Environmental Threats to Venice

Introduction

Venice, a city known for its picturesque buildings, architectural and artistic merits, has encountered many environmental issues that have threatened the entire city. The city is situated on an archipelago of 122 islands, with canals running through the islands, forming a canal system for the inhabitants and tourists of Venice to travel on. The city relies entirely on water transportation or walking to get around. Venice's low level above sea level leaves it susceptible to flooding, and with sea levels rising, and the sinking of the city, the threat to Venice is even more detrimental. However, Venice has implemented some measures to deal with the constant flooding, and they have started to come up with ways to prevent flooding on the entire city during high tides and with rising sea levels. In this paper I will examine what contributes to the flooding of Venice and what is being done to prevent more damage to the city, and whether these are successful and sustainable and realistic to carry out.

Flooding

One of the biggest issues that affect Venice is flooding. The consistent exposure to sea water is detrimental to many of the historical buildings that are situated in Venice. Acqua alta, which means high water, is a natural event that occurs occasionally, which is due to a number of factors that happen all at once. These include high tide, which is usually during a full moon or new moon, winds blowing a certain way that forces water into the Lagoon, low atmospheric pressure, and a rapid change in atmospheric pressure. If all of these events occur at once, acqua alta is likely, and typically occurs when the tide is 35.4 inches above the normal high tide

(Imboden, n.d.). This is most common between September and April, but because of rising sea levels, now it often happens outside of those months. However, the floods in Venice vary depending on the area. From Imboden[HCA2] , it has also been concluded that once the tides hit at or above 130cm, 70% of Venice is flooded, and when it is above 140 cm or above, 90% of it is flooded. The frequent flooding is problematic because the water not only affects the people who live in Venice as well as stores and all of their goods, but also over time salt water deteriorates building materials, putting all of the buildings built in Venice at risk.

Sea level rising is becoming an increasing problem in Venice because the city is extremely sensitive to rising water because it has been built so close to sea level and because of the already frequent flooding that occurs. Another problem that has contributed to Venice's sensitivity to rising sea levels include excavation of canals for more transport and for bigger ships and the use of underground water for industrial activities that has caused more subsidence of the land, which has all affected the frequency and the amount of flooding (Camuffo and Sturaro, 2004).

There have been studies that show the trend of rising sea levels in Venice since the late 1800s. Camuffo and Sturaro (2004) reported that between the years 1872 to 2000, the sea level had risen around 31cm, where there was a continuous rise from 1872 to the 1960s, with less rising after 1970 (shown in Figure 1). This is explained because a law prior to 1970 allowed the extraction of underground water for industrial purposes, which caused the land subsidence, and after 1970 there were laws enacted that banned this from happening. They also state that the rise could have stopped because of climate change in the Mediterranean basin, with less precipitation and more clear days, which causes the sea surface temperature to rise, and causes more winds, which all contribute to a higher evaporation rate. However, the relative rise of sea level because

of climate change has caused the amount of flooding surges to dramatically rise, causing there to be more times of acqua alta in Venice, threatening the city, and causing more destruction of the buildings. (see Figure 2). The increase in surges in the later half of the 20th century can be attributed to changes made by the city, such as excavating a new deeper channel so that bigger ships can get through, and the use of underground water in the early to mid 20th century. Along with that, the relative sea level rise and climate change has also been a factor that has led to the frequent flooding in Venice.

Sinking

Land subsidence is a natural occurrence that has been affecting Venice since the lagoon was formed. This is mostly due to tectonic processes, because it sits on the Adriatic plate, which subducts the Apennines Mountains, which is causing the city to slowly "sink". On average, Venice has been subsiding about one to two millimeters per year (Live Science, 2012). However, the rate at which this causes the city to sink is not extremely substantial to why the city is sinking, it still contributes to the flooding that often occurs in Venice. Though, human-induced land subsidence has caused a bigger issue and has affected the subsidence more than natural land subsidence (See Figure 3). Land subsidence has contributed to Venice's flooding problem because it is causing it to be more vulnerable to floods because it is causing Venice to become even lower to sea level.

The biggest threat to Venice's sinking problem is land subsidence caused by human activity. In the 1930s the post-war industrial development affected Venice because industries began exploiting artesian aquifers, and started taking groundwater from the ground on which Venice

was on. Studies starting in the 197's have shown that as a result of the groundwater withdrawal, the land settled about 15cm over the time that this was happening (Teatini et al., 2005). This "sinking" of Venice has more than likely contributed to the more frequent flooding of the city, and is irreversible. Because of these findings, the Venetian government halted the ability for industries to withdraw from the ground water in the 1970s.

Another human-induced cause of land subsidence in Venice is the withdrawal of gas. According to Teatini et al., the Chioggia Mare field is the largest reservoir of gas in the area, which is located just 25 kilometers away from Venice. The withdrawal of the gas has been found to be a cause of the compaction of the ground there, which also causes the ground to "sink" further. In the study by Teatini et al., they found that in the location where the reservoir was located, the land settled 12cm by the 13th year that it was happening. However, this does not directly affect Venice, because it is not expected to subside as a result of this, it does show another example of how and why industrial activities have affected the area, and that continuing these activities could eventually affect Venice. Though, the withdrawal of gas in this area has been forbidden in the Chioggia Mare reservoir, hopefully halting any further subsidence.

Impacts on the City

Venice, founded in the fifth century, was one of the world's richest cities by the Renaissance. Today, that wealth and history behind Venice is shown through the art and architecture of the city, and has been deemed as a UNESCO world heritage site. The flooding not only damages the goods within the city, and the people who live within it, but also affect the structures and walls built within the city. With the flooding that happens, it slowly eats away at the structures that have defined Venice for centuries. The sea salt eats away at the buildings in

Venice, which causes irreversible damage. Also, salt within the sea water is corrosive to buildings and stays on the bricks and continues to degrade structures even when there is no standing water flooding the areas. According to Camuffo and Sturaro (2004) the people of Venice had originally built their buildings with a basement that had Istia stone, which is not very porous, so it would stop the capillary rise.When the buildings were first built, the height of these basement structures were high enough to prevent the sea water from affecting the structure. But now, with sea levels rising and the sinking of Venice, they are no longer tall enough to keep the water from hitting the vulnerable buildings. Especially in the last few decades this has caused new, irreparable damage to the historic buildings. Not only do the floods affect historic buildings, but also businesses and homeowners. Many people have been forced to move because their first floor homes are often flooded. This has also affected how store owners have conducted business as well, because of the threat of flooding. One way that the flooding affects individuals and homeowners besides the general flooding that comes in through doors is that often the water comes into stores and homes through toilets. To deal with this, people pump the water out with a pump. This is effective sometimes but when the water hits a certain level, the electricity goes out, and people are unable to pump the water out, creating even more flooding (Palus, 2019).

Within the past month, there has been severe flooding that has hit Venice. During this flooding, it was reported that more than 80% of Venice was under water (BBC News, 2019). There were several famous historical buildings (see Figure 4) submerged underwater, which, as stated before is problematic because the salt water eats away at the structures, and there is a possibility that from this flood, there could be structural damage to many of the sites. One of the sites that was most affected was St. Mark's Square, one of Venice's most popular areas for tourists to visit because of the multiple historic landmarks within the square. According to BBC

News, St. Mark's Square was one of the areas with the worst flooding, which had over one meter of water of water. The basilica is the greatest concern with this particular flood, because there is potentially structural damage to the columns. The Gritti Palace, which is now a luxury hotel, is another historical site that was greatly impacted by the recent floods. The interior bottom level on the hotel was flooded. The Vaporetti, Venice's public transport system by boat is currently unoperational because many of the boats were damaged by the high tides and strong winds. Two people have died from these most recent floods, both coming from a strip of land that lies between Venice and the Adriatic Sea. The strip of land was hit severely by the floodwaters, and one death was a result of electrocution which occurred when the individual was trying to start a pump in his home, and another person was found dead in another area of the island, with an unknown cause of death. The flooding has also affected tourism in Venice. In the recent flooding, Palus (2019) reported that they have been an attraction for tourists, and that tourists are always seen taking pictures in the flooded water, and sitting, swimming, etc. in the floods. However, many tourists do not realize how detrimental these floods can be to the people whose houses and businesses in which they are taking pictures of.

How Venice is Dealing with the Flooding

Venice has taken several steps towards dealing with the constant flooding. In the past, rules and regulations have been put in place to try to minimize the human-induced sinking of the city. From individual efforts, such as putting up barriers for store fronts, and replacing bricks with marble, to implementing having elevated sidewalks on the streets. [HCA3] However, since sea levels continue to rise at such a rapid rate, Venetians have tried to come up with new ways to

deal with all of the flooding, including the ambitious MOSE project, which has been in the works since 2003, but has not yet been completed.

There are several different ways that the Venetians have proposed to deal with the flooding problem within the city, as referenced in Teatini et al. (2005). One of them include building safeguards along the shoreline, as well as waterfront reconstructions and defense works in the town center. There have also been proposals that would alter the environment including maintaining channels better, possibly putting sediments back into the lagoon to make it more shallow, reversing what had previously been done to allow larger ships into the area. This would also require minimal to no large ships in the lagoon, such as oil tankers and cruise ships.

Another plan that has been put into action but not yet completed is the MOSE system. Project MOSE is a system of mobile barriers that would separate the lagoon from flood surges in the Adriatic Sea. The construction on the project began in 2003, and is known as one of the biggest engineering projects in the world, and was supposed to be completed in eight years, though, this has not happened and is still incomplete. It is supposed to have 78 gates that are movable at three different areas near the opening of the lagoon. It is supposed to work so that when the tide reaches 43 inches, the gates would rise to the surface of the water and prevent the lagoon from flooding. Then, when the tide goes down, the gates would fill with water and go back into place (Bendix, 2018). (See Figure 5). This would allow protection from surges, but also when there are no longer high tides, it would be reopened and allow traffic in and out of the lagoon. According to Garcia-Navarro (2019), currently the MOSE Project is 90% completed, but if it is not completely finished, it does not work, which is why the flooding is still a problem today for many Venetians. The reason why it has taken so long to complete this project is because of the corruption and mismanagement that has gone on behind the scenes of planning and constructing

the barrier. A quote from an interview by Garcia-Navarro stated that “Now, since five years when the court discovered this corruption, there are more lawyers working than engineers”. This is just one of the many hiccups behind the project and why it is not yet finished after so many years. However, with the recent flooding this past month, the push for the MOSE Project is at an even greater level.

Another factor that is contributing to the delayed finish of this project is the fact that it is extremely expensive. The latest proposed numbers for the complete construction of the barrier is around €6.3 billion. That number is just the total construction of the MOSE project, which does not include the estimated €100 million project cost per year for maintenance on the barrier (Laud, 2019). Along with this, the structures that have already been built are said to be rusting and corroding already, which would increase the price of building, and leaves it questionable whether the barrier is sustainable for long-term use, and if the price of building it is worth it.

The effect that the MOSE project will have on the environment around it has also caused concern for environmental groups. Also, it is unclear whether or not the system will help with the rising sea waters that have recently been predicted because the initial project proposal was based upon scenarios of sea levels rising by 22cm by 2100 (Laud, 2019) but recently it has been predicted that this would only withstand rising sea levels for only a few more decades, which would render the system useless in the near future. Another issue caused by increasing sea level rise at a higher rate is that there would be too many days that the floodgates would be raised most days so that the mobile gates would instead basically be a permanent wall. This would be problematic because there would be little traffic in and out of the lagoon, and the ecosystem would be affected because it would be closed off from the sea (Harlan and Pitrell, 2019).

Another cause for concern about the MOSE project is that it would affect the economy of Venice because it would interfere with port activities and shipping. These costs would include costs of waiting time when passing through, such as potential charter and mooring costs, having more staff on the ships, and warehousing costs. As a result of this, Venice would probably lose traffic through the port, and Venice would potentially lose traffic, which would cost them money, which would cost Venice around €350,000 to €1.3million per year (Vergano et al., 2010). Now, the project is estimated to be incomplete until 2022, leaving many more years for floods to damage the city and affect the people along with it, and allows more time for sea levels to rise to a potential level in which the barrier would be less effective.

Conclusion

There are many factors that contribute to Venice's constant flooding problem, both from natural occurrences and as a result of human activity. The amount of flooding that happens now is detrimental to the historical structures and buildings in Venice, and for the people who live there. There have been efforts put forth to preventing flooding and preventing further damage to happen, but many of the projects and proposals have proven to be not sustainable, or, in the case of implementing the MOSE system, very expensive and time consuming. The economic impact of the floods is detrimental to Venice, but the potential economic impacts of project MOSE may also be detrimental to Venice. It is still unclear when or if the MOSE project will finish because of the many problems that have occurred because of it, and the potential for more problems. However, it is clear that something needs to be done to salvage the city of Venice, it is unclear if any of the efforts that are being put into saving the city will have any lasting effects.

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