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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 Modelling and tools for vulnerability assessment Preparedness and REcovery 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

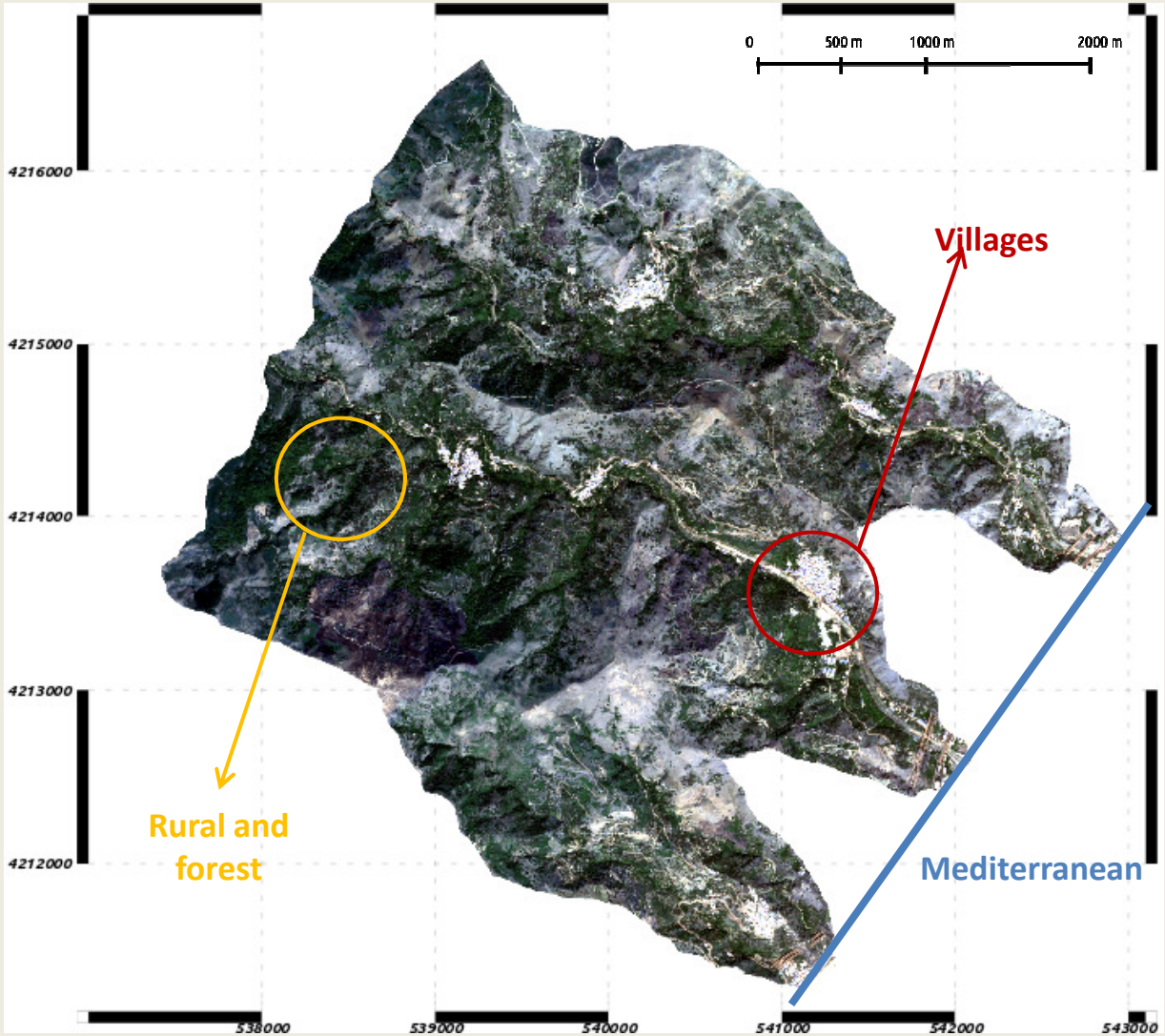
D. Photo-Interpreted Landslide Inventory

E. Downgrade Coarse resolution

F. Spectral discrimination by mixture/size class

Outline

Study area



Total area
15,180,216 m²

3 catchments
C1.Briga (38.5%)
C2.Gianpilieri (45.3%)
C3.Scaletta (16.2%)

Pre-event Quickbird image – 2 September 2006

Data - Satellite Imagery

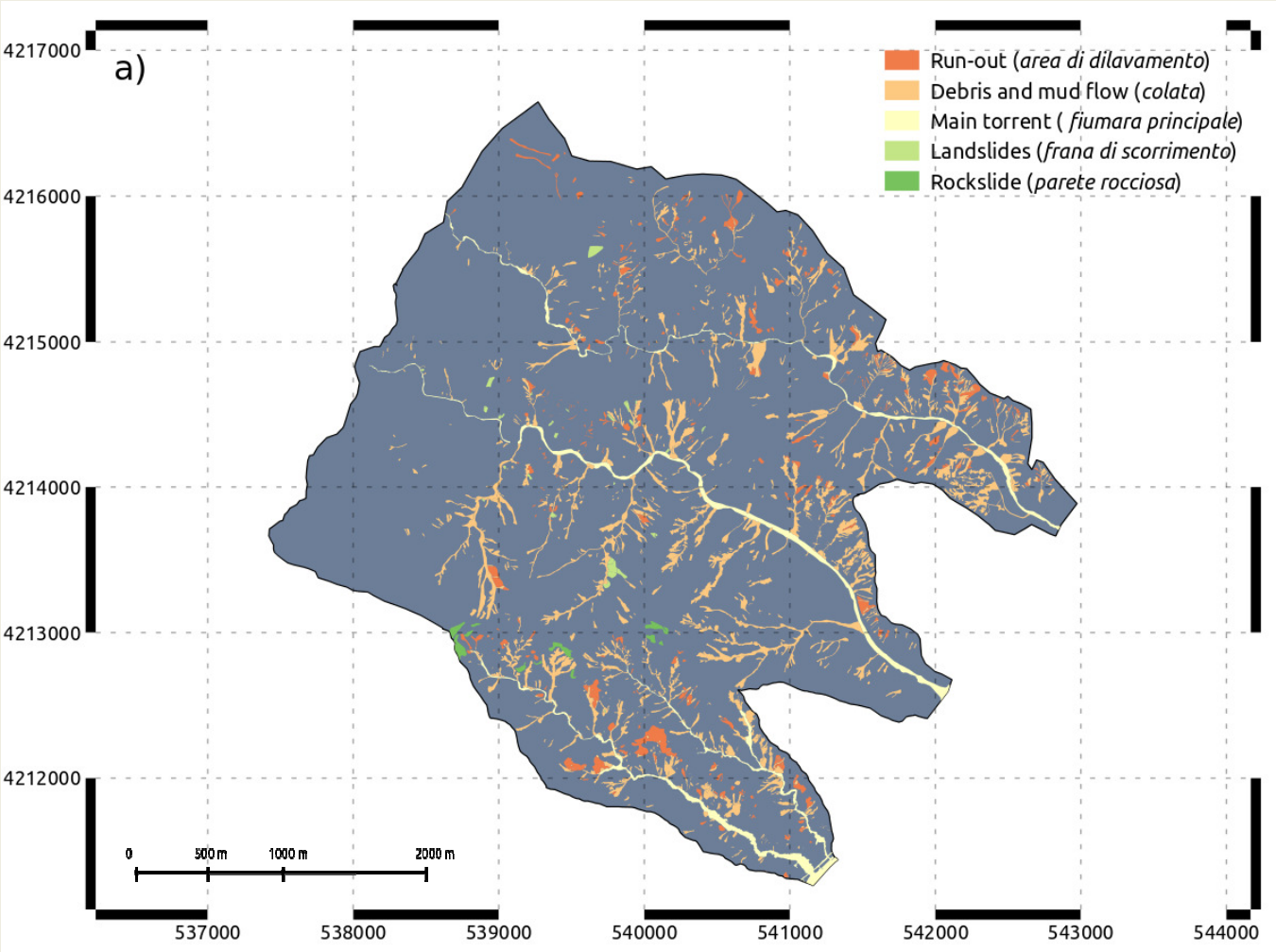
Satellite sensor spectral characteristics

		Sentinel 2			Quickbird		
Spectrum	#	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)

Outline

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

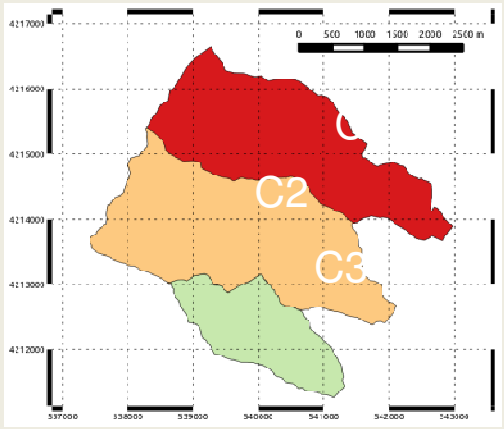
- Ortho-rectify with GCP
- Atmospheric correction (DOS)
- Image pair-set Normalization

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

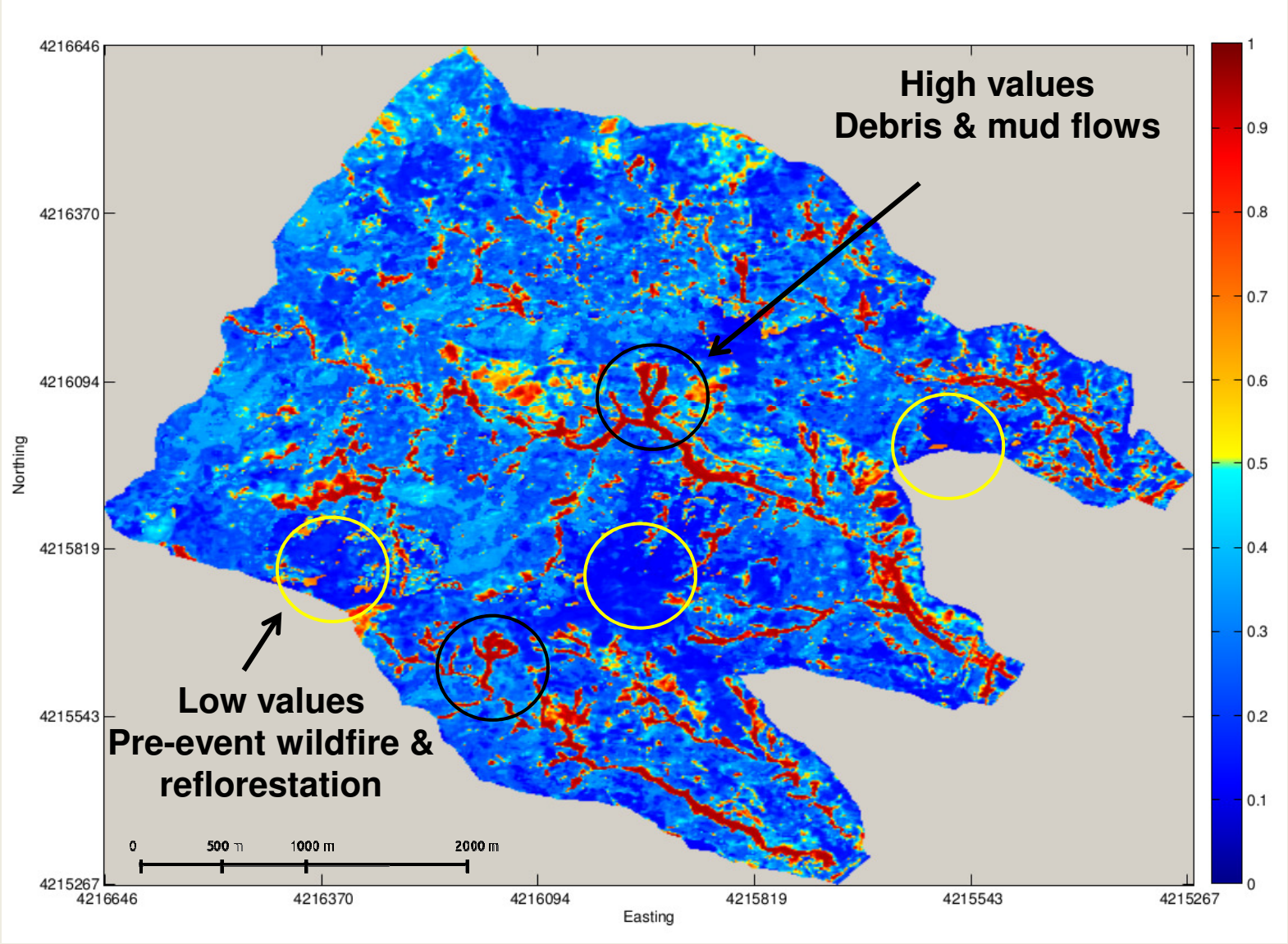
Linear discriminate analysis

Quadratic discriminate analysis

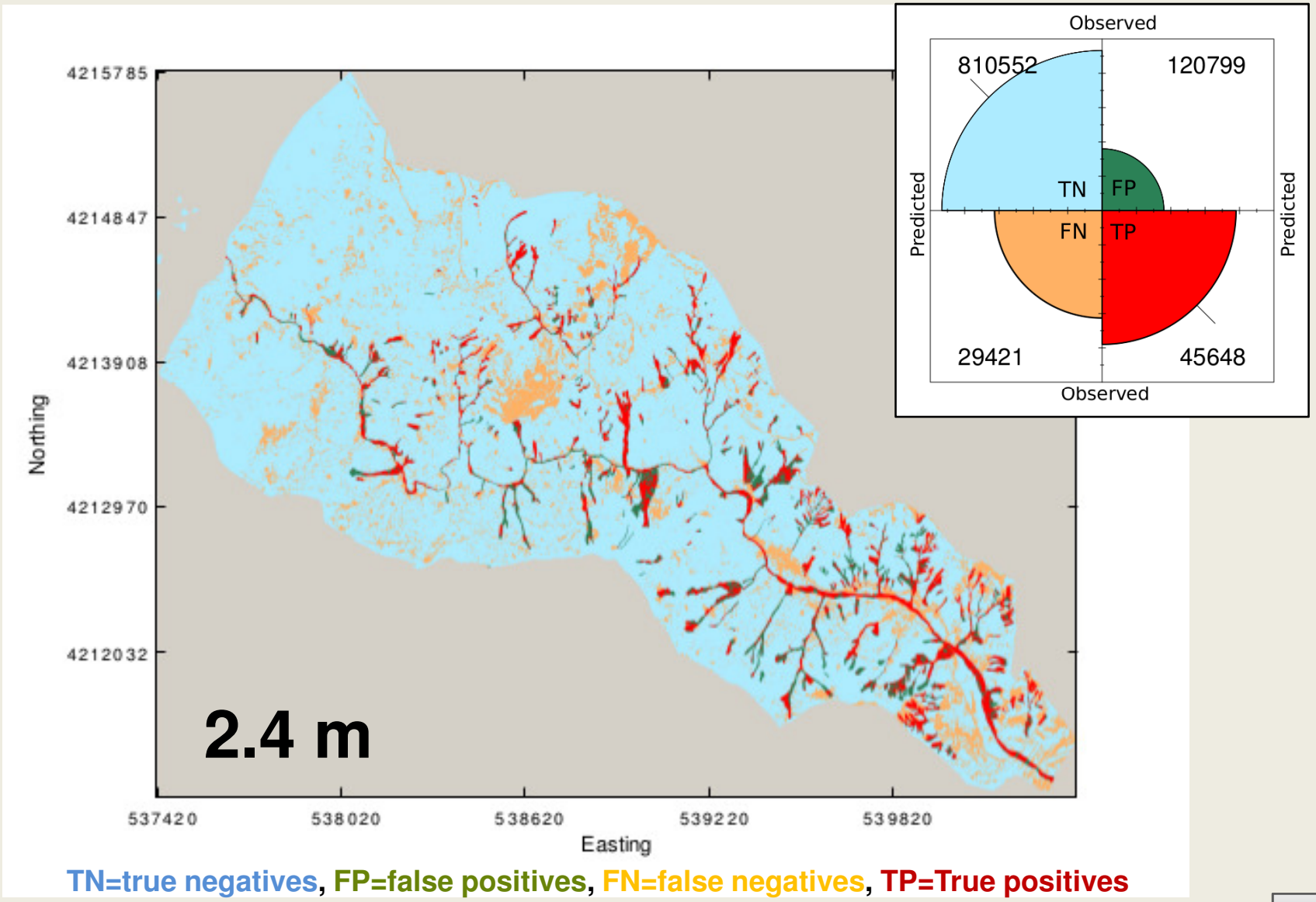
Combine model - logistic regression based

Accuracy assessment based map comparison

Mapping results

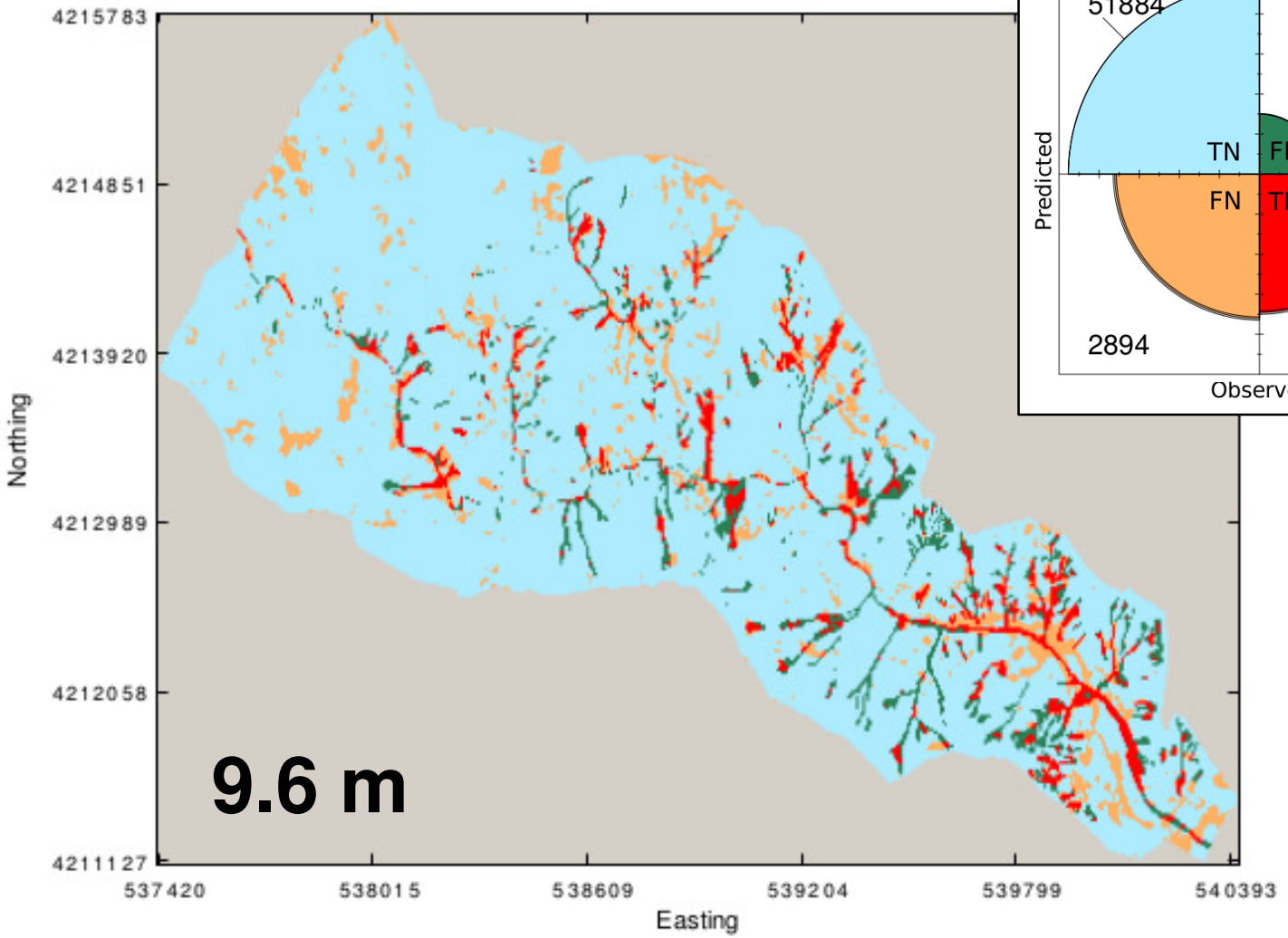


Accuracy – catchment 1



TN=true negatives, FP=false positives, FN=false negatives, TP=True positives

Accuracy – catchment 1



TN=true negatives, FP=false positives, FN=false negatives, TP=True positives

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

Outline

Spectral separability

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

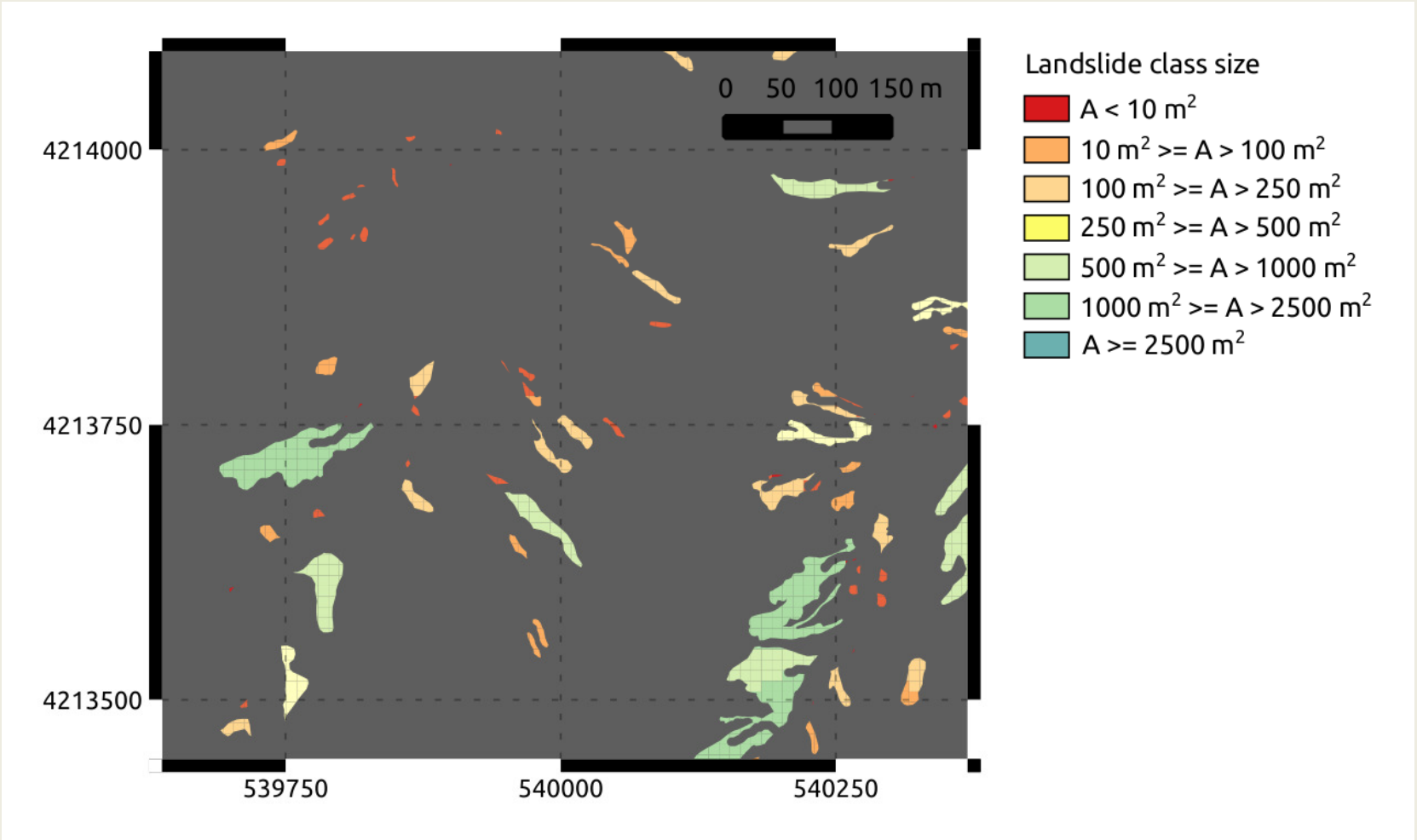
2. Classify individual landslides by area: 10, 100, 250, 500, 1000, 2500 m^2

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

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

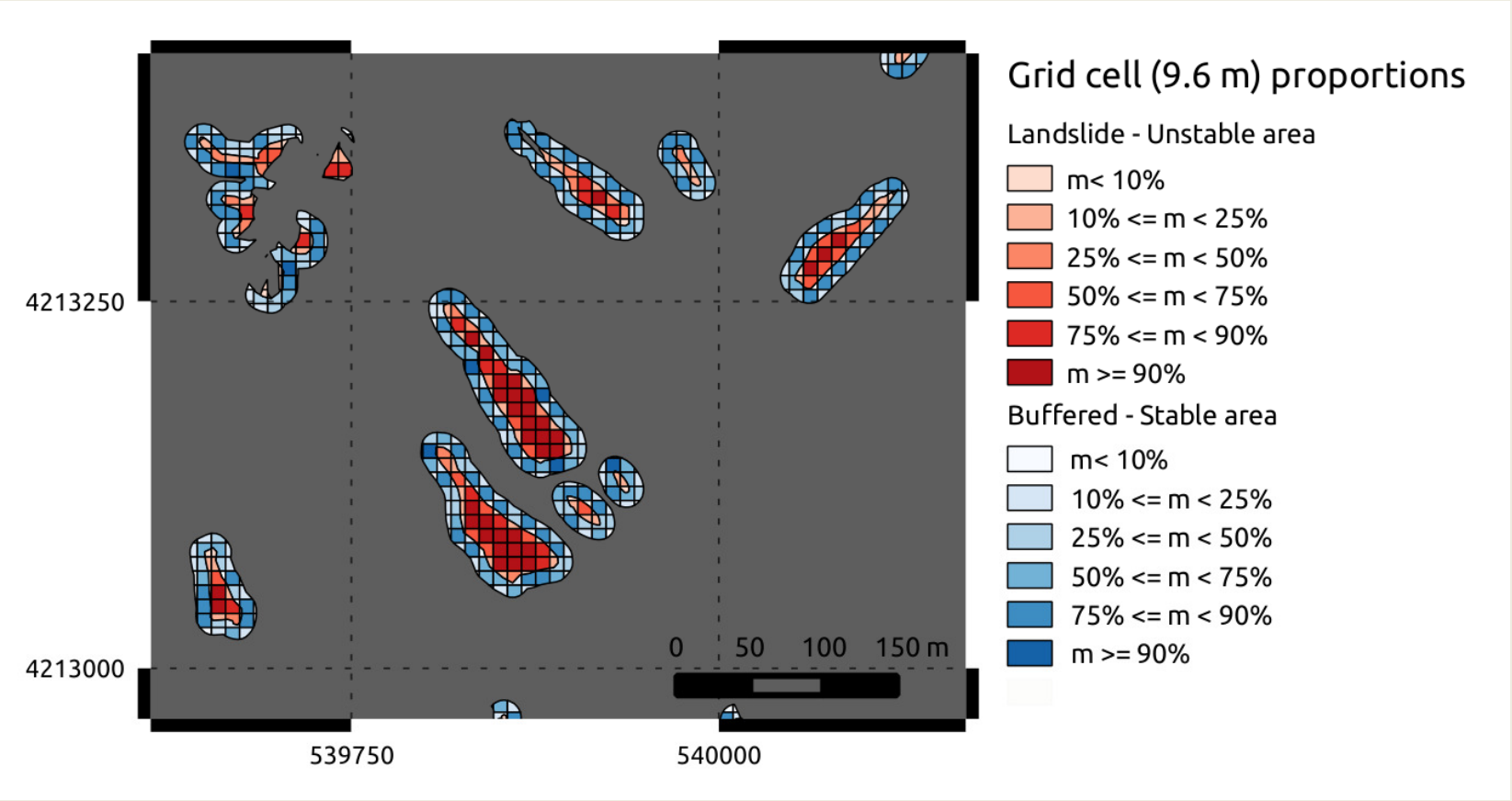
5. Extract Imagery pixels values and evaluate spectral separability

Landslide size classes



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

9.6m resolution Inventory proportions

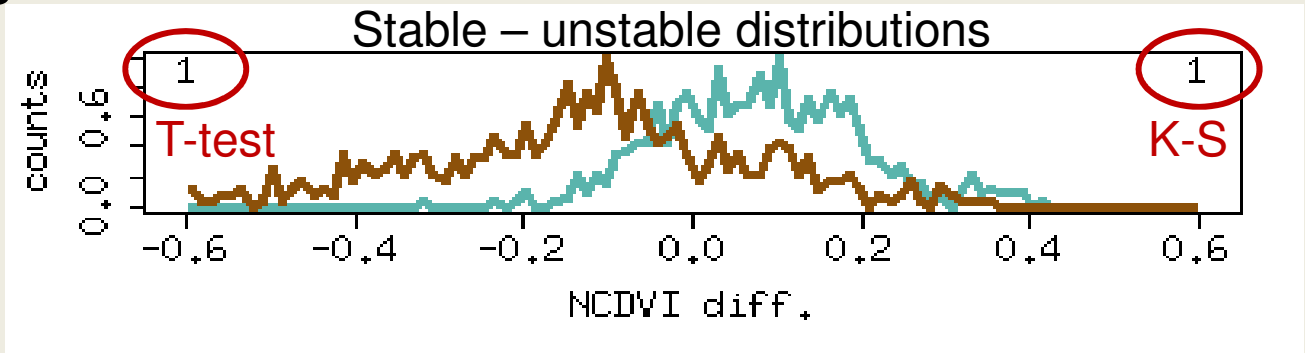


- **Stable areas are defined by buffering unstable stable areas in equal overall area**
- **Overlay 9.6m grid and determine each cell stable and unstable area proportion**

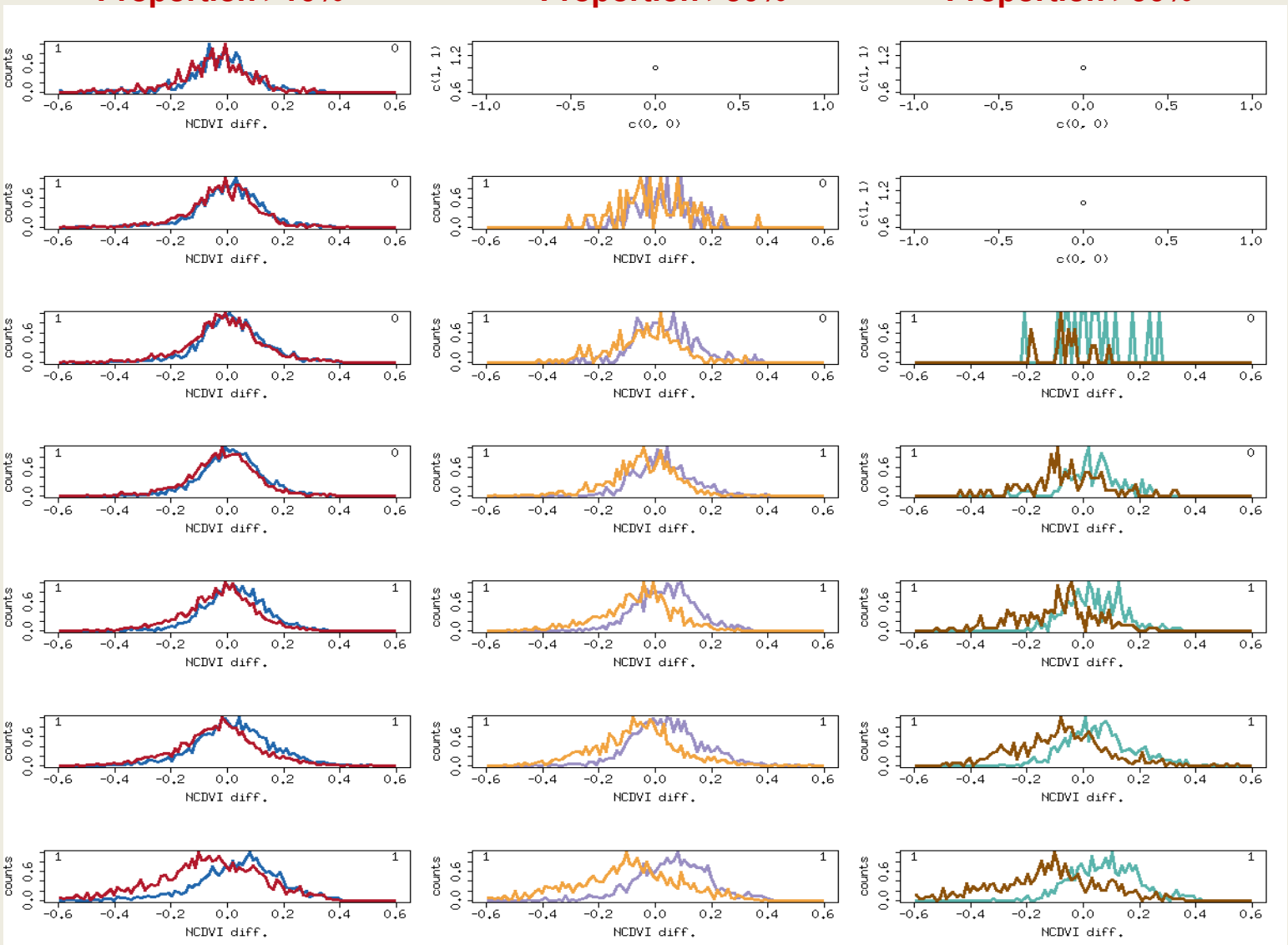
Spectral separability – 1D

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<10m²

10 m²< A ≤ 100 m²

100 m²< A ≤ 250m²

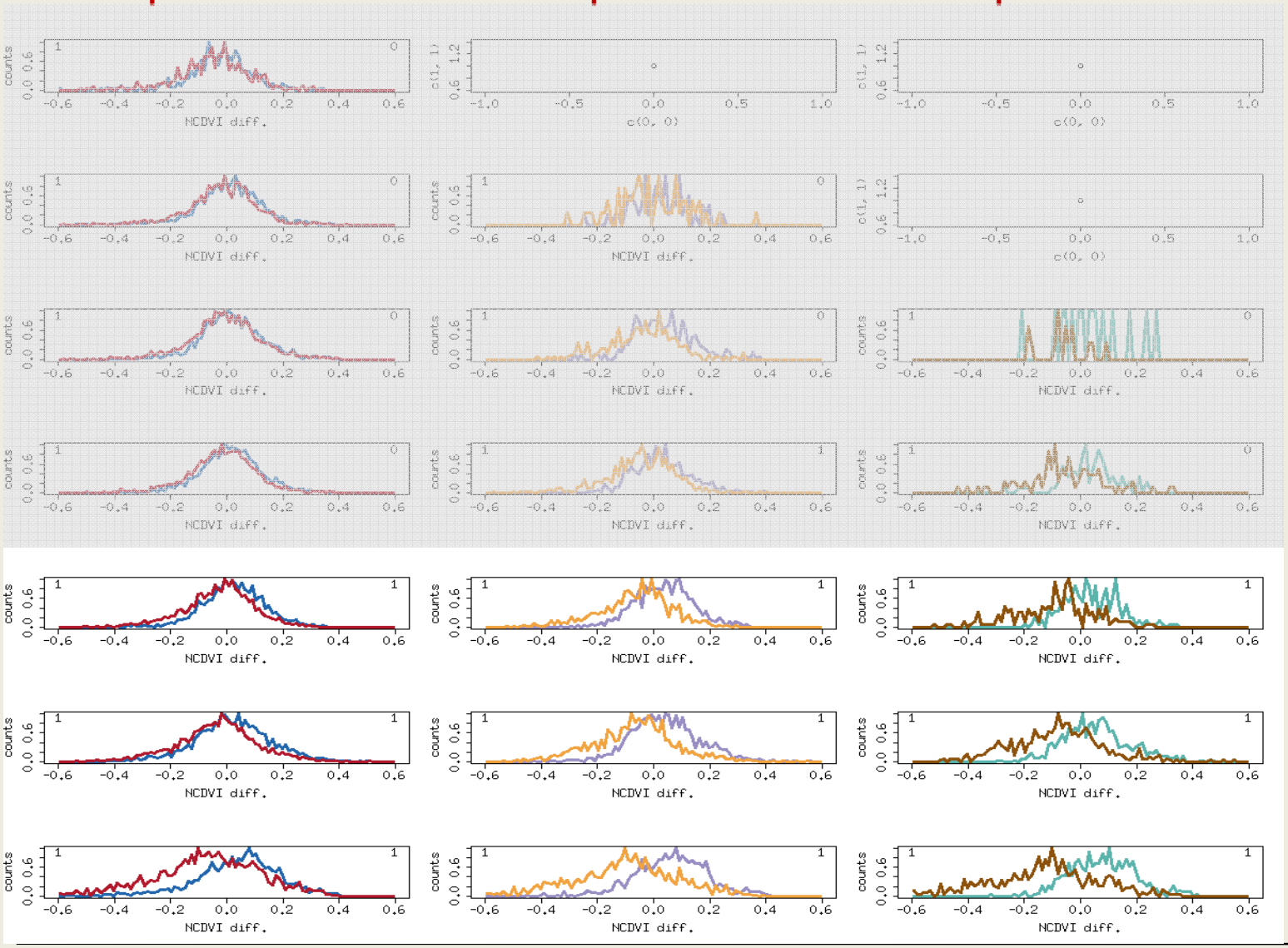
250 m²< A ≤ 500m²

500 m²< A ≤ 1000m²

1000 m²< A ≤ 2500m²

A > 2500 m²

Spectral Seperability: 1-D



A<10m²

10 m²< A ≤ 100 m²

100 m²< A ≤ 250m²

250 m²< A ≤ 500m²

500 m²< A ≤ 1000m²

1000 m²< A ≤ 2500m²

A > 2500 m²

Spectral separability – 4-D

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

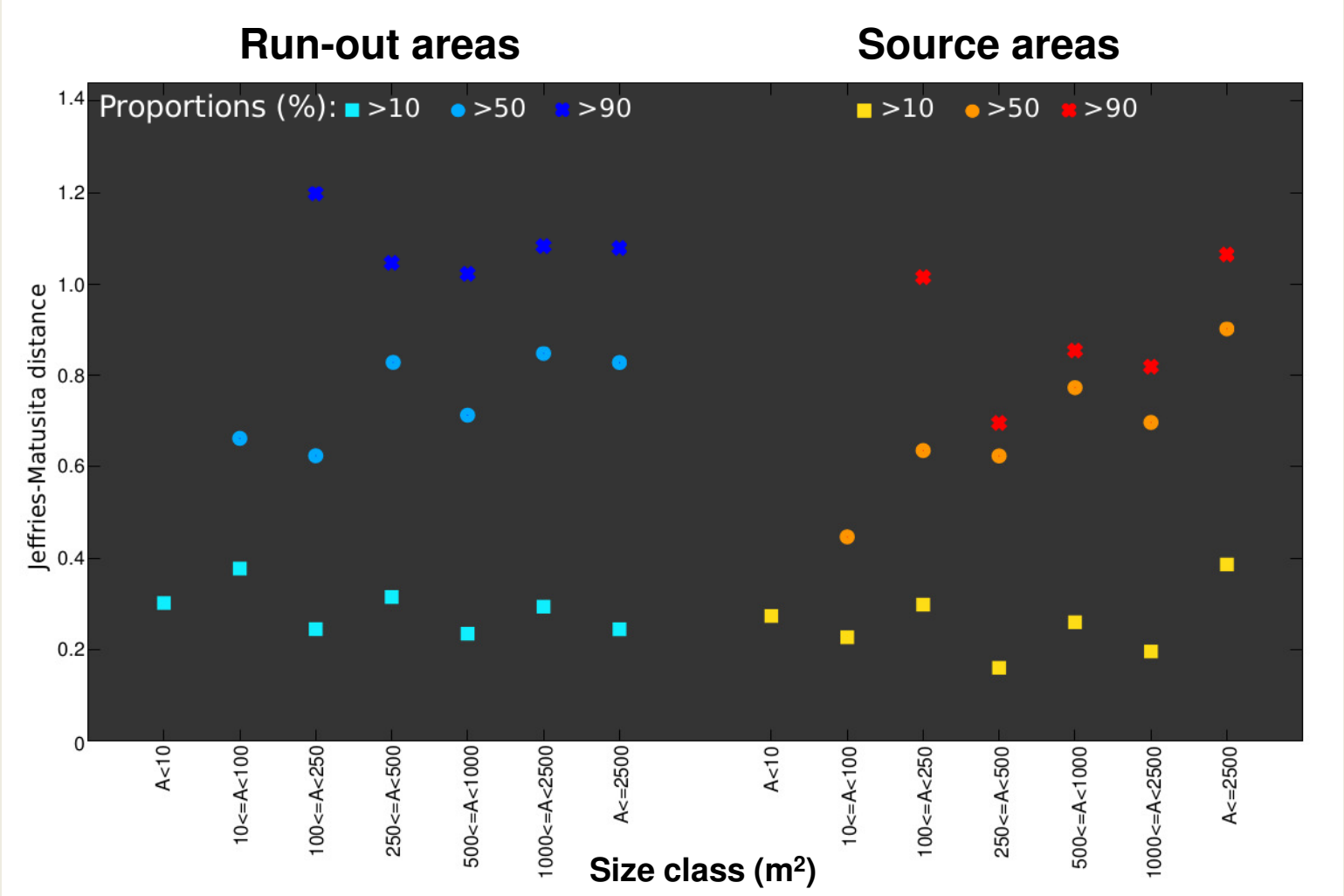
- **NDVI difference**
- **Spectral angle**
- **Principal and independent components**

Calculate Jeffreis-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.
  - Sentinal-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 (~15m^2)
- Apply to different landslide triggered events.
- Determine if a reliable frequency size distribution for triggered event landslides can be extracted using only course 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