Normalized Difference Fraction Index (NDFI): a new spectral index for enhanced detection of forest canopy damage caused by selective logging and forest fires

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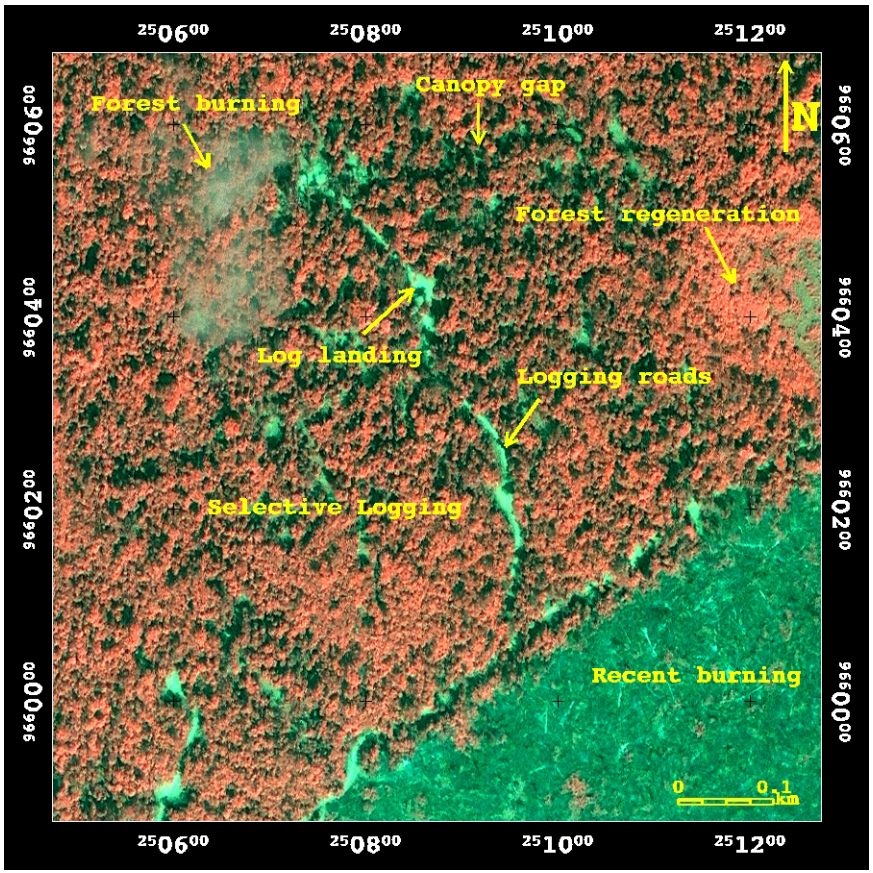
Deforestation vs Forest Degradation

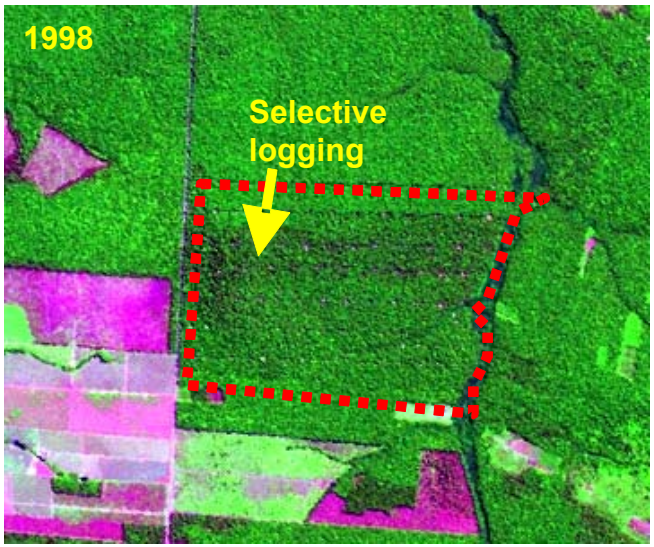
Ikonos Image – Paragominas, PA

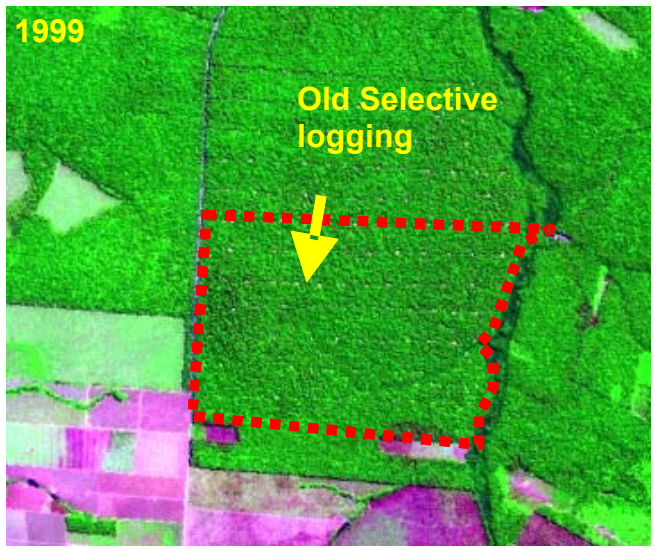


Souza Jr. and Roberts (2005) - IJRS

- Creates a complex environment:
  - Undisturbed forests
  - Canopy gaps
  - Exposed soils
  - Dead vegetation
- Caused by:
  - Selective logging
  - Forest fires
  - Forest fragmentation

Very Challenge with Landsat!





Souza Jr. et al. (2003), Rev. Ciência Hoje

Objective

- Develop a technique that combines spectral and spatial information to enhance the detection and mapping of **canopy damage** caused by selective logging and forest fires

  - New spectral index: Normalized Difference Spectral Index (NDFI)
  - Contextual classification algorithm (CCA)
    - Spectral: NDFI
    - Spatial: log landings

Forest Transect Classes

Degradation Intensity

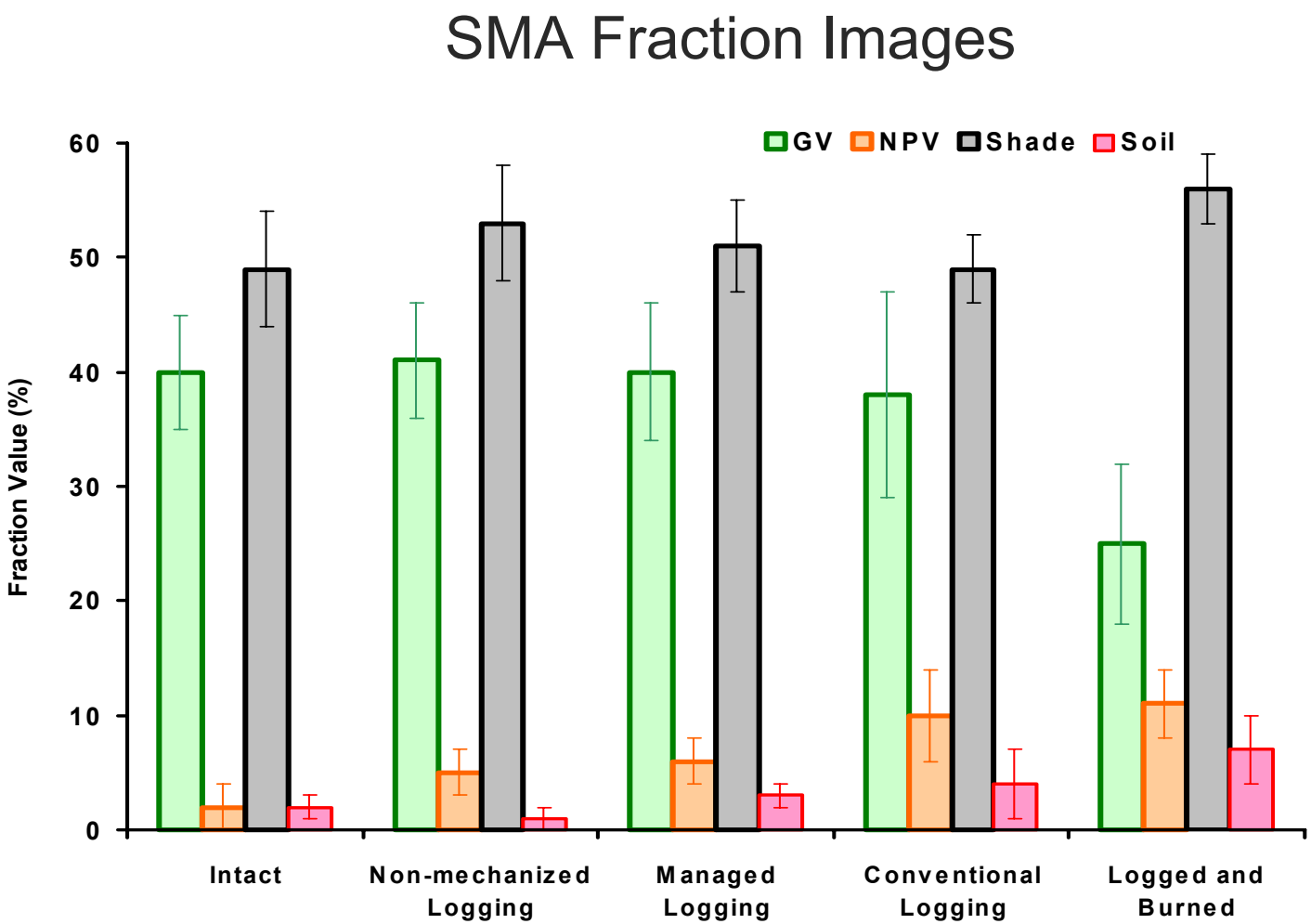
Forest class	Field Description
Intact (n=4)	Mature and undisturbed forest
Non-mechanized logging (n=5)	Logged forest without the use of vehicles such as skidders and trucks, also known as traditional logging. Log landings, roads and skid trails are not built.
Managed logging (n=5)	Planned selective logging where a tree inventory is conducted, followed by road and log landing planning to reduce harvesting impacts.
Conventional Logging (n=2)	Conventional unplanned selective logging using skidders and trucks. Log landings, roads and skid trails are built.
Logged and burned (n=3)	Either non-mechanized or conventionally logged forests that have subsequently been damaged by intense surface fires.

Souza Jr. et al. (2005), Earth Interactions

Forest Transects

- Forest inventories
  - Transects (10 m x 500 m = 0.5 ha)
    - Trees with DBH ≥ 10 cm
    - Sub-plots (10 m x 10 m)
      - All trees
      - Forest canopy cover
      - Vine density
      - % soil exposed
      - % of dead vegetation
- Aboveground biomass estimation
  - Allometric equations (Gerwing, 2000)

Forest Degradation Separability



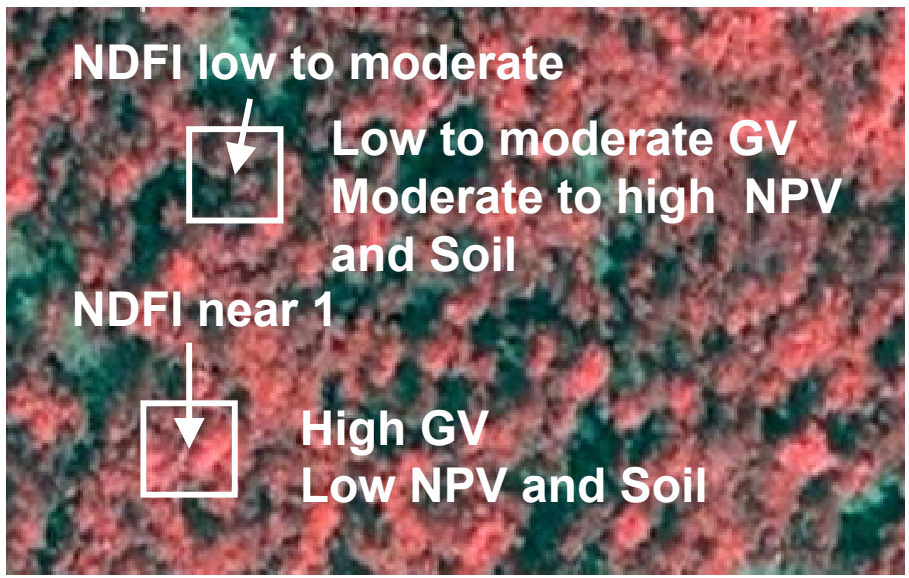
Souza Jr. et al. (2005), Earth Interactions

Normalized Difference Fraction Index

$$NDFI = \frac{GV_{Shade} - (NPV + Soil)}{GV_{Shade} + NPV + Soil}$$

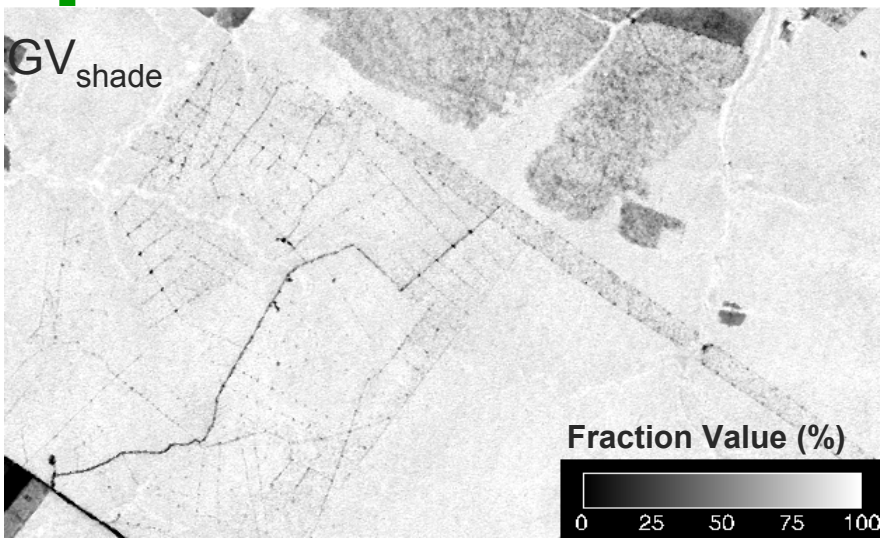
$$GV_{Shade} = \frac{GV}{100 - Shade}$$

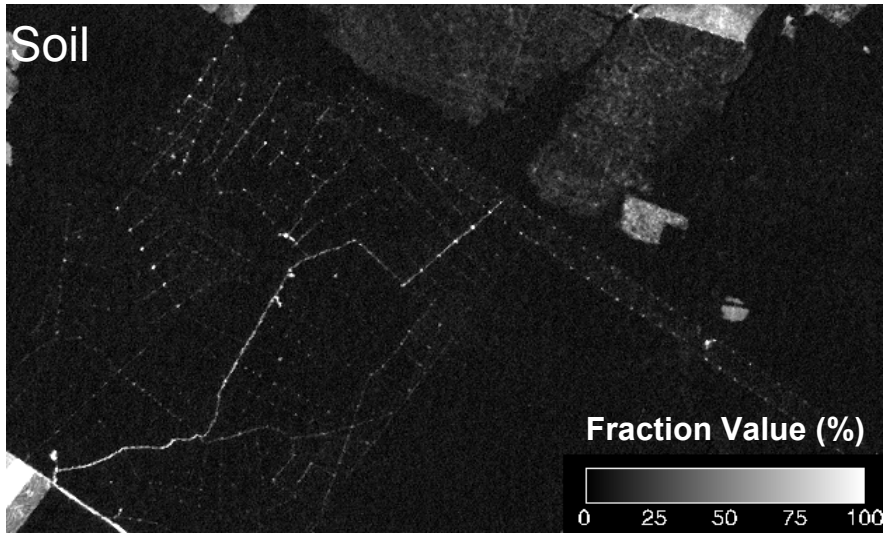
$$-1 \leq NDFI \leq 1$$

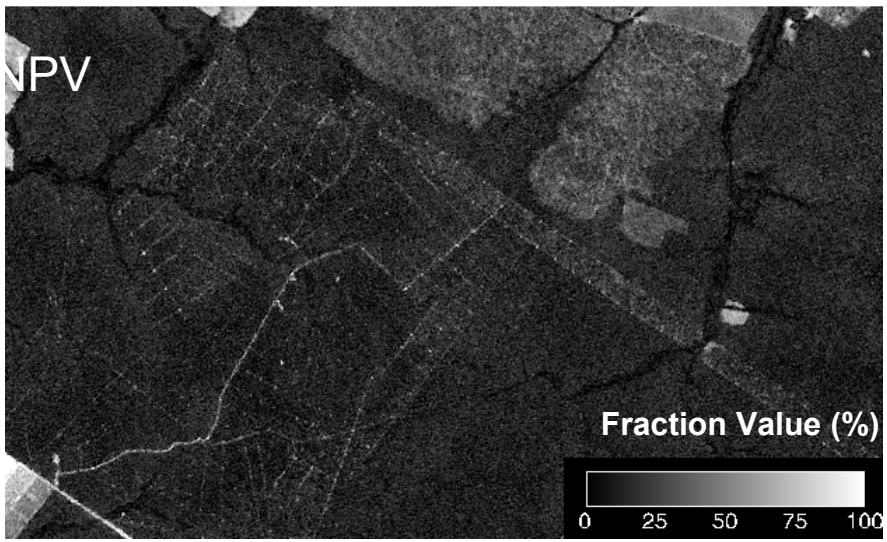


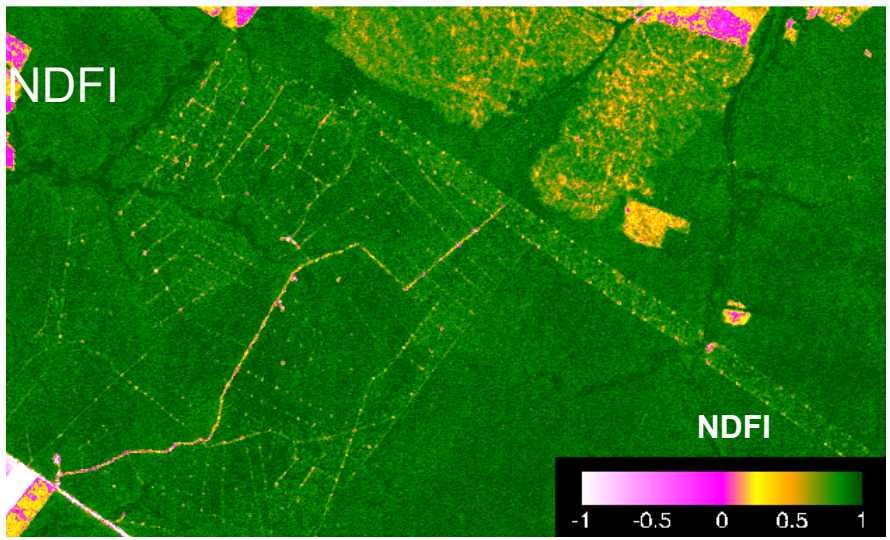
Souza Jr. et al. (2005), RSE

SMA Results



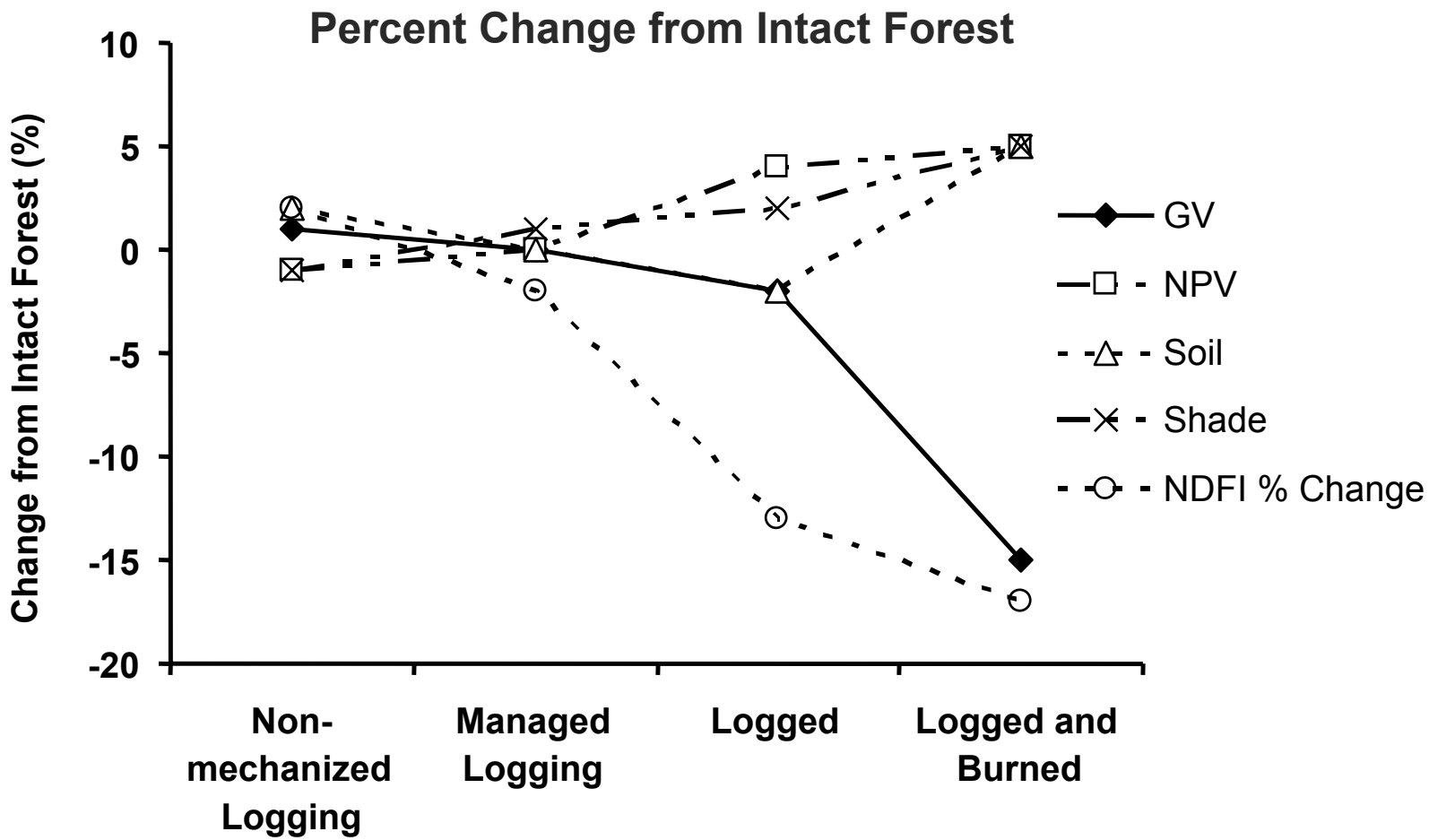






Souza Jr. et al. (2005), RSE

NDFI vs. Fraction Images



Souza Jr. et al. (2005), RSE

Class Separability

Class	Intact		Non-mechanized Logging		Managed Logging		Conventional Logging		Logged and Burned	
	Mean	Stdev.	Mean	Stdev.	Mean	Stdev.	Mean	Stdev.	Mean	Stdev.
GV										
NPV	6^{a}	2	5^{a}	2	6^{a}	2				
Soil	2^{a}	1	1^{a}	1					7^{d}	3
Shade	51^{a}	3	53^{a}	5					56^{d}	3
NDFI										

Tukey test at P<0.01

Souza Jr. et al. (2005), RSE

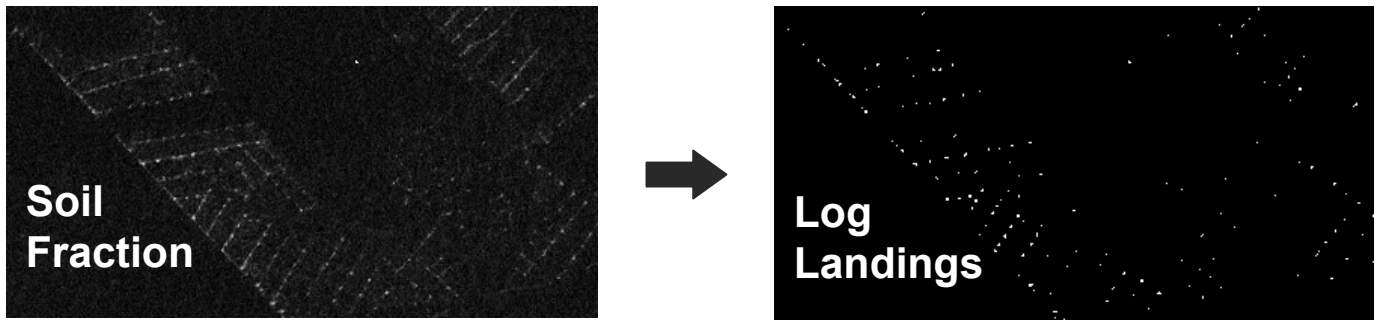
Contextual Classification Algorithm - CCA

Step 1: Find log landings

Soil > 10%

Find regions and calculate area

1 ≤ Area ≤ 4 pixels



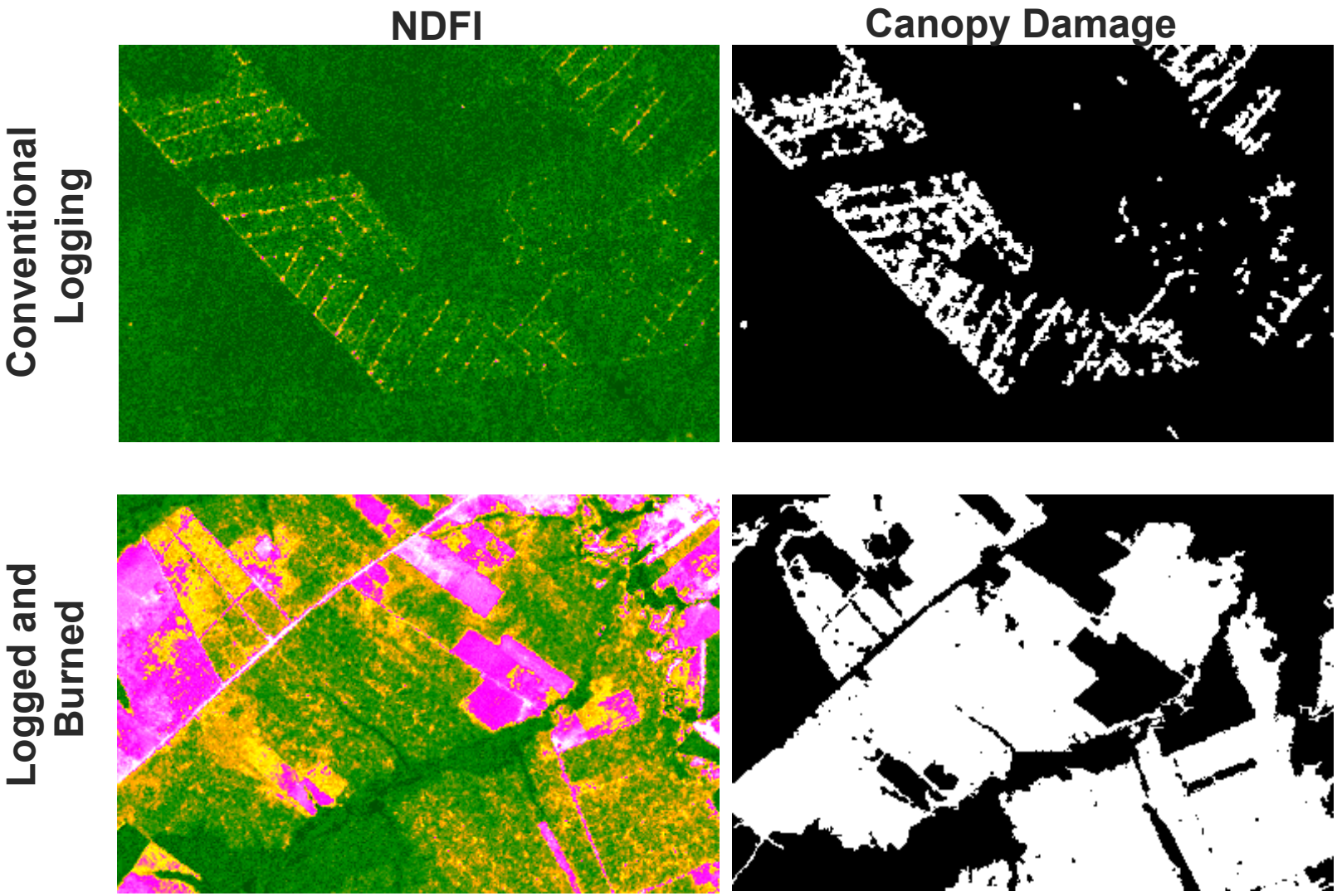
Step 2: Grow a canopy damage region around log landings

Search for NDFI neighboring cell values

If NDFI > 0.75 then **Intact Forest**

if 0 ≤ NDFI ≤ 0.75 then **Canopy Damage**

CCA Results

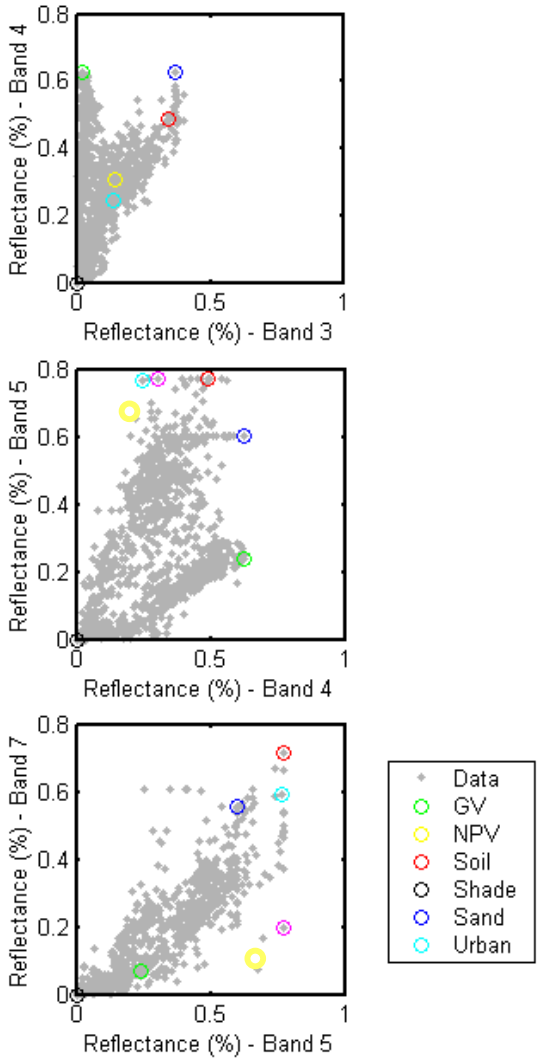

NDFI
Canopy Damage
Conventional Logging
Logged and Burned

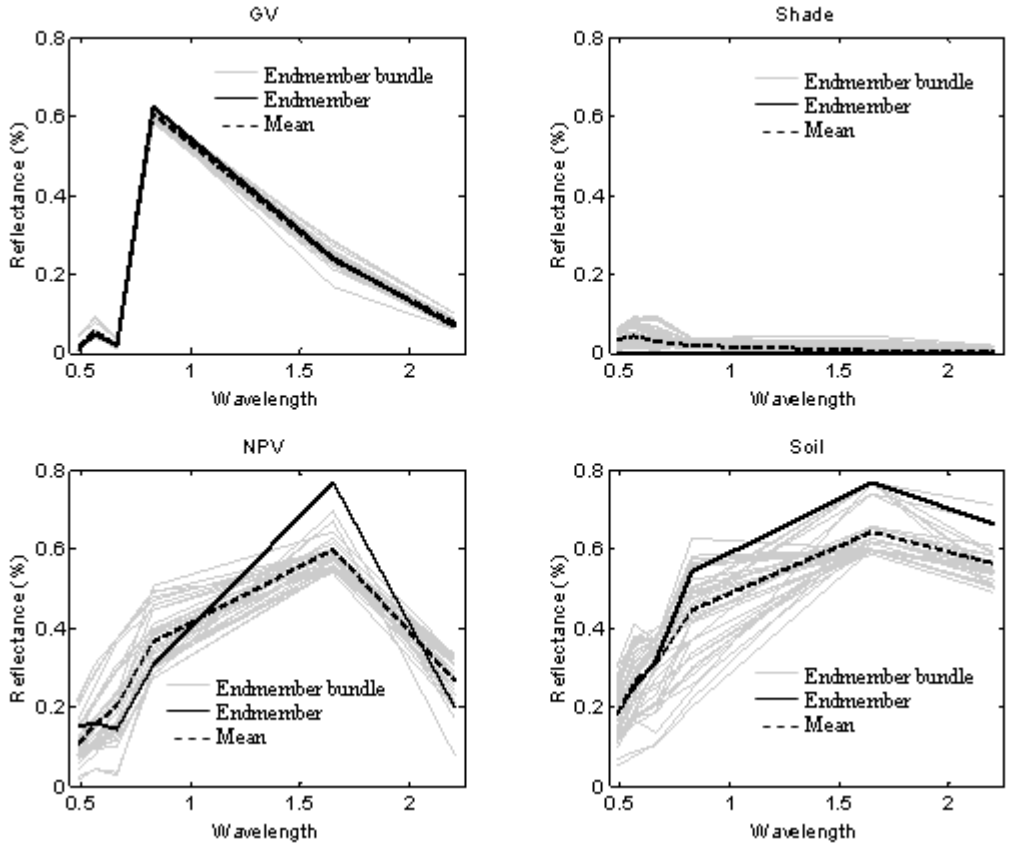
Accuracy Assessment

Classified Pixels	Reference Pixels				Users Accuracy (%)
	Non-forest	**Forest**	**Canopy Damage**	Total	
Non-Forest	454	0	17	471	96.4
Forest	6	625	117	748	83.6
Canopy Damage	40	0	616	656	**93.9**
Total	500	625	750	1875	
Producers Accuracy (%)	91.0	100.0	82.0		

Overall Accuracy = (1695/1875) = **90.4%**
Kappa Coefficient = 0.85

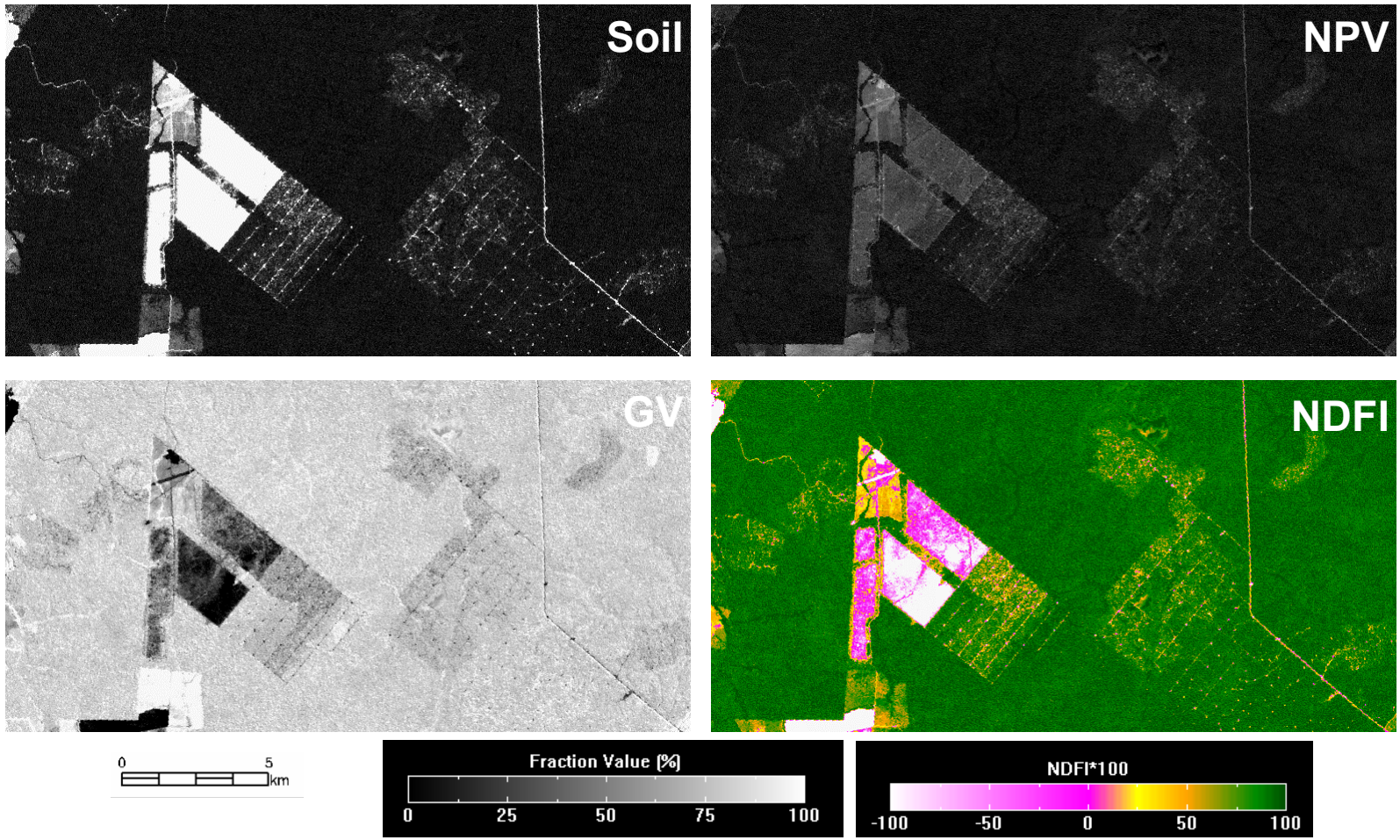
Generic Image Endmembers





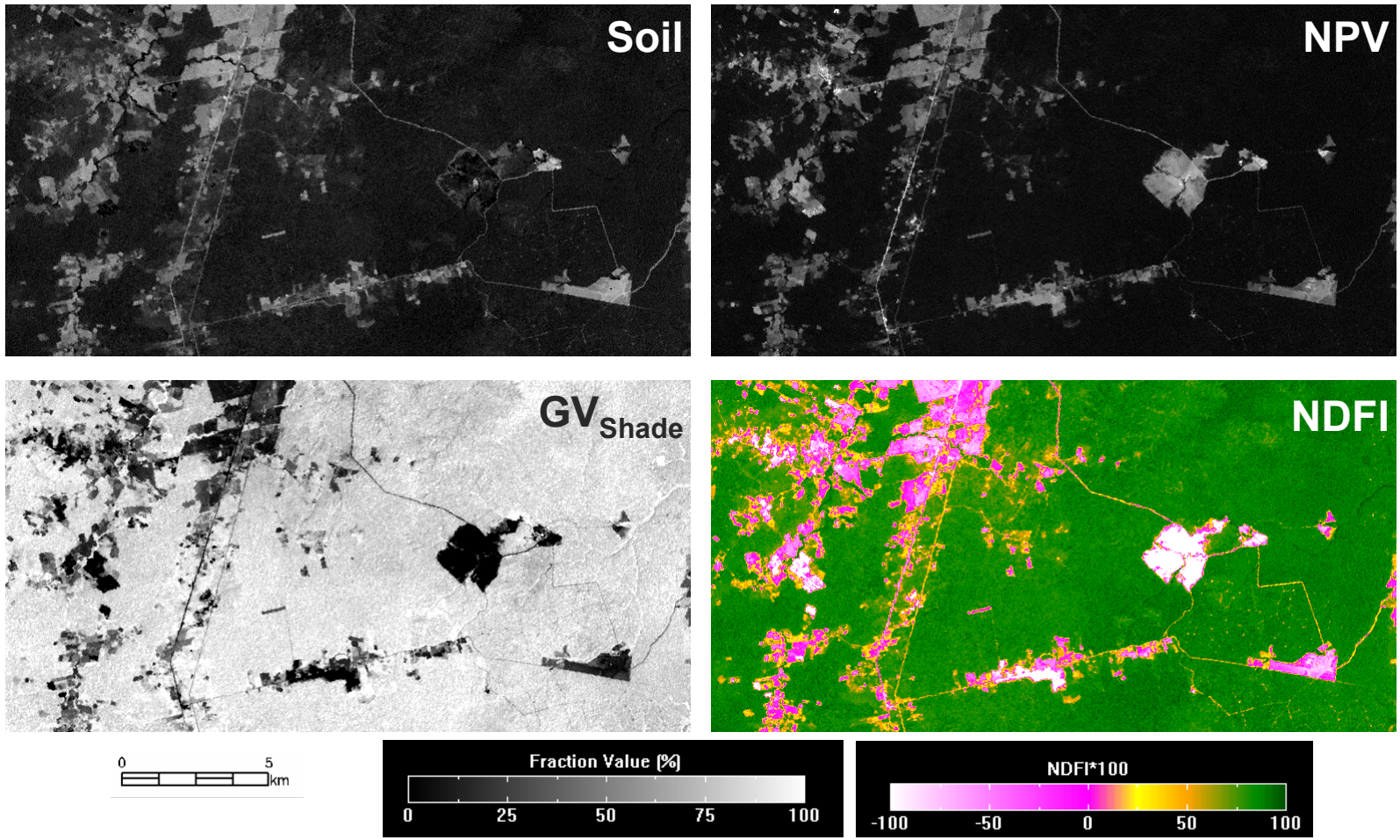
Standardized Fractions and NDFI

a) Paragominas,Pará State - 223/62



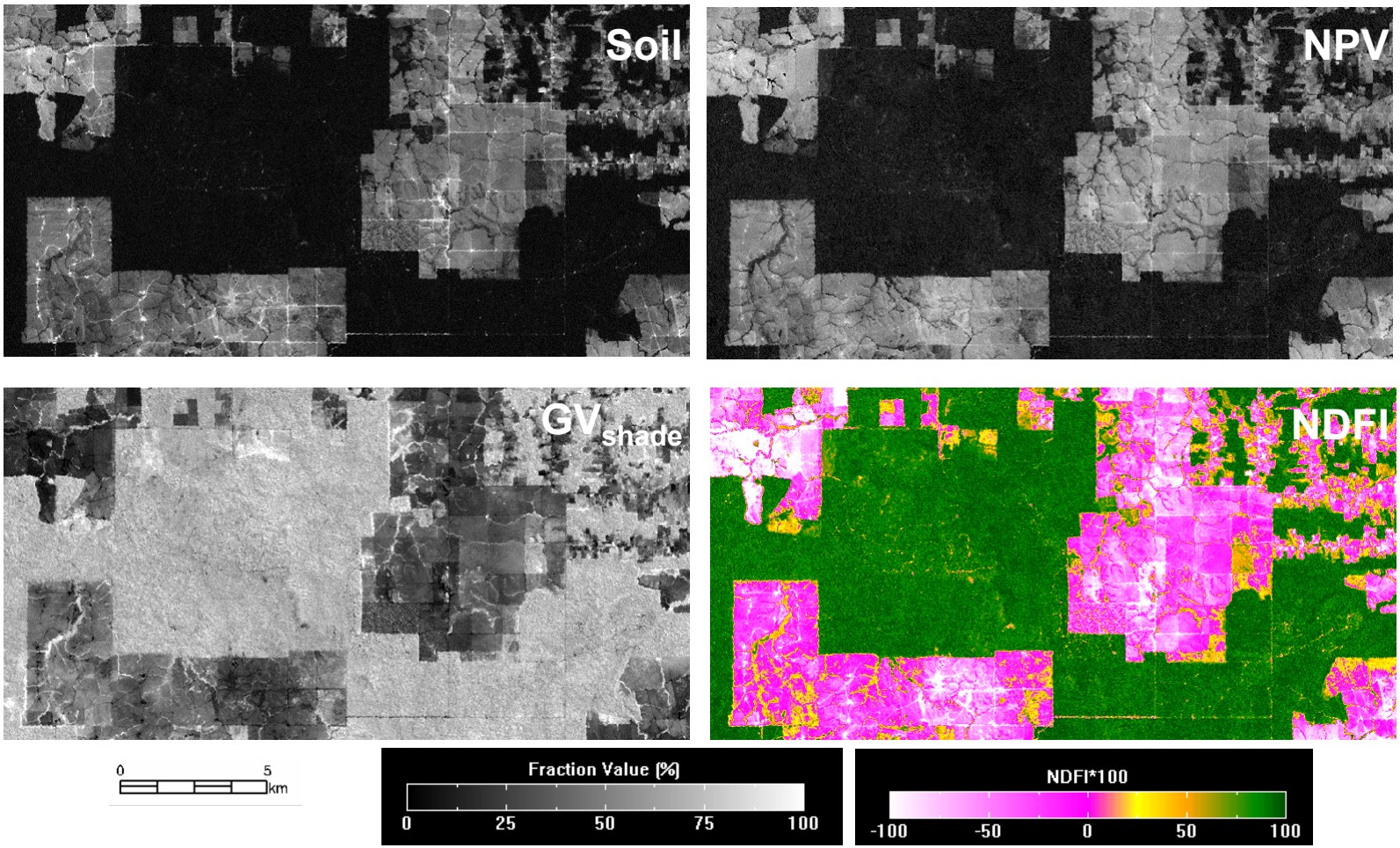
Standardized Fractions and NDFI

b) Santarém, Pará State - 227/62

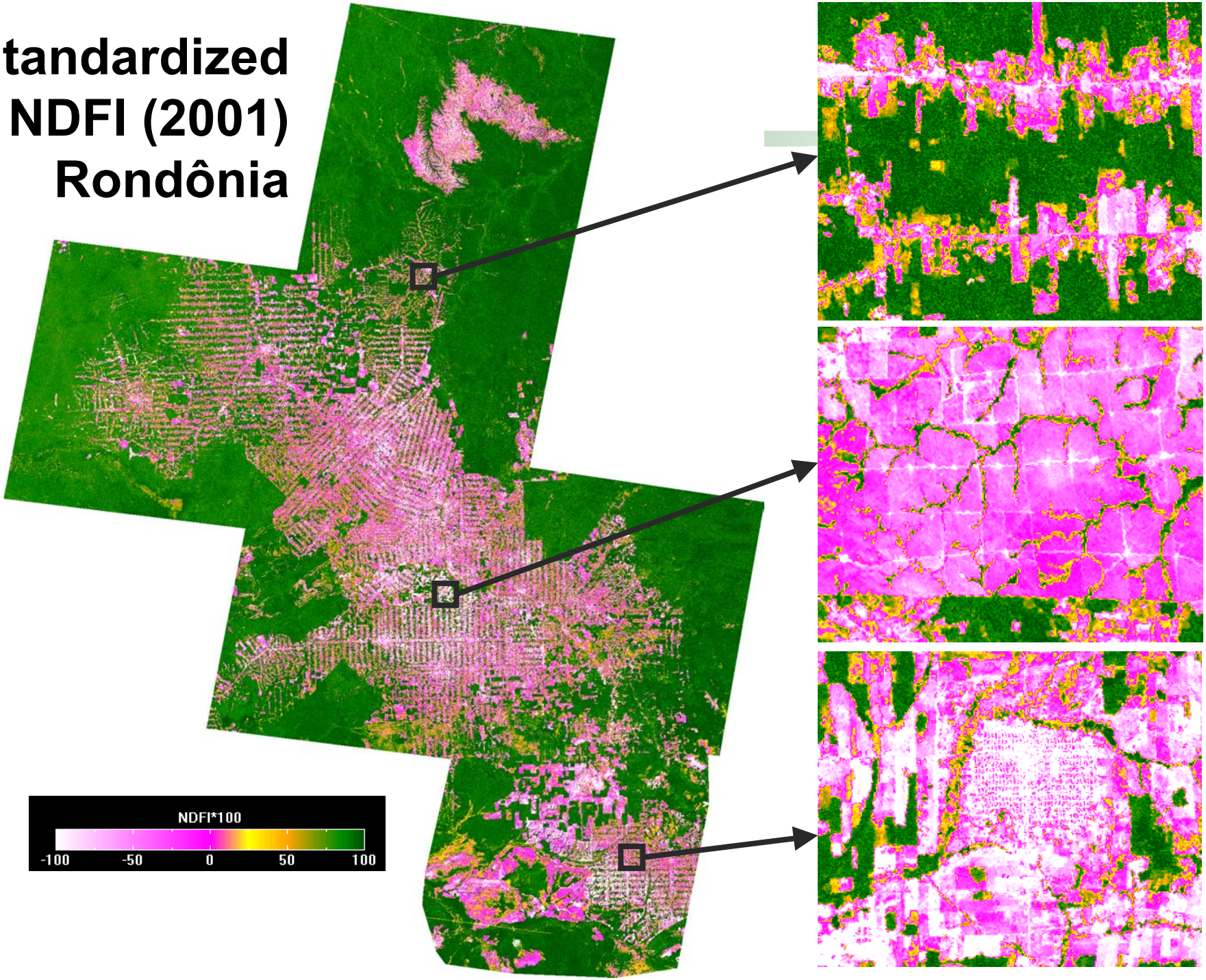


Standardized Fractions and NDFI

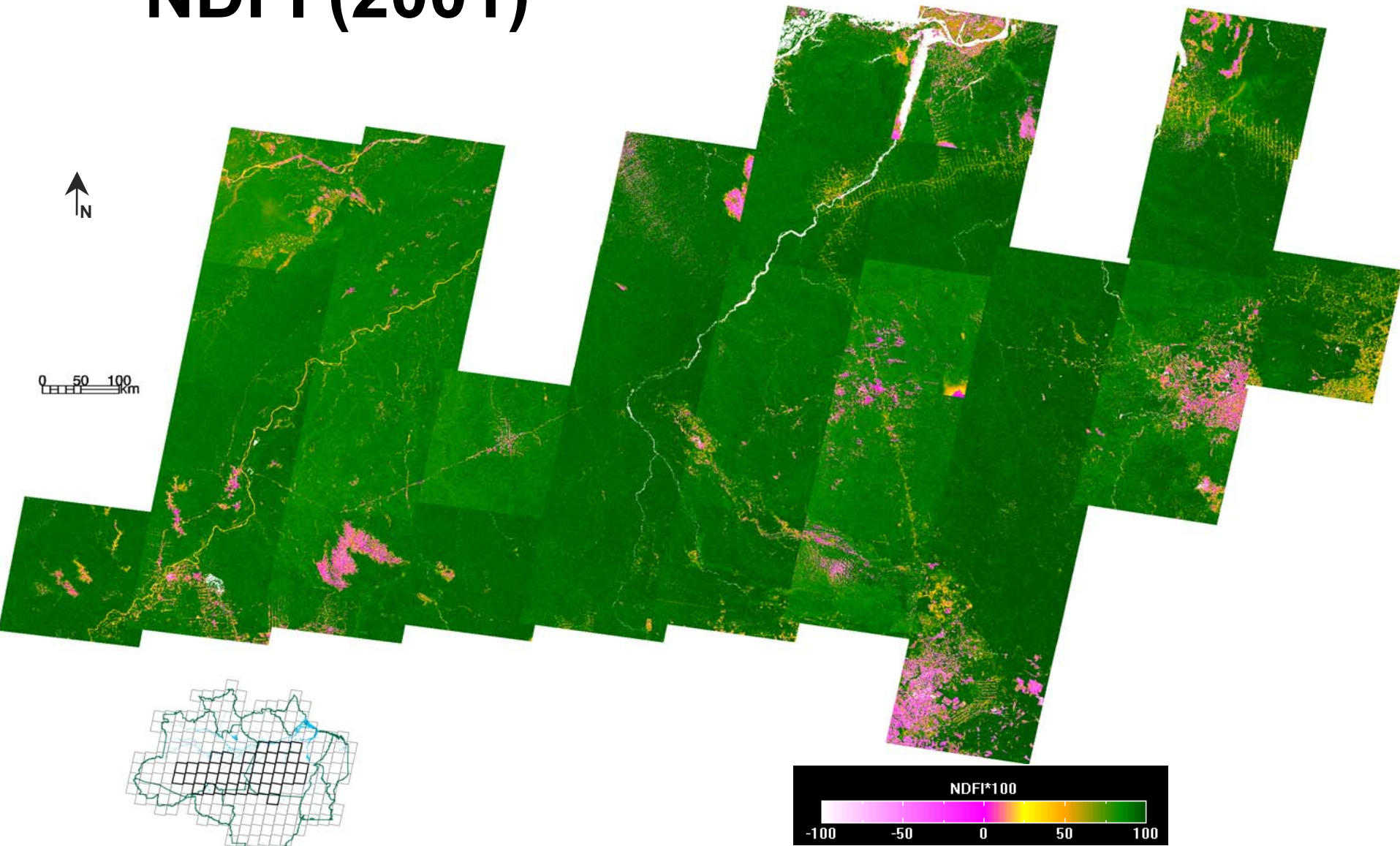
c) Ji-paraná, Rondônia State - 231/67



Standardized NDFI (2001) Rondônia



Standardized NDFI (2001)



Summary

- NDFI enhances the detection and mapping of degraded forests and performs better than any individual fraction.
- CCA can unambiguously map canopy damage due to selective logging and forest fires.
- These techniques can be applied over the Amazon region.