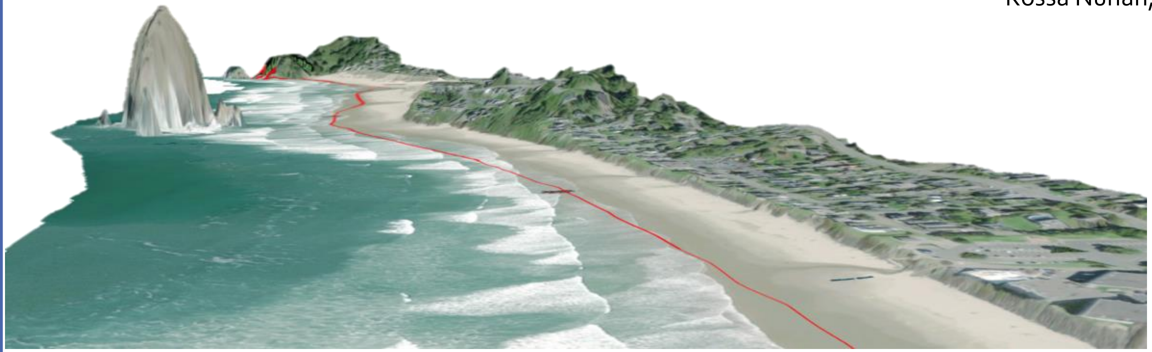
Quantifying And Investigating Coastal Erosion In the Cannon Beach Littoral Cell:

A Volumetric Change Analysis

GEOG-493/593 Digital Terrain Analysis

Professor Geoffrey Duh

Rossa Nunan, Fall 2020.



Abstract

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“Quantifying and Investigating Coastal Erosion in the Cannon Beach Littoral Cell: a Volumetric Change Analysis”

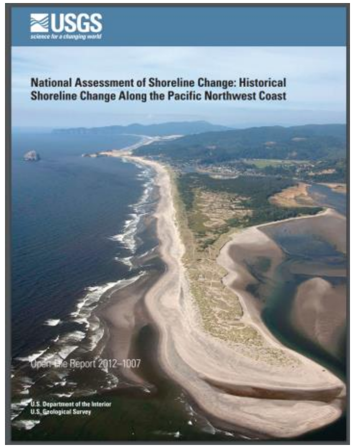
Coastal erosion poses a serious threat to human life, property and is an agent of habitat degradation. Coastal erosion is sensitive to many changes in the natural and anthropogenic environment and the effects of coastal erosion are predicted to worsen with anthropogenic climate change. Much literature regarding coastal erosion involves detailed ground measurements or focuses on coastline migration, therefore the use of LiDAR data in the study of coastal erosion may provide a more feasible means to accurately model this phenomenon whilst also revealing very fine spatial and temporal patterns. This analysis focuses on quantifying the processes of erosion and deposition in a 15 mile stretch of the Oregon coast, the Cannon Beach littoral cell. Seven lidar-based digital terrain models were constructed and compared in six separate volumetric change analyses, ranging over a time interval of 19 years (1997-2016). This report outlines the methods and best practices developed for performing these analyses as well as a method of quantifying the RMSE error for the models. The total erosion, deposition and net volume change within the Cannon Beach littoral cell are described for these 6 time intervals as well as the rates of these processes for each interval (normalized across the study areas). Additionally, estimates of the long-term rates of coastal erosion or accretion are provided via 3 separate regression analyses.

Word Count: 220.

Keywords: coastal erosion, lidar, volumetric change analysis, cannon beach, coastal change analysis, cut fill analysis, erosion rates, regression.

Background

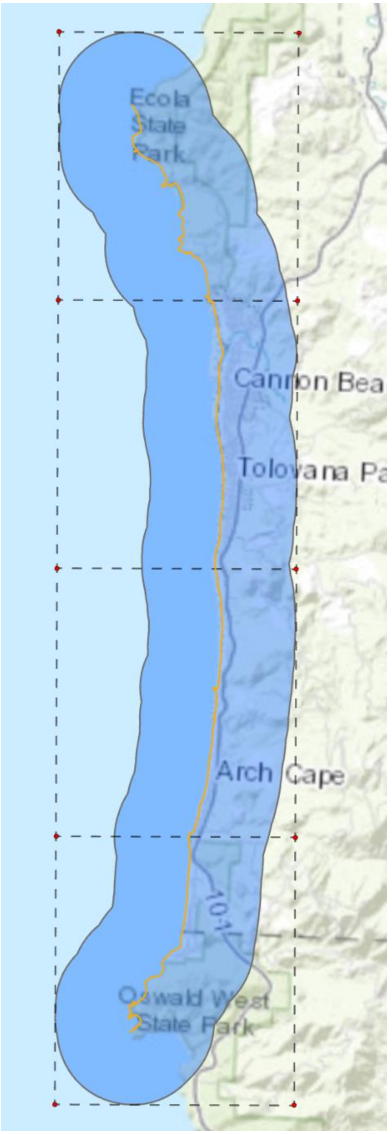
Problem statement:
Coastal erosion is a serious issue that poses a risk to human health, coastal environments and property. In the U.S. an estimated $500 million dollars is lost due to the damages caused by coastal erosion and an estimated $150 million dollars of federal funding is spent combating this process (USCRT, 2019). Although all coastlines can be affected by coastal erosion, its magnitude is a highly localized phenomenon depending on the specifics of a given terrain and it is very sensitive to changes in the natural or anthropogenic environment (USCRT, 2019). Particularly, the construction of 'hard features' to combat erosion and major storm events have been identified as particularly problematic (USCRT, 2019). For example, the 2015-2016 El Niño event was cited to cause an increase in coastal erosion 76% above normal rates (averaged across 29 beaches spanning most of the West Coast) (USGS, 2014). Looking into the future, coastal erosion is only expected to worsen as anthropogenic climate change threatens to intensify storm events and raise sea levels (USCRT, 2019). The use of LiDAR data has been stated as revolutionary in the field of coastal change analysis as it allows for highly accurate assessment of coastal change on smaller timescales than could previously be addressed and it reveals detailed spatial patterns (USGS, n.d). Currently much literature regarding coastal erosion in this area is focused on shoreline migration (Ruggiero et al., 2013) and less of a focus is geared towards volumetric changes.



Primary Research Question:
<u>What is the magnitude of coastal erosion or deposition in the Cannon Beach littoral cell over time?</u>

Data management:

Defining the study area and retrieving the data.



- Cannon beach littoral cell →

Citation

West Coast Ocean Data Network (WCODN), 2015, West Coast Littoral Cells -- Shoreline Based on Washington, Oregon, and California Data Collected from 2002 to 2015: West Coast Ocean Data Portal, https://doi.org/10.5066/F7ZW1HZD.

- 1 mile buffer & minimum bounding rectangle
- Study area divided into 4 sections using "Divide tool"
- "Add XY coordinates tool"

Section	min long	min lat	max long	max lat		string
1	-124.0119115	45.90709715	-123.9469903	45.9620287		-124.01191148,45.90709715,-123.94699031,45.9620287
2	-124.0089252	45.85400782	-123.9440623	45.90893888		-124.00892524,45.85400782,-123.94406228,45.90893888
3	-124.0059446	45.80091732	-123.9411398	45.85584785		-124.00594461,45.80091732,-123.94113975,45.85584785
4	-124.0029696	45.74782571	-123.9382227	45.80275566		-124.00296958,45.74782571,-123.93822271,45.80275566
						,,,
Entire	**-124.0029696**	**45.74782571**	**-123.9469903**	**45.9620287**		**-124.00296958,45.74782571,-123.94699031,45.9620287**

- Study area extents → parsed into NOAA LiDAR data access viewer

Digital Coast Data Access Viewer
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Status of Request: 395695

Submitted: 2020-12-06 18:37
Status: Data jobs queued or being processed
Details: The data jobs associated with this request are being or will soon be processed. Please check the status of the individual data jobs for details. Besides, a confirmation message containing a list of data jobs has been sent to the user, along with a link for the user t

Data Jobs (7)

Job ID	Data Set	
585128	2016 USGS Lidar DEM: West Coast El Nino (WA, OR, CA)	Projection: State Plane 1983 Datum: NAD83 File Format: GeoTIFF Output Resolution: 0.5 meters = 1.64 feet
585129	2014 USACE NCMP Topobathy Lidar DEM: Oregon	Projection: State Plane 1983 Datum: NAD83 File Format: GeoTIFF Output Resolution: 1.0 meters = 3.28 feet
585130	2010 USACE NCMP Topobathy Lidar: Oregon and Washington	Projection: State Plane 1983, Zone: Zone 3601 Oregon North, Horizontal Datum: NAD83, Horizontal Units: International Feet, Vertical Datum: NAVD88, Vertical Units: U.S. Feet, File Format: LAS,
585131	2009 OR DOGAMI Lidar: North Coast	Projection: State Plane 1983, Zone: Zone 3601 Oregon North, Horizontal Datum: NAD83, Horizontal Units: International Feet, Vertical Datum: NAVD88, Vertical Units: U.S. Feet, File Format: LAS,
585132	2002 NASA/USGS Lidar: Pacific Coast Shoreline (CA,OR,WA)	Projection: State Plane 1983, Zone: Zone 3601 Oregon North, Horizontal Datum: NAD83, Horizontal Units: International Feet, Vertical Datum: NAVD88, Vertical Units: U.S. Feet, File Format: LAS,
585133	1998 NASA/NOAA/USGS ATM Lidar: West Coast, Post-El Nino (CA, OR, WA)	Projection: State Plane 1983, Zone: Zone 3601 Oregon North, Horizontal Datum: NAD83, Horizontal Units: International Feet, Vertical Datum: NAVD88, Vertical Units: U.S. Feet, File Format: LAS,
585134	1997 NASA/NOAA/USGS ATM Lidar: West Coast, Pre-El Nino (CA, OR, WA)	Projection: State Plane 1983, Zone: Zone 3601 Oregon North, Horizontal Datum: NAD83, Horizontal Units: International Feet, Vertical Datum: NAVD88, Vertical Units: U.S. Feet, File Format: LAS,

Creating the DEM's

- LAS datasets made using "Create Las Dataset" tool for LiDAR point clouds (years: 1997, 1998, 2002, 2009, 2010)

- LAS dataset statistics → Point spacing → Raster cell size:

""You might think the average point spacing is a good cell size for the output raster, but … [instead] it's better to go with a cell size that is several times larger than the average point spacing but small enough to identify gaps or voids that warrant further investigation. A reasonable size is four times the point spacing. For example, if your data is sampled at 1 meter and you set the cell size to 4, you can expect, on average, to get 16 pulses in a cell."

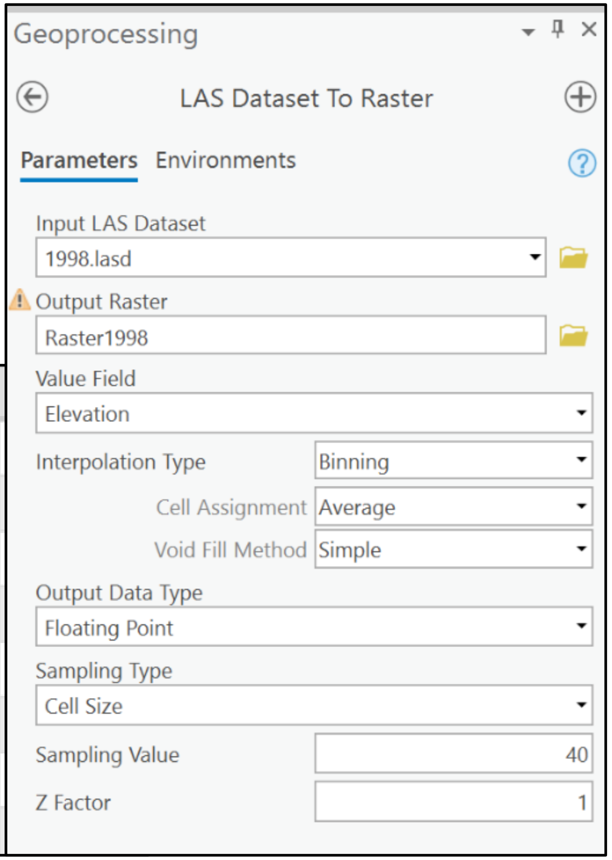
- Rasters (with highest possible spatial resolutions) created with "LAS Dataset to Raster" tool.

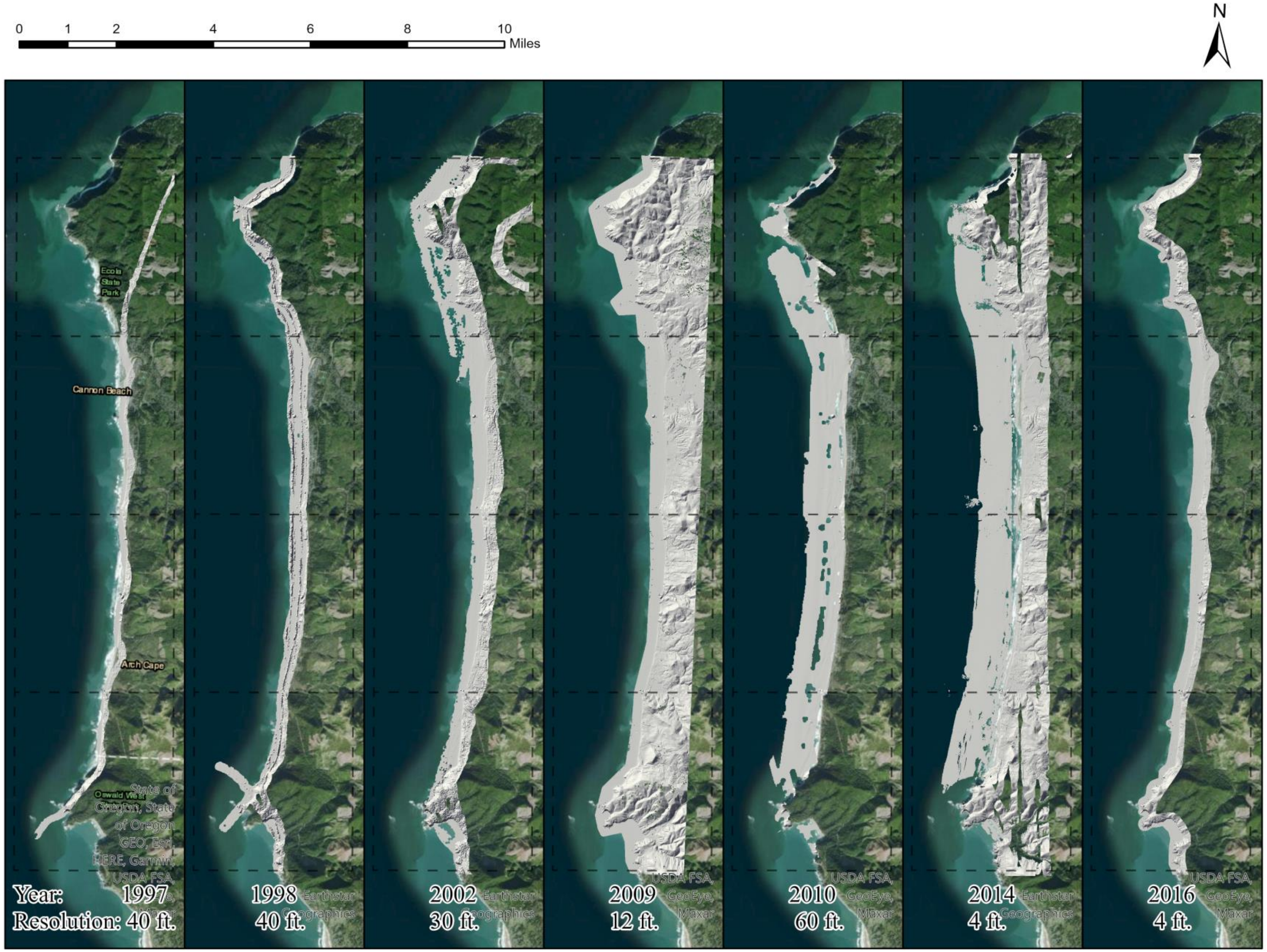
- <u>Parameters:</u>

Binning interpolation with *average* cell assignment method and *Simple* void filling method

- 2014 & 2016 came as .tifs

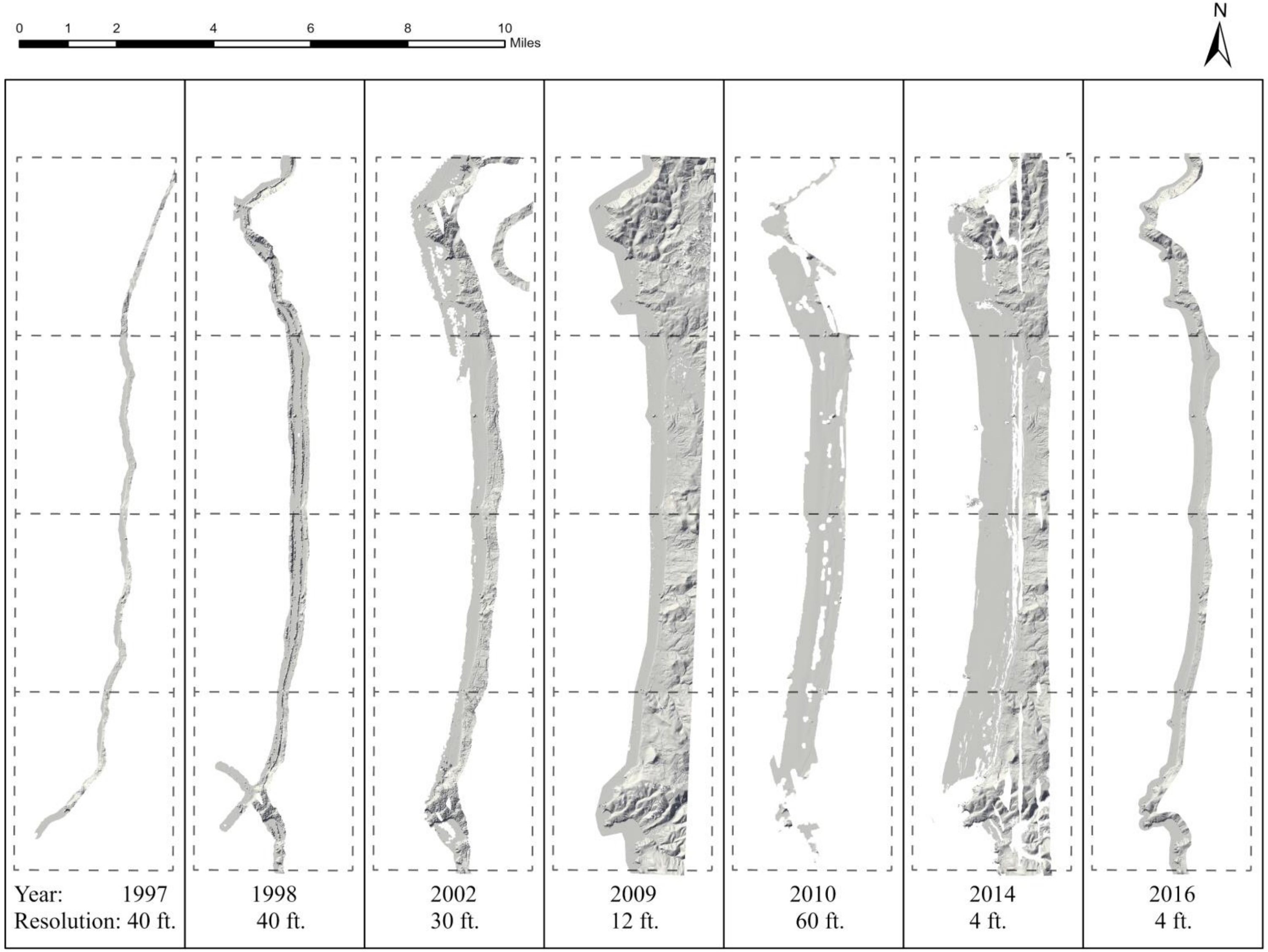
LAS File	Version	Point Count	Point Spacir	Z Min	Z Max
Job585131_45123_74_94.	1.1	29,458	4.217	914.27	1539.44
Job585131_45123_74_95.	1.1	81,447	4.553	746.11	1523.86
Job585131_45123_74_96.	1.1	222,731	2.809	-2.15	815.6
Job585131_45123_74_97.	1.1	15,469	3.016	-0.4	3.63
Job585131_45123_75_94.	1.1	93,722	4.956	310.79	1004.39
Job585131_45123_75_95.	1.1	345,972	4.559	65.65	1042.84
Job585131_45123_75_96.	1.1	892,254	2.78	-3.21	863.86
Job585131_45123_75_97.	1.1	336,833	2.987	-3.17	3.69




0 1 2 4 6 8 10
Miles
N
Ecola State Park
Cannon Beach
Arch Cape
Oswald West
State of Oregon, State of Oregon GEO, Esri, HERE, Garmin, USDA FSA
Year: 1997
Resolution: 40 ft.
1998
40 ft.
Earthstar Geographics
2002
30 ft.
Earthstar Geographics
2009
12 ft.
USDA FSA, GeoEye, Maxar
2010
60 ft.
USDA FSA, GeoEye, Maxar
2014
4 ft.
Earthstar Geographics
2016
4 ft.
USDA FSA, GeoEye, Maxar

Preparing DEMs for Volumetric Change Analysis

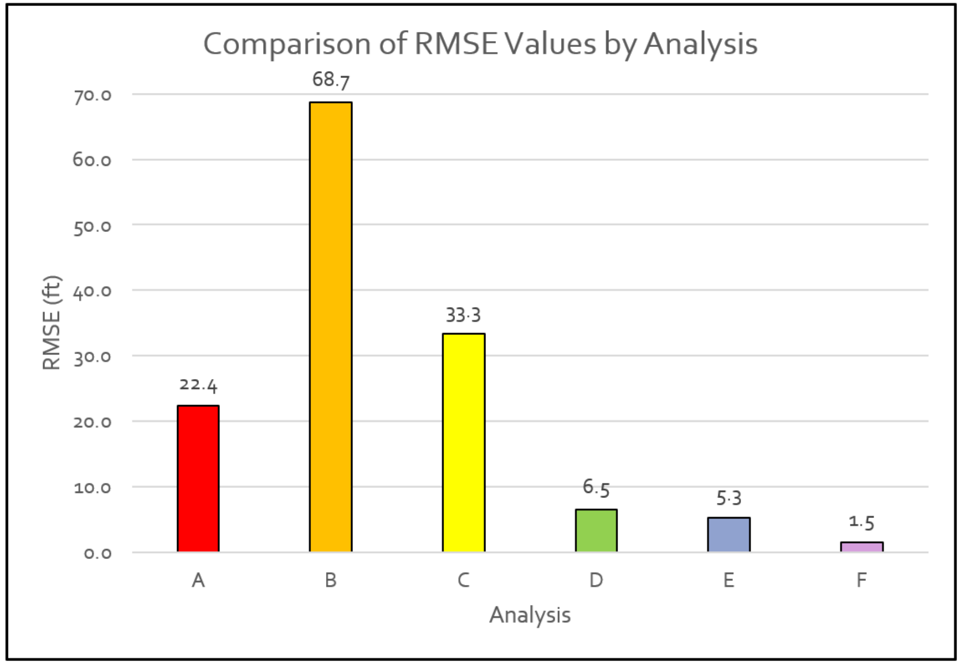
- Cut/Fill analyses require DEMs to be **coincident** →
- "Resample" tool used to ensure coincidence: producing [4] new rasters with matching resolutions and snapped spatial extents for each analysis pair.
- 7 DEMs allow for 6 analyses to be performed (A-E)
- Finest raster coarsened to coarsest resolution
- Cubic resampling method used



Quantifying Error in Models

- The accuracy of the models was assessed by determining the RMSE.

- Followed methodology from Lab 4 with some modifications.
  - Identified areas presumed to experience minimal erosion, digitized polygons →
  - Polygons used to define extent of raster calculator operations:
    - Difference raster calculated
    - Difference raster squared
    - Took square root of mean difference squared values → **RMSE**



Analysis:	A	B	C	D	E	F
Years:	1997 / 1998	1998 / 2002	2002 / 2009	2009 / 2010	2010 / 2014	2014 / 2016

Volumetric Change Analysis

- Performed using "Cut Fill" tool.
    - Processing extent = 'intersection of input
    - All models ensured to be coincident
- Exported attribute tables to excel using 'Table to Excel' tool
- Important to keep track of signs (+/-) in terms or erosion and deposition when using this tool & analyzing data.

Attribute table: (note: cellsize of input is 10)

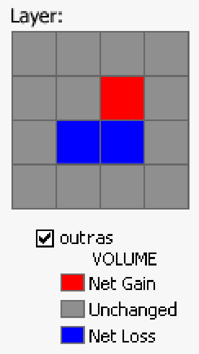
Rowid	VALUE *	COUNT	VOLUME	AREA
0	1	13	0	1300
1	2	1	-500	100
2	3	2	400	200

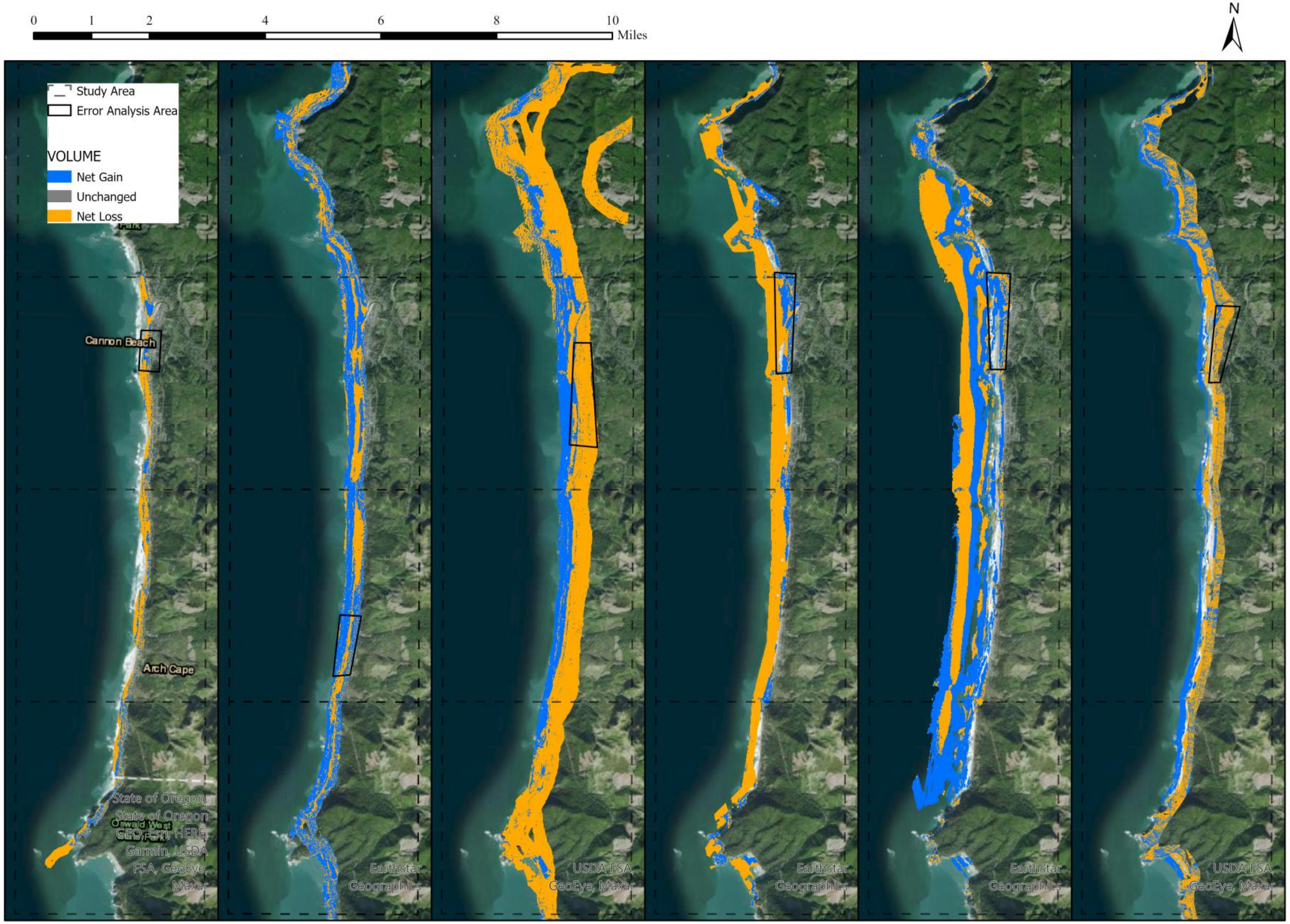
Volume field:

0	0	0	0
0	0	-500	0
0	400	400	0
0	0	0	0

Area field:

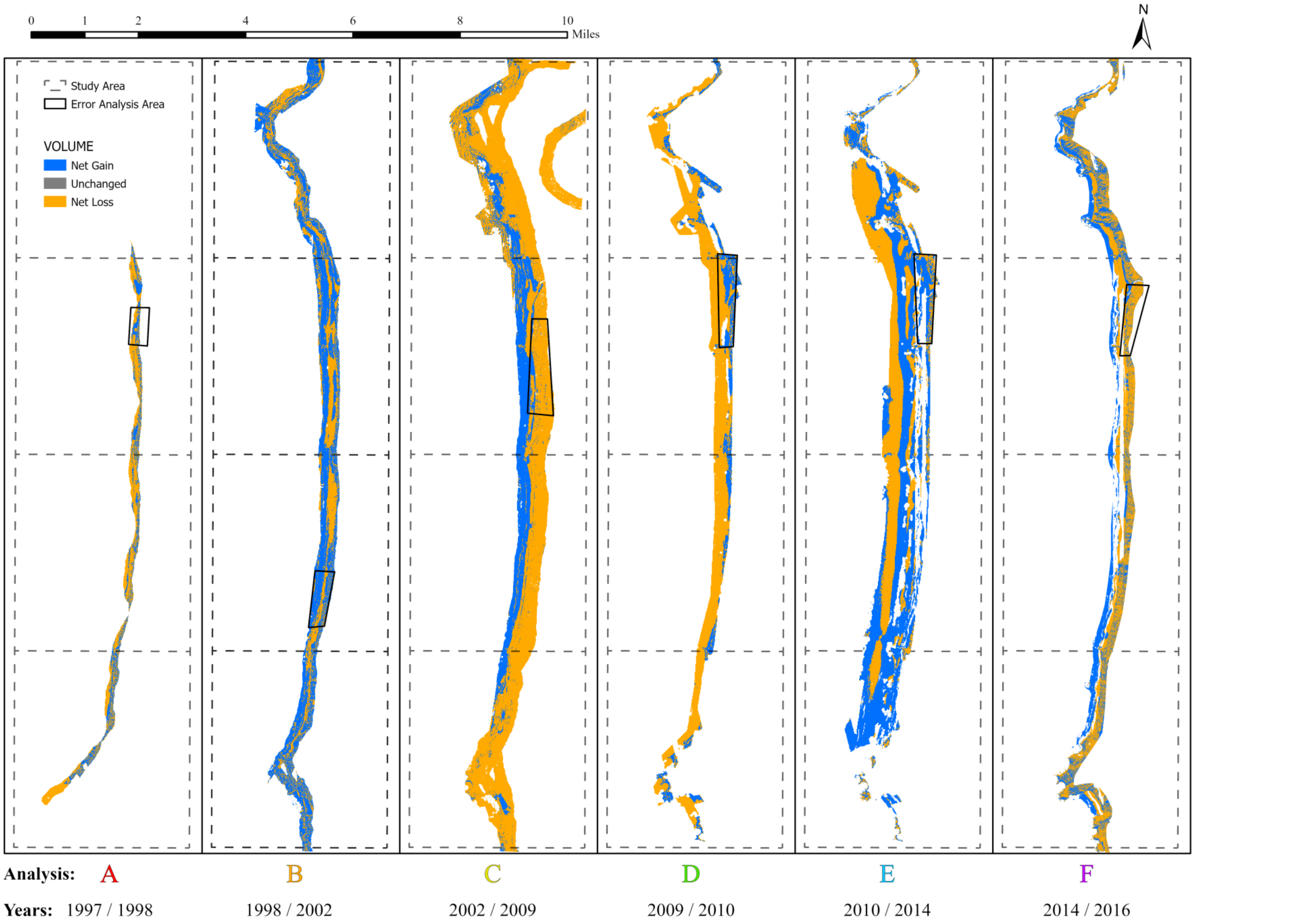
1300	1300	1300	1300
1300	1300	100	1300
1300	200	200	1300
1300	1300	1300	1300





Analysis: A B C D E F

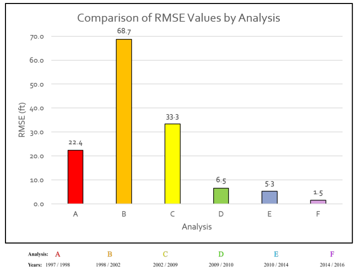
Years: 1997 / 1998 1998 / 2002 2002 / 2009 2009 / 2010 2010 / 2014 2014 / 2016


0 1 2 4 6 8 10
Miles
N
Study Area
Error Analysis Area
VOLUME
Net Gain
Unchanged
Net Loss
Analysis: A B C D E F
Years: 1997 / 1998 1998 / 2002 2002 / 2009 2009 / 2010 2010 / 2014 2014 / 2016

Results

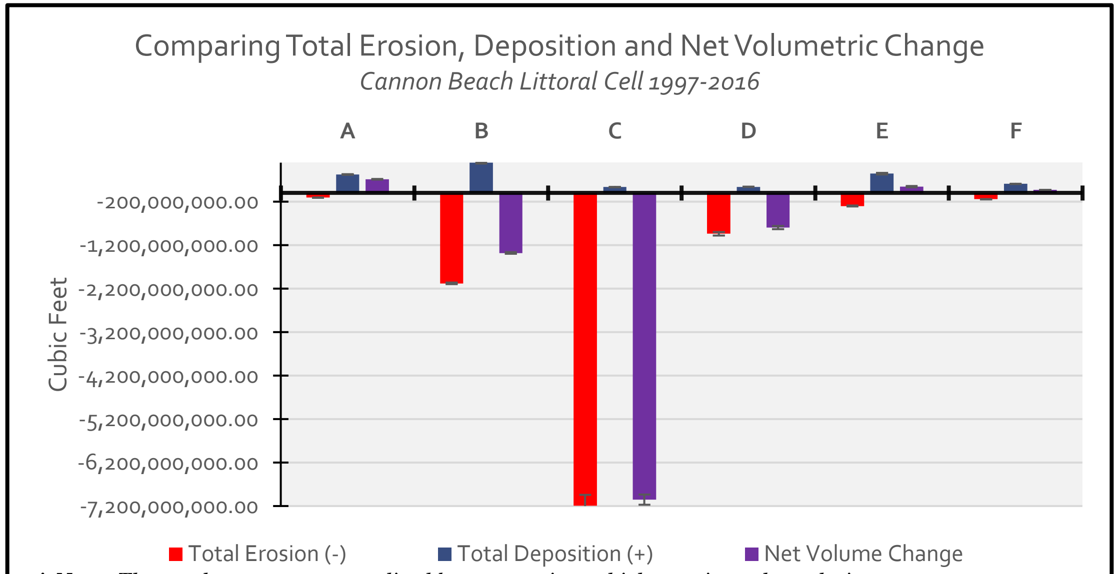
Analysis	Interval (Years)	Total Area (ft^2)	Total Erosion (ft^3)	Net Deposition(ft^3)	Net Volume Change (ft^3)
A	1	40,656,000.0	107,952,787.8	422,268,096.7	314,315,308.8
B	4	138,224,000.0	2,079,612,435.9	699,354,207.2	-1,380,258,228.6
C	7	261,649,800.0	7,187,040,548.4	135,745,964.6	-7,051,294,583.8
D	1	119,584,800.0	936,479,650.8	141,454,898.3	-795,024,752.5
E	4	219,319,200.0	299,712,576.2	444,768,776.8	145,056,200.7
F	2	124,816,928.0	138,978,911.0	208,901,176.6	69,922,265.6

Accounting for variations in time and area

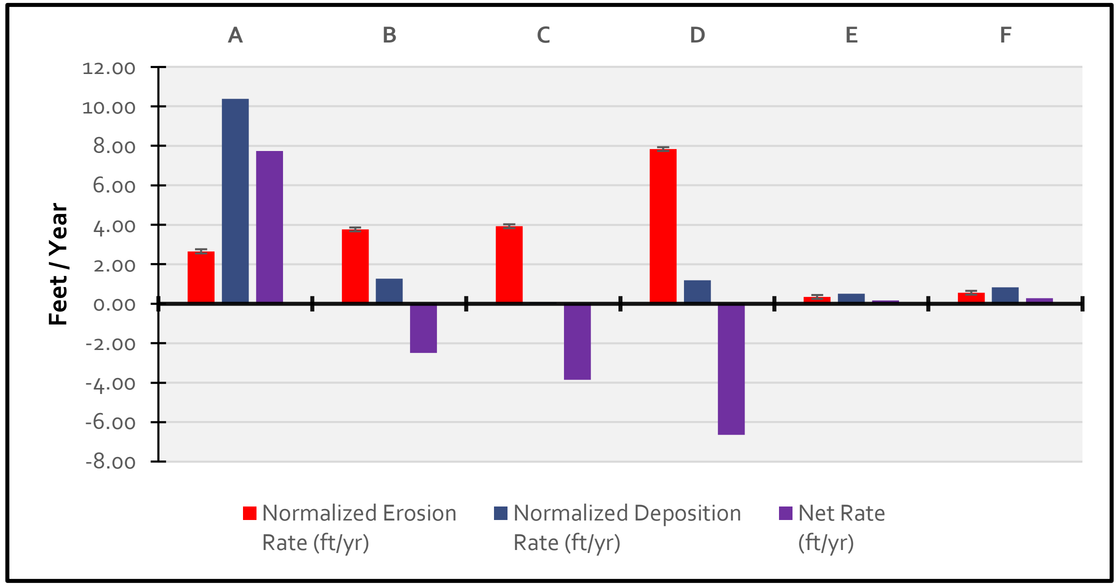


Analysis	Normalized Erosion Rate (ft/yr)	Normalized Deposition Rate (ft/yr)	Net Change Rate (ft/yr)
A	2.7	10.4	7.7
B	3.8	1.3	-2.5
C	3.9	0.1	-3.8
D	7.8	1.2	-6.6
E	0.3	0.5	0.2
F	0.6	0.8	0.3

Analysis:	A	B	C	D	E	F
Years:	1997 / 1998	1998 / 2002	2002 / 2009	2009 / 2010	2010 / 2014	2014 / 2016

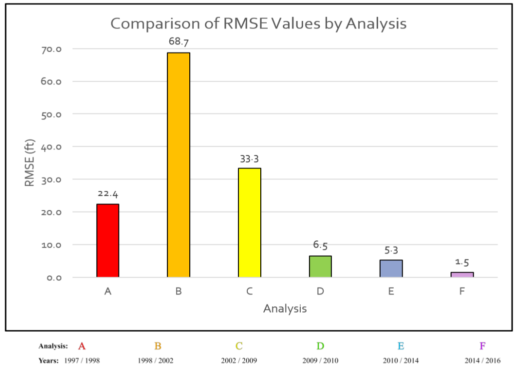


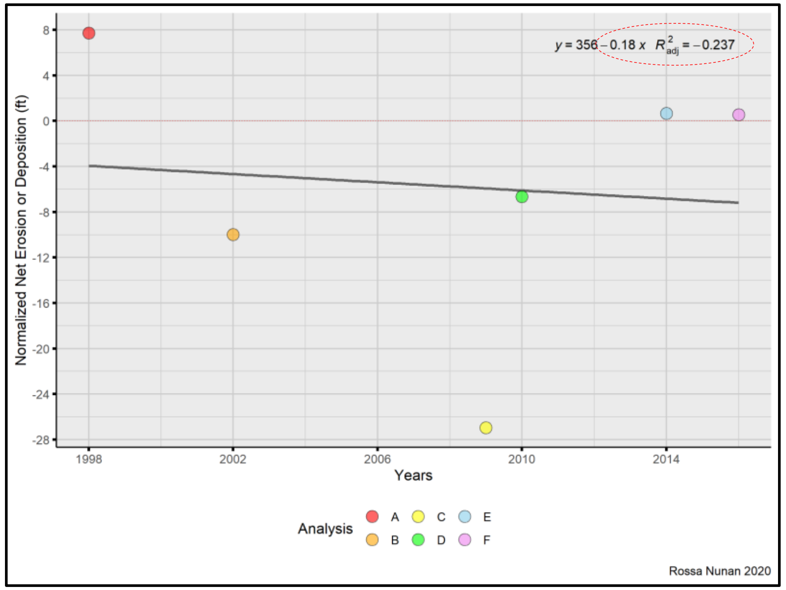
*** Note:** *These values are not normalized by area or time which vary in each analysis*



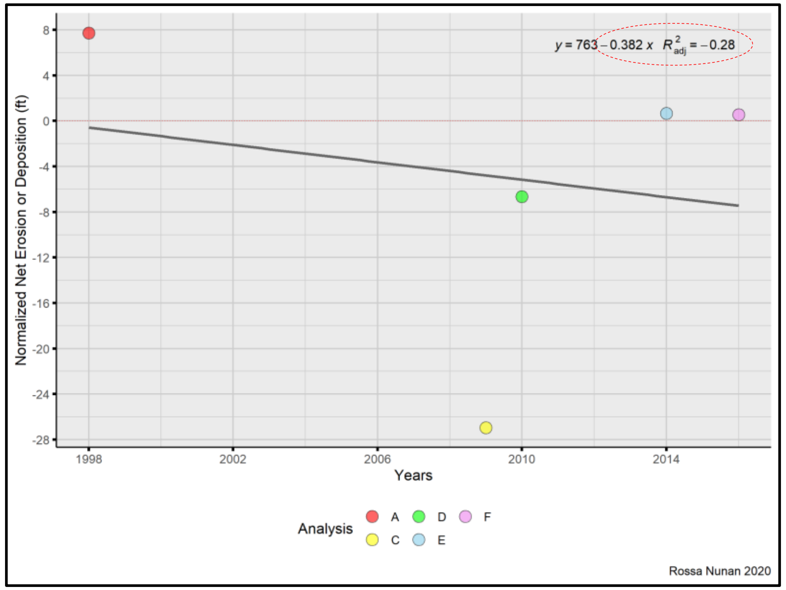
Regression Analysis: Quantifying Long-term coastal erosion rates

Analysis:	A	B	C	D	E	F
Years:	1997 / 1998	1998 / 2002	2002 / 2009	2009 / 2010	2010 / 2014	2014 / 2016

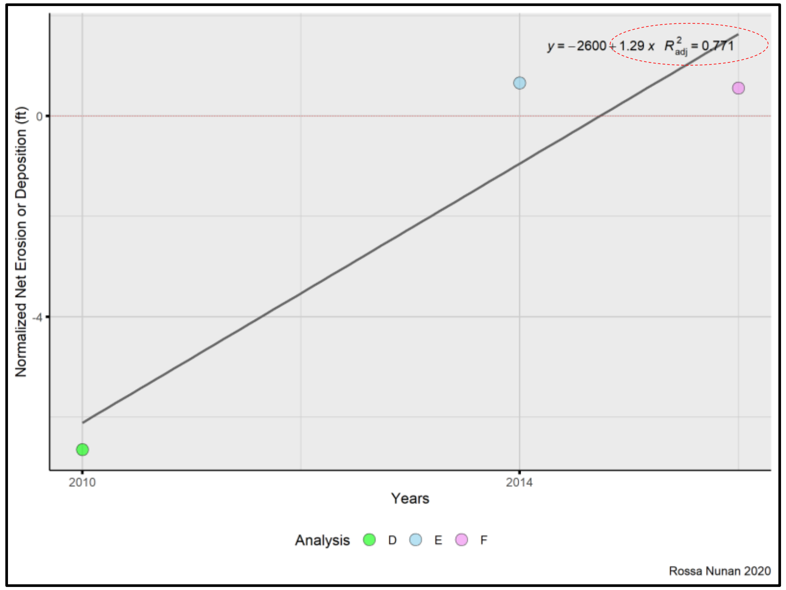




1) 1997-2016: Erosion, -0.18 ft/yr



2) 1997-2016: Erosion, - 0.38 ft/yr



3) 2009-2016: Deposition, + 1.29 ft/yr

Works Cited

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<ins>Terrain datasets used:</ins>

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2014 USACE NCMP Topobathy Lidar DEM: Oregon
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2009 OR DOGAMI Lidar: North Coast
2002 NASA/USGS Lidar: Pacific Coast Shoreline (CA,OR,WA)
1998 NASA/NOAA/USGS ATM Lidar: West Coast, Post-El Nino (CA, OR, WA)
1997 NASA/NOAA/USGS ATM Lidar: West Coast, Pre-El Nino (CA, OR, WA)

(Accessed via https://coast.noaa.gov/dataviewer/#/lidar/search/)