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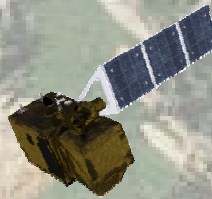
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Landslide Detectability with Coarse Resolution Imagery: A Sentinel-2 Emulation Study to Access Spectral Landslide Discrimination



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LAndslide **M**odelling and tools for vulnerability assessment **P**reparedness and **R**Ecovery management

Outline

- I. Overview***
- II. Data***
- III. Classification analysis***
- IV. Spectral separability analysis***
- V. Discussion and future work***

Aims & Objectives

Aims

To evaluate Sentinel-2 (10m) vs. higher spatial resolution (2.4m) Quickbird imagery for landslide mapping.

Objectives

How accurate is the landslide mapping?

How does this change with spatial resolution?

Overview

Classification analysis

A. Sentinel 2
Emulated imagery

B. Landslide
Mapping
(Mondini *et al.*, 2011)

C. Accuracy
assessment

Spectral analysis

D. Photo-Interpreted
Landslide
Inventory

E. Downgrade Coarse
resolution

F. Spectral
discrimination by
mixture/size class



Outline

I. Overview

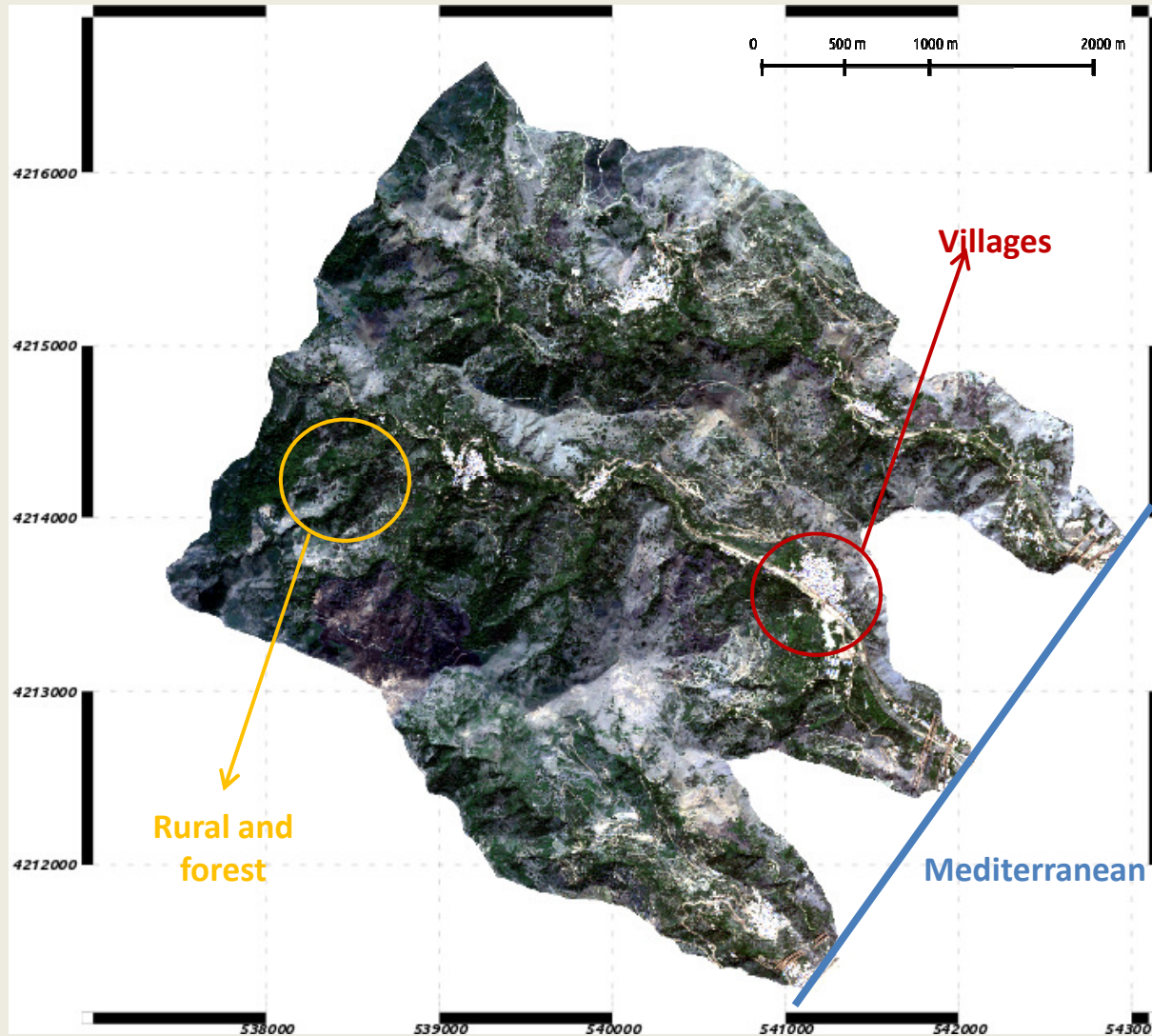
II. Data

III. Classification analysis

IV. Spectral separability analysis

V. Discussion and future work

Study area



Total area
15,180,216 m²

3 catchments

- C1. Briga (38.5%)
- C2. Gianpileri (45.3%)
- C3. Scaletta (16.2%)

Pre-event Quickbird image – 2 September 2006



Data - Satellite Imagery

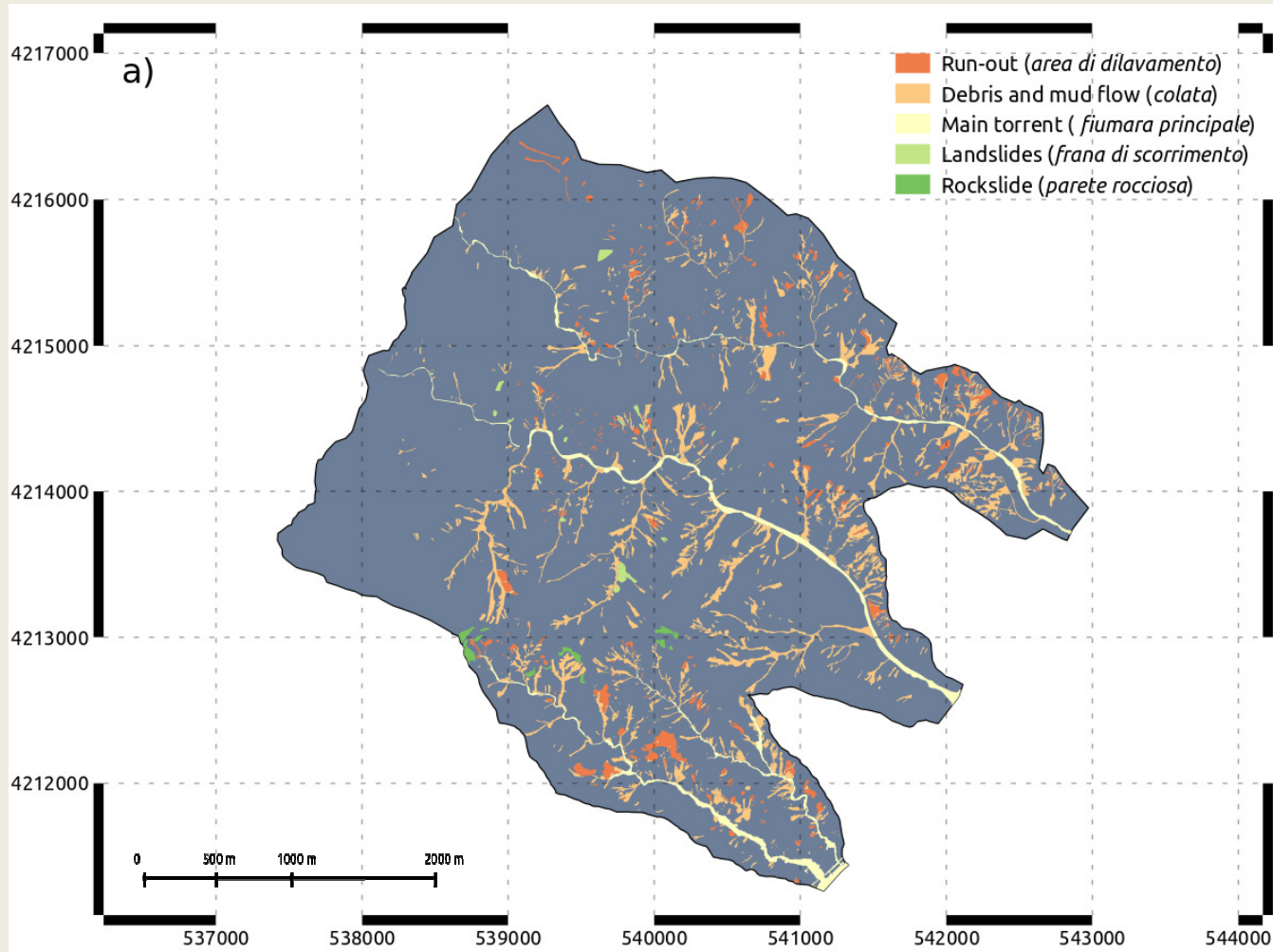
Satellite sensor spectral characteristics

Spectrum	#	Sentinel 2			Quickbird		
		Central wavelength (nm)	Band width (nm)	Spatial resolution (m ²)	Central wavelength (nm)	Band width (nm)	Spatial resolution (m ²)
Pan					625	350	0.6
	1	443	20	60			
Blue	2	490	65	10	485	70	2.4
Green	3	560	35	10	560	80	2.4
Red	4	665	30	10	645	30	2.4
	5	705	15	20			
	6	740	15	20			
	7	783	20	20			
NIR	8	842	115	10	880	240	2.4
	8b	865	20	20			
	9	945	20	20			
	10	1380	30	20			
	11	1610	90	20			
	12	2190	180	20			

Pre-event: Quickbird – 2 September 2006 (~ 3 yr before)

Post-event: Quickbird – 8 October 2009 (7 days after)

Inventory of Debris and Mud Flows



Triggered event

Heavy rainfall on 1 October 2009

Landslide type

Mud and debris flows
7.9%

Inventory

Aerial photo interpretation
(1:10,000)

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Image pre-processing

1. Image emulation

Original
Quickbird 2.4 m²
images

Apply *sinc* function
kernel to obtain 9.6 m²
Images

2. Pre-processing

Ortho-rectify
with GCP

Atmospheric
correction (DOS)

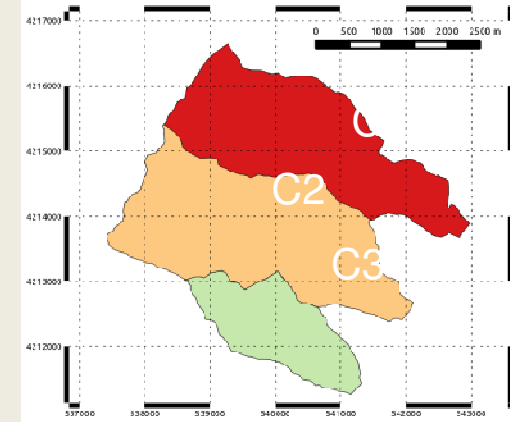
Image pair-set
Normalization

3. Change detection

Calculate Indices (NDVI difference, Spectral angle,
Principal and independent components)

Classification model

1. Use 10% of pixel data from catchment (C2) as training set



Logistic Regression

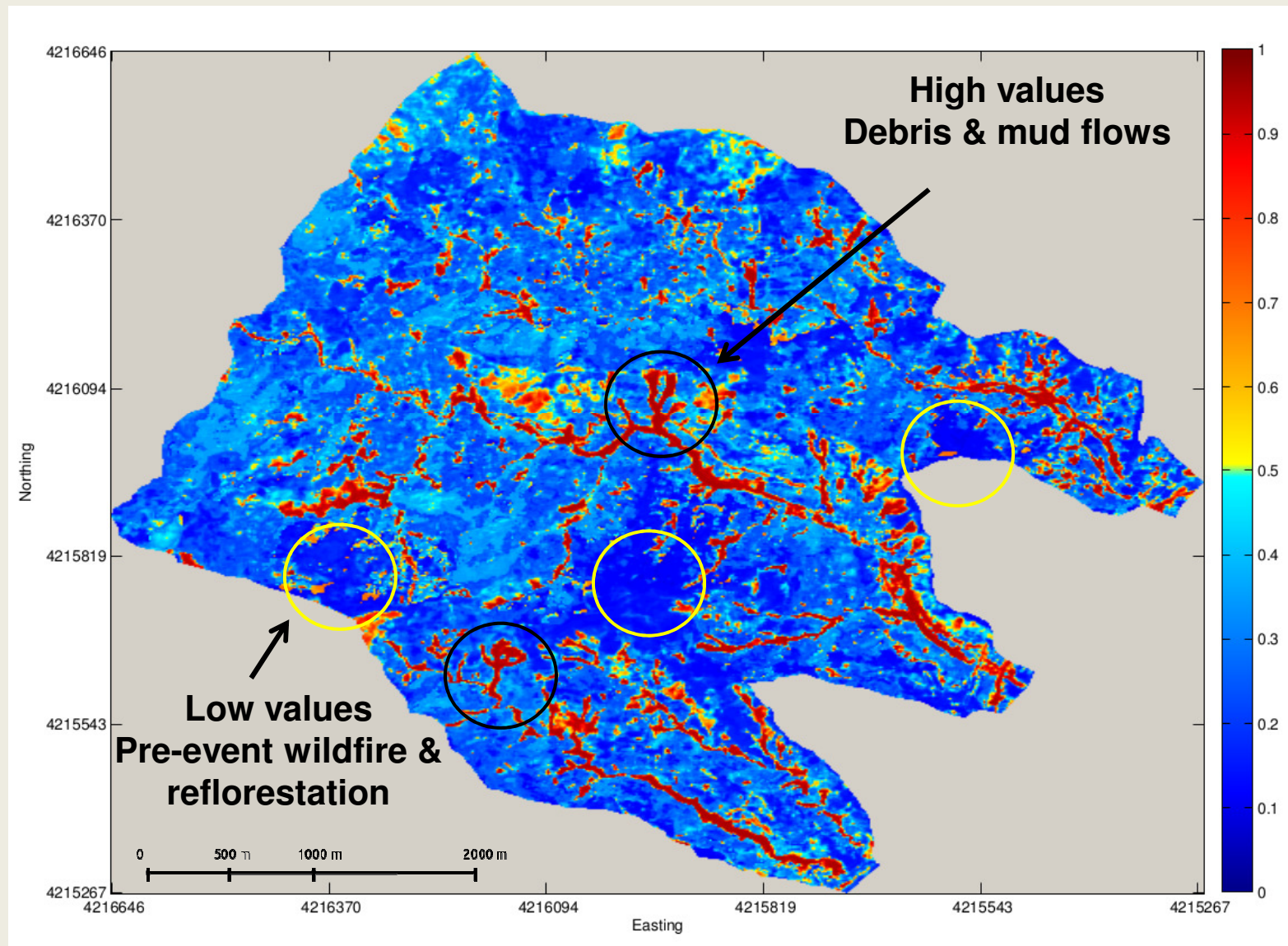
Linear discriminate analysis

Quadratic discriminate analysis

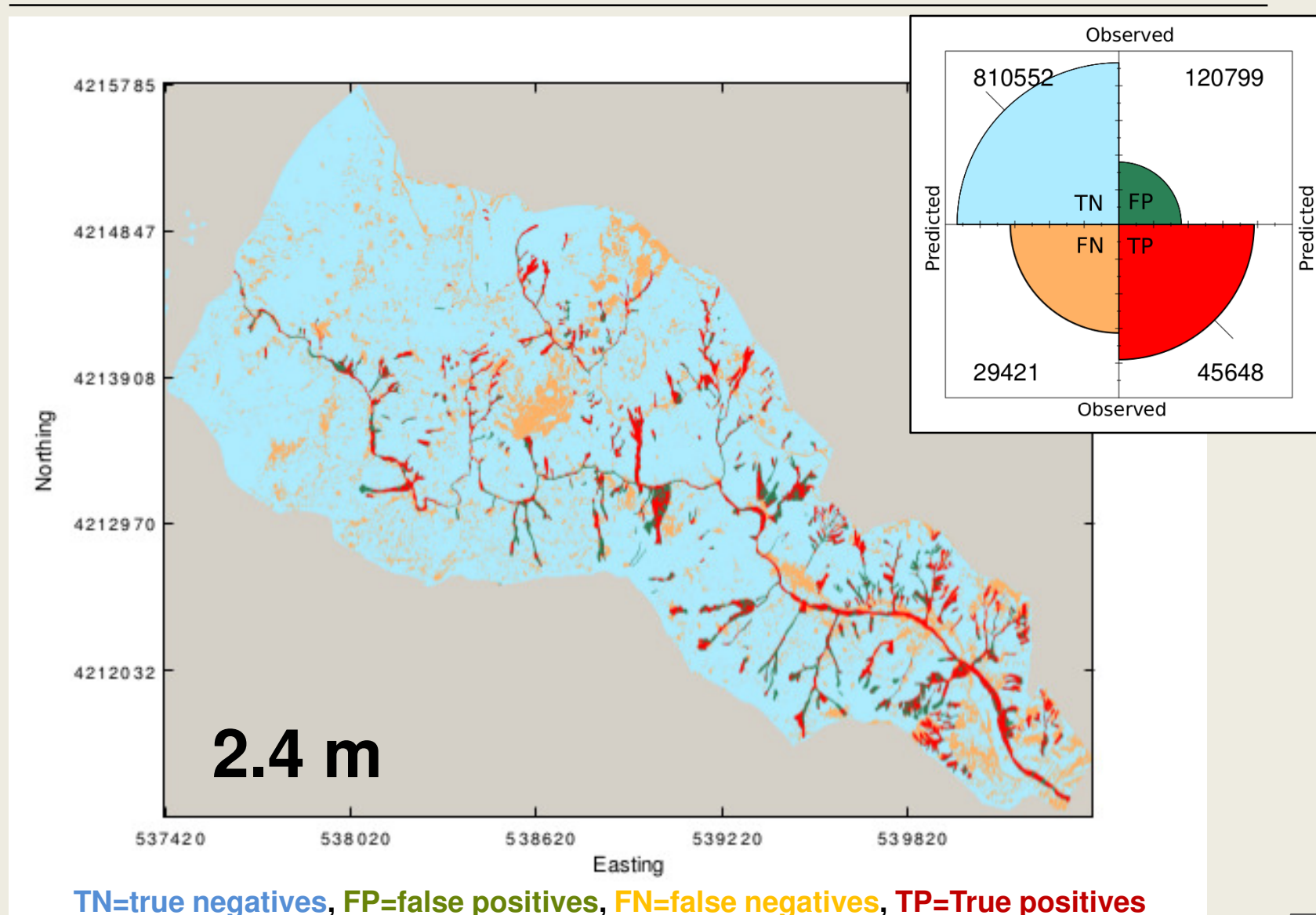
Combine model - logistic regression based

Accuracy assesment based map comparison

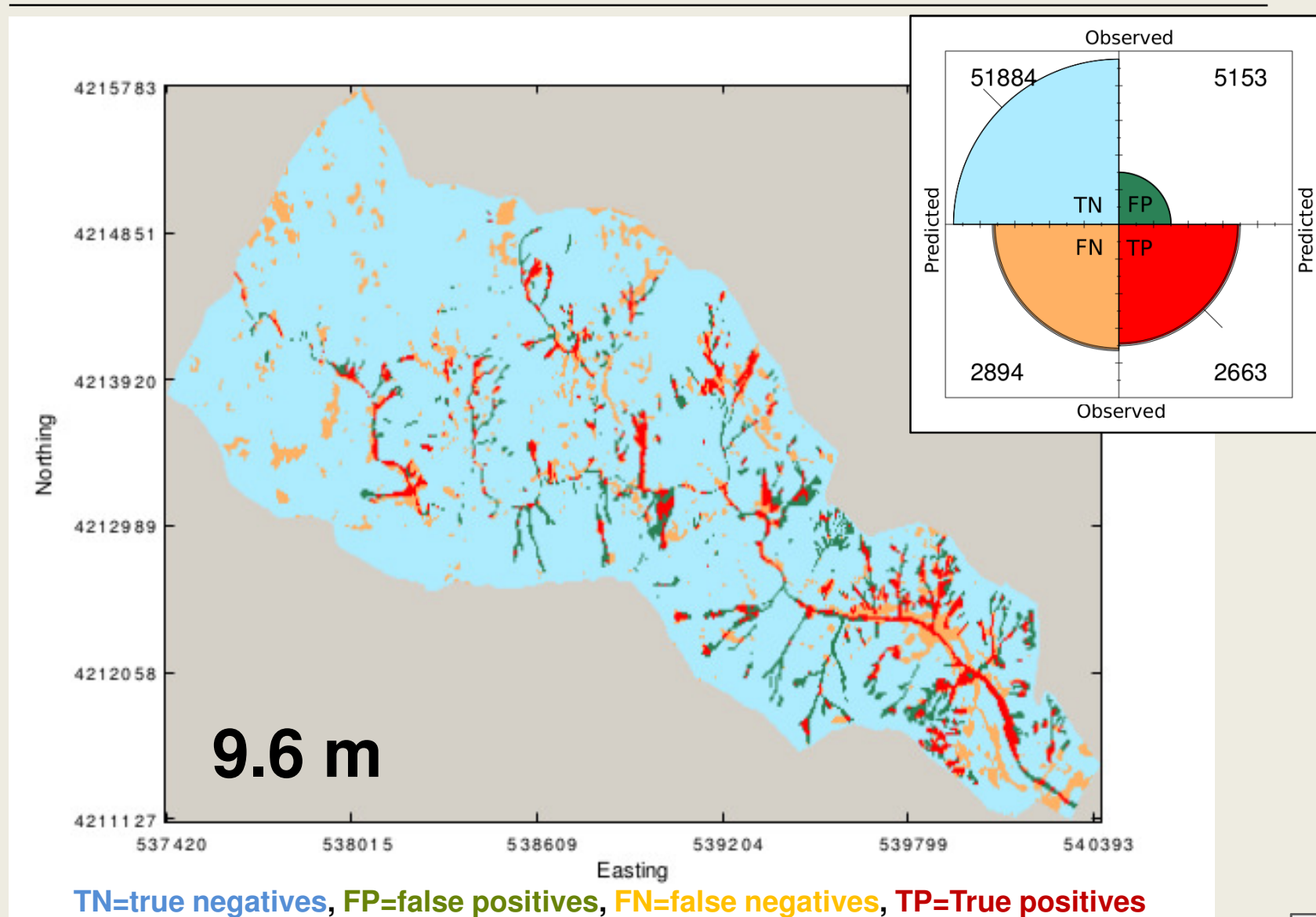
Mapping results



Accuracy – catchment 1



Accuracy – catchment 1



Accuracy – catchment 1

Catchment	Accuracy (%)	2.4 m ²	9.6 m ²
C1	Overall	87.1	85.0
	Commission errors	9.0	12.9
	Omission errors	5.3	3.5
	Kappa	32.6	30.4
C2	Overall	85.2	83.3
	Commission errors	12.4	15.3
	Omission errors	4.2	3.2
	Kappa	36.0	32.1
C3	Overall	86.3	86.2
	Commission errors	12.3	11.3
	Omission errors	3.5	4.9
	Kappa	50.9	50.0

Accuracy decreases by **2%** as spatial resolution is reduced **fourfold**

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Spectral separability

1. Selection of debris flow and landslide class and separate **source** from **run-out** areas

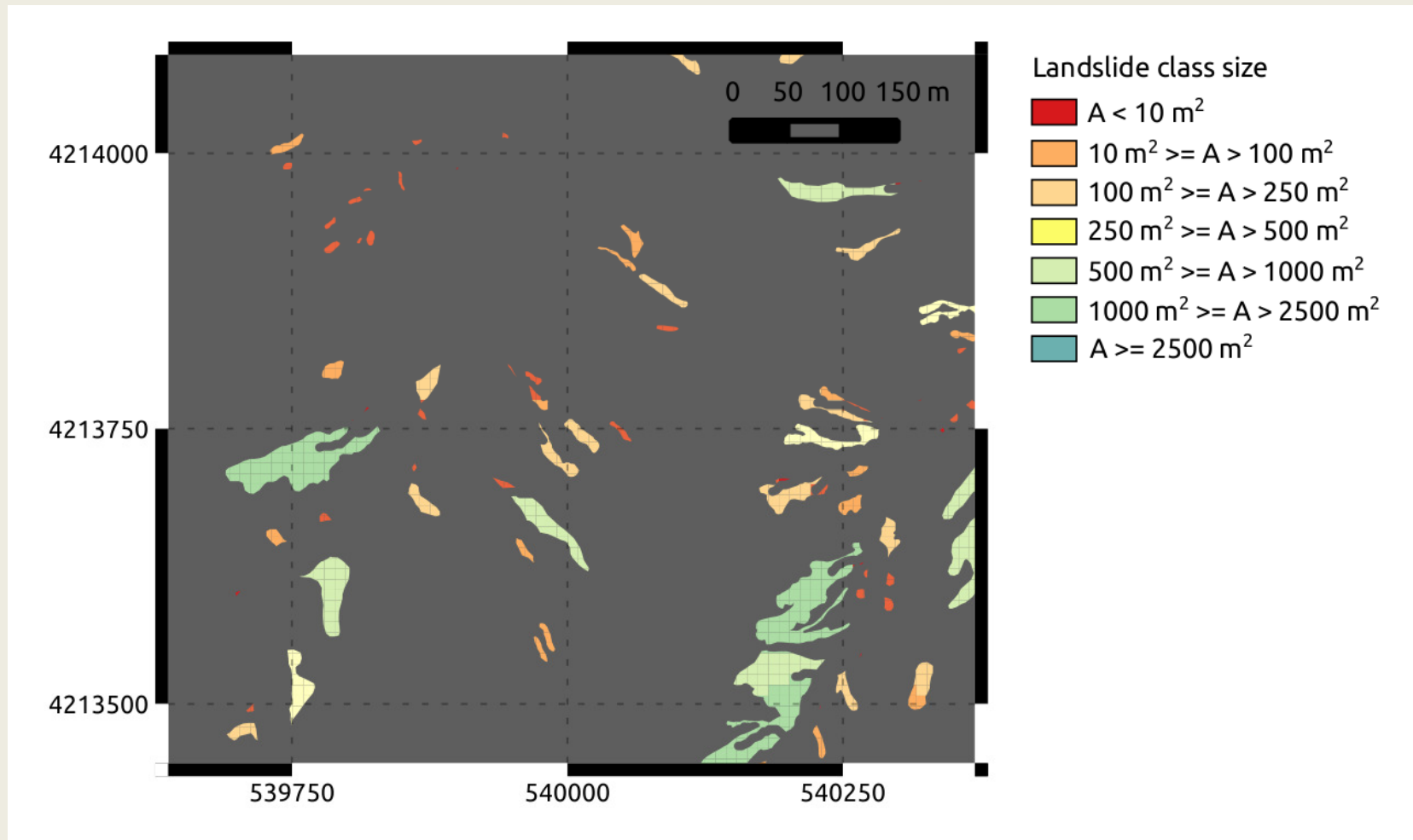
2. Classify individual landslides by **area**:
10, 100, 250, 500, 1000, 2500 m²

3. Landslide buffering with equal area to determine **stable** from **unstable** areas

4. **Downgrade** inventory and determine each cells proportion of stable and unstable

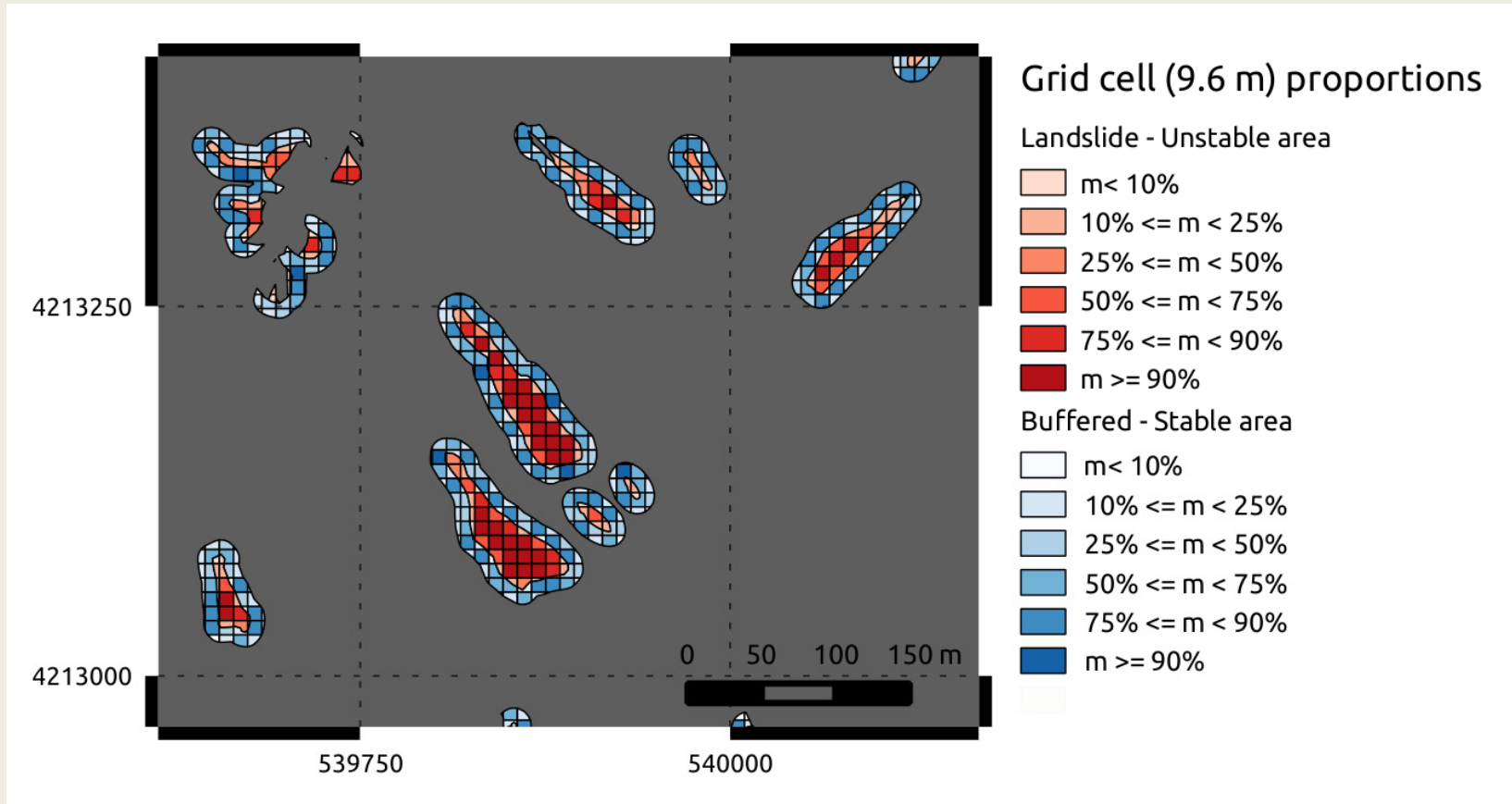
5. Extract **Imagery pixels** values and evaluate spectral separability

Landslide size classes



- Determine individual landslide patch size and divide them into size classes

9.6m resolution Inventory proportions

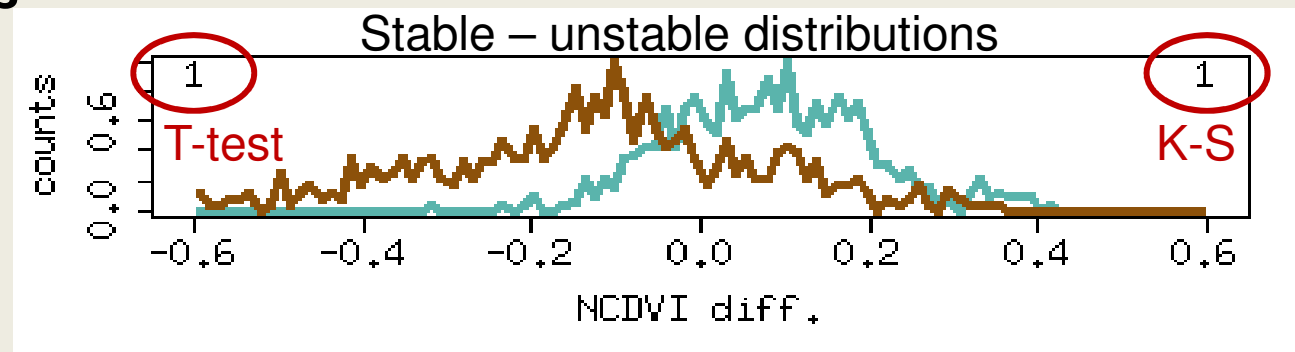


- Stable areas are defined by buffering unstable stable areas in equal overall area
- Overlay 9.6m grid and determine each cell stable and unstable area proportion

Spectral separability – 1D

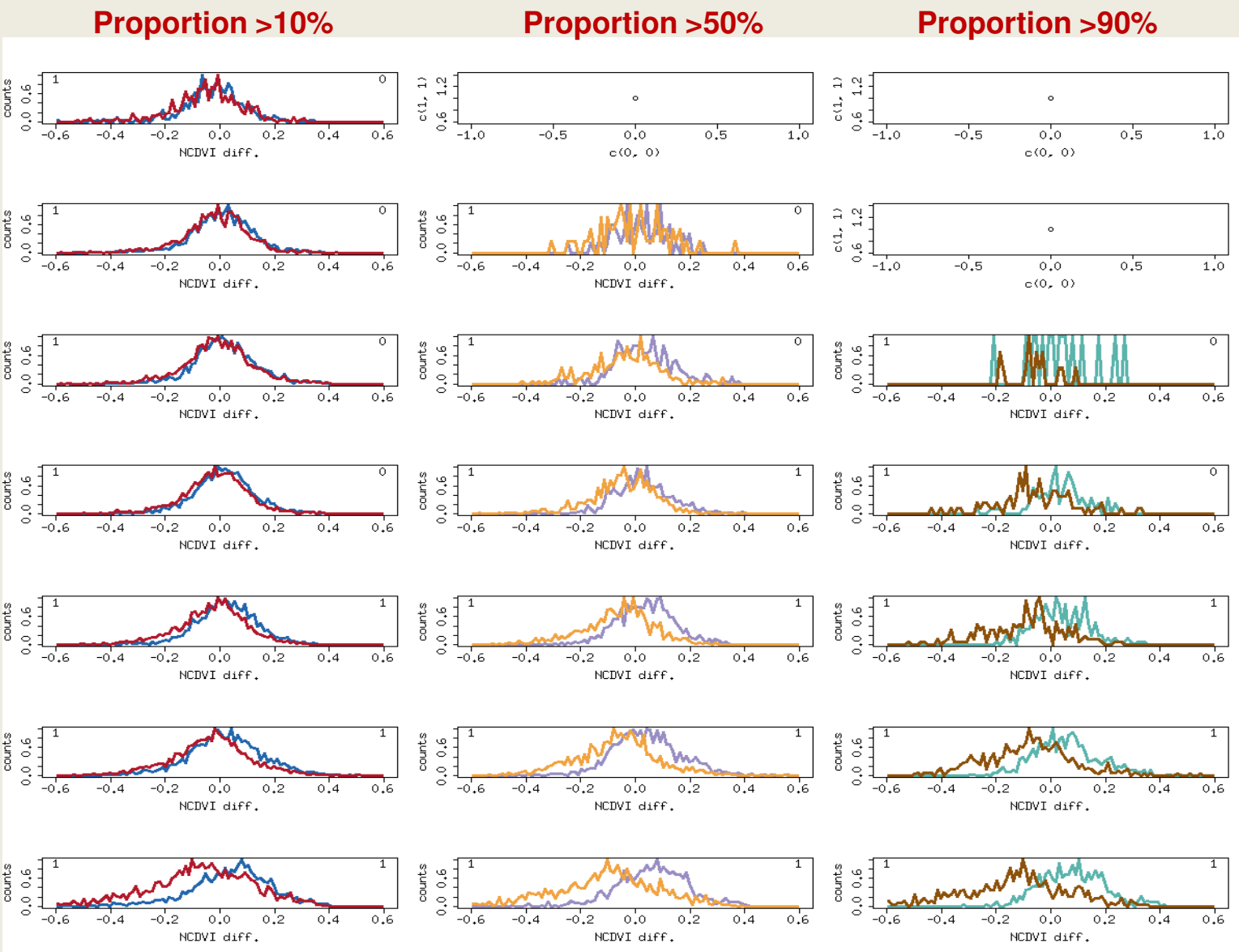
How **distinctive** are the distributions of pixel values for the stable and unstable areas at 9.6 m?

- Used the two-way t-test to evaluate if the mean of the two populations are significantly different
 - 1 = yes
 - 0 = no
- Kolmorov-Smirnov to asses if samples are drawn from the same distribution
 - 1 = yes
 - 0 = no





Spectral Seperability: 1-D



$A < 10m^2$

$10 m^2 < A \leq 100 m^2$

$100 m^2 < A \leq 250m^2$

$250 m^2 < A \leq 500m^2$

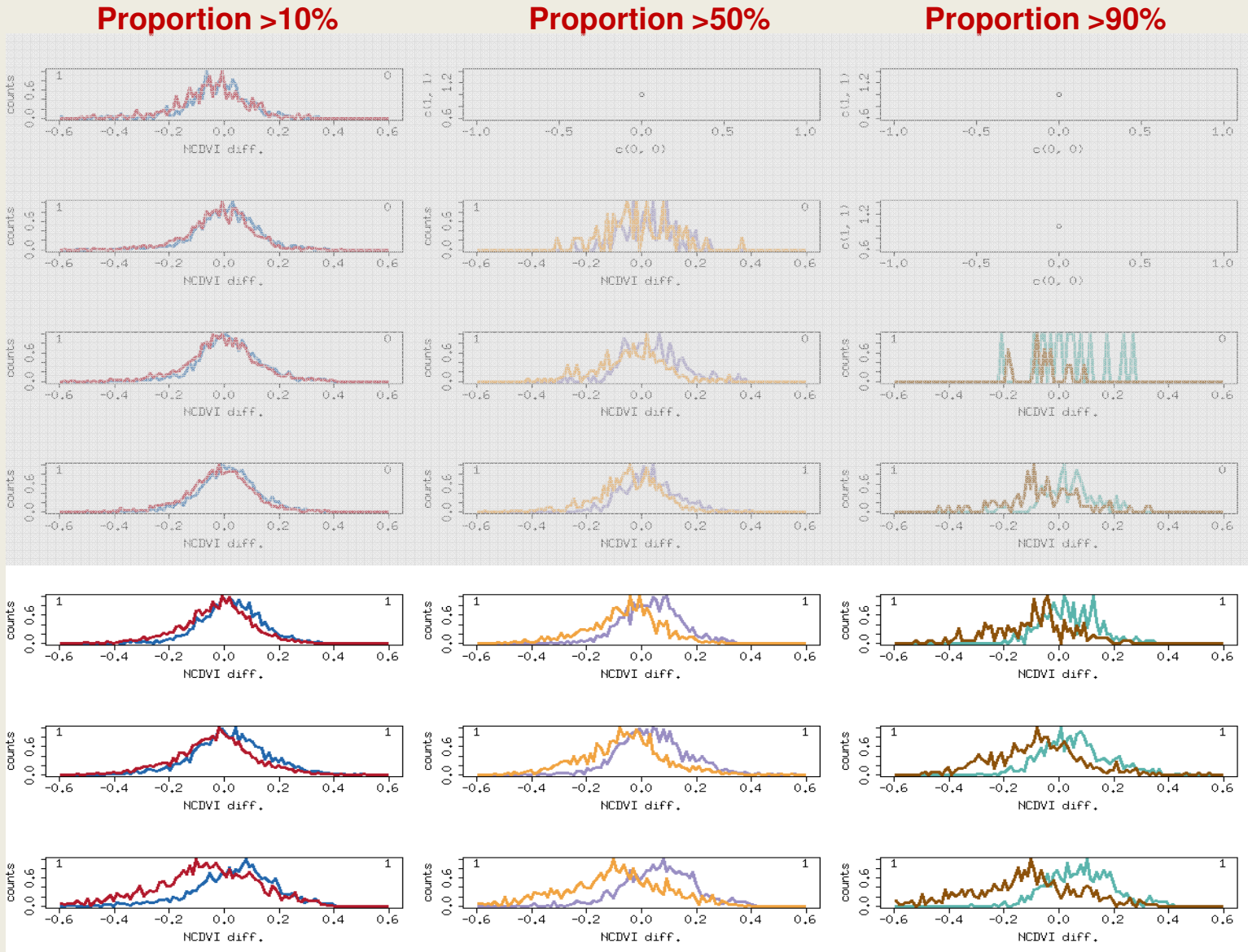
$500 m^2 < A \leq 1000m^2$

$1000 m^2 < A \leq 2500m^2$

$A > 2500 m^2$



Spectral Seperability: 1-D



$A < 10m^2$

$10 m^2 < A \leq 100 m^2$

$100 m^2 < A \leq 250m^2$

$250 m^2 < A \leq 500m^2$

$500 m^2 < A \leq 1000m^2$

$1000 m^2 < A \leq 2500m^2$

$A > 2500 m^2$

Spectral separability – 4-D

What about when we look at the **full dimension** using all the image based derived change detection indexes?

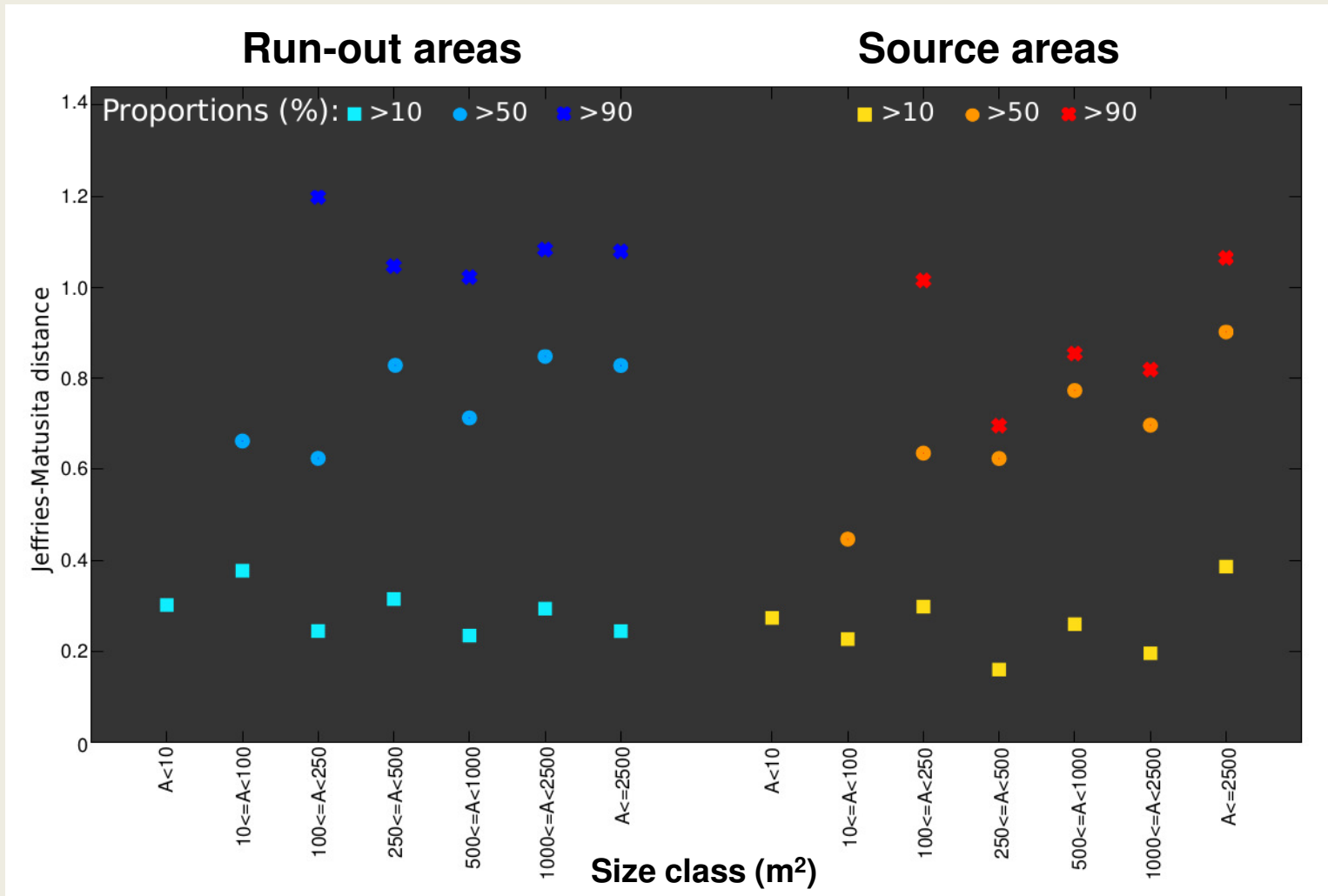
- NDVI difference
- Spectral angle
- Principal and independent components

Calculate Jeffreys-Matusita Distance.

- Based on Bhattacharyya distance
- Takes into account means and co-variances between the two multi-dimensional sets
- Range 0.0 - 1.4

Spectral Separability: 4-D

Stable-unstable spectral separability measure for run-out and source areas by landslide class and level of mixture



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Conclusions

Classification

- Accuracy decreases only slightly for lower resolution.
 - Sentinel-2 should work well for landslide mapping.
- Large patches of commission errors suggest much of this change is not landslide related.
 - Caused by large time between pre-post imagery.
 - Easily overcome by Sentinel-2 (revisit = 5 days at equator).

• Spectral separability

- Stable and unstable pixel value distributions are more distinguishable for larger landslides because of less spectral mixing.
- Separability is lower for source areas than for run-outs.
- For both categories a level of mixture less than 50% provides a significant separation between stable and unstable areas.

Future work

- Explore other mapping classification methods
- Evaluate Landsat-8 pan-sharpened imagery (~15m²)
- Apply to different landslide triggered events.
- Determine if a reliable frequency size distribution for triggered event landslides can be extracted using only coarse resolution imagery.
 - This would allow forecasting of how many small landslides occurred by only detecting the big landslides.
 - Big landslides are easily detected at coarse resolution.

References

A.C. Mondini, F. Guzzetti, P. Reichenbach, M. Rossi, M. Cardinali, F. Ardizzone (2011) "Semi-automatic recognition and mapping of rainfall induced shallow landslides using optical satellite images" Remote sensing of Environment, Vol.115, Issue 7

THANK YOU
