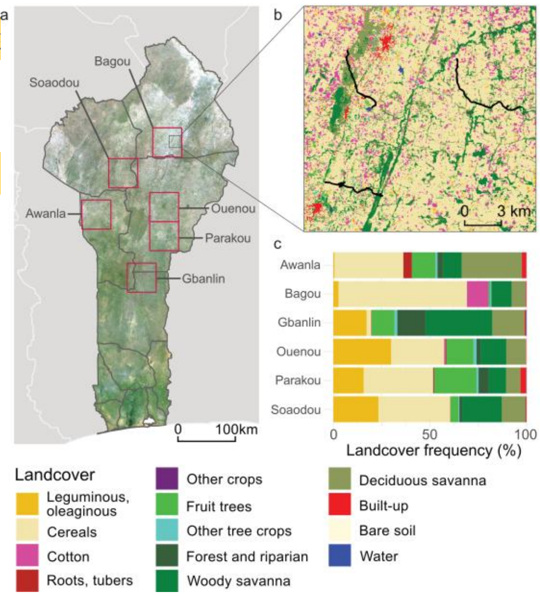


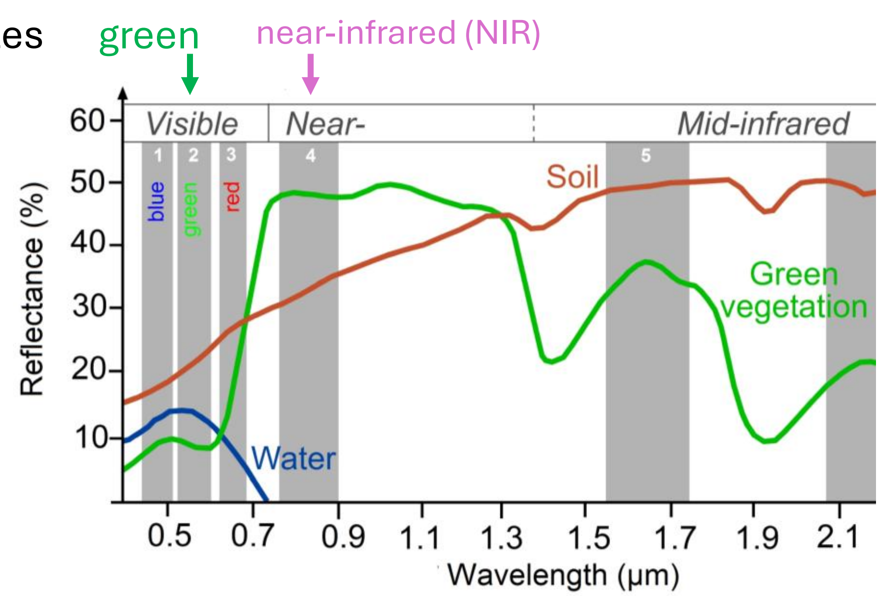
89

3 Landscape remote sensing: conflict mitigation, management

2. Identify water holes

Multispectral data → Index

$$\text{NDWI} = \frac{Green - NearInfrared}{Green + NearInfrared}$$



90

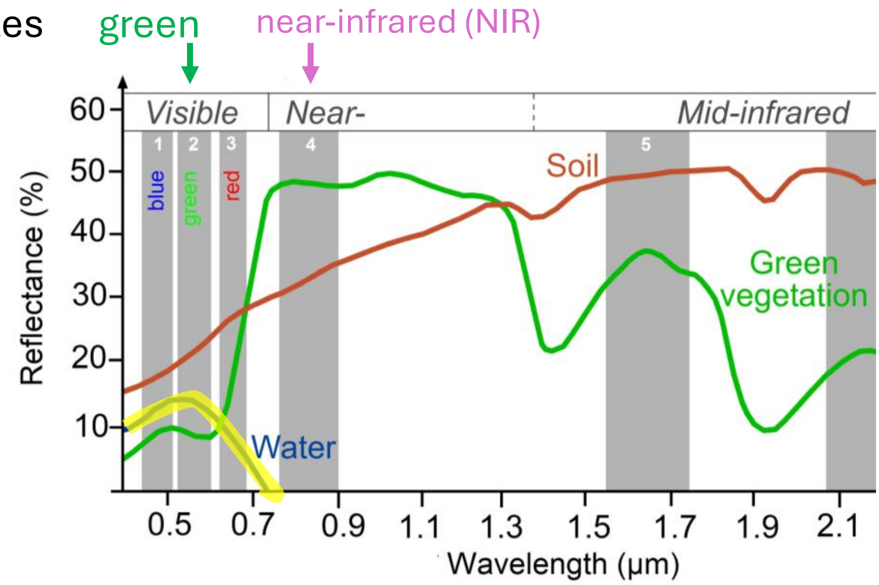
3 Landscape remote sensing: conflict mitigation, management

2. Identify water holes

Multispectral data → Index

$$NDWI = \frac{Green - NearInfrared}{Green + NearInfrared}$$

If Water:
Green > NIR
then NDWI > 0



91

3 Landscape remote sensing: conflict mitigation, management

3. Accessible areas

Herders and farmers interviews

	Dry season	Wet season
Cotton	OK	🚫
Mango	OK	OK
Cashew nut	🚫	OK
Soya	OK	🚫
Grassland	OK	OK
City	🚫	🚫

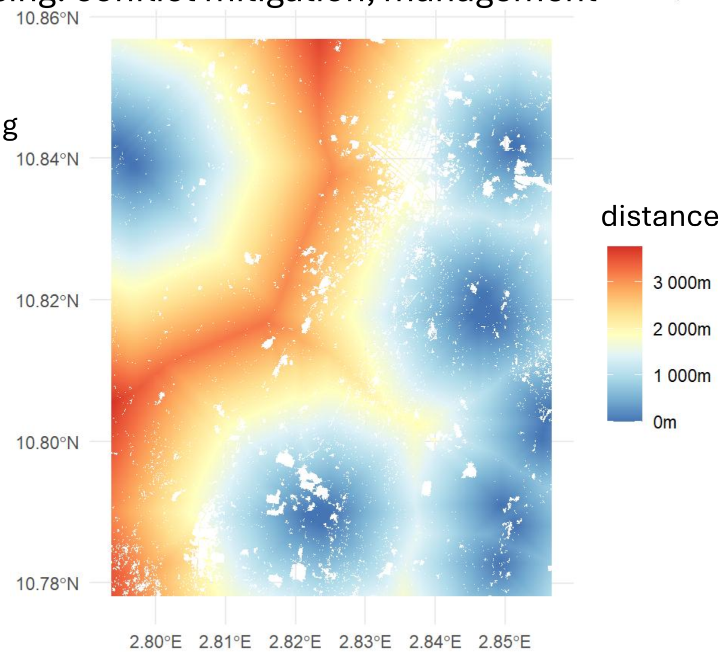
Land Cover + interview data → **access map**

92

3 Landscape remote sensing: conflict mitigation, management

3. Accessible areas

Distance from water holes, avoiding inaccessible areas



93

3 Landscape remote sensing: conflict mitigation, management

3. Accessible areas

Raise warning if :

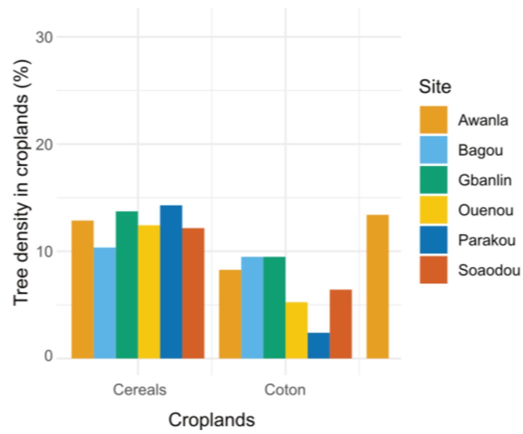
- little area is accessible,
- no water is accessible,
- only protected forests are accessible

Cyrille Cornu

94

3 Landscape remote sensing: conflict mitigation, management

4. Single trees in farms



95

3 Landscape remote sensing: conflict mitigation, management

5. Available biomass

Land Cover map →

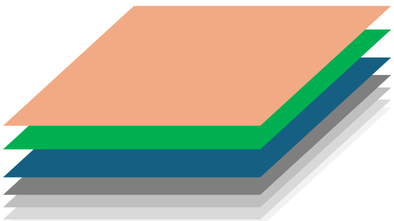
Ground data: biomass sampling for each land cover class → Fit model → Biomass map

Multispectral data →

96

3 Landscape remote sensing: conflict mitigation, management

Use of remote sensing techniques



Maps: Land Cover, water distance, access, biomass…

- water access
- water availability
- food access
- food availability
- conflicts
- fires

Landscape condition for herders, farmers, protected areas

Management decisions

97

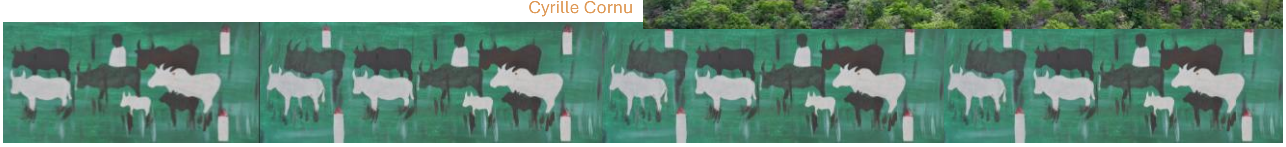
3 Landscape remote sensing: conflict mitigation, management

Integrating RS-derived data with ground-collected information (socio-ecological, …) contribute to large-scale understanding

Creating new data based on RS

Monitoring combining LC maps with field surveys and interviews

Cyrille Cornu



98

Four remote sensing applications in forest ecology

99

4 Mangroves resistance to cyclones

Mangroves
- Subtropical-tropical
- Coastal (ecotone)

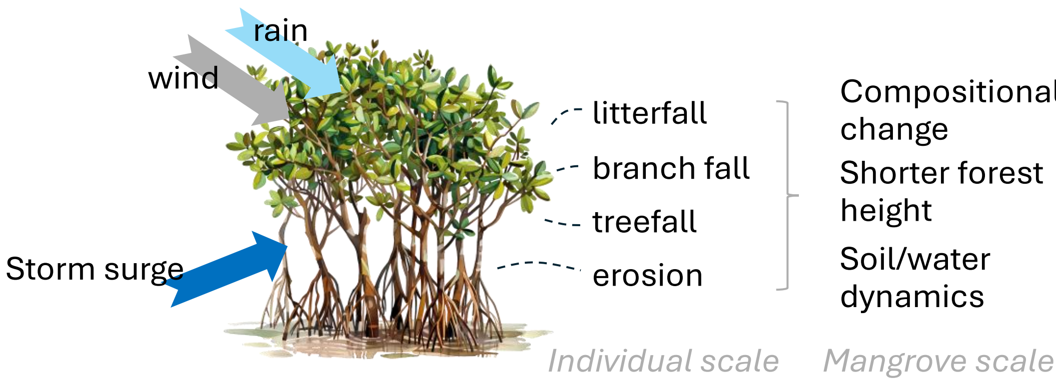
→ exposed to cyclones

100

4 Mangroves resistance to cyclones

Mangroves
- Subtropical-tropical
- Coastal (ecotone)

→ exposed to cyclones



101

4 Mangroves resistance to cyclones


Hurricane Melissa, Sentinel-2

Are mangroves more resistance to cyclones when they are more often exposed?

102

4 Mangroves resistance to cyclones

Remote sensing data

- Global, to include different cyclone basins
- Large scale, to cover entire mangrove forests
- Many years, to include several cyclones
- Fine spatial resolution, to detect canopy change
- Fine temporal resolution, to distinguish cyclone effects from phenology

103

NASA, Landsat 8

4 Mangroves resistance to cyclones

Remote sensing data

- Global, to include different cyclone basins
- Large scale, to cover entire mangrove forests
- Many years, to include several cyclones
- Fine spatial resolution, to detect canopy change
- Fine temporal resolution, to distinguish cyclone effects from phenology

Landsat 5 to 8
multispectral
30-m resolution
~7-10 days
>1990's
global

104

4 Mangroves resistance to cyclones

Methods

Identify mangroves in protected areas ➡ Select cyclone(s) that passed close to the mangrove ➡ Measure ΔVI

$\Delta VI = VI_{after} - VI_{before}$

⬇

Relate *past cyclone frequencies*, and other characteristics to ΔVI

RESEARCH ARTICLE

Global Ecology and Biogeography — WILEY

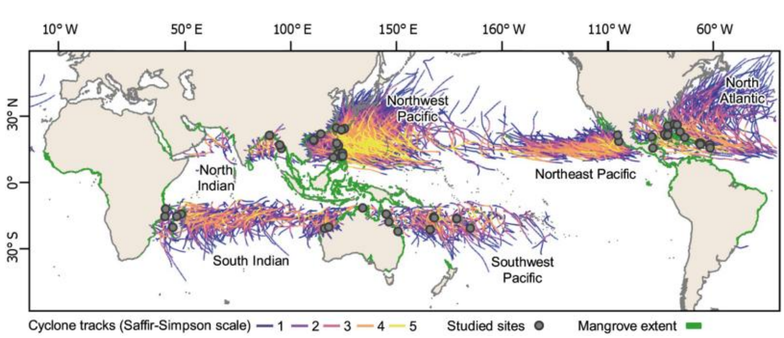
Disturbance frequency, intensity and forest structure modulate cyclone-induced changes in mangrove forest canopy cover

Jonathan Peereman[1] | J. Aaron Hogan[2] | Teng-Chiu Lin[1]

105

4 Mangroves resistance to cyclones

Results



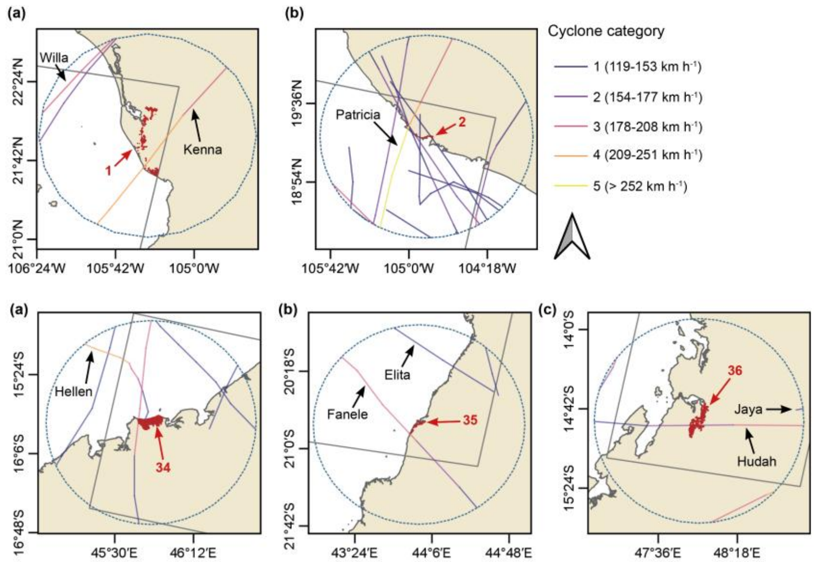
56 sites in the 6 cyclone basins

86 cyclones

106

4 Mangroves resistance to cyclones

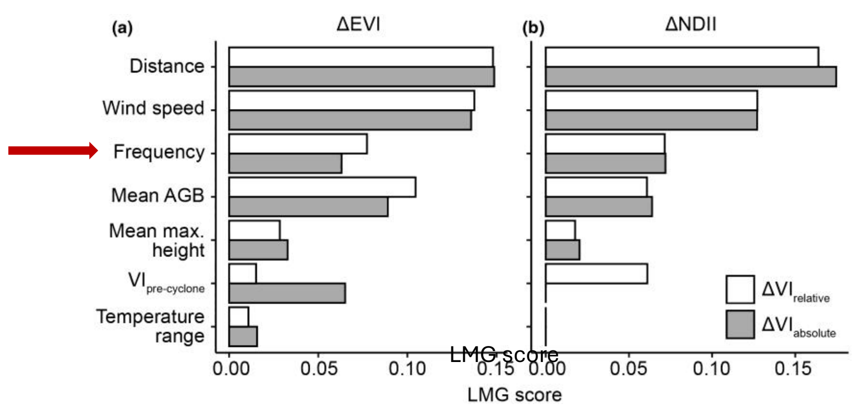
Results



107

4 Mangroves resistance to cyclones

Results



Model of ΔVI ~ cyclone characteristics, forest characteristics…

→ historical frequencies

108

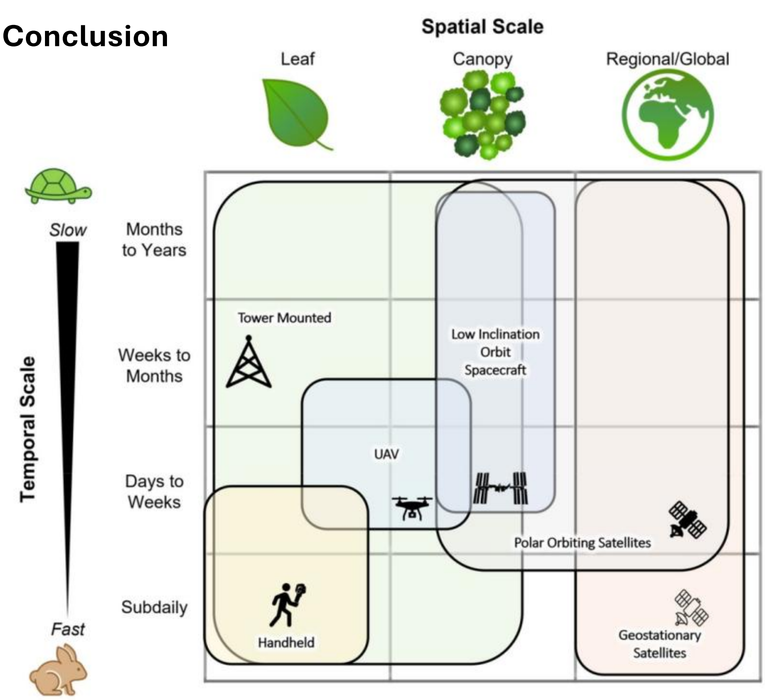
4 Mangroves resistance to cyclones

Time series, change detection…

To study areas that are difficult to study using ground surveys

109

Conclusion



Many tools

Wide range of applications

Main focus or supporting data?

Valuable experience, skills

Farella et al., 2022

110