Anthropogenic Impacts on the Rio Grande River

1. Abstract

The Rio Grande has been an emblematic feature and a source of life for the region. Since Pre-Historic times it has provided the resources that allowed waves of humans to migrate inland from the coast, and communities to thrive in a land where water is scarce. Large scale anthropogenic activities including, river diversions and dam construction have negatively impacted the river. Twenty-three major dams and many small ones built on the main channel and many of its tributaries in the last century, have drastically reduced water discharge and eliminated sediment delivery to the delta. This study explores how the channel sinuosity (degree of how meandering the channel is of the river, in the delta plain, has changed. We test the hypothesis that under a significantly reduced water discharge and a much smaller suspended sediment load, the river has reduced the sinuosity of its channel to achieve equilibrium with the new conditions. Jupyter lab will be the main processing tool use in this project to analyze discharge, sediment, and sinuosity data collected for this research. The processing power of jupyter will help us able to figure out if the delta reach of the Rio Grande has suffered a reduction in sinuosity as a result of human activity.

2. Introduction

The Rio Grande formed a sizable delta of around 7,770 km2 that spans from Southeast Texas to Northeast Tamaulipas with a shoreline length of approximately 300 km, and begins near the city of Harlingen, 88 km from shore, (Ewing and Gonzalez, 2016) (Figure 1). Mostly rural region with a sub-tropical climate with an average precipitation of 1.6 mm in 2020, according National Oceanic and Atmospheric Administration. The major urban hubs within the confines of this area are Brownsville, Texas (population 182,781) and Matamoros, Tamaulipas (population 520,367). Like all modern deltas, the Rio Grande delta is thought to have formed due to the slowdown in the rate of sea-level rise between 8500- and 6500-years BP that allowed the accumulation of sediment in coastal areas (Stanley and Warne, 1994).

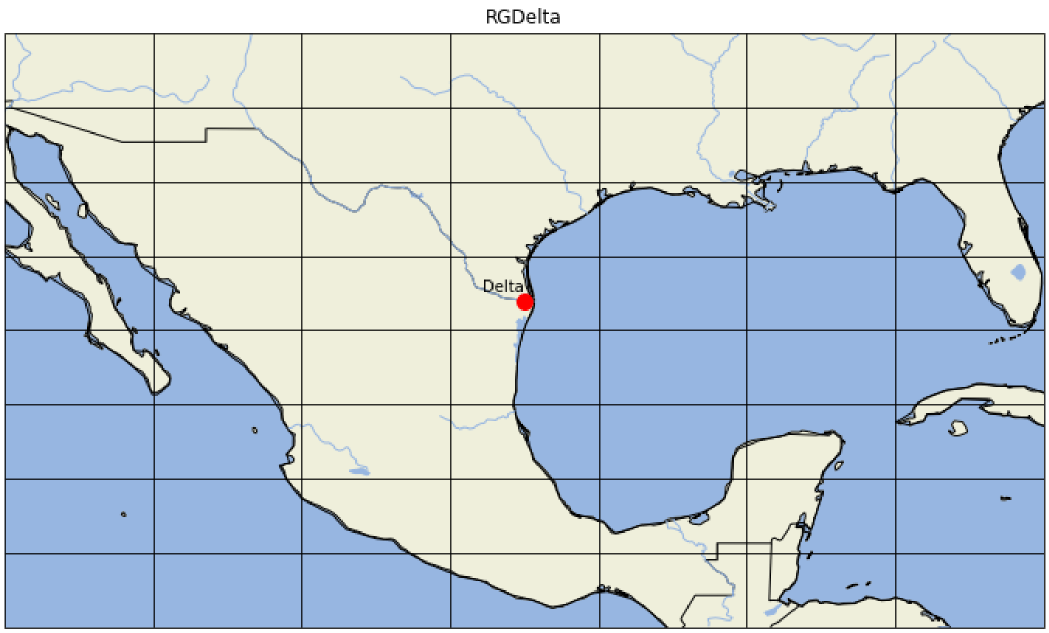

Figure 1.- Location of the Rio Grande Delta. Delta is indicated with red dot.

1.3.- Human activity on the Rio Grande

There is evidence from Franciscan missionaries that tells of Pueblo-Indians already diverting water for irrigation and other uses as far back as the late 1500s. Moreover, when Mormon settlers arrived at the Rio Grande, they also built structures to divert water from the river for irrigation. As communities kept expanding along the Rio Grande, the US Congress realized the need to improve their water management practices. For this reason, they decided to approve the construction of the first major dam on the Rio Grande in 1906; ten years later, Elephant Butte Dam was inaugurated. Since then, over twenty major dams and diversions, and many more minor structures, have been built in the Rio Grande channel and its tributaries. Two of these major dams are located within the Lower Rio Grande reach; these dams are Amistad dam and Falcon dam, which are located at 546 km and 212 km from the mouth of the river, respectively.

As a result of intense human activity, humans are now considered the major force shaping delta landform, and other ecosystems (Rogers and Overeem., 2017; Higgins et al., 2018). Paying attention to the effects of human activity on the Rio Grande is of paramount importance. Coastal erosion, the increase of relative sea level rise rates, sediment depletion, land subsidence, and human pressure on delta land are expected to negatively affect the efficiency of conventional approaches currently use to protect delta environments (Schmitt et al., 2017). It is important for local communities such as the Rio Grande Valley to understand the changes that are happening in the Rio Grande system.

1.4.- Flow Discharge and Sediment Concentration

To understand how much humans affected the Rio Grande delta, it is necessary to see how much flow discharge and sediment budget have changed. Drastic changes in discharge and sediment load have the potential to get the any river out of equilibrium. A river reaches an equilibrium state when there is net balance between deposition and erosion, and when sediment budgets change, rivers get out of balance (Nanson and Huang, 2018). For this reason, it is necessary to understand the current conditions of water flow and sediment concentration reaching the Rio Grande delta

1.5 Hypothesis

After years of constant human development on the Rio Grande, by building dams and diversion structures, it can be assumed that water discharge and sediment budgets have decreased as a result.

3. Methods

To create an assessment of the conditions, present in the Rio Grande delta, I looked at flow discharge data and suspended sediment concentration reaching the delta. I used water flow data provided by the International Water Information System and sediment data from USGS Water Information System.

I used functions and coding in python that allowed me to analyze the records of discharge and sediment data. I used functions such as: .mean(), std(), var() to perform a statistical analysis on my datasets. Additionally, I introduced a loop function to help me create a plotted graph depicting the results from the statistical analysis to help visualize the result from the inquiry.

The data was also divided in groups by decade starting with 1970s, 1980s, 1990s, 2000s. In the case of the sediment data, a group was also made to cover the 2010s; flow data stopped in the year 2011. I perform the same statistical functions (.mean(), .std(), and var()) on the decades groups. This was to identify where the major changes have occurred and try to understand why they happened, if present.

4. Results

Both datasets, flow discharge and suspended sediment concentration (SSC), show decrease starting in the decade of 1970s. Although both datasets experienced a rebound in their decade averages, the overall trend is downward. Suspended sediment had a rebound in the 1980s. Two important facts about this event are that it happened in the following decade after measurements started to be taken, so it cannot be considered an actual rebound, and it can be attributed to an isolated event that happen in the late 1970s that had in inflation effect on the final results. Flow discharge data had an actual rebound in the 2000s decade after a downward trend in the previous decades. Figures 2 and 3 depict the patterns that flow, and sediment followed throughout the decades. Table 1 also shows the results for each decade.

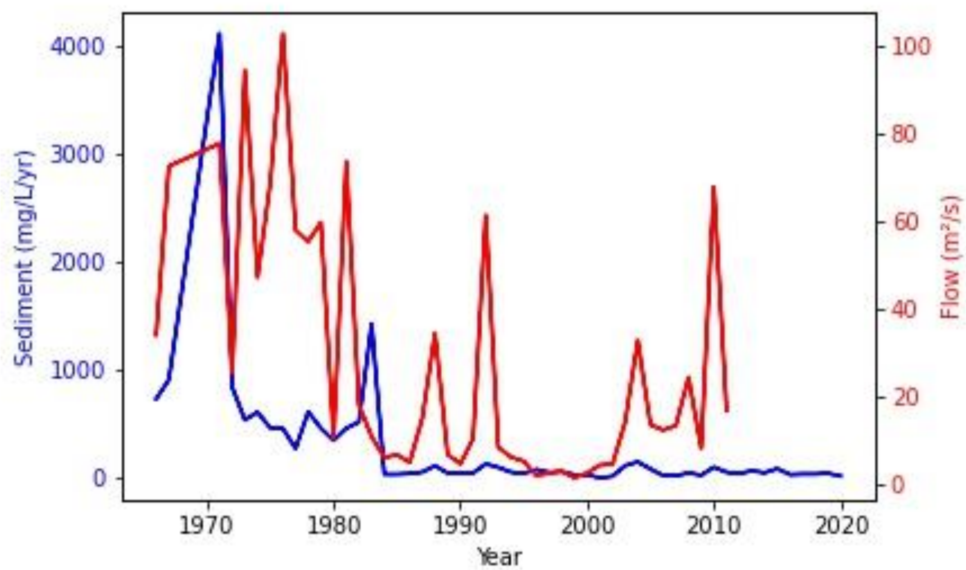

Figure 2.- Plotted graph showing overall patterns of flow (red) and suspended sediment concentration (blue).

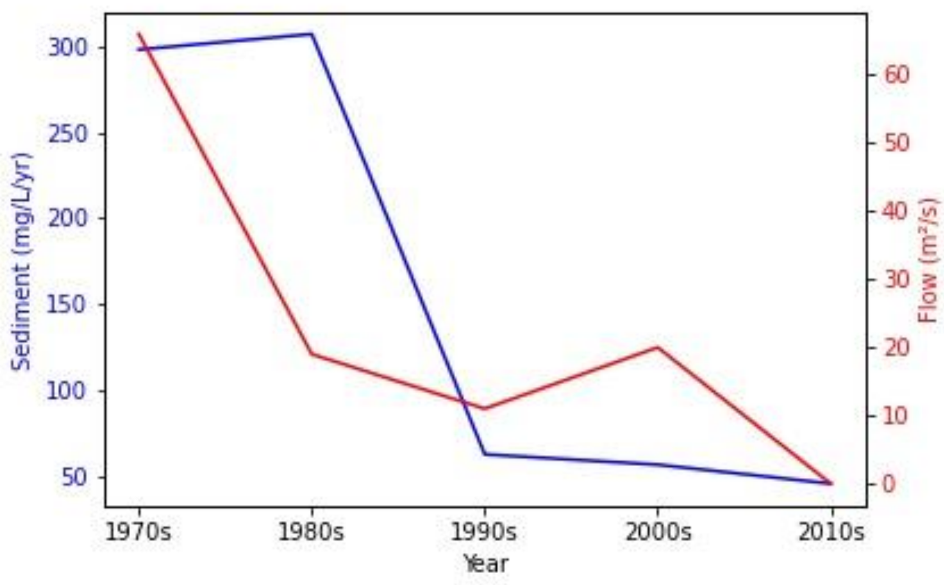

Figure 3.- Plotted graph showing patterns of suspended sediment concentration and flow organized by decades.

Table 1.- Results from the statistical analysis done by decades on both the suspended sediment concentration and flow.

	DecadesSSC	DecadesFlow
1970s	298	66.0
1980s	307	19.0
1990s	63	11.0
2000s	57	20.0
2010s	46	0.0

5. Discussion

Statistical analysis yielded an overall downward pattern for both the flow and sediment data. This same patter was visible when the datasets were organized and analyzed by decades. Although they increased their average at some point during their history, the main trend was a reduction on their levels. Now that it has been confirmed that flow and sediment levels have changed, it is important to assess how the river is reacting to these changes.

6. Conclusion

The result obtained in this brief research serve to support the notion that human activity has had an impact on important settings such as water discharge and sediment budgets in the Rio Grande delta. The initial hypothesis is correct. These results should help increase awareness of the damage that dams and diversion are causing to the Rio Grande delta. Unfortunately, this same situation is happening on deltas all over the world. Dams have become a major force changing the natural water cycles of rivers and their deltas.

Code Appendix

Pakages:

- import pandas as pd
- import numpy as np
- import matplotlib.pyplot as plt
- import csv
- import statistics
- from statistics import mean
- from scipy import stats
- import matplotlib.animation as ani
- from pylab import rcParams
- import cartopy.crs as ccrs
- import cartopy.feature as cfeature
- from cartopy import config
- from cartopy.io import shapereader

Statistical Functions:

- .mean()
- .std()
- .var()

Organizational Functions:

*Loop functions 1 and 2 helped me divide my data by decades

```
1.-def SSC_decades(mydata, istart):
     a=dec_avg=mydata.iloc[istart:istart+9,0]
     b=dec_avg=mydata.iloc[istart:istart+10,0]

     if istart == 2:
        return round(np.std(a),1)

     else:
        return round(mean(b),1)

2.-def flow_decades(mydata, istart):
     a=dec_avg=mydata.iloc[istart:istart+9,1]
     b=dec_avg=mydata.iloc[istart:istart+10,1]

     if istart == 2:
        return round(mean(a),1)

     else:
        return round(mean(b),1)
```

*I used this code to create a table with all my results

```
decades={'DecadesSSC':{'1970s':298,'1980s':307,'1990s':63,'2000s':57,'2010s':46},
            'DecadesFlow':{'1970s':66,'1980s':19,'1990s':11,'2000s':20}}

river_decadesdf=pd.DataFrame(decades)
river_decadesdf
river_decadesdf=river_decadesdf.fillna(0)
river_decadesdf
```

Map Creation:

```
plt.figure(figsize=(12, 9))

ax = plt.axes(projection=ccrs.PlateCarree())
plt.title('RGDelta')
ax.set_extent([-80,-115,35,15], ccrs.PlateCarree())
ax.coastlines(resolution='110m')
ax.gridlines(color='black')

ax.add_feature(cfeature.OCEAN)
ax.add_feature(cfeature.LAND)
ax.add_feature(cfeature.LAKES)
ax.add_feature(cfeature.BORDERS)
ax.add_feature(cfeature.COASTLINE)
ax.add_feature(cfeature.RIVERS)


plt.plot(-97.5110, 25.9815, markersize=10, marker='o', color='red')
plt.text(-97.5110, 26.2815, 'Delta', horizontalalignment='right',
transform=ccrs.PlateCarree())
plt.savefig('delta.png')
plt.show()
```

References

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