Effects of Sea Level Rise on Salt Marsh Vegetative Zones in Morro Bay

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Outline

Introduction
- Salt Marsh Vegetation
- Sea Level Rise
- Hypothesis

Methodology
- Study Area
- Modelling and Vegetation Indexes
- Sampling

Data & Analysis
- Topography
- Vegetative Indexes
- Projection Sea Level Rise

Discussion
- Reflections
- Conclusion

INTRODUCTION

Salt Marsh Vegetation

- Occurs within intertidal zones
- Salt marshes are extremely flat with minute elevation changes [1]
- Performs important ecological functions
  - Habitat
  - Interface between salt and fresh water
  - Runoff control
- **Elevation**, relative to sea level, has been **strongly linked to vegetative zones** [2]

Sea Level Rise (SLR)

- Due to melting glaciers and expansion of water bodies, as a result of global warming
- Expected to rise in **2030, 2050, and 2100 by 14.7cm, 28.4cm, and 93.1cm**, respectively (Los Angeles) [3]
- An indicator for future salt marsh vegetative zones

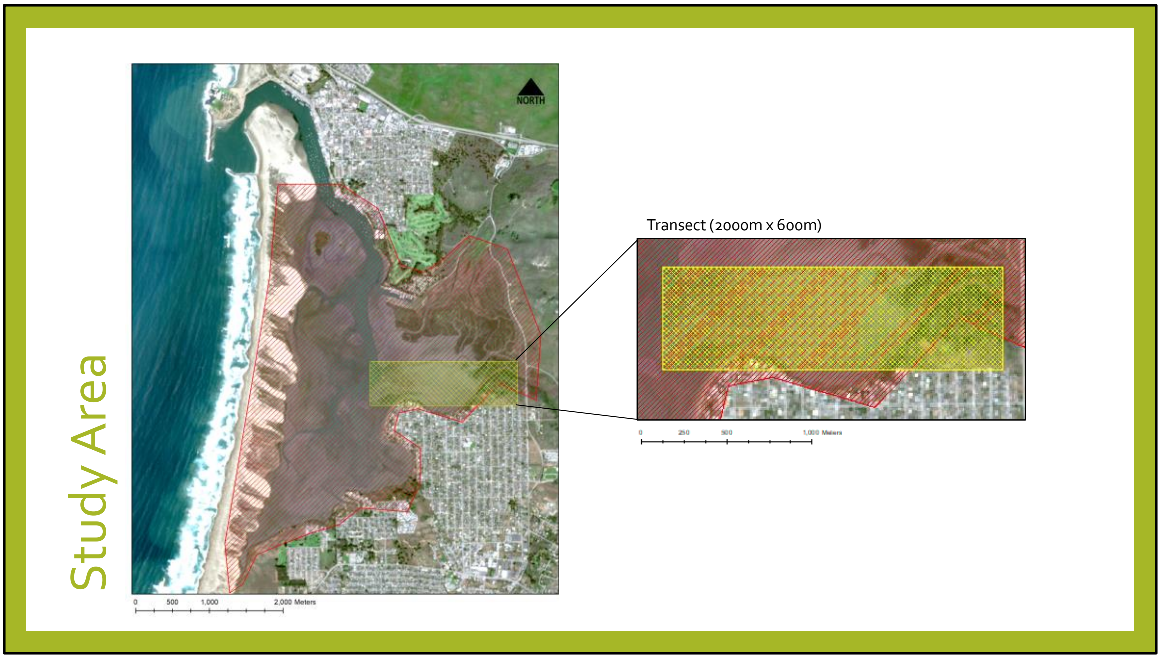
Hypothesis

1. Amount of vegetation will increase with increased elevation.
   - Due to reduction of harsh abiotic stressors with increasing distance from sea water (salinity, periodic flooding)
2. SLR will reduce vegetation coverage
   - As a result of increasing elevation gradient with increased distance from sea water.
   - This will lead to reduced elevational zone sizes.

METHODOLOGY

Study Area

Morro Bay is a salt marsh located in San Luis Obispo County southern California. The bay is fed by two rivers and ultimately drains into the Pacific Ocean.



This is the study area for the vegetation analysis, which is 12,989,049.2756m^2 or 12.98km^2, we are excluding the manmade canal at the outlet of the bay. We are also taking a 2000m x 600m transect to project the effects of SLR.

Modelling and Vegetation Indexes

- Elevation
  - Using light detection and ranging (LiDAR) data to construct digital elevation model (DEM).
  - DEM interpolates the elevation between LiDAR points.
- Normalized Difference Vegetation Index (NDVI) [4]
  - Standard vegetation analysis that quantifies vegetation greenness. Greenness can be interpreted as vegetation health and density.

$$NDVI = (NIR - Red) / (NIR + Red)$$

- Soil Adjusted Vegetation Index (SAVI) [5]
  - Vegetation analysis based on the NDVI that takes into account of soil brightness where vegetative cover is low.

$$SAVI = ((NIR - Red) / (NIR + Red + L)) * 1 + L$$

$L = 0.5$ [Soil Brightness Correlation Factor]

We are doing 3 types of analysis. Elevation by constructing a DEM, NDVI, and SAVI. DEM uses LiDAR data to interpolate elevation points. NDVI compares the near infrared and red bands of satellite imagery to determine vegetation greenness. SAVI, based on NDVI as you can see in the basis of the equation, takes into account soil reflectance, which can be a confounding factor in the NDVI.

DEM

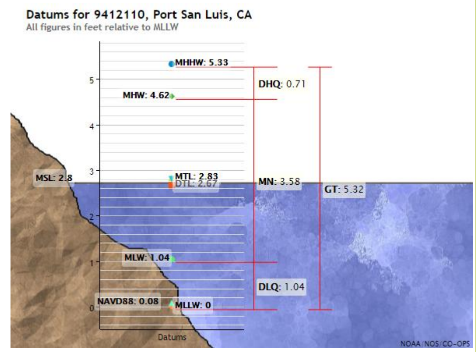
NDVI

SAVI

Here are examples of the different analysis. You can see that SAVI values can sometimes be beyond the threshold, this is due to atmospheric interferences, mostly elsewhere in the satellite imagery outside the study area.

Sampling

- Satellite dates were chosen within +/- 1 month of April 1st with < 10% cloud cover.
- Sample points' x, y distances from each other were plotted dependent on the satellite image resolution.
- Sample points were constricted within the Mean Higher-High Water (1.625m) and the Mean Lower-Low Water (0m) were recorded .



Elevations for tidal readings from NOAA's tide station 9412110 in Port San Luis, CA. This was the closest tide station to the study area.

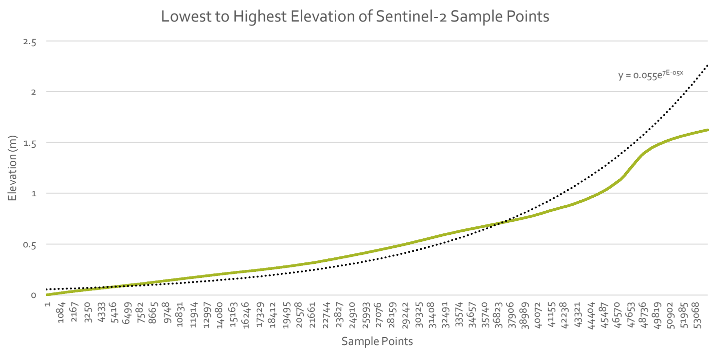
Landsat has a revisit time of 16days, so I needed some options when choosing the image. Restrictions on cloud cover was to reduce atmospheric disturbances.

Remember, a salt marsh is within the intertidal zone, therefore it had to be within an are that salt water can reach.

Although Sentinel-2 has higher resolution, only 2019-2020 dates are available for download for Morro Bay.
Landsat-8 data was available between 2013-2020
We extract values at each points by overlaying the points on top of the DEM, SAVI of each year, NDVI of each year.

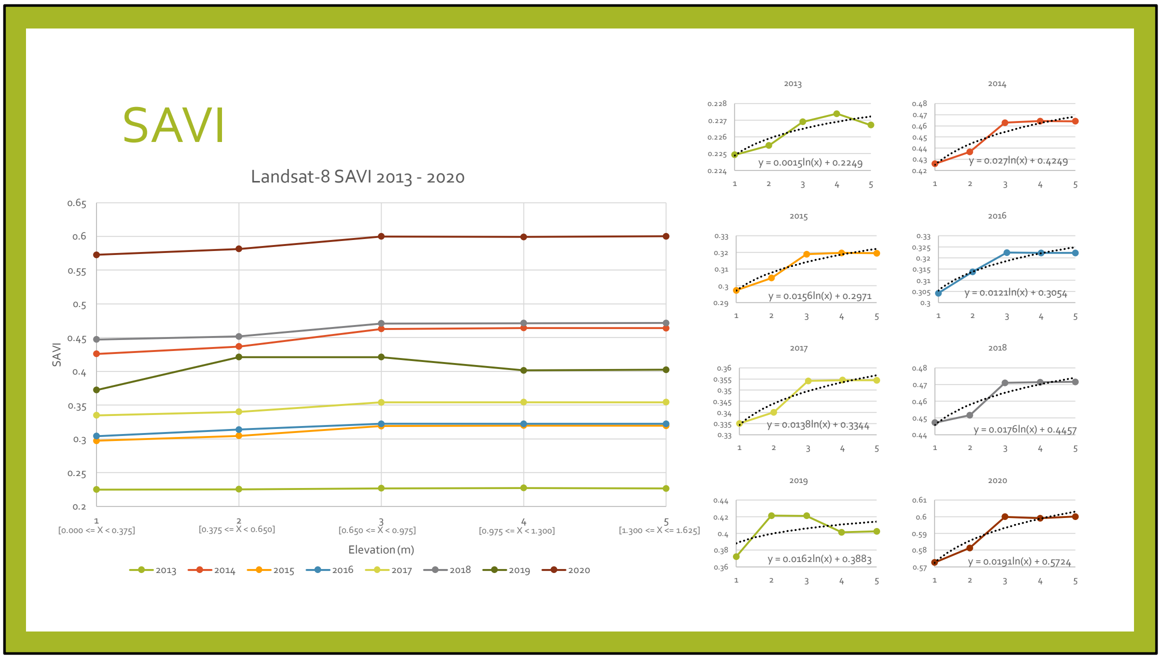
DATA & ANALYSIS

Topography



- In general, density of points decreases with increased distance from the water.
- Elevation gradient increases with increasing elevation.
- Fewer high elevation points.

Plotting the height of all points from lowest to highest acquired by sampling the DEM, we see in general, the density of points decreases with increased distance from the water. This means that there are fewer high elevation points.



Looking at the x-axis of the main graph, you can see that I've split the range of elevation values into 5 zones, by equal intervals of 0.375m per zone. All values within each zone per year were averaged. SAVI values of individual years exhibit a positive correlation between elevation and SAVI values.

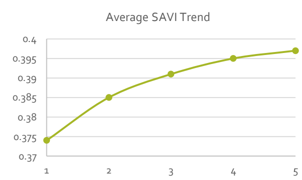
Similar to SAVI, there is a apparent trend within individual years that there is a positive correlation with elevation and NDVI. Something to note about the trends between years is that they fluctuated and were difficult to predict.

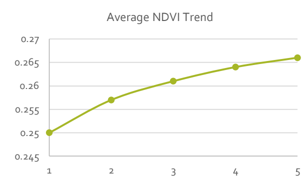
Vegetation Index Trends

- Average trend of all SAVI years is **[$0.0153\ln(x)+0.374$]**
- Average trend of all NDVI years is **[$0.0102\ln(x)+0.250$]**

Table 1. SAVI and NDVI values at each zone based on their average trends.

Elevation (m)	1) 0 <= x <0.375	2) 0.375 <= x < 0.650	3) 0.650 <= x < 0.975	4) 0.975 <= x < 1.30	5) 1.30 <= x <= 1.625
SAVI	0.374	0.385	0.391	0.395	0.397
NDVI	0.250	0.257	0.261	0.264	0.266





This tells us that there is a positive correlation between elevation both SAVI and NDVI values. This places importance on the higher elevations within the marsh, although there are fewer of those high elevations as was shown in the topography deduced by the DEM.

It is also worthy to note that the gradient of the trend reduces with increased distance indicating that there is a elevation to vegetation threshold. This could be due to resource limitation, or some other external stressor that’s coming into play.

Sea Level Rise

- Looking at this 2000m x 600m transect, we can observe how projected SLR in 2030, 2050, and 2100 will effect the study area.

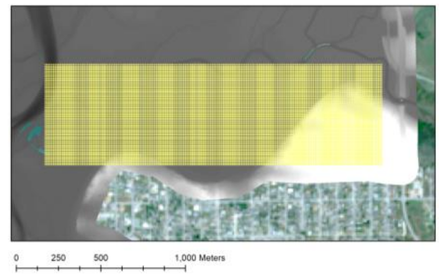
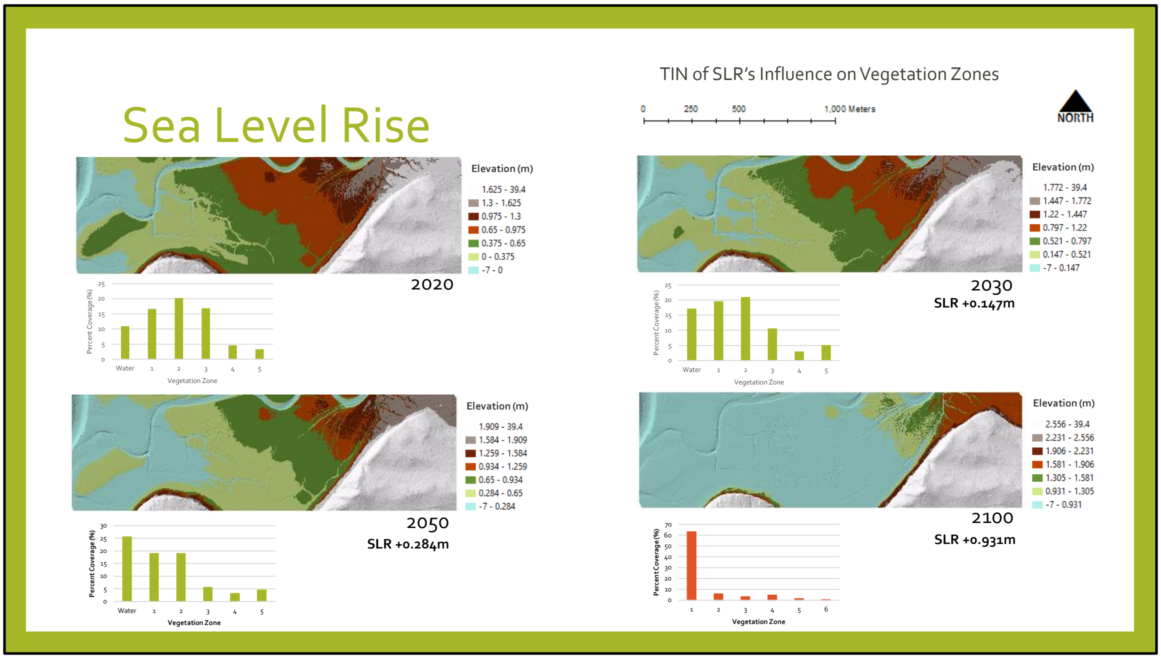


Table 2. Percentage coverage of each vegetation zone within the transect.

Year	Water	1	2	3	4	5	SLR (from 2020)
2020	**10.9**	16.6	20.2	16.9	4.59	3.29	N/A
2030	**16.0**	19.5	20.8	10.4	2.83	4.92	+ 0.147m
2050	**25.6**	19.0	18.9	5.55	3.13	4.47	+ 0.284m
2100	**63.31**	5.64	3.13	4.49	1.37	0.417	+ 0.931m

Table 2.
Green shows where there was an increases in percent coverage from the previous years. Red shows a decrease in percent coverage from the previous year.

So we are using values previously mentioned. The percent coverage of water dramatically increases. Although some values increase in 2030 and 2050, or don't change much, ultimately in 2100, all zones are significantly minimized.



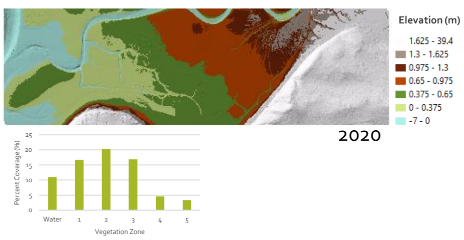
The percent coverage data is better displayed in these TIN models where the retraction of zones within the transect significant, especially in the high marsh.

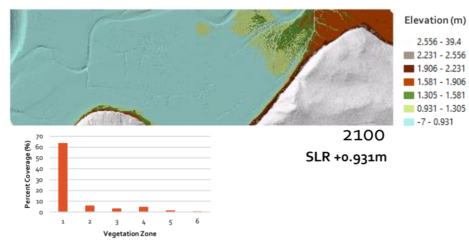
DISCUSSION

Conclusion

Hypothesis

1. Amount of vegetation will increase with increased elevation.
   - This is somewhat true. Although there are greater SAVI and NDVI values associated with higher elevations, including a positive correlation between elevation and these vegetative values, the gradient associated with increasing distance from sea level reduces the available area for these high marsh environments.
2. SLR will reduce vegetation coverage
   - It appears to be the case. SLR, especially as projected in 2100, restricts the salt marsh into current high gradient, high marsh areas. The effect of this is reduced sizes of all vegetative zones, especially those at higher elevations.





SLR will reduce vegetation coverage.
Higher elevations as prev identified are more vegetative valuable, and already in lower abundance.

Reflections

Limitations

- More available years for high resolution satellite imagery.
- Many other factors to consider.
  - Effects of deposition and erosion, salt marshes are constantly changing environments.
  - Size of transect, could be non-representative of the marsh on a whole.
- Reliability of data.
  - LiDAR was +/- 10cm
  - Vegetation Index
    - Atmospheric effects
    - Clouds
    - Etc.

To Expand on the Study

- Field Work sampling could determine species distributions and biodiversity to determine which species inhabit a future environment.
- Creating spectral libraries of individual species with spectrometer for remote spectral unmixing.
- Other remote sensing analysis to explore other vegetative influences (ie soil moisture, soil salinity).

Thank you for listening

References

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2. Chapman, V., 1976. Salt Marshes And Salt Deserts Of The World. University of California.

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4. Zhang, M., Ustin, S., Rejmankova, E., & Sanderson, E. (1997). Monitoring Pacific Coast Salt Marshes Using Remote Sensing.

5. Huete, A., 1988. A soil-adjusted vegetation index (SAVI). Remote Sensing of Environment, 25(3), pp.295-309.

References