Usage of remote sensing data for the identification of Shoreline evolution of the Holderness, UK

STEPHANIE D. MONTALVO DELGADO

Geology Department, University of Puerto Rico, Mayagüez Campus
P.O. Box 9017 Mayagüez, Puerto Rico, 00681-9017
email: stephanie.montalvo1@upr.edu

ABSTRACT: The Holderness coastline in UK is one of the fastest eroding coasts in Europe transporting the sediments southward by longshore currents. A study of the evolution of the coastline is of importance to the community and the infrastructure of the area. The purpose of the research is find out whether or not geomorphological changes along the Holderness coastline can be recognized and studied using images from TM and OLI. The main objectives are to identify and evaluate the changes in the coastline of Holderness using ENVI, offer valuable information for future studies of coastline hazard assessment, and offer a better understanding of the erosional processes which affect Holderness. Images of four years were picked over a period of 26 years. All images were taken from the EarthExplorer webpage. Once the images were obtained, several tools were used to obtain the final images. They were layer-stacked, georeference and mosaic. The end product was four georeference mosaic images. Polylines were traced along the coastline of each image. Afterwards, the distance between the lines of oldest and youngest was measured to obtain the rate of erosion, which was 2.15 m/yr. Another observation made is that there was more erosion at the top than the bottom of the coastline. This can be attributed to the geology of the area and the long shore currents that move south (top) and southeast (bottom). In conclusion, images from TM and OLI can be used to study the coastal changes of Holderness, UK.

KEYWORDS: ENVI, longshore currents, Landsat 8 OLI, rate of erosion, shoreline erosion, Landsat 5 TM

INTRODUCTION

The Holderness coastline in the East Riding of Yorkshire, UK, has an estimated rate of erosion of approximately 1.9 - 2.4 m/yr, and a 1,400 kt/yr material annual loss making it one of the fastest eroding coasts in Europe (Valentin, 1971; McCave, 1987; Duvivier, 1993). This low glacial drift cliff (3-35 m high) extends 61 km throughout the shore from Flamborough Head to Spurn Head (McCave, 1987). The area has chalk, bolder clay and alluvium deposits, see Figure 1 (Punnet, 2000; Sistermans and Nieuwenhuis, 2007).

At 1 Ma, the coastline was a cliff of chalk deposits that was located 32 km west of its current position (Sistermans and Nieuwenhuis, 2007). In the ice age of the Pleistocene epoch, deposits of glacial till accumulated along the coast changing the morphology of the coastline (Sistermans and Nieuwenhuis, 2007). The glacial till or boulder clay is composed of 72% mud, 27 % sand, and 1% gravel (Sistermans and Nieuwenhuis, 2007).

The eroded sediments from the glacial cliff of the Holderness are transported southward by longshore currents, where they combine with the sediments of the Humber Estuary’s plume (Blewett and Huntley, 1998). Hence, a reduction of the coastline of the upper part of the Holderness is to be expected.

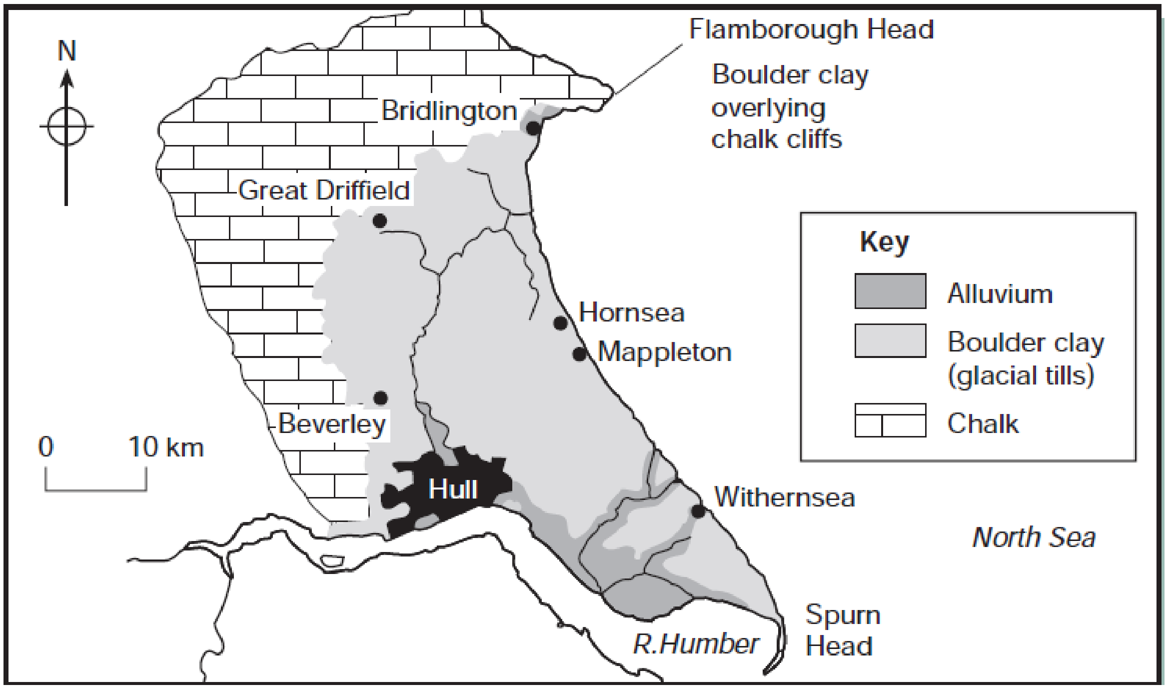

Figure 1. Simplified geology of Holderness (Punnet, 2000).

Taking into account the longshore currents, geology and rate of erosion that affects the Holderness coast, a study of the evolution of the coastline is of importance to the community that lives nearby. It is also important for determining the direct effects on the infrastructure of the area, see Figure 2. A promising way to study this area is by using remote sensing systems.

Previous research has been conducted in the Karachi coast in Pakistan to study geomorphological changes using remote sensing systems such as Multispectral Scanner (MSS) and Thematic Mapper (TM) (Siddiqui and Maajid, 2004). The digital enhancement techniques provided a way to recognize several features in the land and the ocean, which contributed in the monitoring and mapping of coastal changes in the area of study (Siddiqui and Maajid, 2004).

For this research, images from TM of Landsat 5 and Operational Land Imager (OLI) from Landsat 8 were used to study Holderness coastline changes over a period of time. The scientific question addressed is whether or not the geomorphological changes, such as land accretion and erosion, along the Holderness coastline in UK can be recognized and studied using images from TM and OLI sensors. The different resolutions of both sensors can be seen in Table 1.

The main objectives of this research are to identify and evaluate the changes in the coastline of Holderness using ENVI, to offer valuable information for future studies of coastline hazard assessment, and to provide a better understanding of the erosional processes which affect Holderness.

Figure 2. Photograph of the impact the erosion has on the coast of Holderness and its habitants (White, 2011).

Table 1. Resolutions of TM and OLI

Resolutions	TM Landsat 5	OLI Landsat 8
Spatial	30 m, 120 m (FIR)	30 m, 15 m (PAN)
Spectral	B, G, R, NIR, 2 MIR, FIR	2B, G, R, NIR, 3MIR, PAN
Temporal	16 days	16 days
Radiometric	8 bits	12 bits

Methodology

Images of Holderness from four different years were picked (1987, 2003, 2011, & 2013), covering a period of 26 years. All images were taken during the summer season to separate the seasonal tidal changes from the coastline evolution. Summer was chosen over the other seasons due to better image quality and low abundance of clouds in the available images. Taking into account that the area of interest is divided into two separate images, a total of eight images were obtained. Three sets of two images were taken from TM of Landsat 5, and one set of two from OLI of Landsat 8; the images were acquired from the EarthExplorer webpage of the USGS.

The program used to analyze and process the images was ENVI from Exelis. The processes and functions involved in the making of the final images included layer staking, georeference, image mosaic, feathering, subset, enhancement, polylines, and measurement tool.

The images from OLI were downloaded as separate bands; consequently the function of "layer stacking" was used to build a new multiband file. The images from TM did not have the coordinates of the area. Therefore they were "georeference" using OLI images coordinates. Since the area of study is divided in two images from each year, the function of "image mosaic" was used to superimpose the two images that have an overlapping area. The "feathering technique" was used to blend the interception of the overlapping images. A subset of the Holderness coast was created and enhanced, see Figure 3. The end product of these steps was four georeferenced mosaic images of the Holderness coast.

Figure 3. An example of a subset image of the Holderness coast from TM (1987).

To identify and evaluate the shoreline changes, a "polyline" was drawn around the coast (define by the cliff) of the different images using the red band. The reason for choosing this band is that the NIR band was missing from the downloaded files. Once all of the "polylines" were created they were overlaid on the most recent image (2013) for an easier comparison, see Figures 4-5.

Unfortunately the coastal change could not be easily identified from these images. To solve this problem, the youngest (2013) and oldest (1987) "polylines" were overlaid on the 2013 image, see Figure 6-9. Then, the distance between the two "polylines" was measured using the "measurement tool" function.

RESULTS & DISCUSSION

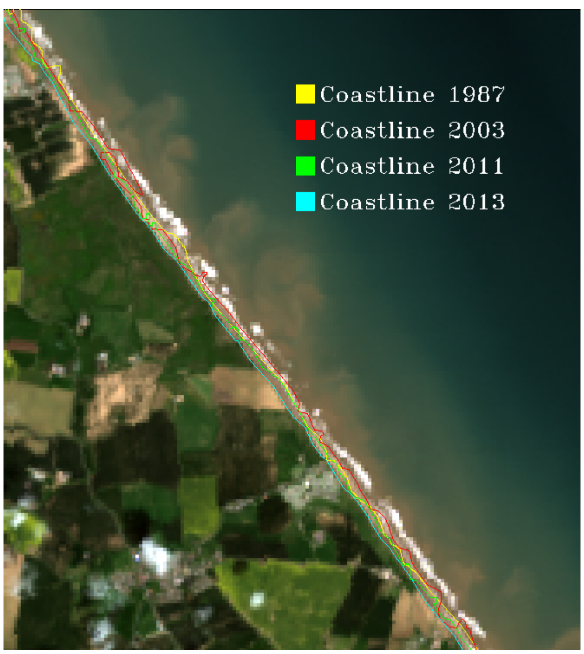

Figure 4. Upper part of the OLI 2013 image with the polylines of the different years. Yellow - coastline in 1987; red - coastline in 203; green - coastline in 2011; cyan- coastline in 2013.

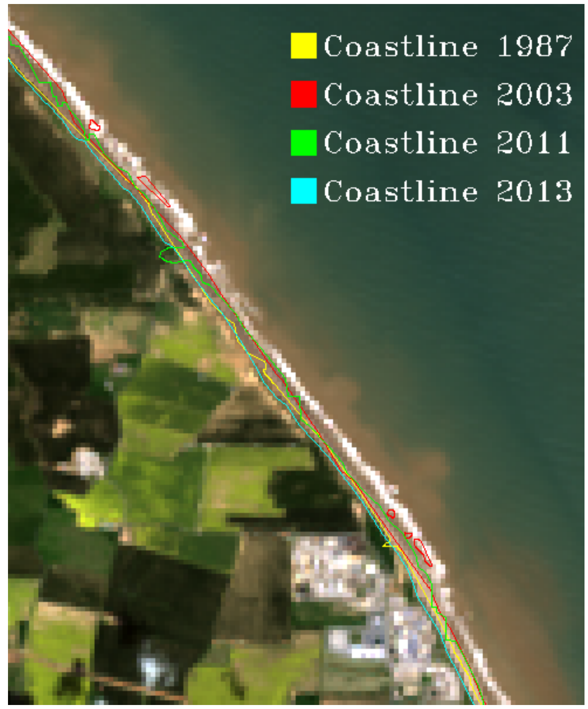

Figure 5. Lower part of the OLI 2013 image with the polylines of the different years. Yellow - coastline in 1987; red - coastline in 203; green - coastline in 2011; cyan- coastline in 2013

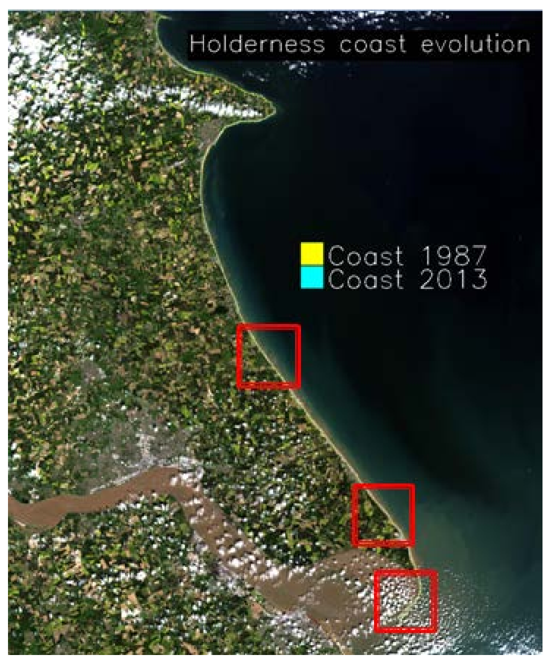

Figure 6. Holderness coast evolution using two polylines (1987 and 2013). Red squares represent the area of the following three images.

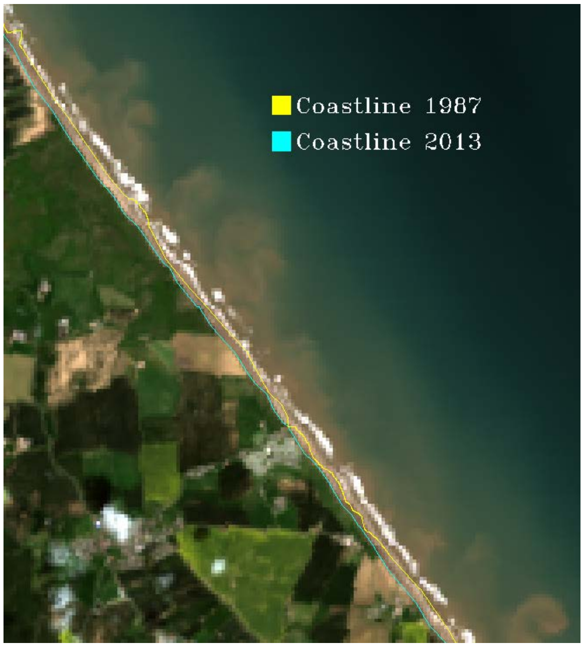

Figure 7. Holderness coast evolution of the upper part. The two polylines from 1987 (yellow) and 2013 (cyan) can be seen.

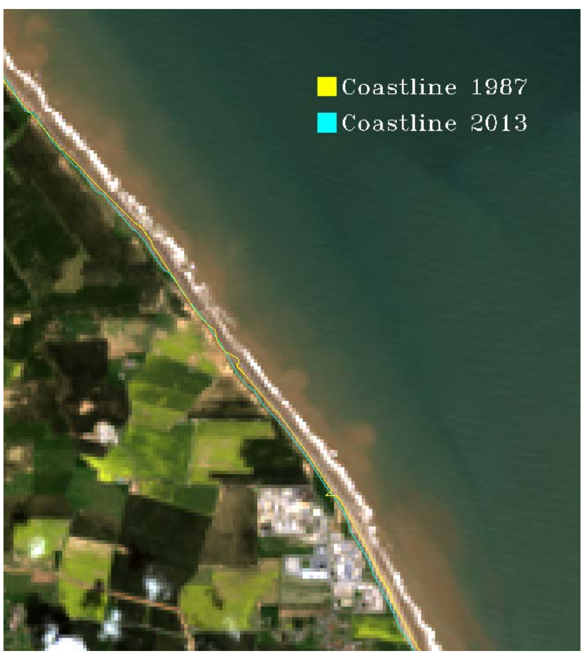

Figure 8. Holderness coast evolution of the middle part. The two polylines from 1987 (yellow) and 2013 (cyan) can be seen.

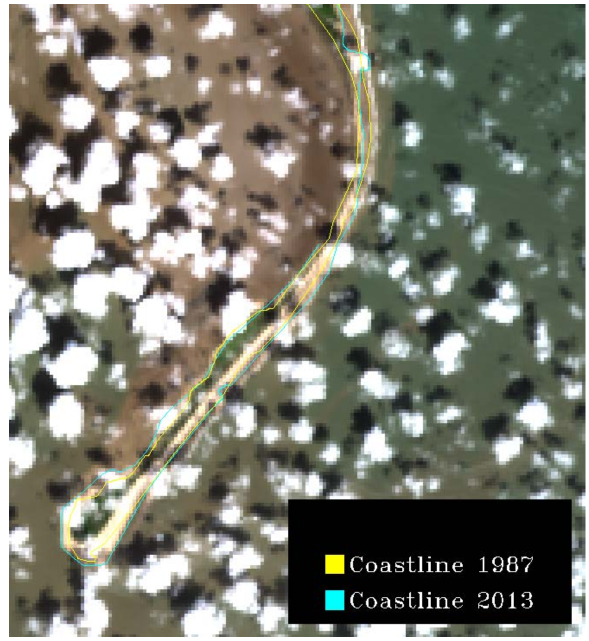

Figure 9. Holderness coast evolution of the lower part. The two polylines from 1987 (yellow) and 2013 (cyan) can be seen.

The images from above show the results obtained. Since coastal change is hard to identify in Figure 4 and 5, Figures 6-9 were created where only two “polylines” are visible. Bigger images of Figures 7 & 8 are located in the appendix for a better appreciation of the “polylines”.

An apparent decrease in the difference of the “polylines” (1987 and 2013) from North to South can be seen in the close up images, Figures 7-8. Several data points were chosen arbitrarily to measure the difference between the “polylines”, see Table 2. They were taken north to south to see the difference in a southward direction. A decrease in the difference of the “polylines” is also apparent in the data points. The coastlines around the spit in Figure 9 were not used to calculate the difference because the presence of clouds interfered with the “polylines”.

Table 2. Difference of the distance between the two "polylines" of 1987 and 2013

Segments	Difference (meters)
North	102.5006
	87.5006
	62.4997
	129.1552
	51.4787
middle	82.2340
	44.7227
	69.4616
	35.5307
	23.0470
South	25.4932
	65.6239
	12.5039
	19.1221
	27.1202

To better visualize the decrease of the difference between the "polylines" the data points were plotted, see Figure 10. The graph has a negative lineal trendline which also supports the decrease in the difference of the "polylines". In other words, there is more erosion at the top than at the bottom of the Holderness coast. This can be attributed to the geology of the area and the longshore currents that affects the area.

The Flamborough Head is composed of chalk while the rest of the coast consists of the boulder clay of alluvium deposits. Chalk is more resistant to erosion than the unconsolidated boulder clay, which is mainly mud. This explains why this area extends seaward, see Figure 1.

In the North Sea, the longshore currents of the Atlantic waters hit the Holderness in a

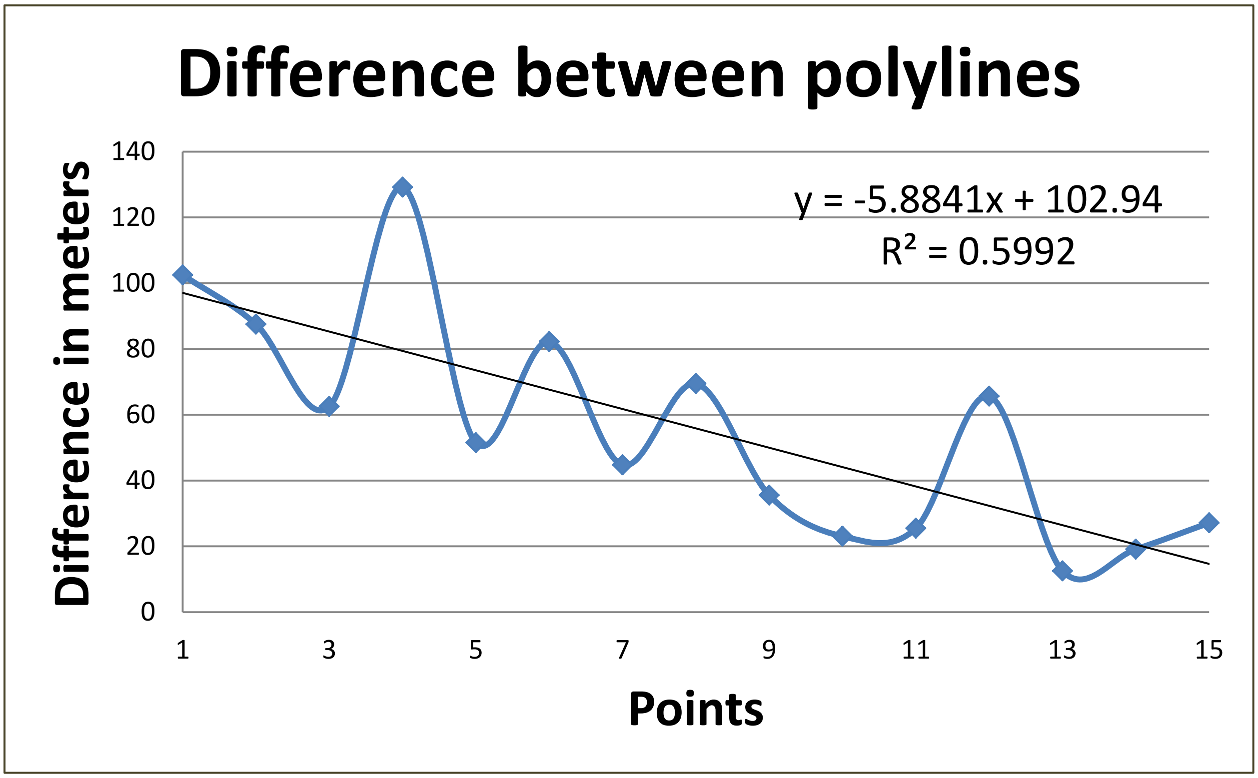

Figure 10. Graph of the data points showing the difference in meters between the "polylines" of 1987 and 2013. In the X-axis the lower values are closer to the North and the higher values are closer to the South.

southward-southeastward direction, see Figure 11. The evidence for this is the spit in the Spurn Head. This direction can affect the erosion of the area explaining the decrease of erosion as one move southward from 1987 to 2013.

Some studies suggest that the main reason for the form of erosion is cause by the reshape of the area into a bay to achieve a more efficient coastal shape (Sistermans and Nieuwenhuis, 2007).

Figure 11. The longshore currents that affects the North Sea. Image obtained from the European Enviromental Agency webpage (http://www.eea.europa.eu).

The average difference of the distance between the “polylines” is 55.87 m. With this information and the period of the images (26 years), the rate of erosion for the Holderness coast was calculated to be 2.15 m/yr. This value falls in the range of 1.9 to 2.4 m/yr previously calculated by Duviver (1993).

CONCLUSION

From the results obtained, it can be concluded that there is a visible change in the evolution of the coastline from 1987 to 2013 using images from TM and OLI. There was more erosion at the top than the bottom of the Holderness coast that can be attributed to the longshore current, which moves in a southward-southeastward direction, and to the geology of the area. The coastal changes of Holderness could also be calculated using images from TM and OLI and the ENVI program. The result obtained is 2.15 m/yr, which agrees to previous calculation done by other studies.

RECOMMENDATION

The usage of more images, years covered, and data points of the area are recommended. This would make a better estimation of the rate of erosion. Another recommendation is the usage of sensors that have a higher spatial resolution than 30 m (e.g. IKONOS).

ACKNOWLEDGMENTS

I would like to thank Dr. Fernando Gilbes of the UPRM for helping me throughout the project. His knowledge and patience guided me to the conclusion of this research. I would also like to thank my husband for pushing me into continuing my educational career at difficult times.

LITERATURE CITED

Blewett, J., and Huntley, D., 1998, Measurement of suspended sediment transport processes in shallow water off the Holderness Coast, UK: *Marine Pollution Bulletin*, **37**, p. 134-143.

McCave, I.N., 1987, Fine sediment sources and sinks around the East Anglian Coast (UK): *Journal of the Geological Society*, London, **144**, p. 149-152.

Duvivier, P, 1993, Easington Coast Protection: Environmental Statement, Posford Duvivier, Peterborough.

Punnet, N., 2000, Coastal erosion – back to nature: Geofile Online, 388, p. 1-4.

Siddiqui, M.N., and Maajid, S., 2004, Monitoring of geomorphological changes for planning reclamation work in coastal area of Karachi, Pakistan: *Advances in Space Research*, **33**, p. 1200-1205.

Sistermans, P., and Nieuwenhuis, O., 2007, Holderness Coast (United Kingdom): *EUROSION Case Study*, p.1-22.

Valentin, H., 1971, Land loss at Holderness, *in* Steers, J.A. (ed.): Applied Coastal Geomorphology, Macmillan, London, p. 116-137.

White, N.A., 2011, Print vs. Internet: CIWEM Environmental Photographer of the Year 2011 award winners. (http://www.telegraph.co.uk/earth/earthpicturegalleries/8848522/CIWEM-Environmental-Photographer-of-the-Year-2011-award-winners.html?image=11)

APPENDIX

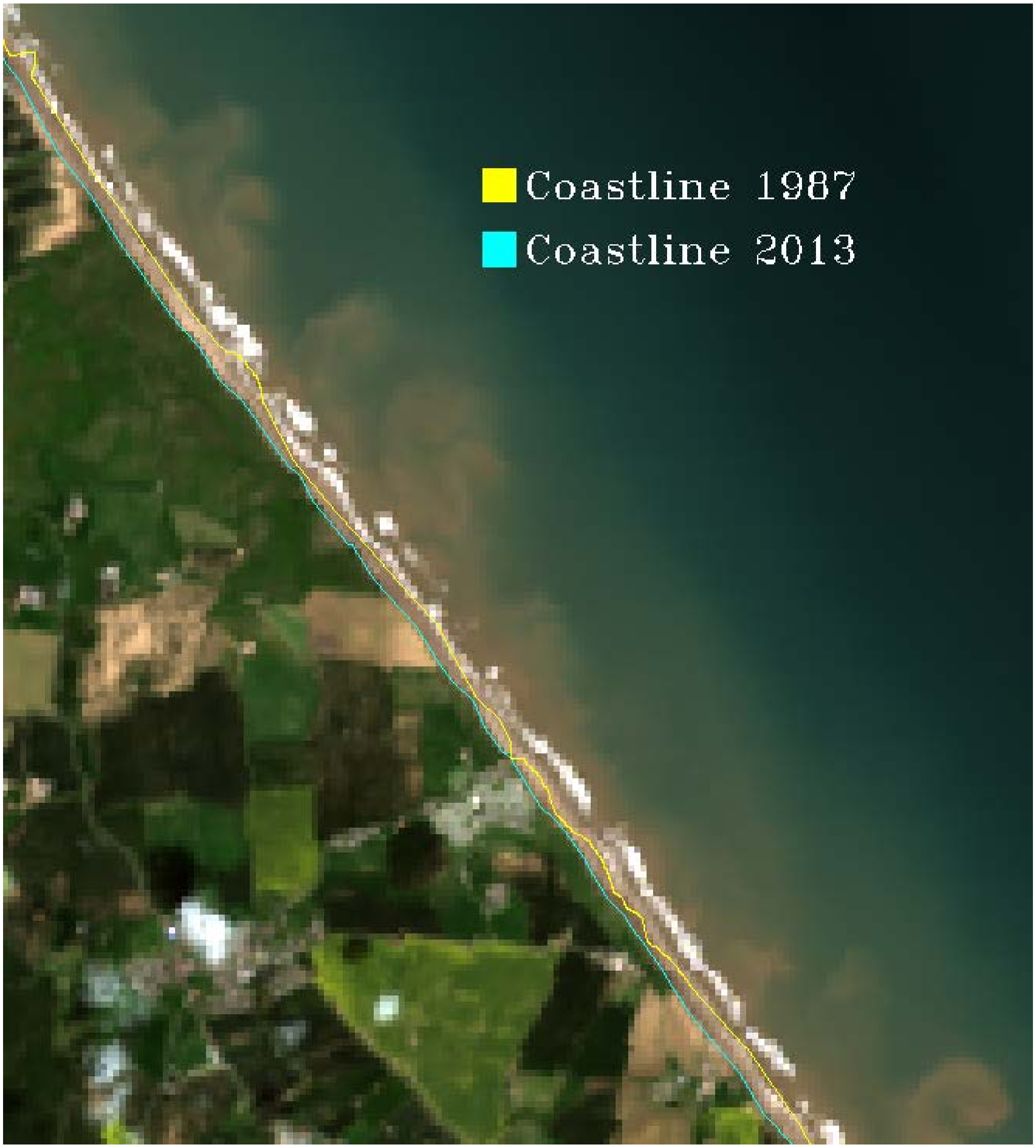

Figure 7, larger image where the polylines can be seen.

Figure 8, larger image where the polylines can be seen.