USING REMOTE SENSING TO INFORM INTERGRATED COASTAL ZONE MANAGEMENT

GISSA Western Cape Regional Meeting

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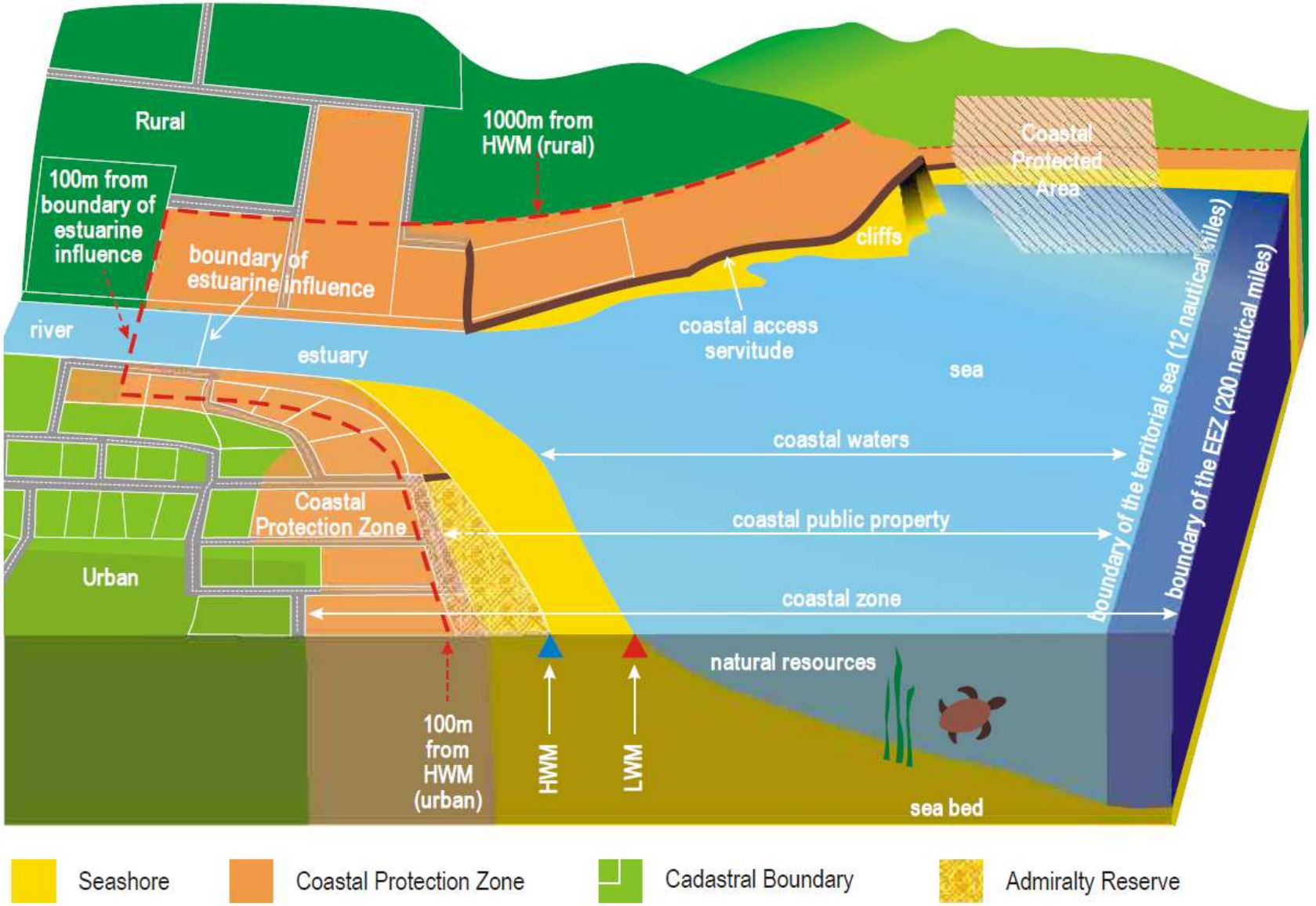
CSIR NRE Ecosystems Earth Observation Group

What is Integrated Coastal Zone Management?

Integrated coastal management (ICM) is a process for the management of the coast using an integrated approach, regarding all aspects of the coastal zone, including geographical and political boundaries, in an attempt to achieve sustainability (Wikkipedia)

Where is the “Coastal Zone”?

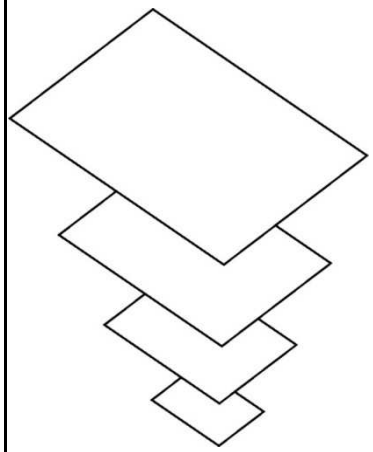
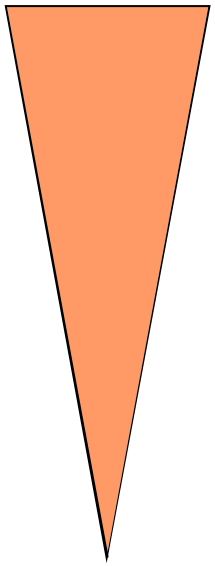
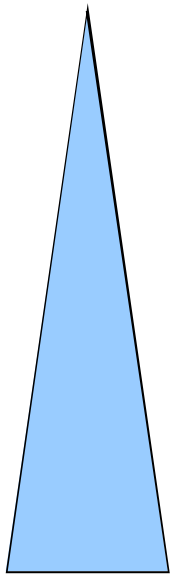
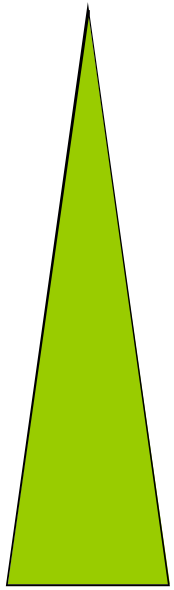


Celliers, L., Breetzke, T., Moore, L. and Malan, D. 2009. A User-friendly Guide to South Africa's Integrated Coastal Management Act. The Department of Environmental Affairs and SSI Engineers and Environmental Consultants. Cape Town, South Africa.

Spatial features of interest for ICM

- Coastline
- Beach width
- Vegetation line / health
- Surf Zone Width
- Erosion and Accretion
- Pollution
- Coastal Development
- Shoreline protection (Vulnerability to climate change)
- Water Quality

Remote Sensing Trade-offs

Examples Sensors	Spatial Resolution	Temporal Resolution	Acquisition costs	Processing effort/area
NOAA, MODIS	1 km	Daily data	free	low
Landsat, SPOT				
Quickbird Aerial photos	1m	„On demand“ only	Pricing per km²	high

Exceptions: new sensors like RapidEye

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Image Systems and costs (circa 2008)

System	Spectral range	Spatial resolution	Cost per km² ($)
Aerial photography	PAN or VIS/NIR	1:12,000	Depends on size of study area
Quickbird	PAN or VIS/NIR	0.61 m / 2.4 m	$14 – 83 (depending on accuracy)
IKONOS	PAN or VIS/NIR	0.8 m or 3.2 m	$10 – 50 (depending on accuracy)
RapidEye	VIS/NIR	5 m	EUR ±0.50 (depending on size of study area)
Resourcesat	G/R/NIR/SWIR	5 m / 60 m	$ 0.005 (AWiFS) – 4.80 (LISS4)
Landsat-7 ETM+	VIS/NIR/MIR/TIR/ PAN	30 m / 60 m / 15 m	Free
SPOT 5 imagery	PAN or VIS/NIR/MIR	10 m or 20 m	EUR 500 – 4860 (processing and spatial resolution)
RADARSAT	Fine-beam Standard-beam	10 m 30 m	$3600 - $5400 (spatial resolution & polarization)
Lidar	Typically 532 nm or 1064 nm	Depends on altitude	> R100 ha

Case Studies

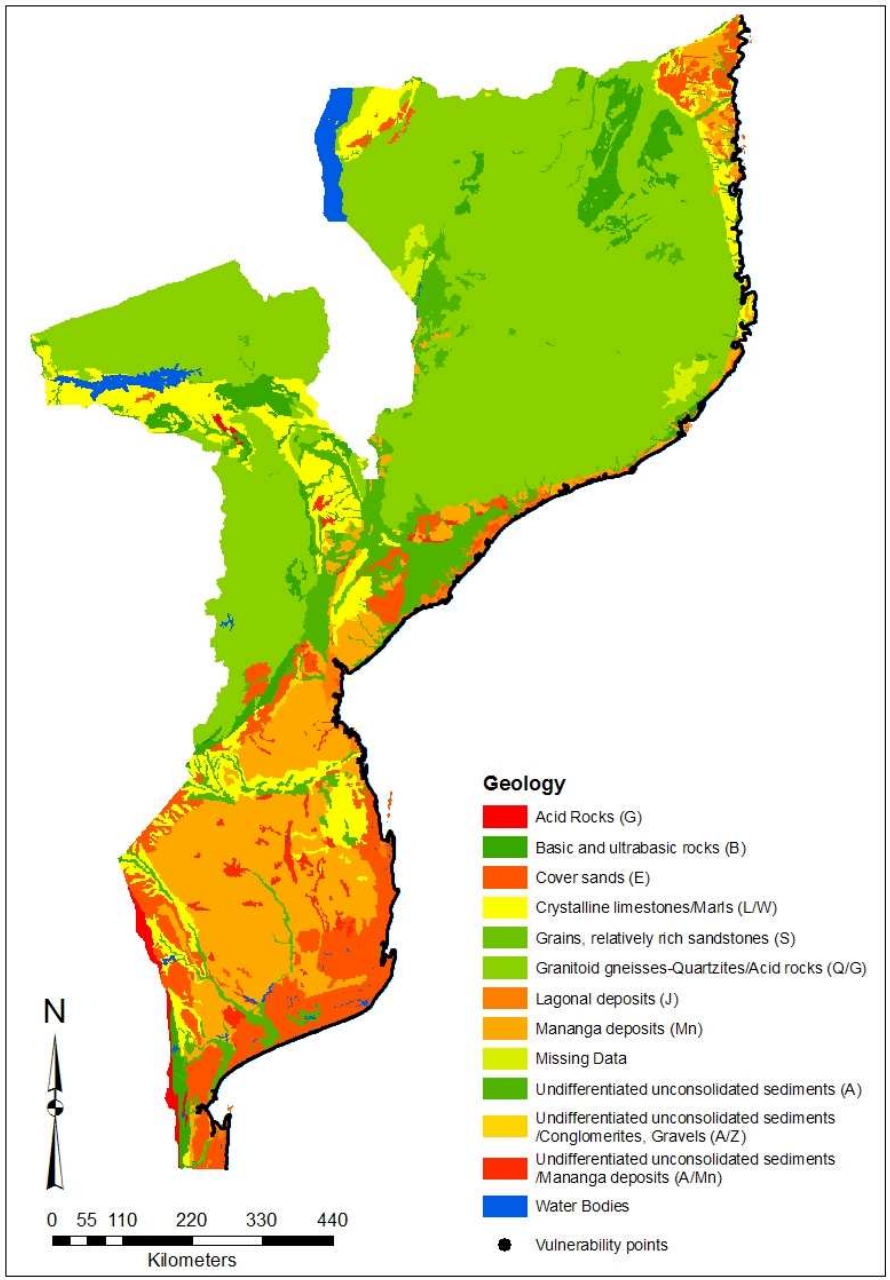
- Coastal Vulnerability to Climate Change
- Erosion and Accretion

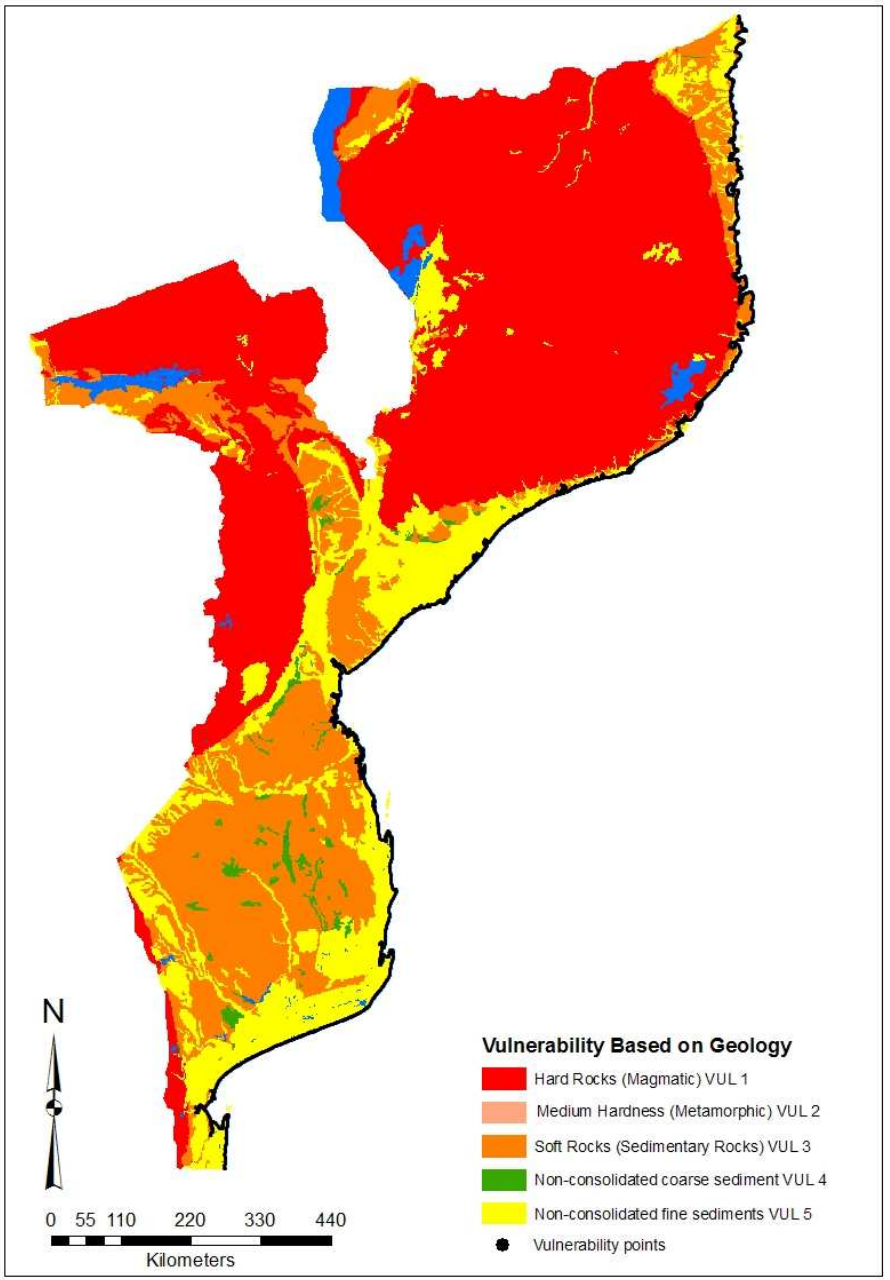
Coastal Vulnerability to Climate Change (Mozambique coastline)

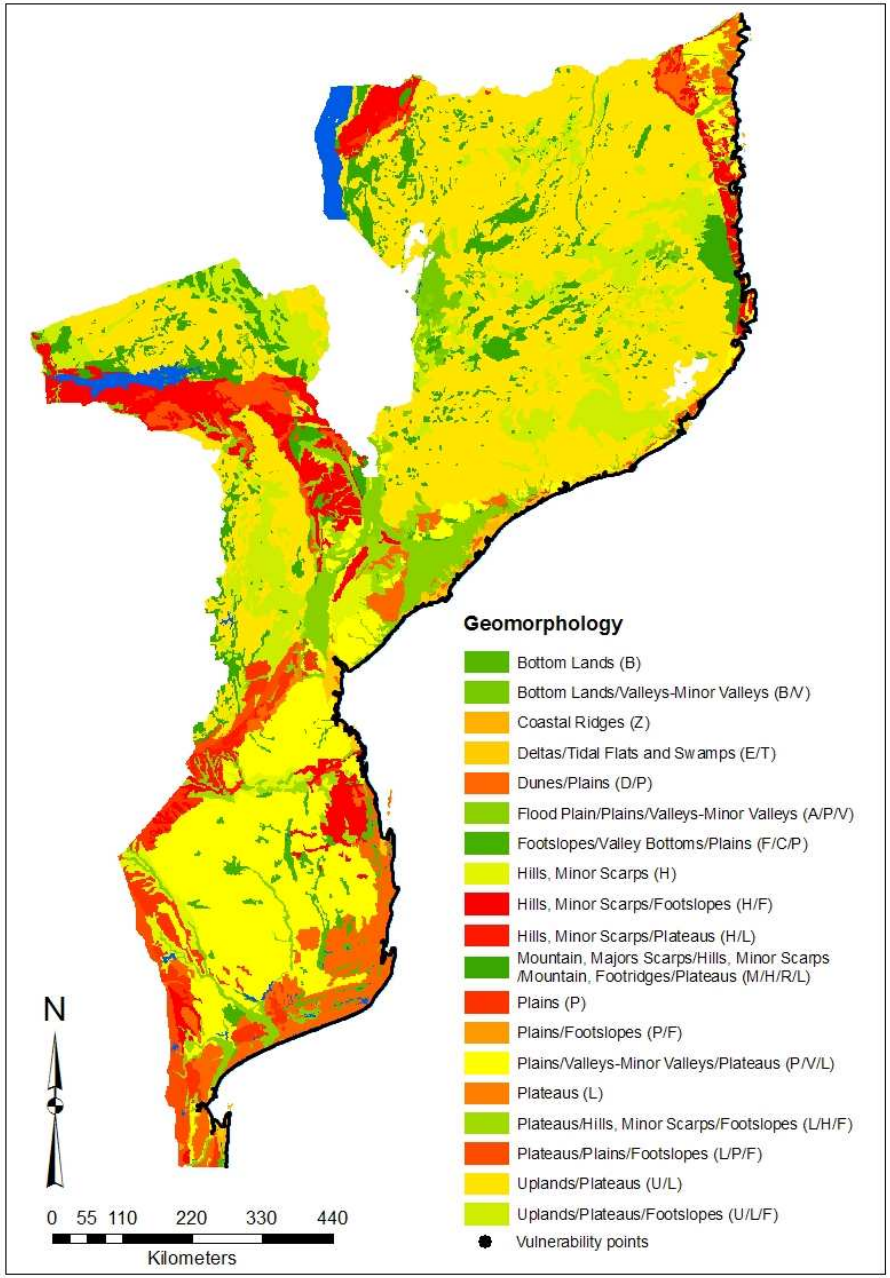
- Identifying areas that vulnerable to extreme climatic events
- Develop/Apply Vulnerability Index (Coelho, et al 2006)
- Important Input GIS Layers
  - Topographic elevation
  - Distance to urban infrastructure
  - Geology / Geomorphology
  - Land cover
  - Tidal range / Max wave height / Erosion - accretion
- Data stored in spatial database (ESRI - *.shp)

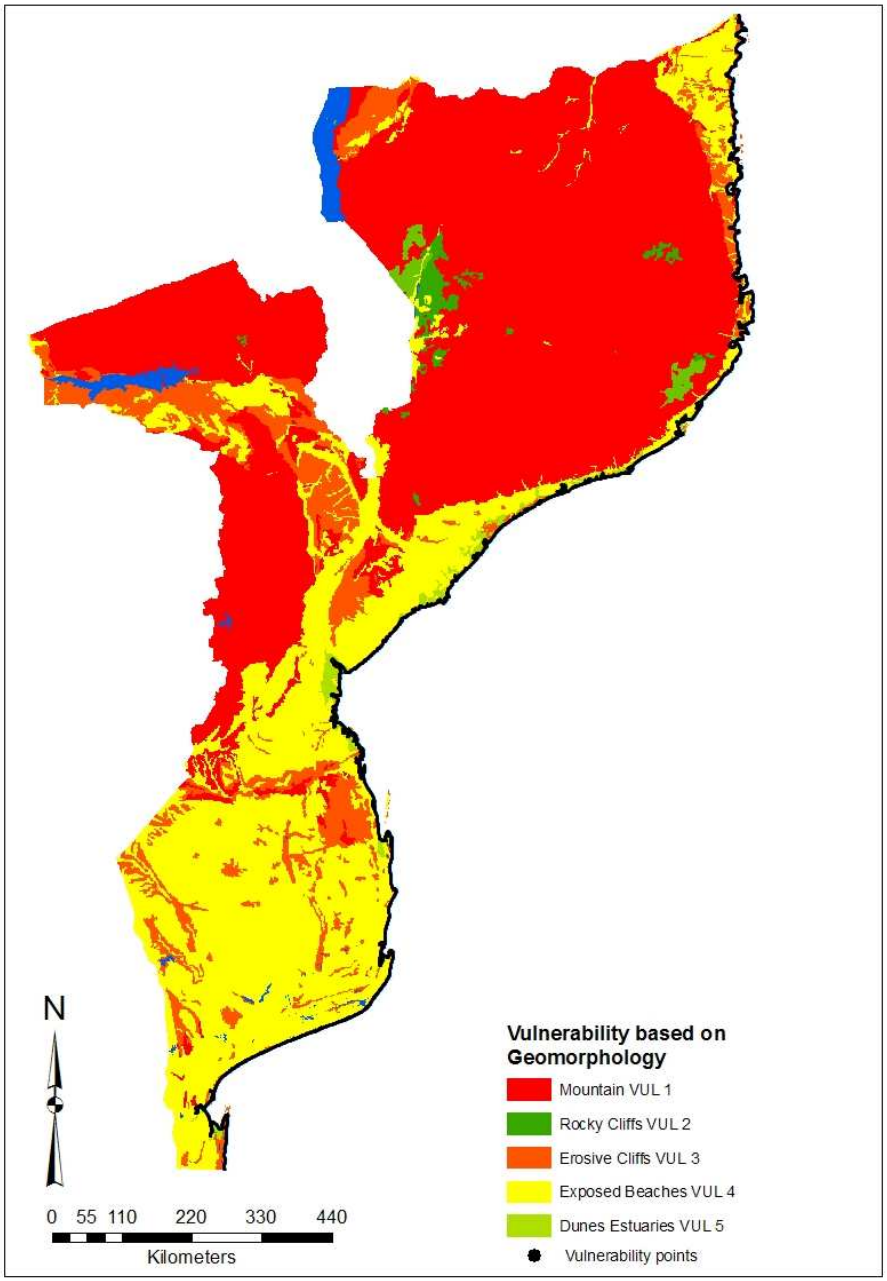
Vulnerability Index (Coelho, et al 2006)

	Vulnerability Classification	Very Low	Low	Moderate	High	Very High
	Score =>	1	2	3	4	5
1	TE: Elevation (m)	>30	21 - 30	11 - 20	6 - 10	<5
2	DS: Distance to shore (m)	>1000	200 - 1000	50 -200	20 -50	<20
3	TR: Tidal range (m)	<1	1 - 2	2 – 4	4 – 6	>6
4	WH: Max wave height (m)	<3	3 - 4	5 - 6	6 – 6.9	>7
5	EA: Erosion / accretion rate (m/yr)	>0 (erosion)	-1 to 0	-3 to -1	-5 to -3	< -5 (accretion)
6	GL: Geology	Hard rocks (Magmatic)	Medium hardness (Metamorphic)	Soft rocks (Sedimentary)	Non-consolidated coarse sediment	Non-consolidated fine sediments
7	GM: Geomorphology	Mountains	Rocky cliffs	Erosive cliffs, Sheltered beaches	Exposed beaches, flats	Dunes, river mouths, estuaries
8	GC: Ground Cover	Forest	Mangroves	Ground Vegetation, cultivated	Non-covered, Rural urbanised	Urbanised Industrial


Geology
Acid Rocks (G)
Basic and ultrabasic rocks (B)
Cover sands (E)
Crystalline limestones/Marls (L/W)
Grains, relatively rich sandstones (S)
Granitoid gneisses-Quartzites/Acid rocks (Q/G)
Lagonal deposits (J)
Mananga deposits (Mn)
Missing Data
Undifferentiated unconsolidated sediments (A)
Undifferentiated unconsolidated sediments /Conglomerites, Gravels (A/Z)
Undifferentiated unconsolidated sediments /Mananga deposits (A/Mn)
Water Bodies
Vulnerability points
N
0 55 110 220 330 440
Kilometers

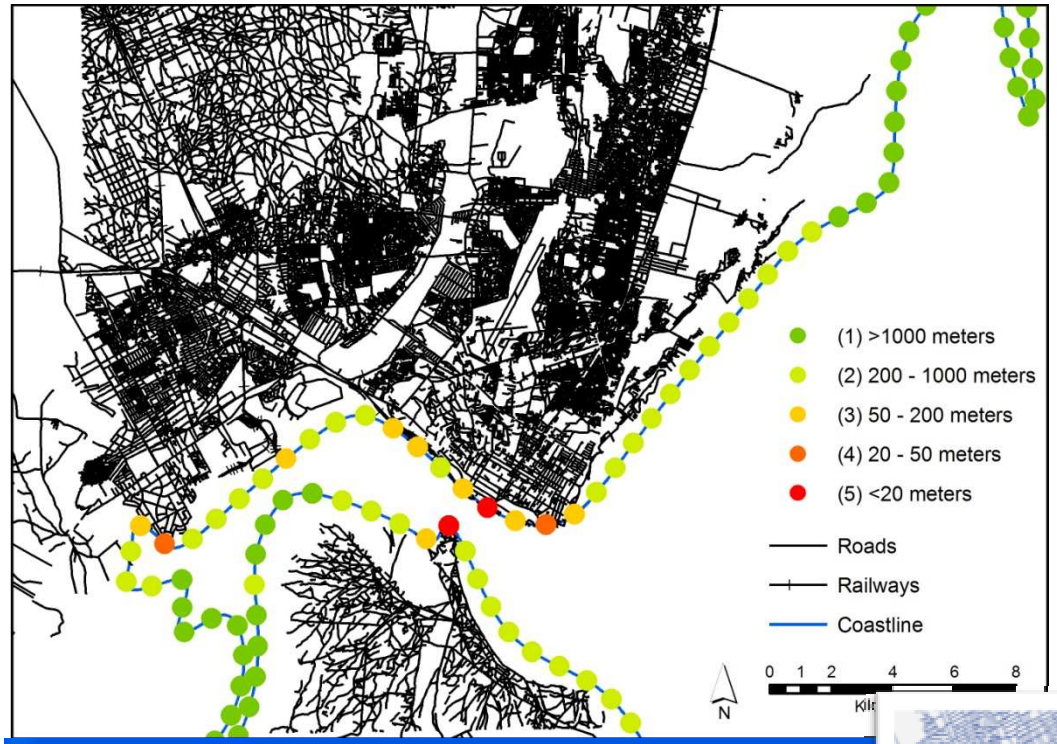

Vulnerability Based on Geology
Hard Rocks (Magmatic) VUL 1
Medium Hardness (Metamorphic) VUL 2
Soft Rocks (Sedimentary Rocks) VUL 3
Non-consolidated coarse sediment VUL 4
Non-consolidated fine sediments VUL 5
Vulnerability points
N
0 55 110 220 330 440
Kilometers


Geomorphology
Bottom Lands (B)
Bottom Lands/Valleys-Minor Valleys (B/V)
Coastal Ridges (Z)
Deltas/Tidal Flats and Swamps (E/T)
Dunes/Plains (D/P)
Flood Plain/Plains/Valleys-Minor Valleys (A/P/V)
Footslopes/Valley Bottoms/Plains (F/C/P)
Hills, Minor Scarps (H)
Hills, Minor Scarps/Footslopes (H/F)
Hills, Minor Scarps/Plateaus (H/L)
Mountain, Majors Scarps/Hills, Minor Scarps /Mountain, Footridges/Plateaus (M/H/R/L)
Plains (P)
Plains/Footslopes (P/F)
Plains/Valleys-Minor Valleys/Plateaus (P/V/L)
Plateaus (L)
Plateaus/Hills, Minor Scarps/Footslopes (L/H/F)
Plateaus/Plains/Footslopes (L/P/F)
Uplands/Plateaus (U/L)
Uplands/Plateaus/Footslopes (U/L/F)
Vulnerability points
N
0 55 110 220 330 440
Kilometers


Vulnerability based on Geomorphology
Mountain VUL 1
Rocky Cliffs VUL 2
Erosive Cliffs VUL 3
Exposed Beaches VUL 4
Dunes Estuaries VUL 5
Vulnerability points
N
0 55 110 220 330 440
Kilometers

Distance to Urban Infrastructure

- Input to Coelho et al (2006)
- Straight line distance to closest road or railway
- Maputo urban area shown
- Urban areas well mapped



Attributes of Export_Output

FID	Shape *	ELEV1KM	ELEV100M	LNDCOVER	CYCLONE	WAVE	TIDE	GEOLOGY	GEO_M
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168	Polygon	5	5	3	5	3	2	5	
276	Polygon	5	5	5	3	4	2	5	
374	Polygon	5	5	5	3	4	2	5	
516	Polygon	5	5	5	3	4	2	5	
558	Polygon	5	5	5	3	4	2	5	
620	Polygon	5	4	3	5	3	2	5	
1112	Polygon	5	5	5	3	4	2	5	
1114	Polygon	5	5	5	5	3	2	5	
1197	Polygon	5	5	5	3	4	2	5	
1901	Polygon	5	5	5	3	4	2	5	
2145	Polygon	5	4	3	5	3	2	5	
4022	Polygon	5	5	3	3	4	2	5	
4081	Polygon	5	5	5	3	4	2	5	
4153	Polygon	5	5	3	5	3	2	5	
4171	Polygon	5	5	3	5	3	2	5	
4181	Polygon	5	5	3	5	3	2	5	
1	Polygon	3	3	1	3	2	3	5	
4	Polygon	3	5	1	3	2	3	5	
10	Polygon	3	3	1	2	2	3	5	
12	Polygon	1	1	2	5	3	2	5	
18	Polygon	3	3	1	3	4	2	5	
20	Polygon	4	4	2	2	2	3	3	
23	Polygon	4	4	1	3	2	3	3	
24	Polygon	1	5	1	4	4	2	5	
26	Polygon	4	3	1	5	3	2	3	

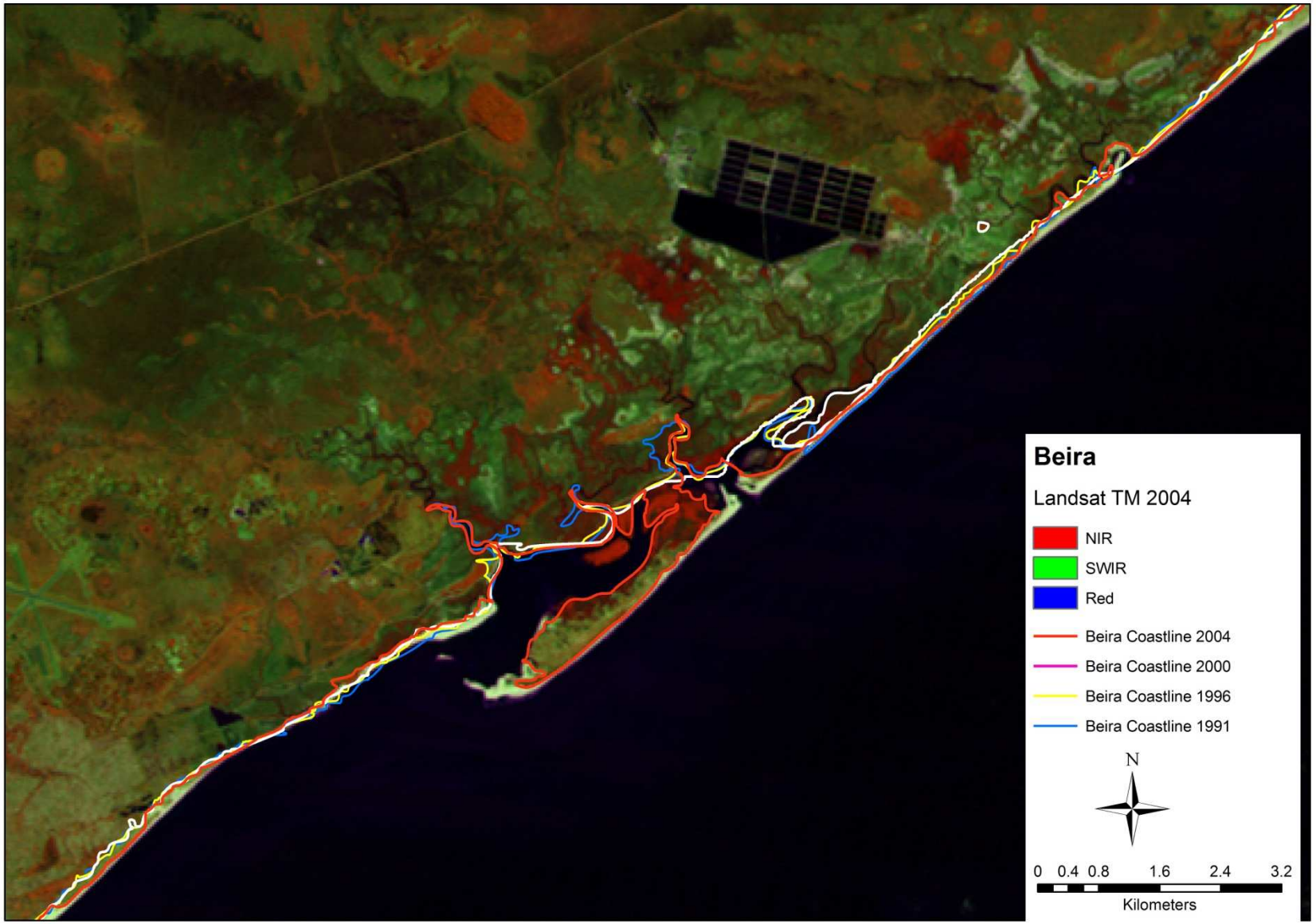
Erosion and Accretion

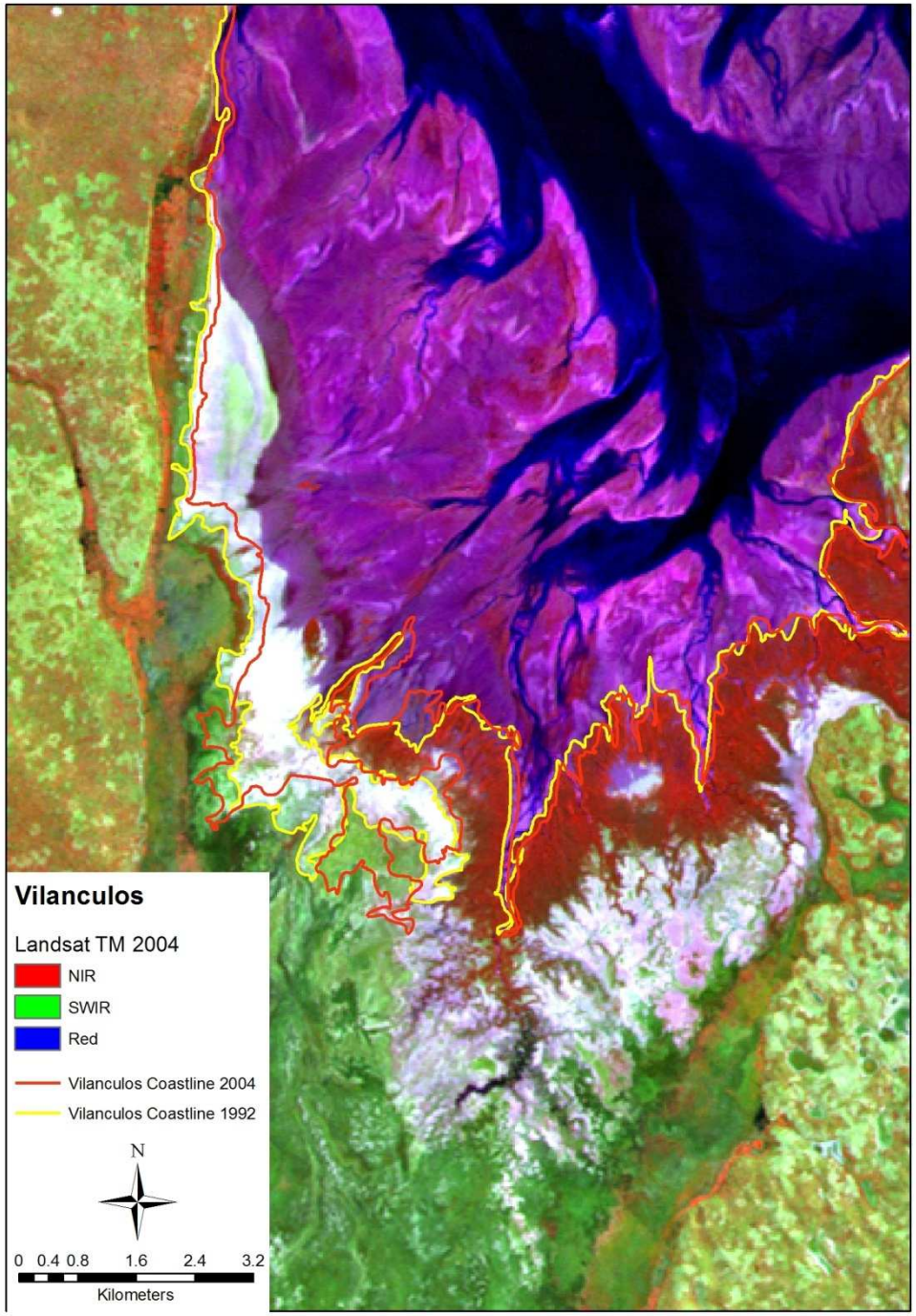
- Key input to Coelho et al 2006
- Historical analysis of coastal change
- Landsat TM and ETM+ (where available), optimally with higher resolution data
- Methods
  - Object Oriented Analysis
  - Change Vector Analysis

Object Oriented Analysis

- Hierarchical segmentation and classification
- Use Landsat time series
- Extract coastline at 5 year intervals
- Identify areas where significant erosion and or accretion was taking place

Object Oriented Analysis cont…





Limiting factors:

- Quality of Imagery
- Tidal differences
- Accuracy of Landsat TM & ETM+
  - ±60m error

Benefits of Landsat:

- Long time series available
- Suitable for large areas

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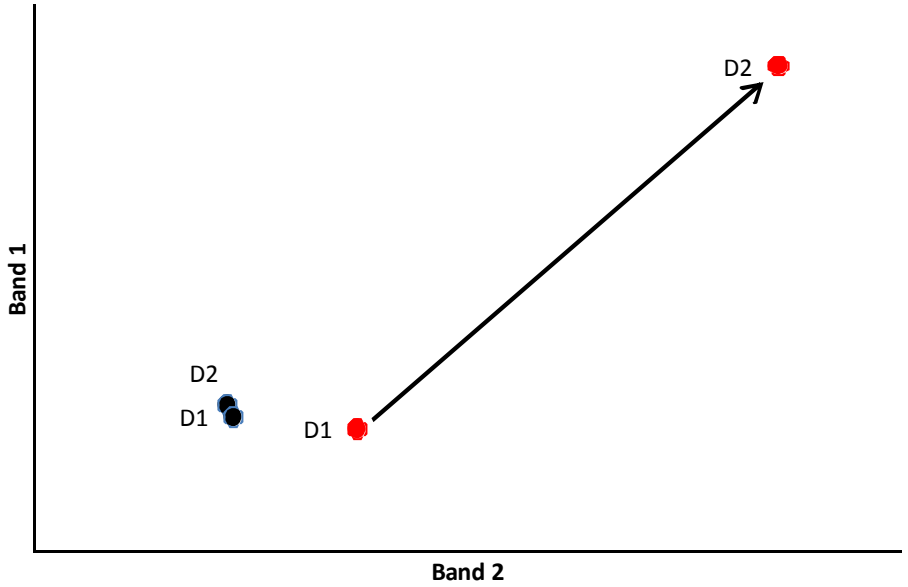
Change Vector Analysis

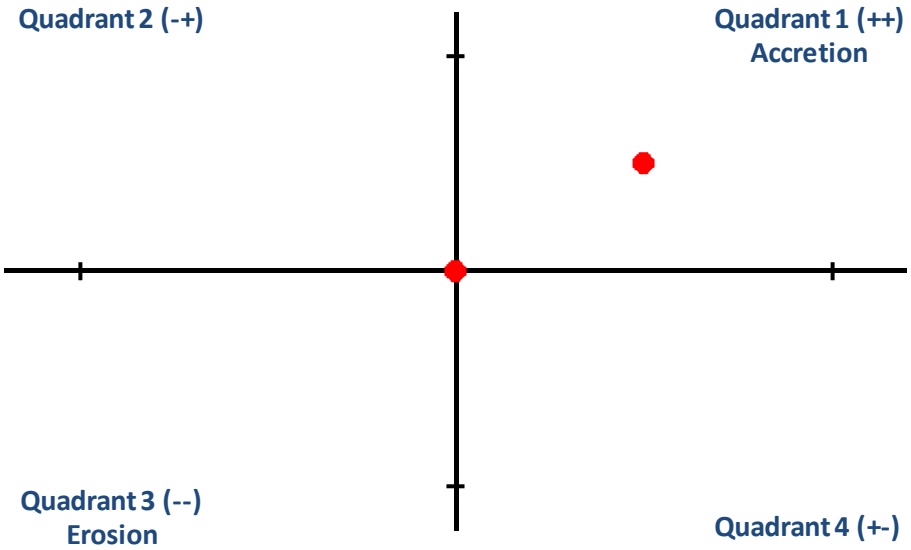
- Purpose: extraction of Magnitude and Direction of change btw two dated images.
- Used in this case: Landsat TM and ETM, NIR & PCA band 1
- CVA conducted between several image pairs (Beira)
- 1991 – 1996*; 1996 – 2000; 2000 – 2004.

Quick theory of CVA



Magnitude

$$M = \sqrt{(yb - ya)^2 + (xb - xa)^2}$$



Direction

2004

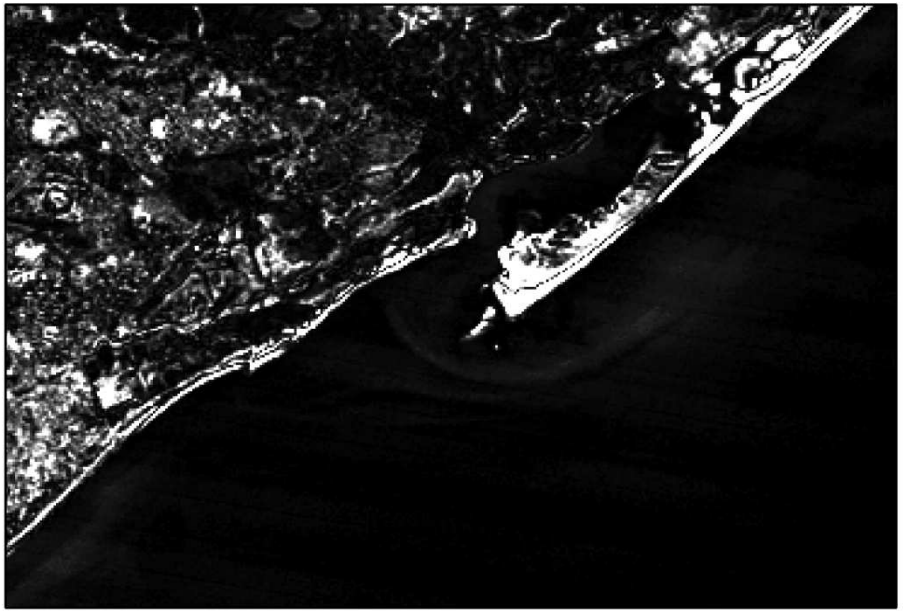
1991

1996

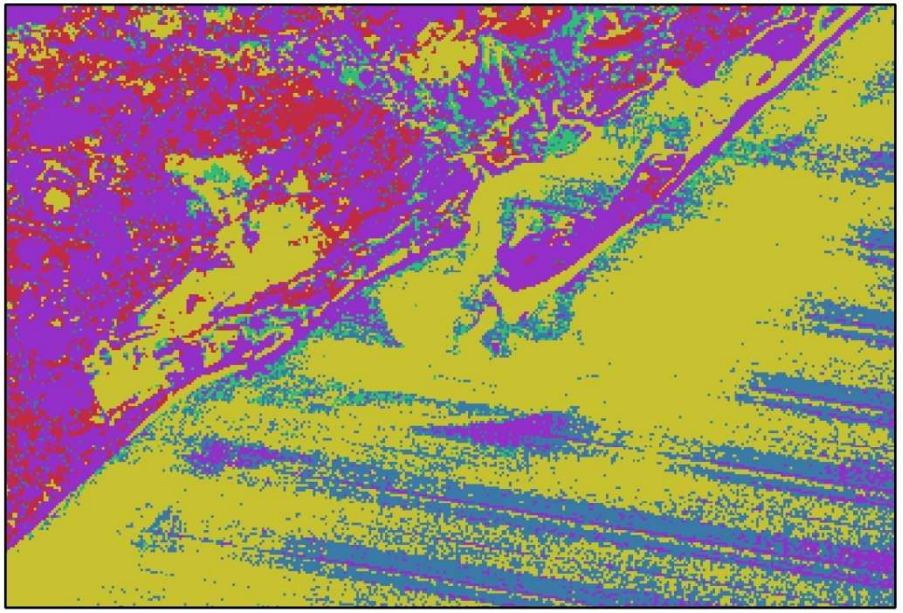
4

Kilometers

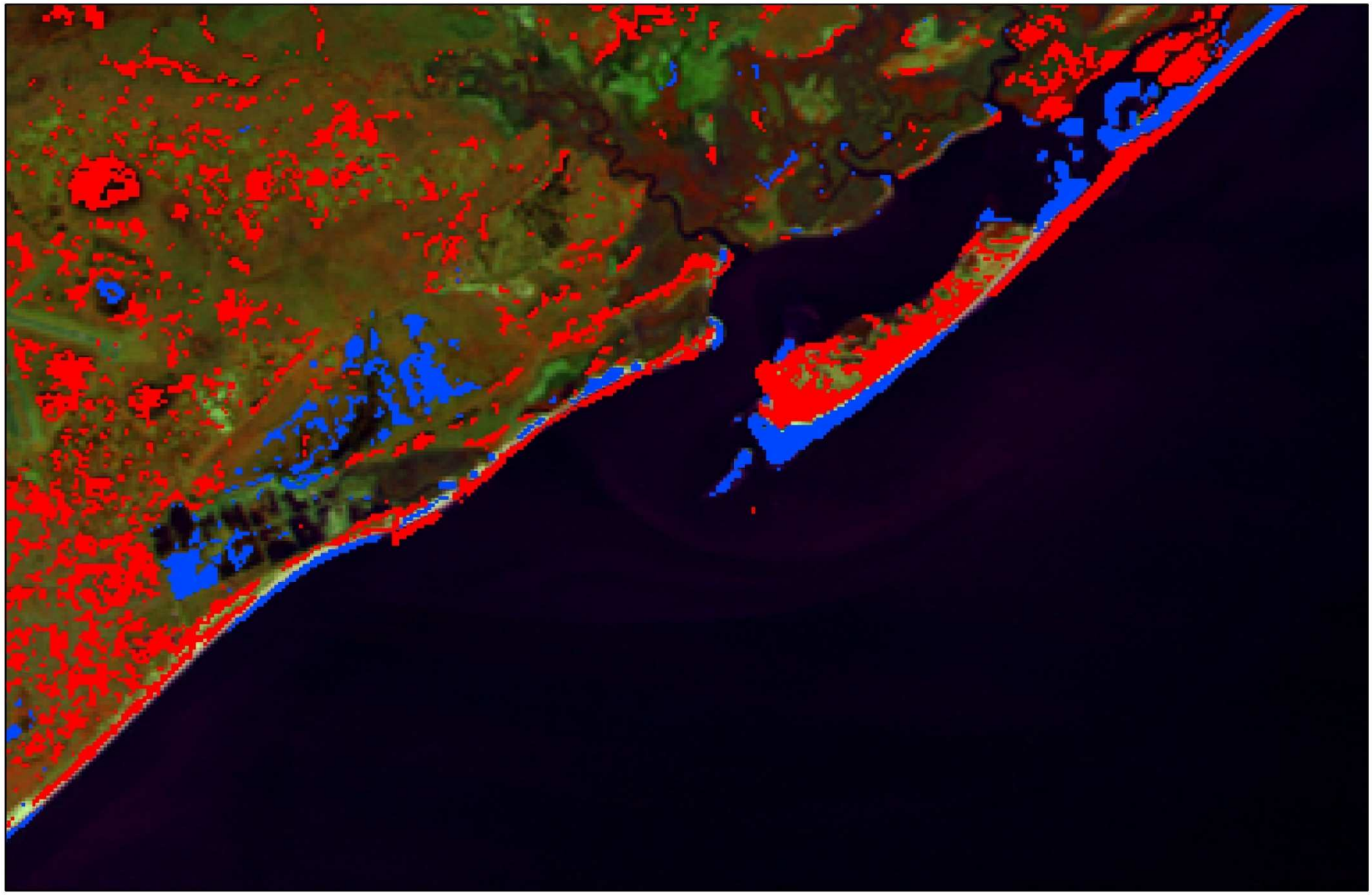
Magnitude



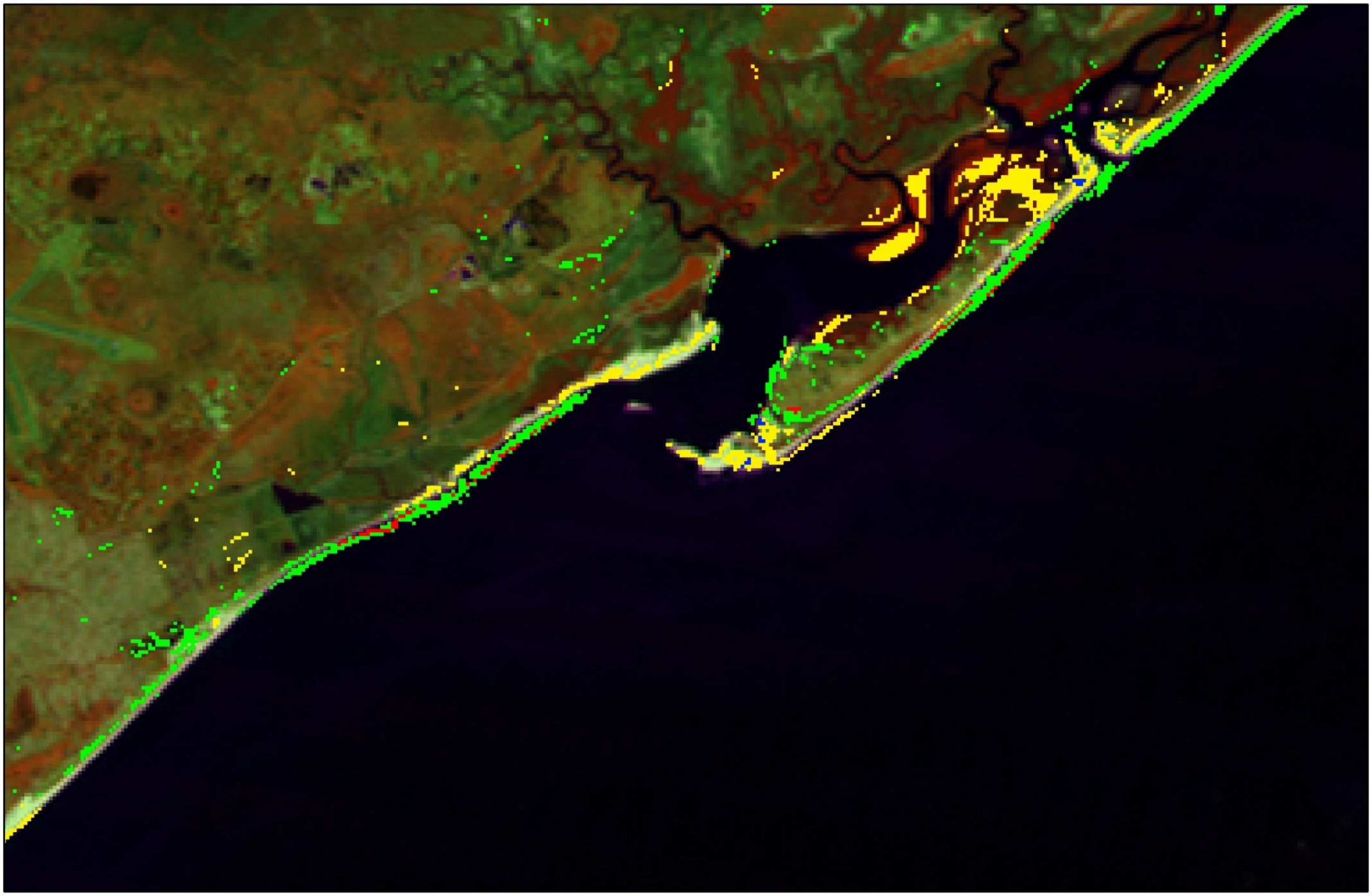
Direction



1996


Quadrant 1 (Accretion)
Quadrant 3 (Erosion)
0 0.45 0.9 1.8 2.7 3.6
Kilometers
N

2004


2
3
Quadrant 3 (Erosion)
2
3
Quadrant 1 (Accretion)
0 0.45 0.9 1.8 2.7 3.6
Kilometers
N

CVA Results & Conclusions

- Change in image time series easily identified
- Nature of change (erosion / accretion)
- RS not 100% definitive
  - Must be accompanied with detailed field work
- The scale of the question and of the investigated area is crucial for finding appropriate imagery: Resolution of Landsat TM & ETM+ too coarse for detecting small scale changes
- Not possible to determine rates of change using Landsat data. Possible with high resolution data (aerial photography etc)

Thank you

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