Quantifying erosion in the Normanby catchment using repeat LiDAR and historical air photos

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Sediment Sinks Sources & Drivers
in the Normanby Basin

CAPE YORK WATER QUALITY

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Overview

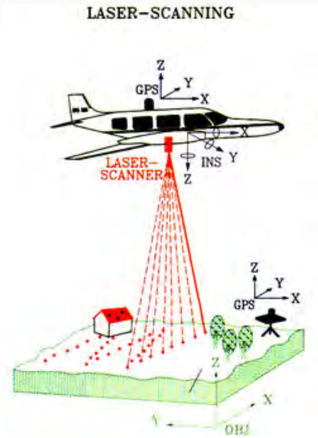
- Advantages and limitations of remote sensing for erosion detection
- Processing LiDAR data for erosion detection
- Using repeat LiDAR to detect real change
- Where is the erosion occurring in the landscape?

- Calculating medium term erosion volumes from historical air photos and LiDAR

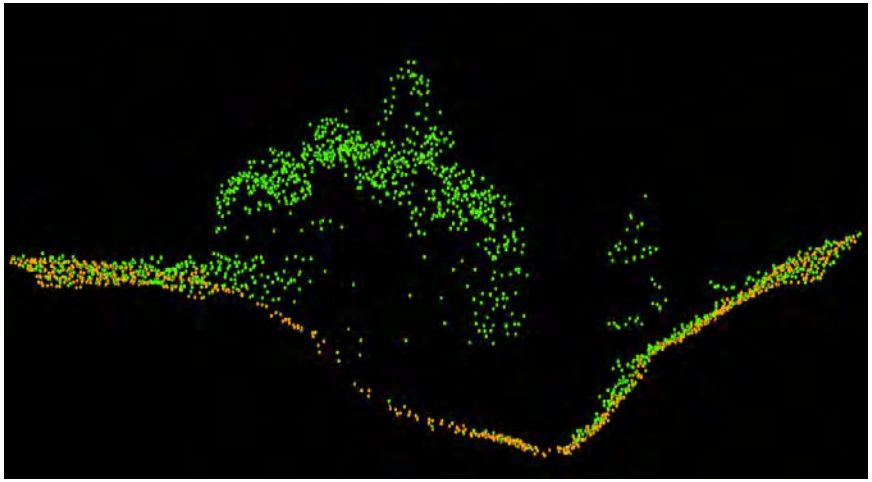
Overview of remote sensing methods

	Advantages	Limitations
LiDAR – Laser Imaging, Detection and Ranging	• High resolution – 1 m pixel • Penetrates vegetation • 3D digital elevation model (DEM) • Data manipulation	• Expensive • Short time interval • Need for expertise
Google Earth	• Accurate georeferencing • Entire catchment coverage • Can quantify area of bare earth • Recent imagery at ~ 1m pixel resolution • Freely available	• Imagery available back to 2003 • Variable resolution in earlier imagery • Only bare earth gullies could be mapped
Aerial photographs	• Historical coverage: available since 1950s • Can quantify area of bare earth	• Variable resolution • Difficult to accurately place in landscape (georeference) in remote areas • Can't quantify erosion volume • Incomplete catchment coverage • Variable temporal resolution

LiDAR: Laser Imaging Detection and Ranging – remote sensing, provides an image of the landscape in three dimensions



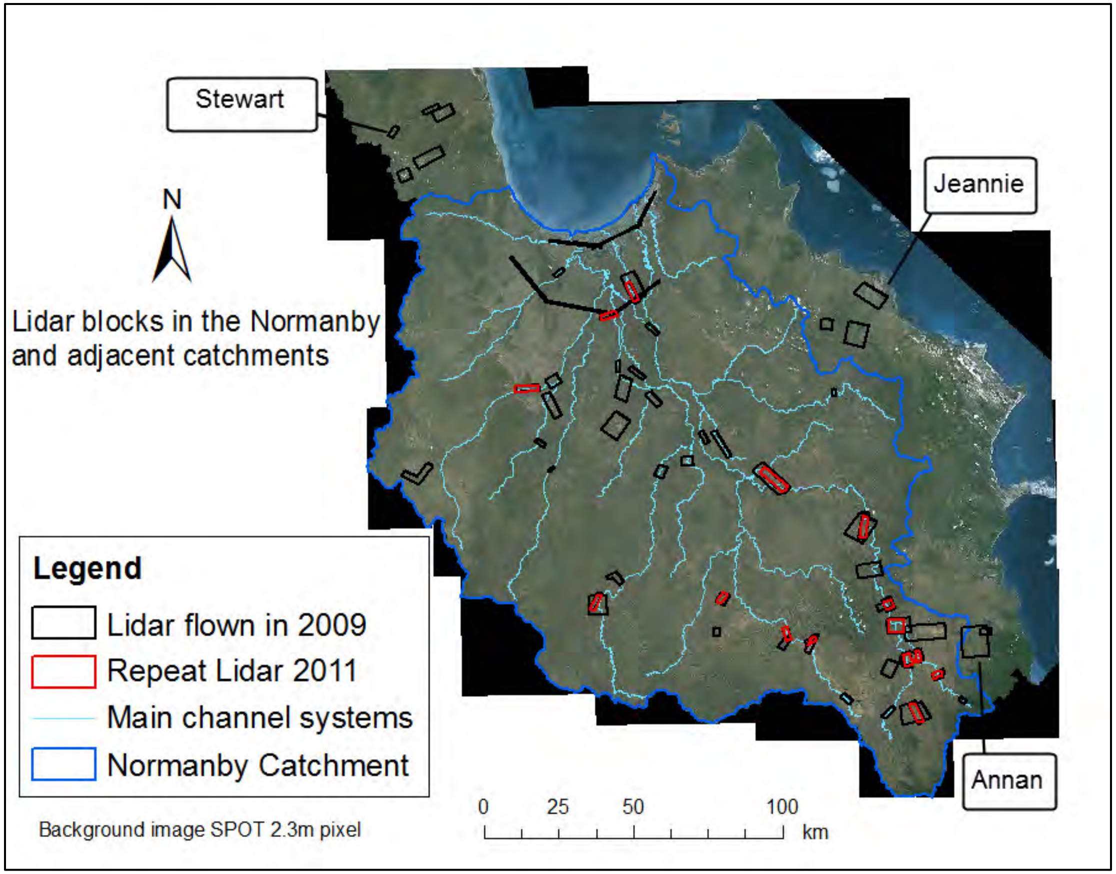
- Flown by **Terranean** (now RPS)
- Flying height 600m
- Pulse rate 160 kHz
- GPS base station in Cooktown
- Control points sparse in remote areas
- 2.5 points per square metre
- Automated and manual processing by vendor to produce DEM



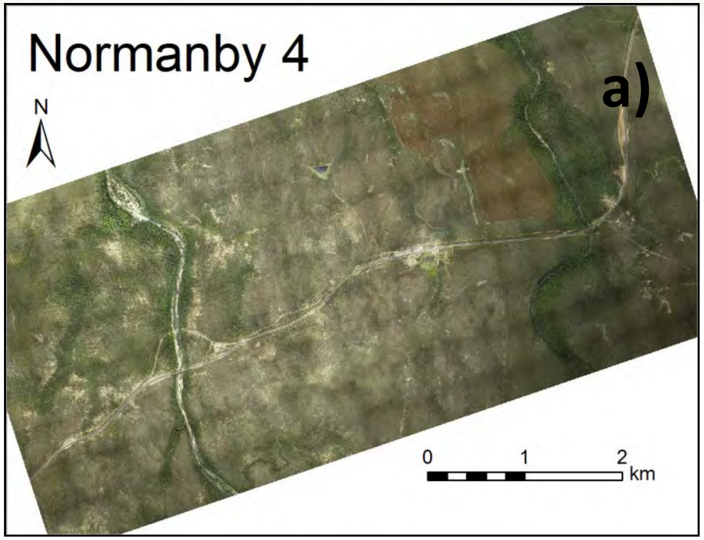
When and where was LiDAR collected in Normanby catchment?

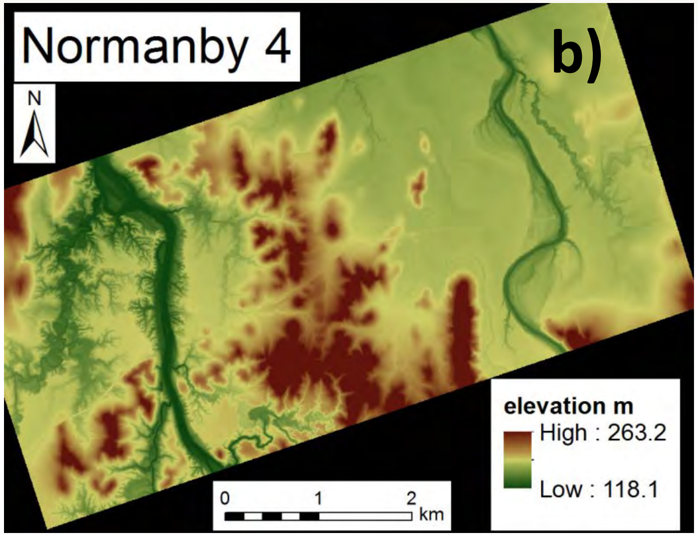
- **45 blocks** in Normanby in 2009
- **782 km^2**
- **3.2%** of Normanby catchment

- **14** blocks reflown in 2011
- **163.1 km^2**
- **0.7%** of catchment

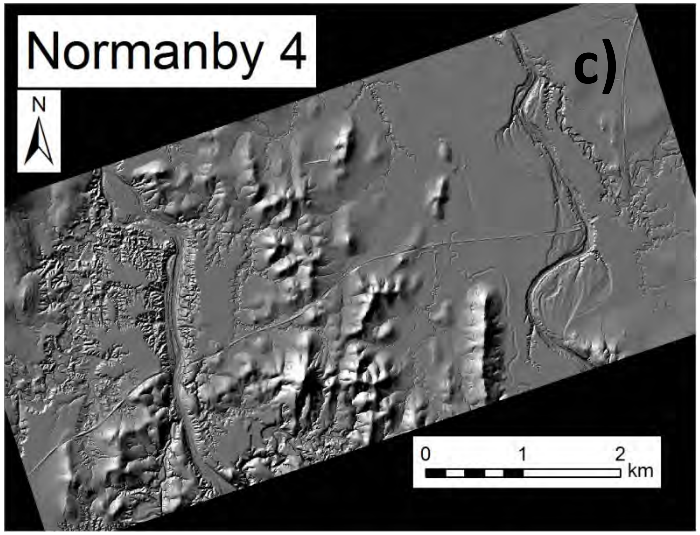


Different remote sensing imagery available





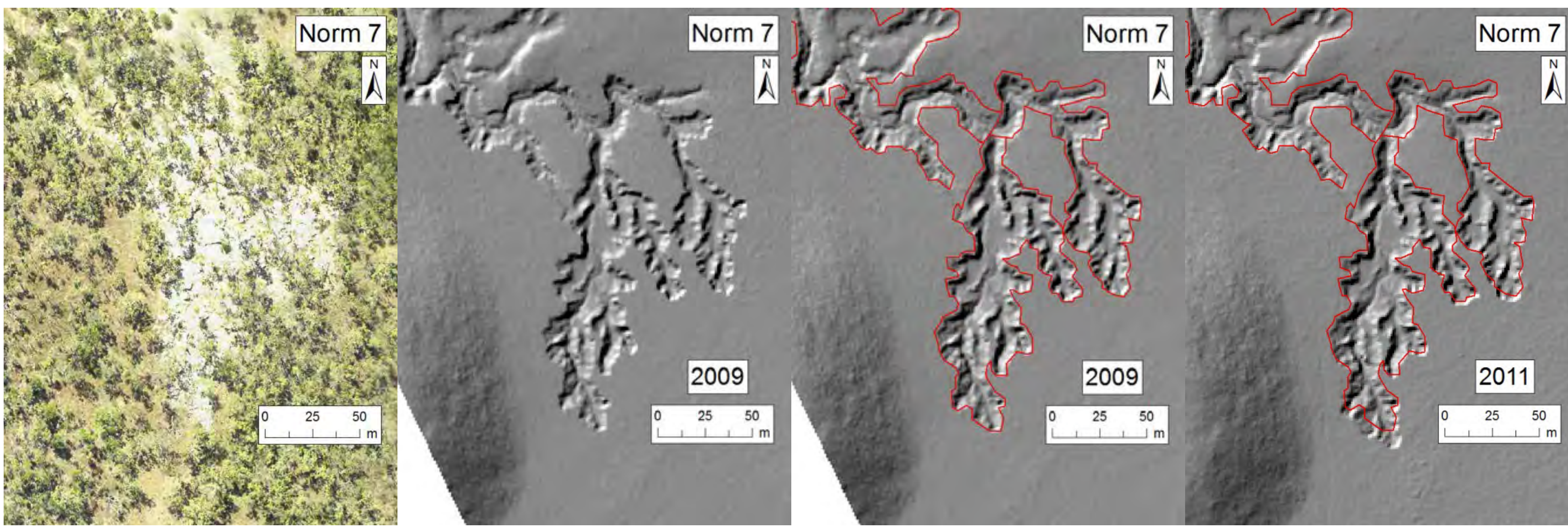
a) **Orthophoto** (georeferenced photo): 2D picture
b) **Digital elevation model (DEM):** 3D model of bare land surface, generated from LiDAR
c) **Hill shade rendering of DEM**: highlights landscape features



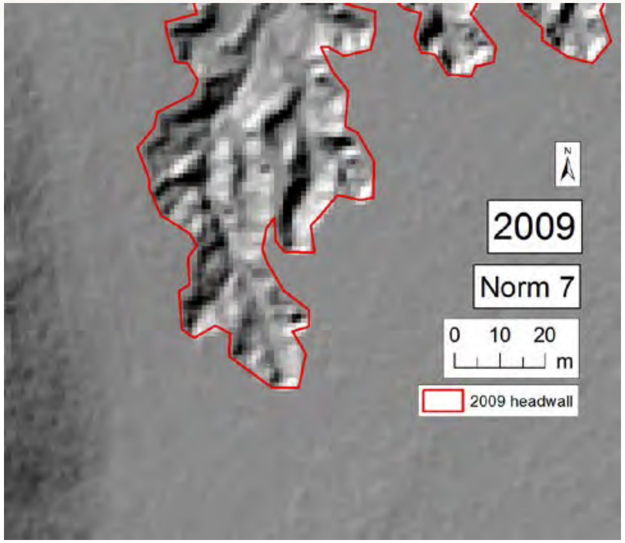
Determining erosion from LiDAR images

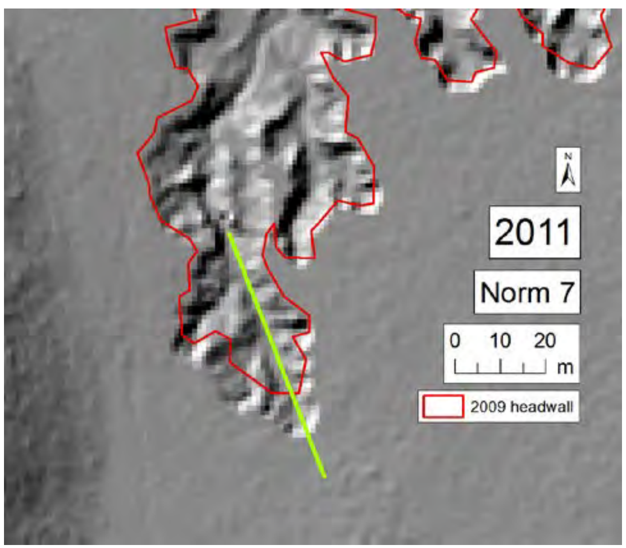
1. Remove vegetation from image (by LiDAR providers)
2. Digitize and classify landscape features, e.g. gullies, channels, floodplains***: automation routines miss details at gully scale***
3. Calculate changes in area and volume due to erosion

Fine scale analysis: 1m resolution of LiDAR images makes gully advance of 2-3 m detectable



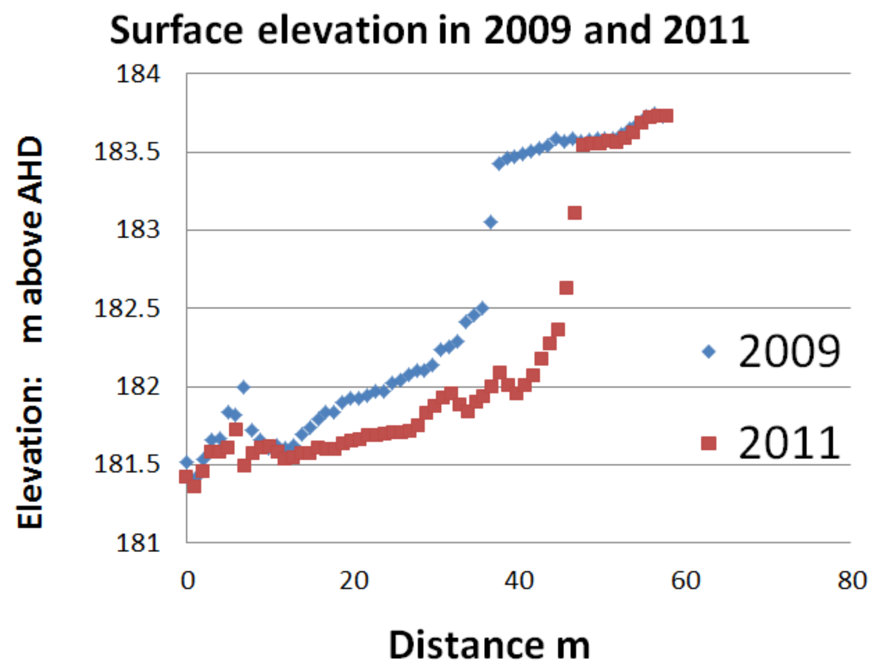
Quantifying changes in area and volume from digital elevation model (DEM)





Compare gullies between 2009 and 2011:

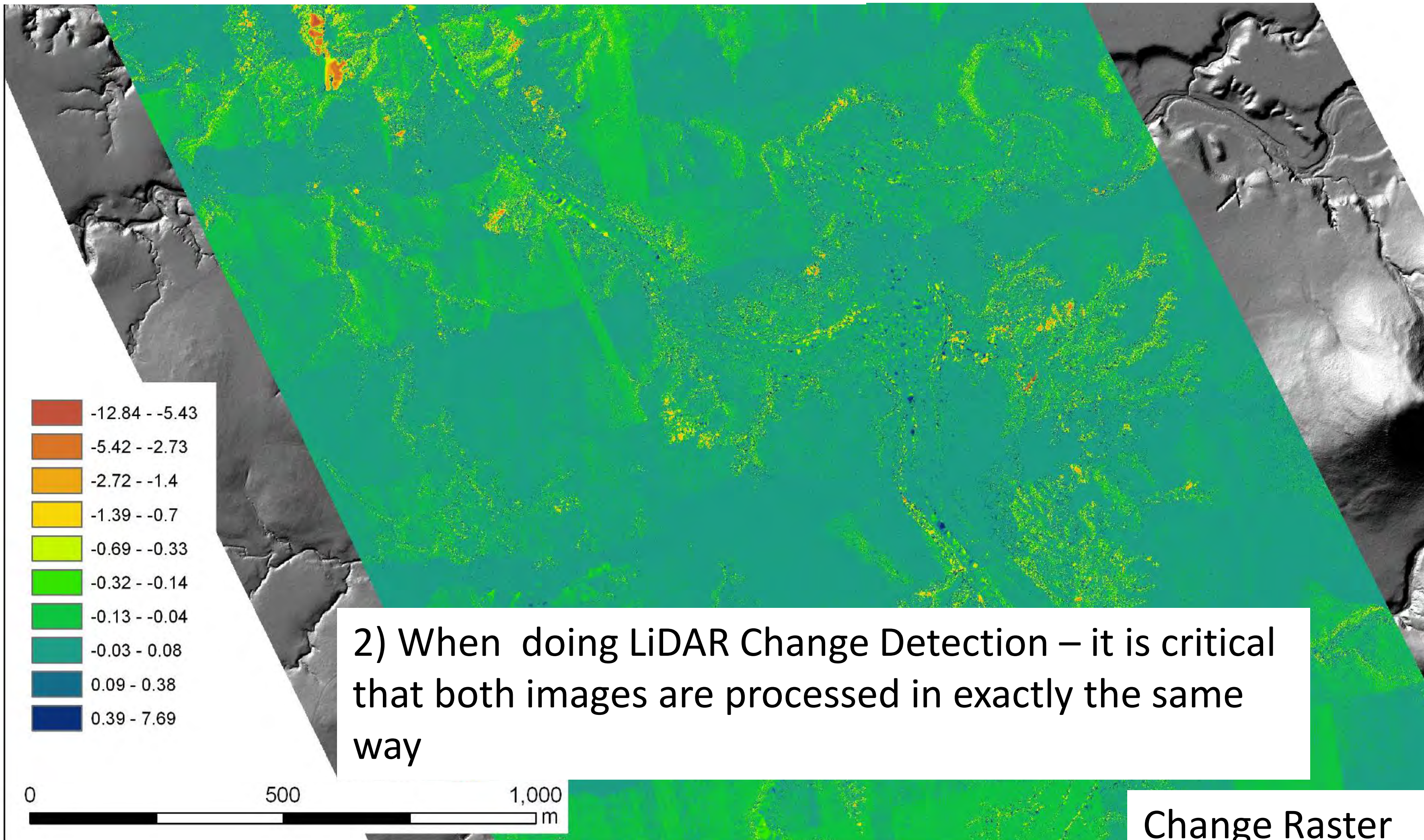
1. Extract height along transect line through DEM
2. Determine change in headwall position over time



LiDAR Change Detection - Processing Issues

Norm 7

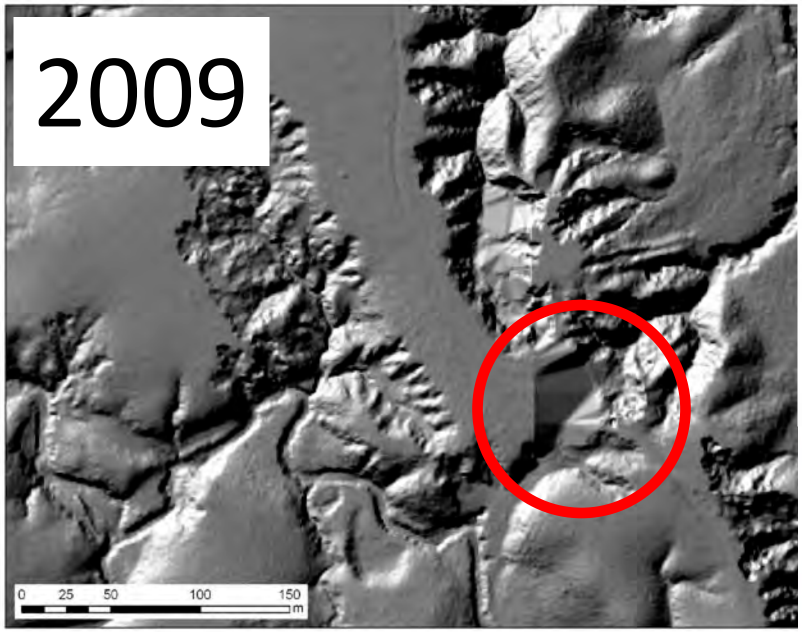
(Original 2009) – (Original 2012)

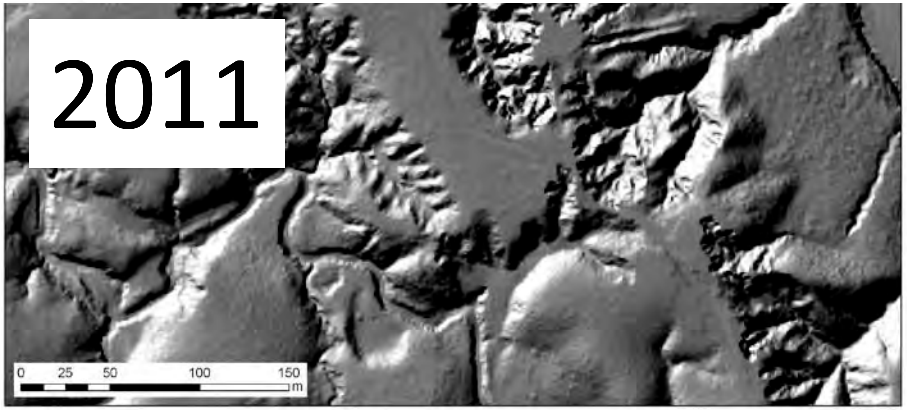


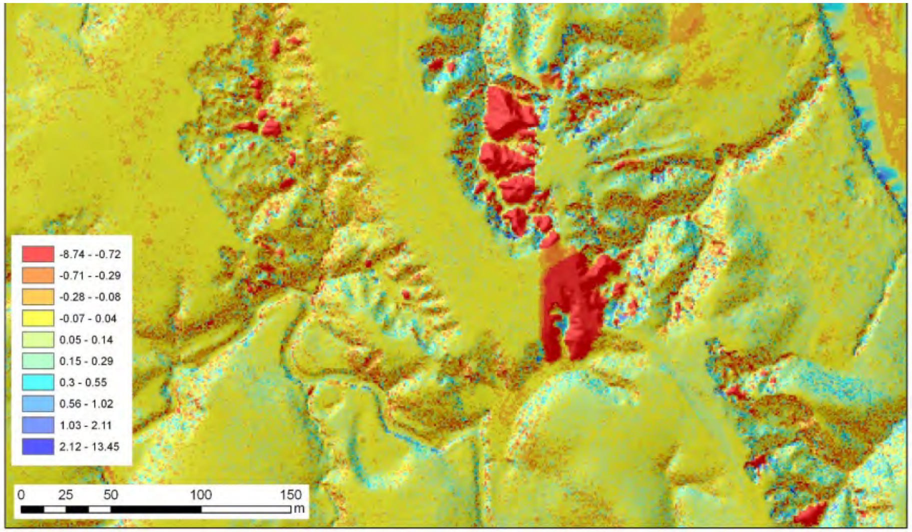
2) When doing LiDAR Change Detection – it is critical that both images are processed in exactly the same way

Change Raster

Artefacts in the data give false evidence of erosion

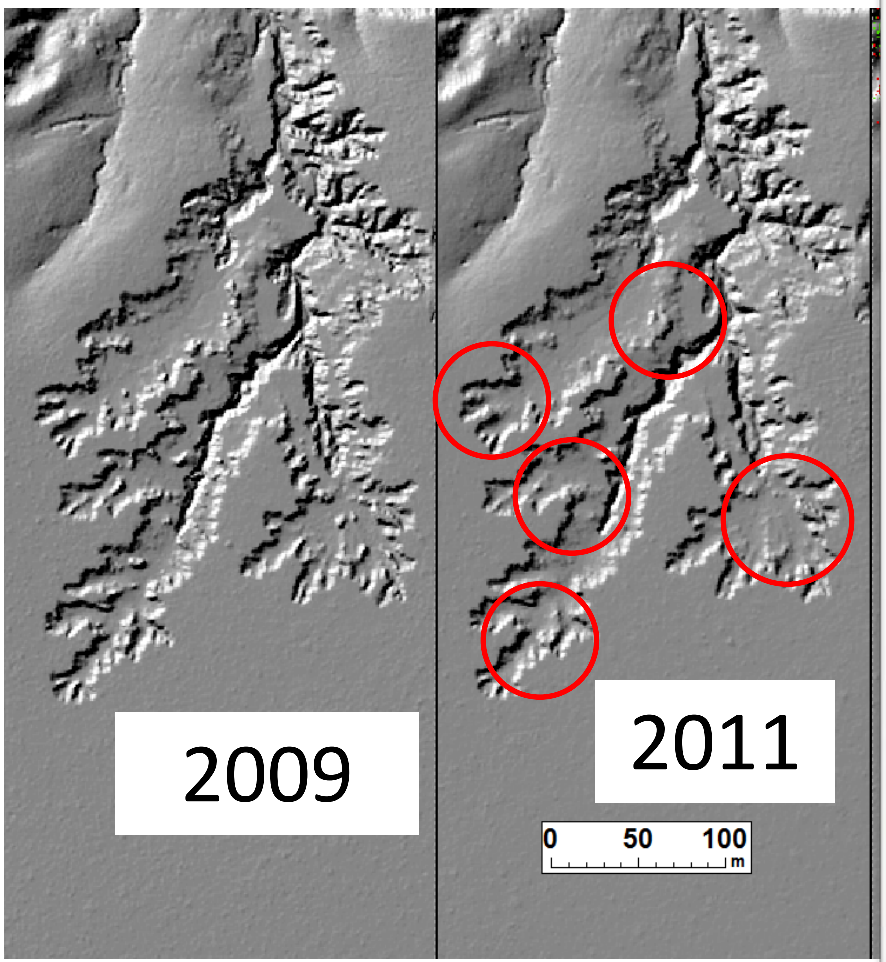


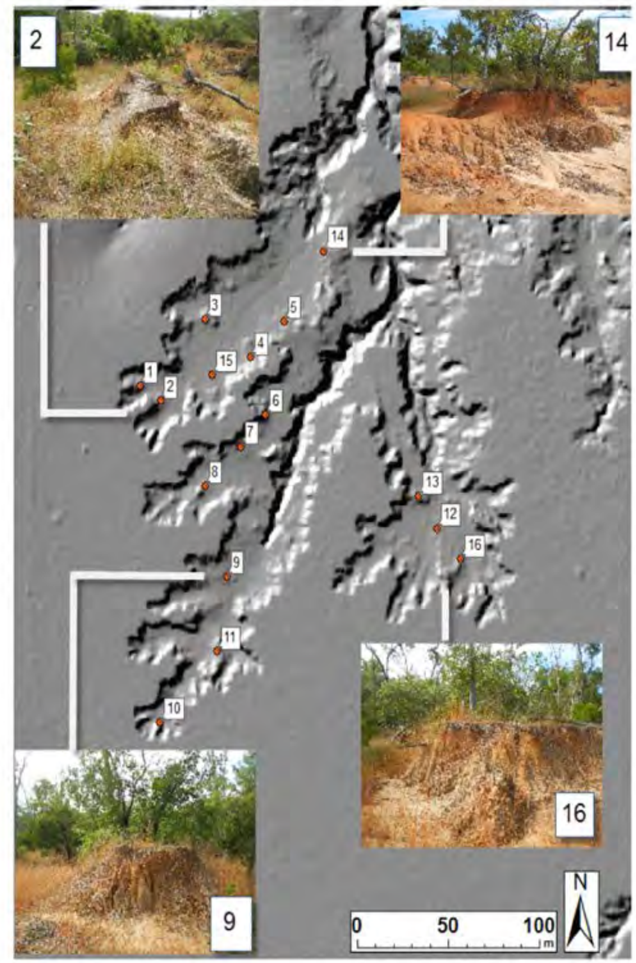




Loss of detail due to dense vegetation preventing LiDAR penetration to ground, evident on steeper slopes

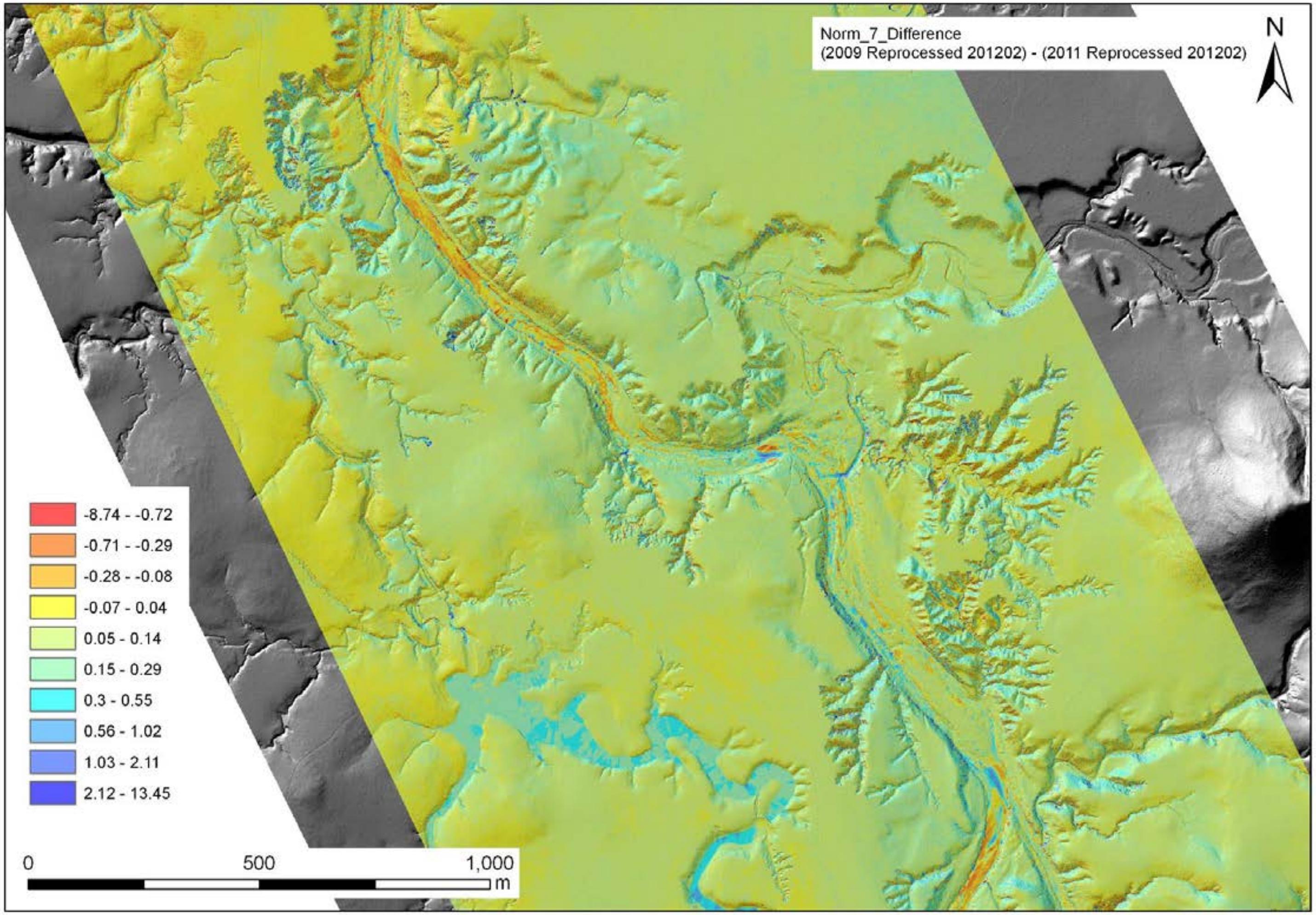
Automated vegetation removal can remove landscape features





Photos: Jeff Shellberg

Substantial effort in reprocessing produced difference layers free from visual defects

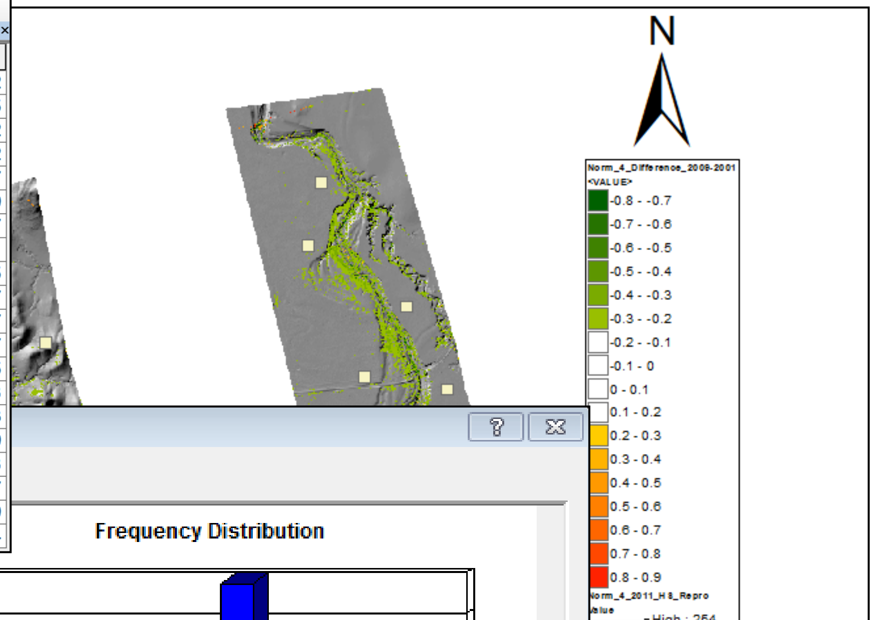


Reduction of background noise in change detection data

Table

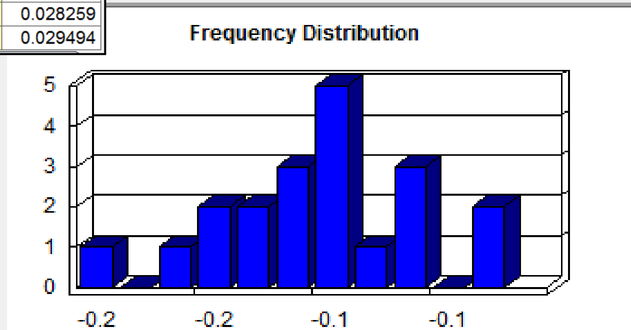
b4difference_check

ID *	AREA	MIN	MAX	RANGE	MEAN	STD
1	10000	-0.41	0.09	0.5	-0.11483	0.051342
2	10000	-1.77	1.36	3.13	-0.16912	0.123785
3	10000	-1.22	0.41	1.63	-0.18178	0.073742
4	10000	-0.4	0.13	0.53	-0.14731	0.047272
5	10000	-0.22	0.03	0.25	-0.09083	0.02487
6	10000	-0.58	0.05	0.63	-0.14393	0.048669
7	10000	-0.52	0.16	0.68	-0.22681	0.051547
8	10000	-0.31	0.24	0.55	-0.08252	0.064471
9	10000	-0.37	0.25	0.62	-0.13189	0.038815
10	10000	-0.58	0.34	0.92	-0.12764	0.095767
11	10000	-0.33	0.13	0.46	-0.08527	0.033727
12	10000	-0.46	0.24	0.7	-0.12256	0.0597
13	10000	-0.48	0.03	0.51	-0.15207	0.041015
14	10000	-0.44	0.37	0.81	-0.04824	0.069038
15	10000	-0.68	0.58	1.26	-0.05993	0.113753
16	10000	-0.38	0.17	0.55	-0.11948	0.027899
17	10000	-0.42	0.02	0.44	-0.16517	0.032168
18	10000	-0.4	0.13	0.53	-0.13860	0.034697
19	10000	-0.28	0.09	0.37	-0.11532	0.028259
20	10000	-0.28	0.04	0.32	-0.10643	0.029494

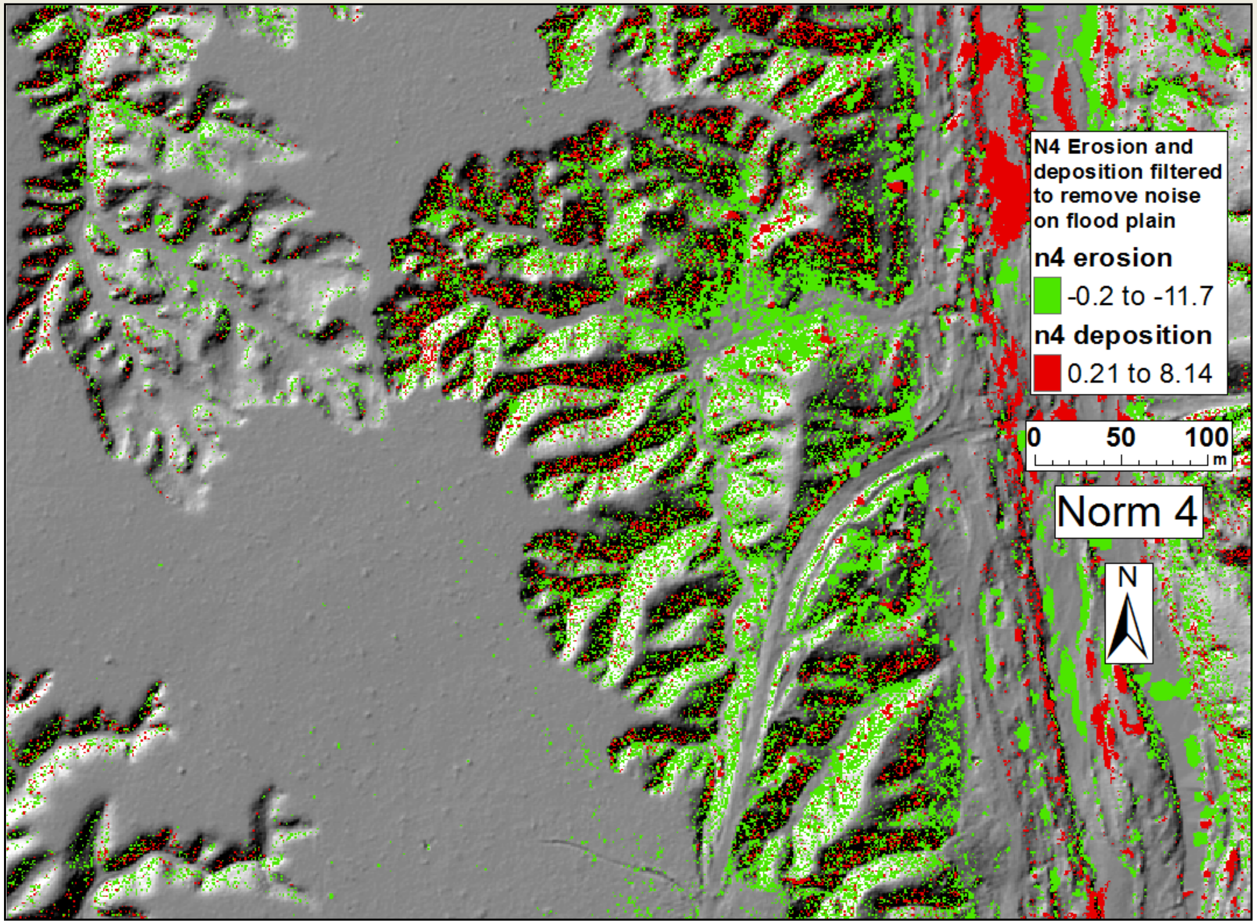


Statistics:

Count: 20
Minimum: -0.226812
Maximum: -0.048243
Sum: -2.529838
Mean: -0.126492
Standard Deviation: 0.041345



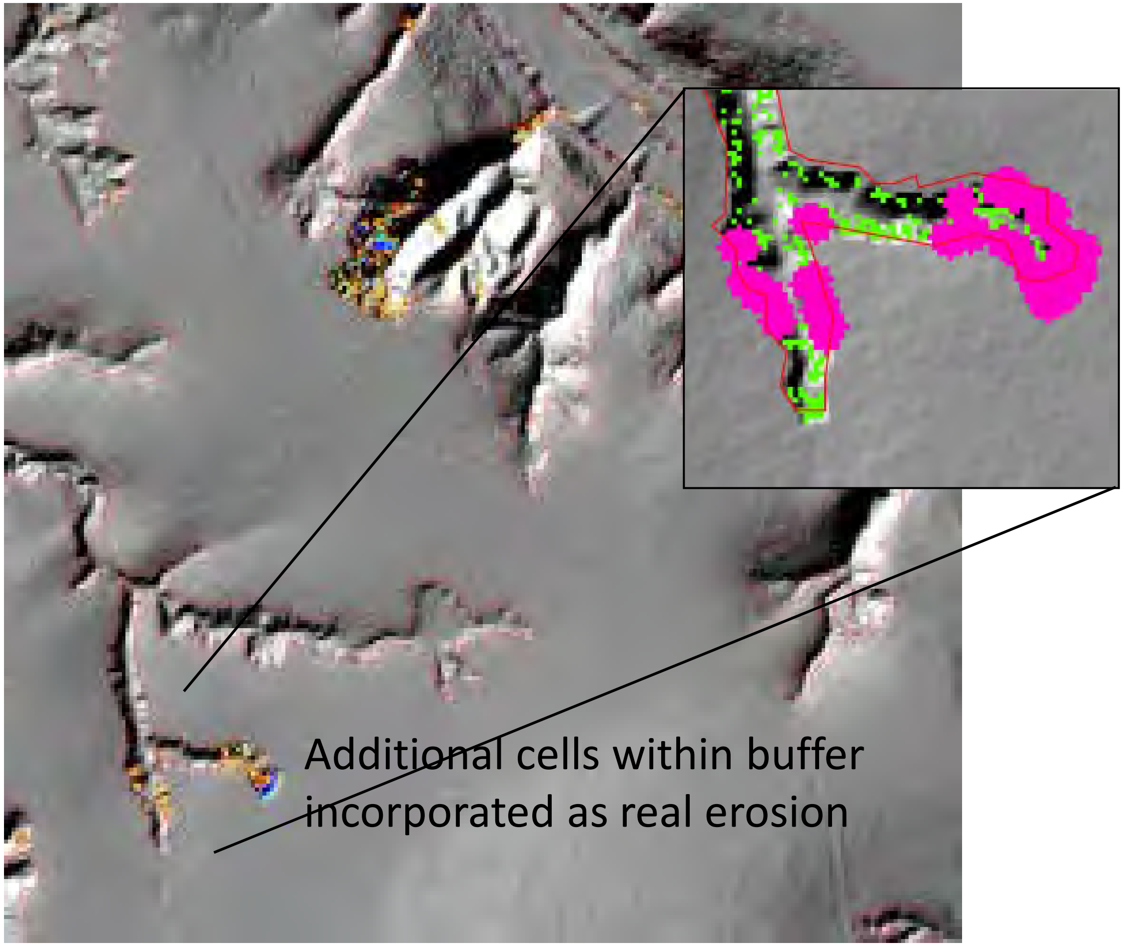
Aggressive filtering to improve signal to noise ratio



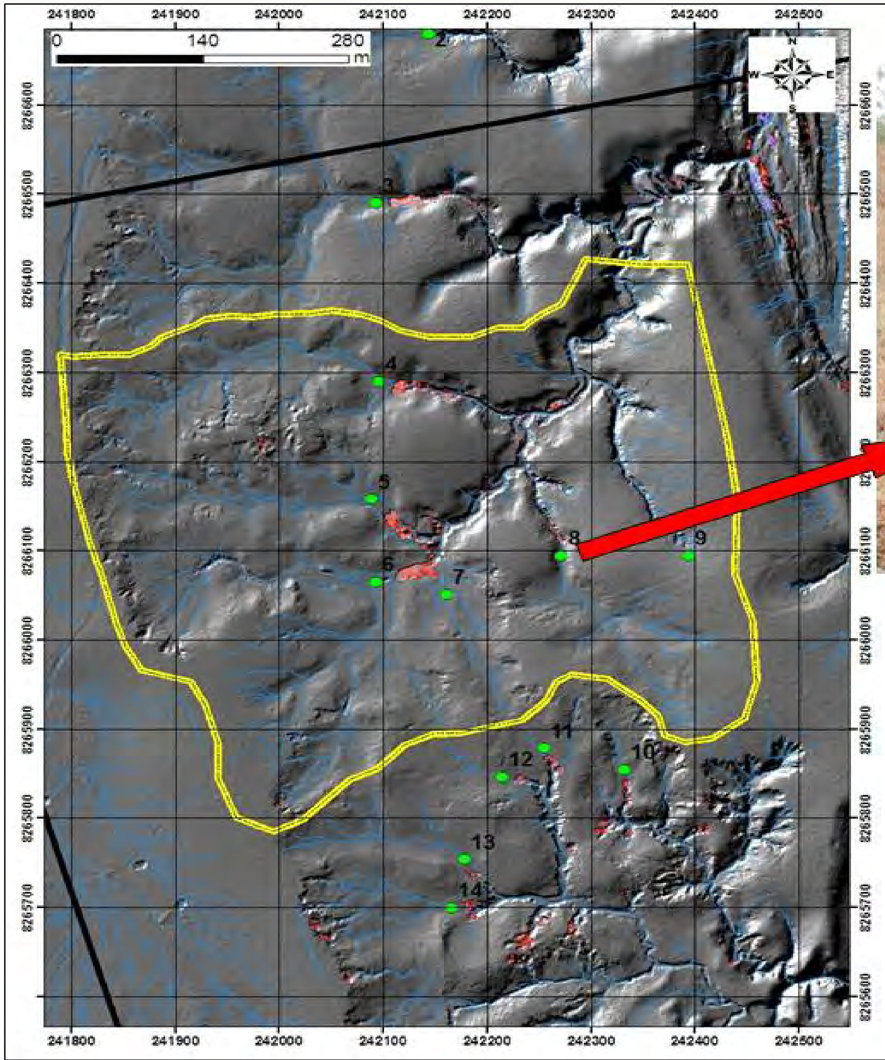
- Flat surfaces cleared of “noise” by filtering values between -0.2 and +0.2m
- But deposition on gully walls is not real

Real erosion/deposition was assumed to be greater than 1m deep

- Pixels with less than 1m change were excluded
- Isolated single pixels removed
- Hand editing removed erroneous pixels (6.8ha→1.2ha)
- Remaining "real" change was buffered by 3m to include pixels on cusp of advancing headwalls



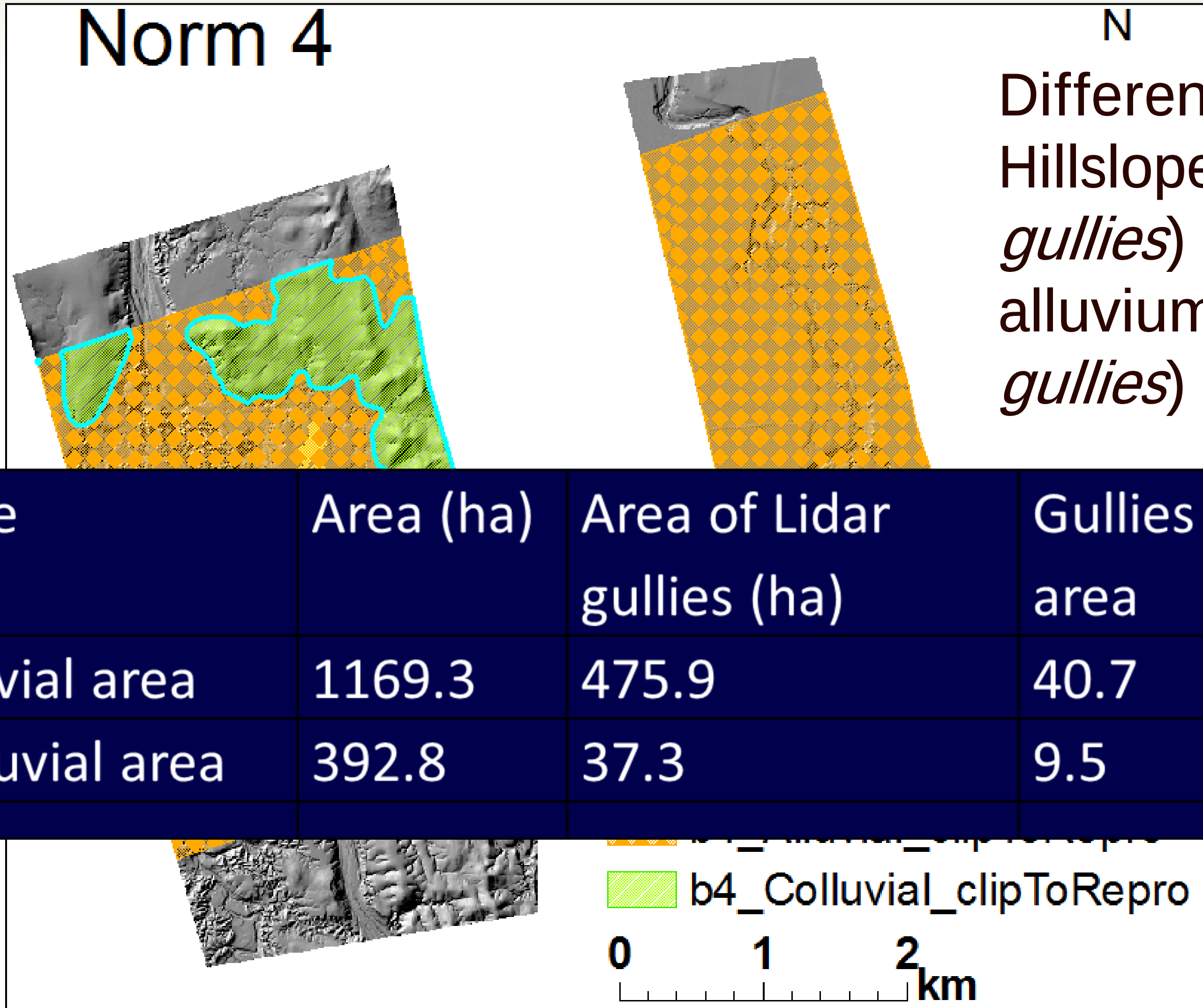
Erosion hotspots were ground truthed



Laura River at Crocodile Gap (Norm 16)

Photo: Jeff Shellberg

Where in the landscape was erosion occuring?



Differentiate Hillslopes (*colluvial gullies*) from alluvium (*alluvial gullies*)

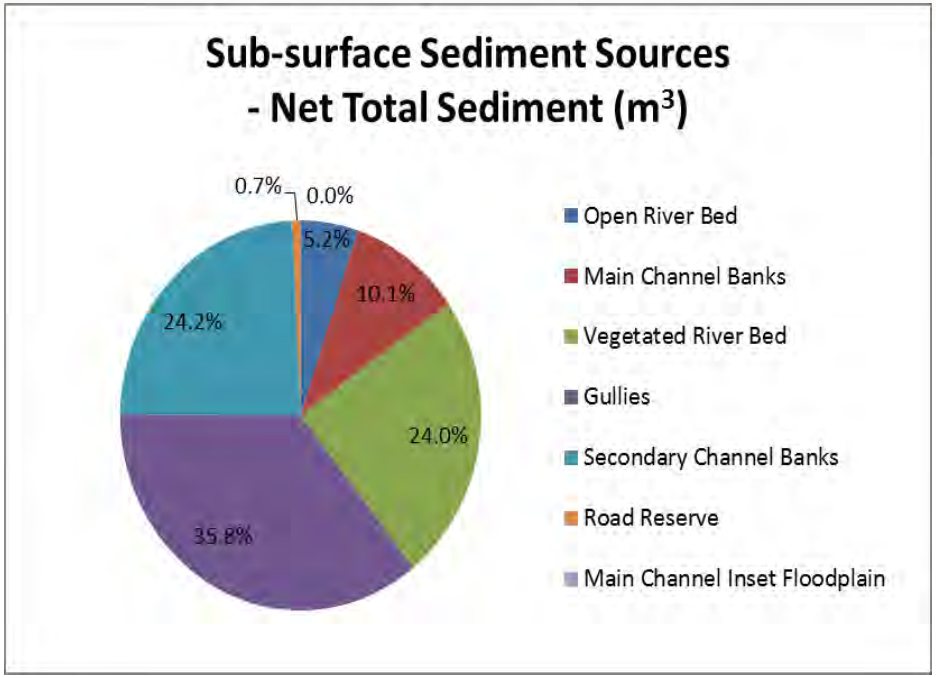
Zone	Area (ha)	Area of Lidar gullies (ha)	Gullies as % of area
Alluvial area	1169.3	475.9	40.7
Colluvial area	392.8	37.3	9.5

The landscape was classified into 9 functional units

Classification of Polygons	Feature	Description
1	Waterbodies	Ponded or flowing water present
2	Open riverbed	Sand, gravel, or rock substrate visible in orthophoto
3	Main channel banks	Steep rise from main channel to floodplain or terrace
4	Vegetated channel beds	Adjacent to permanent or temporary watercourses, show characteristics of flow patterns, vegetated.
5	Proper off channel gullies	Discrete units of gully erosion
6	Secondary channels	Linear, loping watercourse bed, receive inputs from numerous other gullies, little lateral expansion, usually heavily vegetated
7	Roads, verges and associated works	Affected by roads with in the polygon
8	Inset flood plain – main channel	Flat or nearly flat surfaces adjacent to main channel, vegetated, elevated above main channel but below the surface of extensive ancient flood plain.
9	Inset flood plain – secondary channel	This is the distinct floodplain associated with secondary channels described.

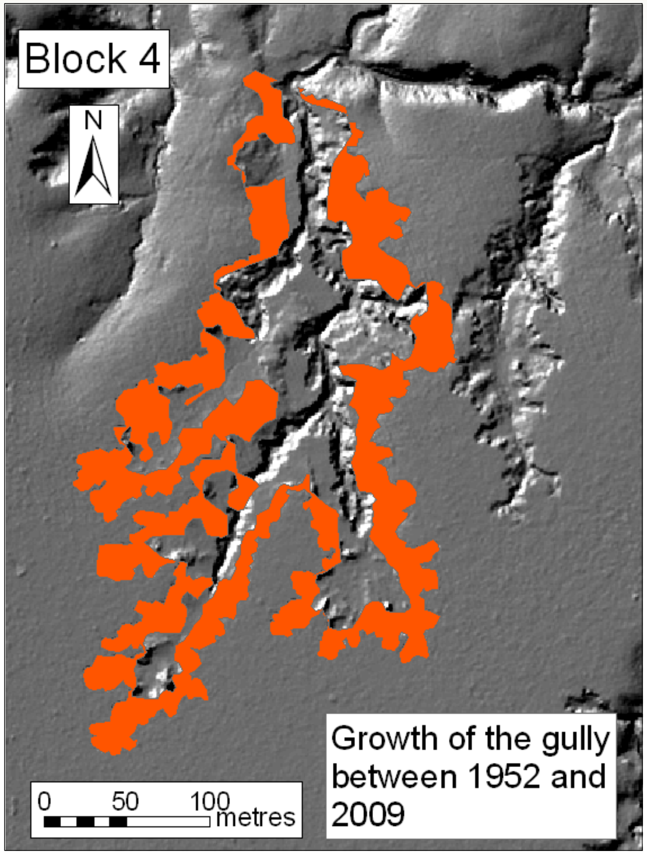
Results

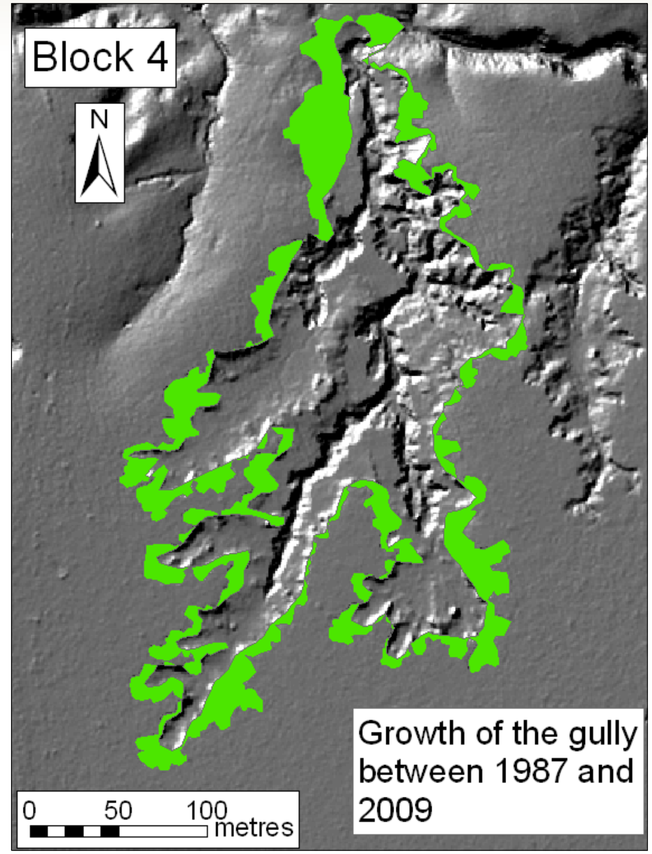
- Sub surface sediment sources were dominated by losses from gullies, 35.8%.
- Secondary channels contributed 24.2%, and vegetated riverbed 24%



Note – these data are for the LiDAR blocks alone - i.e. Not for the total catchment .

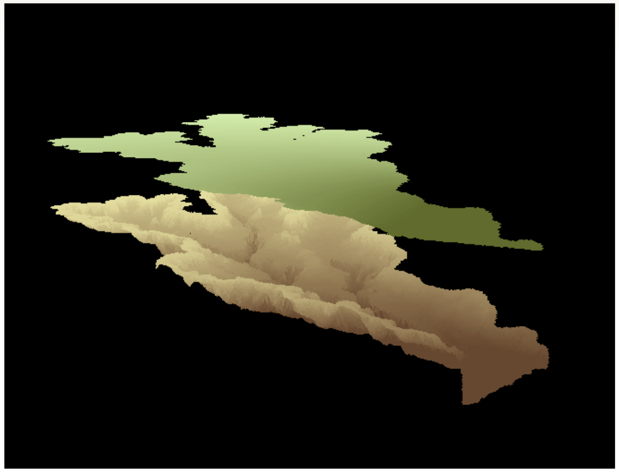
Use of historical air photos to determine medium term erosion rates





- 21 gullies were digitised from airphotos dating back to 1951
- The most time slices was 4, and average was 2
- Air photos were georeferenced to stable features visible in LiDAR imagery

Sediment yield - LiDAR vs A/P



- 60 year mean 91 m^3/ha/yr
- 30 year mean 112 m^3/ha/yr
- 2 year mean 115 m^3/ha/yr
- Climactic conditions?
- Airphoto processing?

	Yield: volume material lost divided by area of 2009 gully divided by interval m3/ha/yr		
	Air photo data		Lidar data
	1950s to 2009	1980s to 2009	2009 to 2011
N04 g1	100	94	470
N05 eg1	no data	22	28
N05 eg2	51	91	0
N05 eg3	47	161	46
N05 wg1	111	97	13
N09 g1	86	164	37
N09 g2	177	89	160
N10 g1	81	170	104
N14 g3	71	no data	77
N16 g1	75	160	15
N17 g1	175	121	571
N17 g2	no data	71	9
N20 g1	28	53	3
min	28	22	0
max	177	210	571
average	91	112	115

Summary

- Vitally important to get **technical aspects** of LiDAR acquisition and processing **correct**
- No escape from **hands on editing of LiDAR** to detect real erosion
- Repeat LiDAR is a **fantastic tool** for analysis of fine scale landscape change … BUT
- Calculated erosion and deposition volumes will **substantially underestimate real volumes** due to limitations of data
- Historical air photos allow back-casting of dates of gully initiation, and back-calculation of medium term erosion volumes

End