THE APPLICATION OF SATELLITE-BORNE REMOTE SENSORS FOR MONITORING COASTAL EROSION AND ECOSYSTEMS IN IRELAND.

PhD Research Project (1st Year)

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Abstract:

Advances in the resolution and availability of imagery from satellite-borne remote sensors have presented an opportunity to utilise the data for near real-time monitoring of coastal erosion and coastal ecosystems. This research project focuses on developing a technique for measuring changes in coastal geomorphology and vegetation cover using a combination of synthetic aperture radar and multispectral imagery.

The technique is being developed, tested and refined using data collected from two study sites on the west coast of Ireland. Extracted shoreline positions are validated against aerial photography and LiDAR archives and repeat field survey data. Time series analyses are used to determine localised erosion rates and forecasting techniques will be utilised to produce predicted shoreline positions for years 2020, 2030 and 2050. These results will be benchmarked against equivalent shoreline predictions published in the Irish Coastal Protection Strategy Study (OPW, 2014).

The imagery will further be used to generate vegetation maps for the purposes of monitoring the ecological status of coastal habitats (with respect to the EU Habitats Directive) and identifying and delineating areas of invasive vegetation species.

Objectives / Study Sites:

Primary Objective:

- Develop technique for monitoring and forecasting coastal erosion (Risk Management, Long-term Planning)

Secondary Objectives:

- Monitor ecological status of coastal habitats (EU Habitats Directive)
- Identify and delineate areas of invasive vegetative species

Study Sites:

Where? West coast of Ireland

Why? 1) Sites are very susceptible to Atlantic storms.

2) Special Area of Conservation, proposed Natural Heritage Area and Special Protected Area designations

3) ICPSS Predicted Erosion Maps (2030 & 2050)

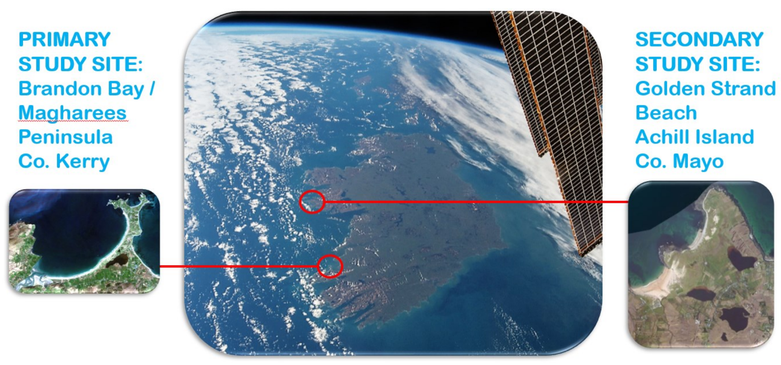

Figure 1: Location of Study Sites - Primary: Kerry Study Site (KSS) & Secondary: Mayo Study Site (MSS)

Irish Coastal Protection Strategy Study:

Study Duration: 2003 - 2013

Objective: "*Provide information to support decision making about how best to manage risks associated with coastal flooding and coastal erosion"* (OPW, 2014).

Issue: "Predictive" coastal erosion maps for 2030 and 2050 based on a projection of past erosion rates derived from historic aerial photographs (from the 1970's, 2000 and 2005).

Inherent Uncertainty: 1) Annual erosion rate for future years was assumed to be the same as in the past, 2) no account for climate change.

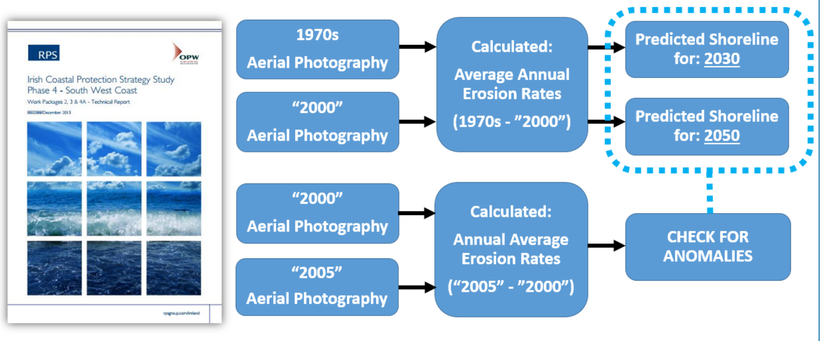

Figure 2: Overview of ICPSS Methodology for Generating Predicted Erosion Maps for Years 2030 & 2050

Methodology:

An overview of the methodology used to generate shoreline vectors and ground cover rasters is provided in **Figure 3**.

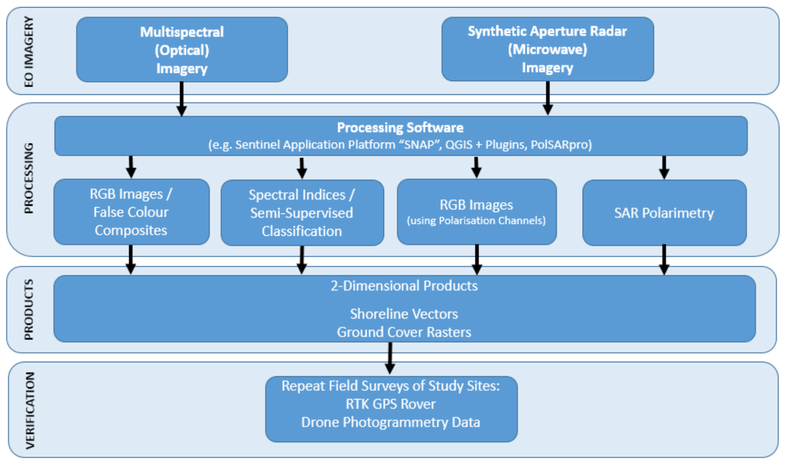

Figure 3: Overview of Methodology

Techniques Employed:

Panchromatic & Multispectral Imagery:

- Pansharpening
- Spectral Indices (e.g. NVDI, DVI, NDWI & SAVI)
- Semi-supervised Classification

Synthetic Aperture Radar Imagery:

- SAR Polarimetry

Multispectral & Synthetic Aperture Radar Imagery:

- Generation of Fused/Hybrid Imagery

Preliminary Results:

Data Mining (for Kerry Study Site):

A comprehensive search all available EO imagery from the 1970s to March 2017 was carried out for KSS. A summary of the results is shown in **Figure 4**.

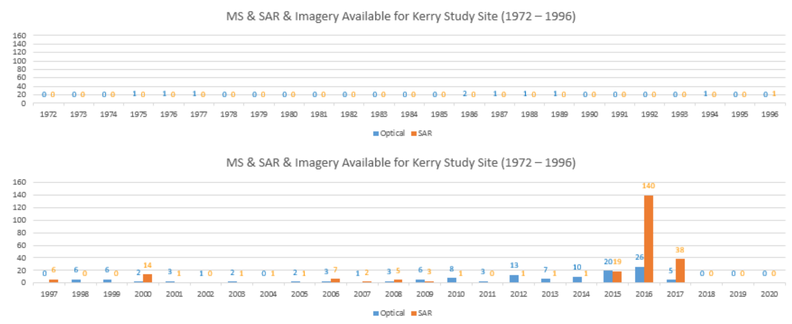

Figure 4: Overview of MS and SAR Imagery Available for KSS (1972 - March 2017)

Note: Annual number of MS/Optical images refers to images with full visibility of study site (i.e. not obscured by clouds)

Figure 5 provides a summary of the spatial resolution of the available MS and SAR imagery for KSS:

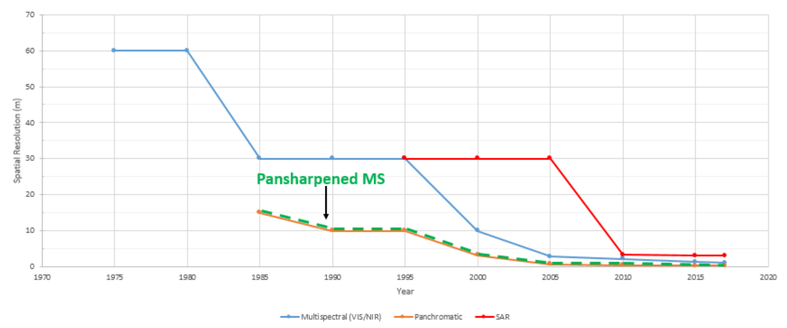

Figure 5: Overview of Spatial Resolution Available for KSS (1972 - March 2017)

An overview of available shoreline datasets and major storm events for the period 2000 to 2017 is shown in **Figure 6** below. Also included is a graphical overview showing when various EO satellites were launched.

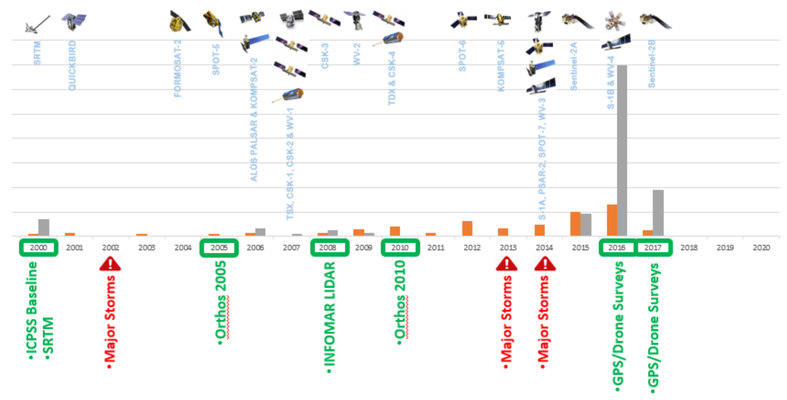

Figure 6: Overview of Major Storm Events (Red) and Available Shoreline Datasets (Green) for KSS (2000 - March 2017)

Preliminary Results: (continued)

Historic Coastal Erosion Rates for Kerry Study Site:

Minimum Annual Rate of Erosion (1900 - 2015) = **0.37m/year**

Average Annual Rate of Erosion (1900 - 2015) = **0.64m/year**

Erosion Rates versus Available Spatial Resolution:

An assessment of spatial resolution against historic coastal erosion rates (for KSS) is provided in **Table 1** (based on a 5-year measuring cycle).

Satellite Platform	Imagery Type	Spatial Resolution	Ability to Detect Erosion Over a 5-year Period Based on Minimum Annual Rate of Erosion (= 5 x 0.37 = 1.85m)	Ability to Detect Erosion Over a 5-year Period Based on Average Annual Rate of Erosion (5 x 0.64m = 3.2m)
Pléiades-1A/B Worldview 1-4	Pan	0.5m x 0.5m	✓	✓
KOMPSAT-2	Pan	1m x 1m	✓	✓
SPOT 6 & 7	Pan	1.5m x 1.5m	✓	✓
TerraSAR-X ALOS PALSAR 2 COSMO-SKYMED 1-4	SAR	3m x 3m	×	✓
Sentinel-1A/B (IWS)	SAR	5m x 20m	×	×
Rapideye 1- 5	MS	6.5m x 6.5m	×	×
RADARSAT-1/2	SAR	8m x 8m	×	×
Sentinel-2A/B	MS	10m x 10m	×	×
Landsat 4-5 TM Landsat 7 ETM Landsat 8 OLI	Pan	15m x 15m	×	×
Landsat 4-5 TM Landsat 7 ETM Landsat 8 OLI	MS	30m x 30m	×	×

Table 1: Assessment of Available Spatial Resolution Against Historic Coastal Erosion Rates (5-year measuring cycle)

Fused / Hybrid Imagery (SAR & MS):

An example of a fused/hybrid image (of KSS) derived from Sentinel-1B and Sentinel 2A is provided in **Figure 7**.

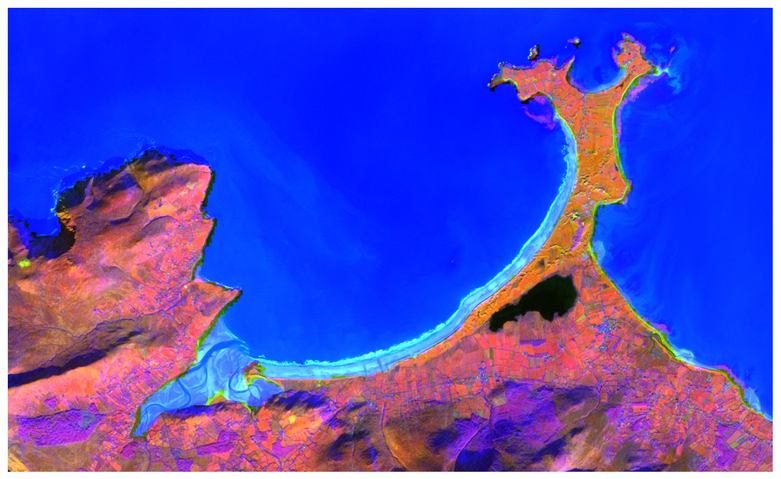

Figure 7: Fused / Hybrid Image of Kerry Study Site Derived from a Combination of Sentinel-1 and Sentinel-2 Imagery (ESA, 2016)

Conclusions (to-date):

- Generation of 3D products (digital elevation models) of study sites not currently feasible due to the effects of temporal decorrelation (bistatic SAR imagery required)
- From 2010 onwards, there is MS imagery with sufficient spatial resolution to measure the expected minimum annual rate of erosion at the Kerry Study Site.
- From 2008 onwards, there is SAR imagery available with sufficient spatial resolution (3m x 3m) to measure the average annual rate of erosion at the Kerry Study Site.

Plans for Next Phases of Research:

- Fabricate and install corner reflectors at Kerry Study Site.
- Automate shoreline extraction and generation of ground cover rasters using Python scripting.
- Investigate suitable time series forecasting techniques for generating forecasted shoreline positions for 2030 & 2050.
- Continue experimenting with fused MS and SAR imagery.

References:

Office of Public Works (2014), Irish Coastal Protection Strategy Study - Phase 4, Strategic Assessment of Coastal Flooding and Erosion Extents, Work Packages 2, 3 & 4A, Office of Public Works, January 2014

European Parliament (1992),. 92/43/EC of the European Parliament and of the Council of 21st May 1992 on the conservation of natural habitats and of wild fauna and flora.

European Space Agency (2016), Copernicus Sentinel-1 & Sentinel-2 from December 2016 and November 2016