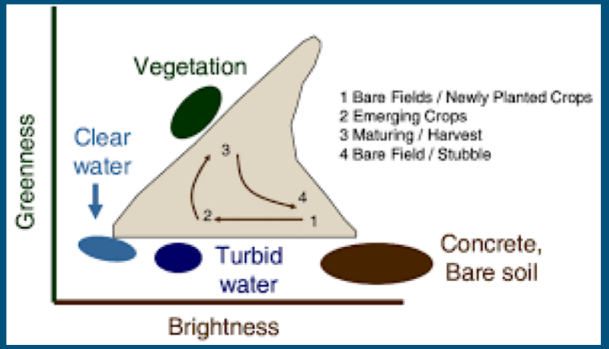
Coastal Erosion in the Ipswich River Estuary:

Utilizing a Tasseled Cap Transformation

Malcolm Stuart

What is a Tassel Cap?



A Sensor Specific Equation that gives three Primary values:

- Brightness
  - A measure of reflectance (primarily for urban land cover)
- Greenness
  - A measure of vegetation
- Wetness
  - A measure of soil moisture, or moisture in general.

Wetness and Coastal Erosion

- Wetness could potentially serve as a proxy indicator for coastal erosion.
  - Trends over time.
  - Without the availability of a fine spatial resolution satellite .

- If shore lines are eroding, and we control for variables like tide, by selecting our data points well, some trends should appear.
    - Tide matters less if using larger spatial resolution such as Landsat 5TM as the monthly high might be 8-10 feet nearby.

Study Area

- Ipswich Massachusetts: The Ipswich River Estuary, Crane's Beach and other well traveled beaches and salt marsh.
  - These salt marshes and rivers are state protected wildlife preserves, but they exist downstream and next to some of the most popular beaches in the State.
  - If coastal erosion affected these areas it could be very damaging for the local ecosystem

Ipswich Estuary & Plum Island Sound

How do we know Erosion is occuring?

The Massachusetts Coastal Erosion Commision was established in 2013 to investigate potential coastal erosion along the shorelines and popular beaches.

The council used primarily surveyed and measured data to find the rate at which many shorelines were eroding. Data was recorded and available back to the year 1880. The Commision found within the last 50 years, coastal erosion had increased from 1 foot a year on average to nearly 5 feet per year in many parts of the State.

This includes Crane’s Beach in Ipswich.

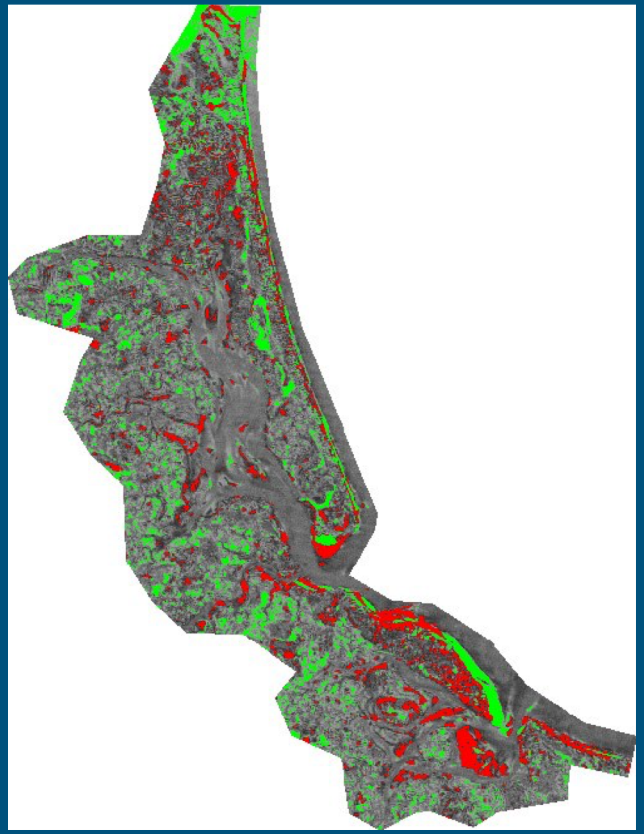
Plymouth Massachusetts (Boston Globe)

Hypothesis

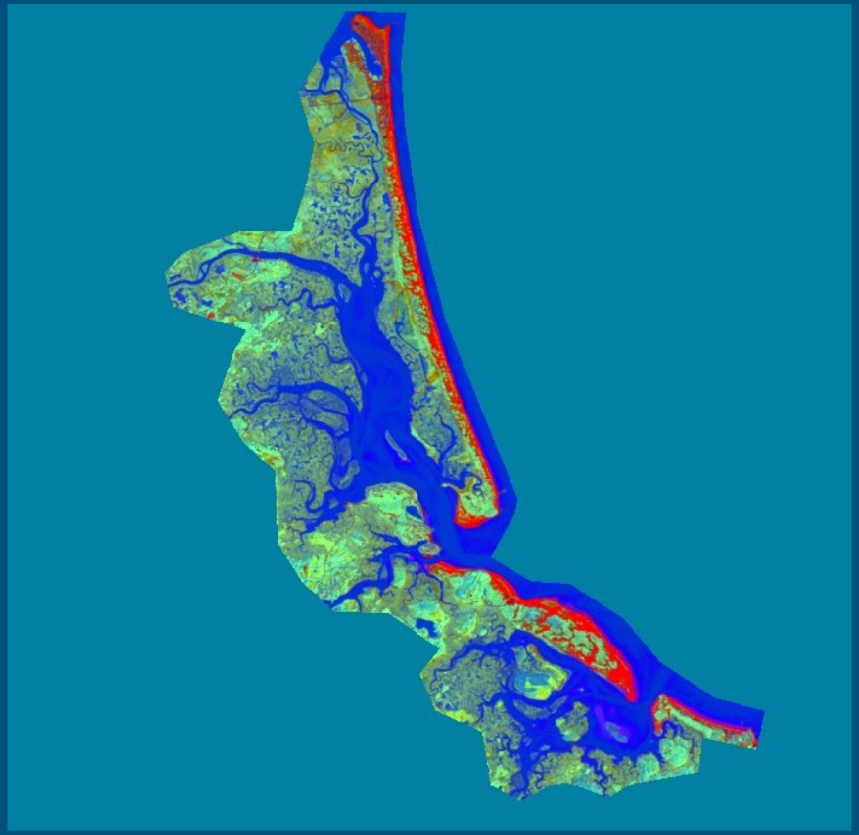
- Comparing Wetness values in a time series will show a significant increase in wetness values as the coast erodes and more water floods the coast.
  - This effect may go inland as well, within the salt marsh and river estuaries.
  - This effect will be most pronounced on areas with the most anthropogenic factors, i.e. the best beaches.

Methods

- Landsat 4-5 Thematic Mapper will be the only sensor/s used.
- A Study Area will be manually defined including some coastal ocean and inland salt marsh and the mouth of the estuaries, to best capture the complexity of the area.
- A Tasseled Cap transformation for Thematic Mapper will be used.
- Then the date September 29th 1982 will be compared to September 2nd 2011, with alternate comparisons between 2001, 2006 and 2009 to best capture the range of the data.



Difference of Tassel Caps
1986-2011 with 10% changes



Tassel Cap for 1986

Preliminary Observations

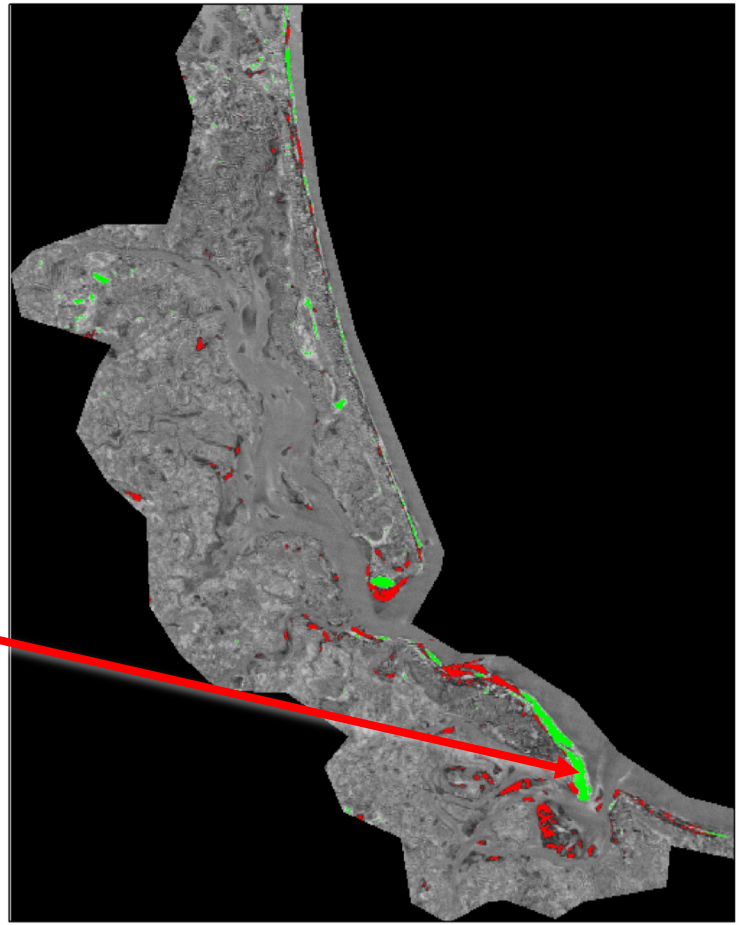
Some things to note:

- The first tassel cap gives a good idea about what land cover types are being displayed by brightness, greenness and wetness.
    - Sand is being displayed by brightness
    - Water and edges of shorelines have high wetness
    - Inland vegetation and some salt marsh has high greenness

- 10% tolerance for change seems low as the timescale is 25 years.

Map of Wetness Differences greater than 25% from 1988-2011.

Here you can see that already some green or increased wetness has been observed all over the two primary beaches. Crane's is here



1986-2011 Difference of Tassle Caps

Pixels with a 25% or greater Difference

- Background
- Decreased
- Increased

0 1 2 4 Miles

Cartographer: Malcolm Stuart
Date: 5/30/20

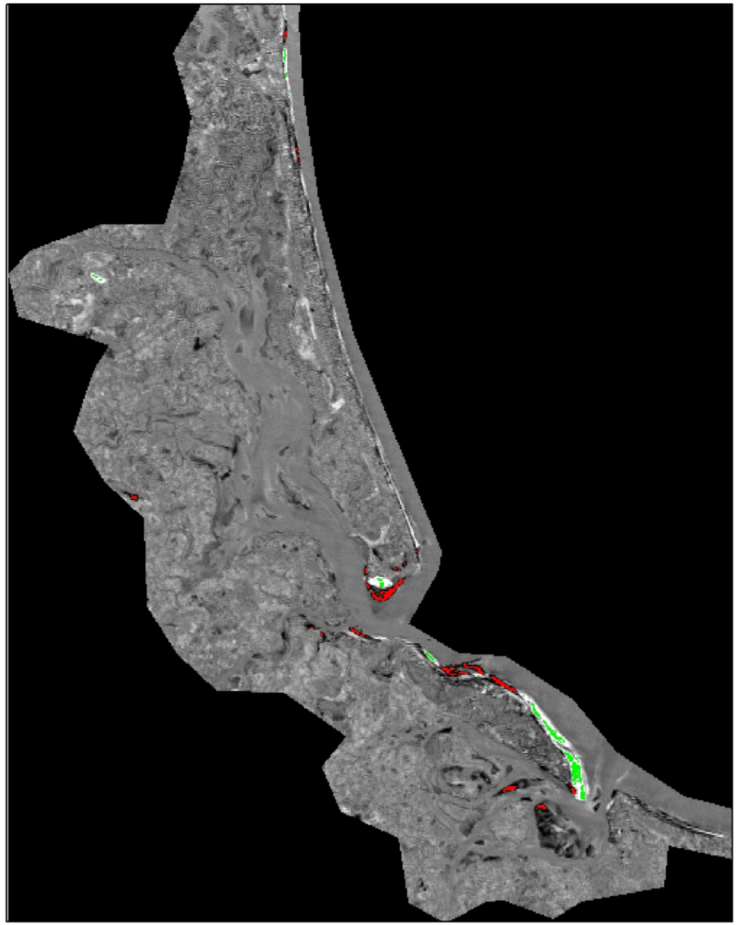
Data: USGS Landsat5 TM
Projection: UTM19N

Refining

This difference transformation still seems to capture too many pixels.

There are fewer pixels which saw a decrease in wetness, suggesting those which saw an increase seem to be of higher percentages. Raising the percentage is a good way to see potential outliers. 50% is already a large increase or decrease in wetness therefore, 75% would be a very large proportional change in wetness.

50% or Greater



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- Background
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0 1 2 4 Miles

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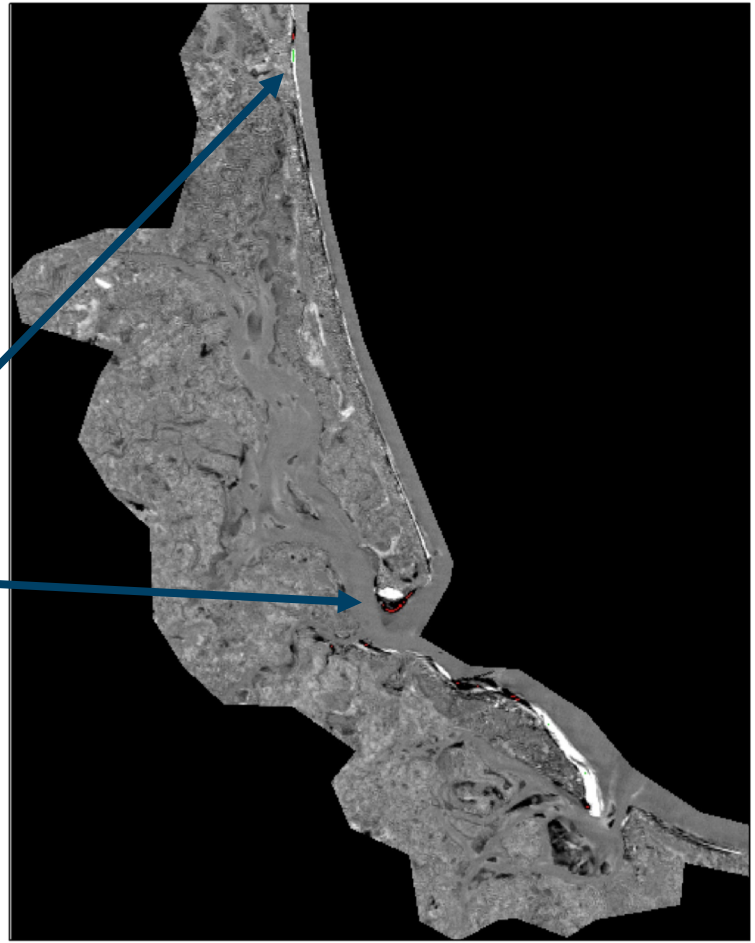
Map 75%

Here we see very few pixels at all but some red ones on the entry to the estuary and some very far here. These locations might be outliers or have special circumstances as the difference is so large in the scale of geologic time.



1986-2011 Difference of Tassle Caps

Pixels with a 75% or greater Difference

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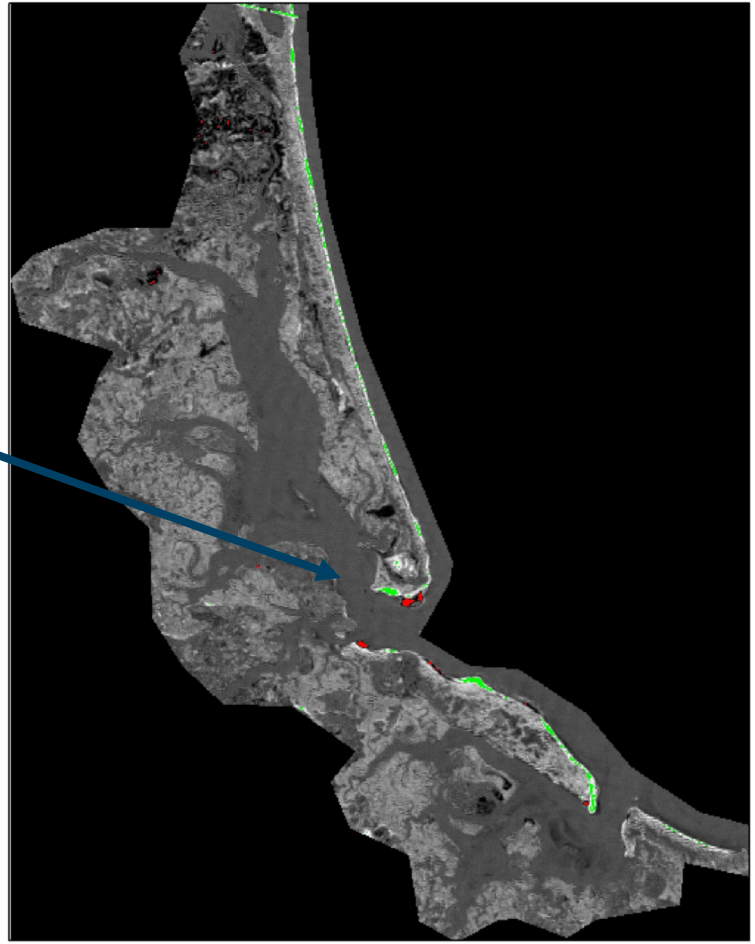
Looking at temporal increments

- In addition to the 25 year range (1986-2011), it's potentially worthwhile to look at some ranges in between.

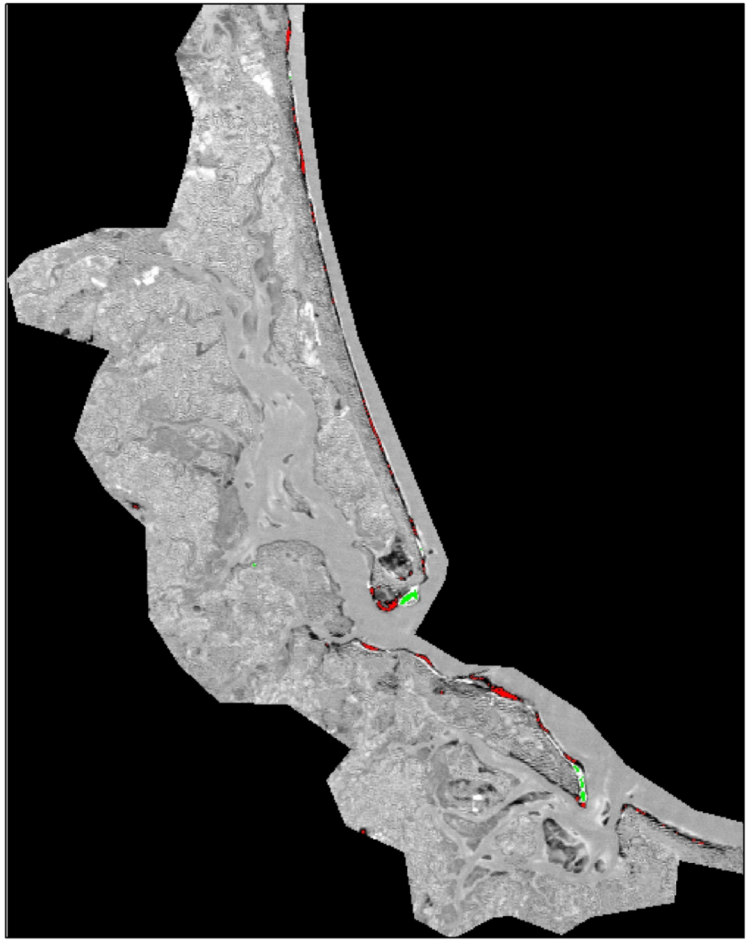
- The point where the wetness keeps decreasing on these maps, is called Sandy Point, a location of extremely large sand dunes. An inference we might make, is that these dunes could be being replenished through a natural or anthropogenic process. Since dunes are quite fragile and this spot is a popular beach destination this may be the site of sand dumping to bolster the dunes and protect the beach.

2001-2006

Few points in time where Sandy Point is increasing in wetness. Storms or Hurricanes could have well contributed.



2006-2011



2006-2011 Difference of Tassle Caps

Pixels with a 50% or greater Difference

- Background
- Decreased
- Increased

0 1 2 4 Miles

Cartographer: Malcolm Stuart
Date: 5/30/20

Data: USGS Landsat5 TM
Projection: UTM19N

Statistics from difference of Tassled Caps

Range Years	1986-2001 50%	2001	2006	2009-2011
Mean	-4.771	4.426	.656	1.176
Max	81	135	83	85
Standard Dev	11.909	13.188	6.474	8.523

These stats are just some slightly interesting results, especially considering the large spike in wetness in 2001-2006. Not many inferences could be made from such small changes.

Conclusions

Wetness may be a proxy variable for the eroding coasts of Massachusetts, but it’s far from a perfect one. Any precision that this method offers is far overshadowed by the work of a surveyor.

This method is useful for seeing some broader implications behind coastal erosion. Spotting trends and patterns in coastline utilization and protection.

This method does effectively visualize the considerable effect that erosion is having on beaches, protected wildlife refuges, and important ecosystems.

Sources:

https://www.researchgate.net/publication/329183655_ORTHOGONAL_TRANSFORMATION_OF_SEGMENTED_IMAGES_FROM_THE_SATELLITE_SENTINEL-2_Roumen_Nedkov

https://community.hexagongeospatial.com/t5/Spatial-Modeler-Tutorials/WorldView-2-Tasseled-Cap-transformation/ta-p/27074

Sieger, D. Et Al. (2015). Report of the Massachusetts Coastal Erosion Commission (Vol. 1). State of MA.

Tide Predictions - NOAA Tides & Currents. (2020, March 6). Retrieved March 6, 2020, from https://tidesandcurrents.noaa.gov/noaatidepredictions.html

https://journals.sagepub.com/doi/pdf/10.1260/1759-3131.5.4.211