ENVS 3991
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Assignment 3
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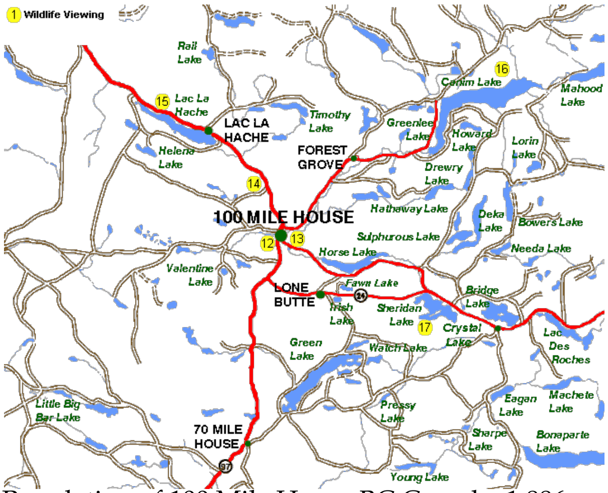
Topic 2
<u>Climate Change: Comparing and Contrasting the city of 100 Mile House BC, Canada, with Mumbai, India.</u>

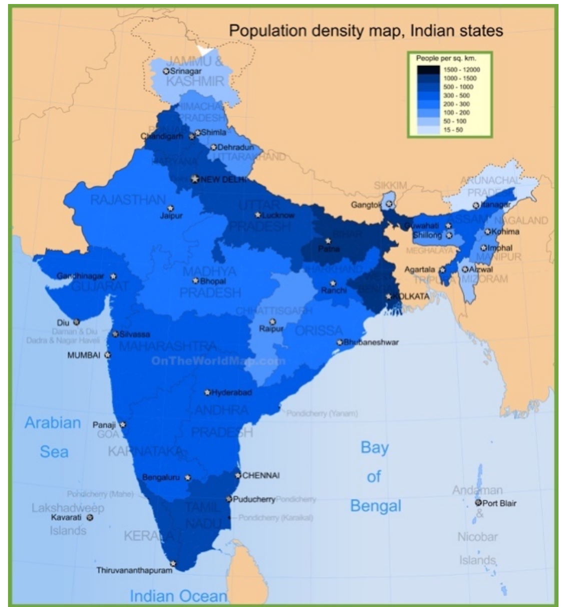
Preface: Personal Contemplation of Climate Change

Climate change extends beyond increased levels of atmospheric carbon dioxide resulting from anthropogenic use of fossil fuels. It is an urgent warning for humankind to use our available knowledge, technologies, and resources to address the problem. We cannot continue to deplete our natural resources at the current rate; we must find renewable energy options. Climate change is more than global warming, with increasing temperatures altering biodiversity. This investigation into climate change allows me to couple my Geological studies with Social and Economic Perspectives. Discovering my ecological footprint has given me insight into that fact that individual and small community changes can improve climate impact. Foremost, climate change is an indicator that we only have one world and need to unite to preserve it for future generations.

This paper will compare and contrast the potential impacts of continued climate change in my community of 100 Mile House, British Columbia and that of Mumbai, India. I will discuss the apparent effects of climate change on these two cities, followed by the possible result of an annual temperature increase of two and four degrees Celsius. I will then report on possible mitigations and adaptations to climate change in these two areas.



Population of 100 Mile House BC Canada: 1,886
(BCAdventure 2018)



Population of Mumbai, India: 18.41 million
(OnTheWorldMap 2019)

I will refer to the following climate graphs when comparing data for average temperatures and precipitation:

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	12.0 (53.6)	13.5 (56.3)	21.0 (69.8)	30.0 (86.0)	34.5 (94.1)	34.5 (94.1)	35.5 (95.9)	36.0 (96.8)	36.0 (96.8)	29.0 (84.2)	18.3 (64.9)	12.5 (54.5)	36.0 (96.8)
Average high °C (°F)	−2.1 (28.2)	2.1 (35.8)	7.4 (45.3)	12.2 (54.0)	17.0 (62.6)	20.3 (68.5)	23.1 (73.6)	23.3 (73.9)	18.5 (65.3)	11.1 (52.0)	2.4 (36.3)	−2.9 (26.8)	11.0 (51.8)
Daily mean °C (°F)	−7.2 (19.0)	−3.7 (25.3)	0.8 (33.4)	5.2 (41.4)	9.5 (49.1)	13.0 (55.4)	15.3 (59.5)	14.9 (58.8)	10.4 (50.7)	4.8 (40.6)	−2.1 (28.2)	−7.7 (18.1)	4.4 (39.9)
Average low °C (°F)	−12.3 (9.9)	−9.4 (15.1)	−5.9 (21.4)	−1.9 (28.6)	2.0 (35.6)	5.7 (42.3)	7.4 (45.3)	6.3 (43.3)	2.2 (36.0)	−1.6 (29.1)	−6.5 (20.3)	−12.5 (9.5)	−2.2 (28.0)
Record low °C (°F)	−44.5 (−48.1)	−40.5 (−40.9)	−37.8 (−36.0)	−15.0 (5.0)	−9.0 (15.8)	−4.0 (24.8)	−1.5 (29.3)	−6.0 (21.2)	−10.0 (14.0)	−32.0 (−25.6)	−40.5 (−40.9)	−48.0 (−54.4)	−48.0 (−54.4)
Average precipitation mm (inches)	35.1 (1.38)	21.3 (0.84)	16.5 (0.65)	29.2 (1.15)	42.9 (1.69)	56.6 (2.23)	68.2 (2.69)	47.5 (1.87)	37.0 (1.46)	32.3 (1.27)	42.4 (1.67)	48.2 (1.90)	477.1 (18.78)
Average rainfall mm (inches)	3.0 (0.12)	2.5 (0.10)	5.0 (0.20)	20.4 (0.80)	41.9 (1.65)	56.4 (2.22)	68.2 (2.69)	47.5 (1.87)	36.3 (1.43)	26.8 (1.06)	14.0 (0.55)	1.4 (0.06)	323.4 (12.73)
Average snowfall cm (inches)	32.1 (12.6)	18.8 (7.4)	11.5 (4.5)	8.8 (3.5)	1.0 (0.4)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.7 (0.3)	5.5 (2.2)	28.5 (11.2)	46.8 (18.4)	153.7 (60.5)
Average precipitation days (≥ 0.2 mm)	9.4	7.2	6.7	8.6	11.9	13.0	13.0	10.5	8.7	9.5	11.1	10.4	120.0
Average rainy days (≥ 0.2 mm)	1.3	1.1	2.6	6.4	11.6	13.0	13.0	10.5	8.5	8.2	4.2	0.7	81.0
Average snowy days (≥ 0.2 cm)	8.7	6.2	4.2	3.0	0.7	0.1	0.0	0.0	0.4	2.0	8.0	10.2	43.4

Climate graph 1: 100 Mile House BC, Canada (Wiki 2019)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	37.1 (98.8)	39.6 (103.3)	41.7 (107.1)	42.2 (108.0)	41.0 (105.8)	37.1 (98.8)	34.8 (94.6)	33.5 (92.3)	36.4 (97.5)	37.9 (100.2)	37.4 (99.3)	39.8 (103.6)	42.2 (108.0)
Average high °C (°F)	31.1 (88.0)	31.3 (88.3)	32.8 (91.0)	33.2 (91.8)	33.6 (92.5)	32.4 (90.3)	30.4 (86.7)	30.0 (86.0)	30.7 (87.3)	33.4 (92.1)	33.7 (92.7)	32.4 (90.3)	32.1 (89.8)
Average low °C (°F)	17.3 (63.1)	18.2 (64.8)	21.4 (70.5)	24.2 (75.6)	27.0 (80.6)	26.6 (79.9)	25.5 (77.9)	25.1 (77.2)	24.8 (76.6)	23.8 (74.8)	21.3 (70.3)	18.5 (65.3)	22.8 (73.0)
Record low °C (°F)	7.4 (45.3)	8.5 (47.3)	13.8 (56.8)	16.9 (62.4)	20.2 (68.4)	19.8 (67.6)	21.2 (70.2)	19.4 (66.9)	20.7 (69.3)	16.7 (62.1)	13.3 (55.9)	10.6 (51.1)	7.4 (45.3)
Average rainfall mm (inches)	0.3 (0.01)	0.4 (0.02)	0.0 (0.0)	0.1 (0.00)	11.3 (0.44)	493.1 (19.41)	840.7 (33.10)	585.2 (23.04)	341.4 (13.44)	89.3 (3.52)	9.9 (0.39)	1.6 (0.06)	2,373.4 (93.44)
Average rainy days	0.0	0.1	0.0	0.0	0.8	13.6	22.9	21.5	13.9	3.4	0.6	0.2	77.0
Average relative humidity (%)	69	67	69	71	70	80	86	86	83	78	71	69	75
Mean monthly sunshine hours	269.5	257.6	274.3	283.7	296.2	148.6	73.4	75.9	165.1	240.2	245.8	253.2	2,583.5

Climate graph 2: Mumbai, India (Wiki 2019)

General Impacts of Climate Change

100 Mile House, British Columbia and Mumbai, India have different climates, yet both cities are susceptible to the effects of climate change. In 100 Mile House, the most significant impact of global warming is on winter precipitation, which results in five major impact areas: "increasing wildfire risk, changing hydrology, increased variability, changing pests, diseases, and invasive plants, and changing wildlife and ecological systems" (BCAFCAI).

Climate change also affects precipitation patterns in Mumbai, India. According to S. Hosalikar from the India Meteorological Department, Mumbai will experience extreme rainfall, record high temperatures, and an erratic supply of drinking water. However, the primary area of concern is the issue of sea level rise. Rising sea levels can increase the salinity of coastal groundwater, endanger wetland ecosystems, and flood valuable land, and threaten the lives of Mumbai's 18 million inhabitants.

Effects of Climate Changes on 100 Mile House

In 100 Mile House, an annual increase of 2°C would cause two potentially damaging situations; warmer winter temperatures that will decrease snowfall and subsequent snowpack reserves for water during summer months, and, warmer summer temperatures that will create drought conditions, increasing the forest fire hazard. According to climate graph 1, the average temperature for the winter months in 100 Mile House (September-May, taken from av. low) is -5.1°C. An increase would raise the winter average from -5.1°C to -3.1°C., raising the chance that precipitation will fall as rain:

"Spring snow water equivalent is the average amount of water that is stored as snow during March-April-May of each year. It integrates the effects of both precipitation and temperature over preceding seasons. The level and distribution of water stored as snow at the end of the winter have great impacts on the hydrological regime and numerous ecological processes" (Dawson 2008).

A water shortage will also affect the summer months, with the average summer temperature increasing to 24.3°C. According to Dawson: "Projections of summer precipitation changes are near zero" (Dawson 2008). Summers will become drier, and forest fire hazard is imminent. Since the wildfires in 2017, this area has seen two years of flash-flooding following extreme rainfall. Human life and highway safety have been affected by numerous road closures due to mudslides and debris fields. The loss of trees from fires has damaged land stability, making it more susceptible to flooding and mass wastage.

A decline in available fresh water will affect agriculture, drinking water for humans and wildlife, freshwater streams/lakes, fish, and water for forests and grasslands.

The indicated changes will affect the quality of life for the residents of 100 Mile House, and surrounding First Nations populations. Fresh drinking water may be inadequate to support the community. Another notable consequence would be a decrease in stream flow, affecting fish spawning and therefore reducing the food supply and livelihood of Aboriginal groups. The potential increased risk of fire damage could displace both wildlife and humans from their homes, causing social and economic disaster.

An annual increase of 4°C would bring the average winter temperature of 100 Mile House to -1.1°C. An extreme decrease in snowpack could bring extreme drought conditions in the summer months. Smaller streams may evaporate, altering freshwater ecosystems and threatening fish populations, with potentially permanent consequences. The elimination of fish populations will threaten the livelihood of some First Nations, decimating their territories.

The Mountain Pine Beetle epidemic is another repercussion of local climate change. Winters have not been cold enough to kill the beetle and prevent infection to surrounding trees: "Mountain pine beetle populations have historically been controlled by extreme winter temperature events (colder than -35°C over several days or weeks" (BCMFLNRO 2012). According to a report from the University of Northern British Columbia, trees already killed by the beetles may be contributing further to CO2 emissions: "'Old forests store tremendous amounts of carbon that they acquire during photosynthesis,'… 'If trees are cut down or are killed by the pine beetle, they don't absorb carbon anymore. Climate change may be a final result.'"(Freedon 2019). If the winter temperatures continue to rise, further damage from insects and other pests may increase through their spread to other tree species.

"UNBC professor Art Fredeen measures the precise amount of carbon used by pine trees" (Freeden 2019).

Effects of Climate Changes on Mumbai, India

An annual temperature increase of 2°C in Mumbai, India would increase the likelihood of flooding. The monthly temperature average of 32.1°C (based on climate graph 2) would increase to 34.1°C. The subsequent rise in ocean and land temperatures will lead to increased rainfall: "Studies by IIT professor Subimal Ghosh have shown that a combination of urbanization and increased moisture from the Arabian Sea have led to a rise in extreme rainfall over Mumbai" (IPCC 2018). According to climate graph 2, the average rainfall from June to September is 565.1 millimetres. The National Institute of Oceanography conducted a study that shows: "the average sea level in India rose 3.2mm a year between 1993 and 2012…compared with an increase of 1.3mm during much of the 20th century" (IPCC 2018). Assuming the same rate of increase, a sea-level rise of 12.8 centimetres is probably by 2050, especially if combined with further flooding from increased rainfall, potentially causing death and displacement to the millions of people living at sea-level.

If we consider a higher rise of 4°C in Mumbai, the flooding will get worse. The average temperature would then be 36.1°C, escalating the moisture from the Arabian Sea. Continued industrialization and urbanization will exacerbate the condition: "Higher temperatures due to urbanization – a phenomenon called urban heat islands – also contributes to heavy rainfall" (Ghosh 2018). If we consider the previous hypothetical figure of a sea level rise of 128 mm and add it to increased rainfall, perhaps raising the number from an average of 565.1 mm up to 600 mm, disaster-level flooding throughout Mumbai is plausible.

"Mumbai is the world's second densest city, with 31,700 people per square kilometre" (Kaifee 2017); thus the outcome of a flood-disaster in Mumbai is catastrophic. Flooding from increased storms during the monsoon season will lead to more injury and deaths caused by rushing water and torrential rains. If the monsoon season shortens, water reservoirs may dry out: "Freshwater resources are not getting recharged to the extent they were being recharged 50 years ago" (Gupta 2018). There may be a shortage of drinking water, directly affecting the health of people in Mumbai. Mosquito-borne diseases may also increase and deteriorate health: "Dengue has seen a nearly 15-20% annual increase across the country" (IPCC). Furthermore, increased flooding will cause economic devastation if much of the city is underwater. Mumbai's infrastructure will be decimated, and people will lose their homes and businesses.

Mitigation and Adaption Strategies

Both 100 Mile House and Mumbai must mitigate CO_2 emissions to slow climate change, as clearly, both cities will suffer a decreased quality of human life if global warming intensifies. Several strategies are being implemented in 100 Mile House to combat the effects of climate change. Adaptation plans are in place to "inventory and prioritize existing dams and water storage, and develop cooperative approaches to dam assessments, upgrades, maintenance and management" (Charlton 2014). The water source for the residents of 100 Mile House was switched from surface to well groundwater to create "a sustainable water source" (District 100 Mile House) after prior summer shortages.

The local lumber mills do not have green energy sources implemented, but the nearby Atlantic Power Williams Lake Project (APWL) is a " 66-megawatt biomass-fired generating facility. Biomass fuel consists of wood waste from sawmill operations and roadside logging operations" (APWL 2019). Another, albeit controversial, suggestion to reduce carbon emissions in 100 Mile House is to reduce methane emissions by limiting or modifying cattle production. Restricting beef production is currently not a discussion topic, but according to an article by Koneswaran "the animal agriculture sector emits

18%, or nearly one-fifth, of human-induced GHG emissions, more than the transportation sector" (Steinfeld et al. 2006). Some strategies for greener ranching include: ”investigating the reformulation of ruminant diets to reduce enteric fermentation and some methane emissions” (Connolly 2007).

Mumbai is beginning to take similar steps. “The country intends to generate 40% of its energy from low or no-carbon sources by 2030” (Palmer 2015). As a developing city, Mumbai needs to focus on greener energy sources, such as solar. It “receives 300 days of sunlight per year, making solar energy a limitless and free resource” (Chatterjee 2016). The Arcade building currently uses solar power. According to Chatterjee, it is a 120-office complex that has a 250-kilowatt power system with 808 solar panels which provide for all daily consumption, including the air conditioning system. It took four years to install the system, but they have cut their yearly electricity bills by 30%. Palmer also reports that buildings are designed with high ceilings and cross ventilation to deal with extreme heat. Houses are built on elevated platforms to reduce damage from flooding. The IPCC report mentions that mandatory water recycling and rainwater harvesting helps conserve water from a reduced monsoon season. The IPCC also suggests to "promote green roofs and greenbelts to lower temperatures and promote paving materials that allow water to infiltrate and recharge groundwater" (IPCC 2018).

In conclusion, widespread temperature increases attributed to global warming are responsible for the increasingly catastrophic climate patterns being felt worldwide. As a result, all communities, big and small, face significant consequences that threaten the livelihood of their inhabitants, and therefore share in the responsibility to mitigate these effects before it is too late.

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